Florida Scientist

QUARTERLY JOURNAL
of the
FLORIDA ACADEMY OF SCIENCES

VOLUME 40

Editor
HARVEY A. MILLER

Associate Editors
WALTER K. TAYLOR
HENRY O. WHITTIER

Published by the

FLORIDA ACADEMY OF SCIENCES, INC.
Orlando, Florida
1977

The Florida Scientist continues the series formerly issued as the Quarterly Journal of the Florida Academy of Sciences. The Annual Program Issue is published independently of the journal and is issued as a separately paged Supplement.

CONTENTS OF VOLUME 40

NUMBER 1

NUMBER 2

Number 3

Number 4

Florida Scientist 39(4) was mailed on March 4, 1977.
Florida Scientist 40(1) was mailed on March 14, 1977.
Florida Scientist 40(2) was mailed on November 23, 1977.
Florida Scientist 40(3) was mailed on December 21, 1977.

Florida Scientist

Volume 40 | Winter, 1977 | No. 1

CONTENTS

(*Continued on back*)

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

FLORIDA SCIENTIST

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

The FLORIDA SCIENTIST is published quarterly by the Florida Academy of Sciences, Inc., a non-profit scientific and educational association. Membership is open to individuals or institutions interested in supporting science in its broadest sense. Applications may be obtained from the Treasurer. Both individual and institutional members receive a subscription to the FLORIDA SCIENTIST. Direct subscription is available at $13.00 per calendar year.

Original articles containing new knowledge, or new interpretation of knowledge, are welcomed in any field of Science as represented by the sections of the Academy, viz., Biological Sciences, Conservation, Earth and Planetary Sciences, Medical Sciences, Physical Sciences, Science Teaching, and Social Sciences. Also, contributions will be considered which present new applications of scientific knowledge to practical problems within fields of interest to the Academy. Articles must not duplicate in any substantial way material that is published elsewhere. Contributions from members of the Academy may be given priority. Instructions for preparation of manuscripts are inside the back cover.

Published by the Florida Academy of Sciences
810 East Rollins Street
Orlando, Florida 32803

Printed by the Storter Printing Company
Gainesville, Florida

Florida Scientist

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Harvey A. Miller, *Editor* Walter K. Taylor, *Associate Editor*

Vol. 40 Winter, 1977 No. 1

Editorial

THE STATE OF THINGS

PUBLICATION of this issue of the FLORIDA SCIENTIST marks the beginning of the fortieth year of continuous journal publication by the Florida Academy of Sciences. With the vigor displayed in our current membership campaign, it may be that, indeed, life begins at forty. We look forward to increasing involvement of the Academy in every aspect of scientific endeavor in Florida. As the single organization to speak only for Florida within the American Association for the Advancement of Science, the Florida Academy of Sciences is potentially a significant organ for communication in the national scientific community.

Just as the AAAS is comprised of members from a broad spectrum of scientific disciplines, so is the FAS. Each year many of the affiliated organizations meet jointly with the AAAS and occasionally specialized groups or regional branches of large national associations meet jointly with FAS. Further extension of cooperative meetings is clearly in everyone's best interest. The Academy is in an exceptionally strong position to provide the logistic and organizational framework for significant programs. We can guarantee to any scientific organization seeking to meet with us a series of extraordinarily valuable auxiliary benefits. Beyond accomodations and meeting rooms, publication of abstracts which are distributed and read world-wide in our Program Issue of the FLORIDA SCIENTIST constitutes a tangible benefit to individual participants.

Why then are we not overwhelmed with specialized science associations seeking to achieve the substantial benefits? Of course, we don't really *know*, but we strongly suspect that most program chairmen do not know about the possibilities. We must get the word out. The most efficient way is for Academy members to make direct input to their discipline-oriented societies. Alternatively, a FAS member may send the name of the program director or chief officer of a potential affiliate to the Executive Secretary in Orlando for official follow-up. A postcard or hand-scratched note will do a lot to get key people in contact. *The time is long overdue for the scientific community in Florida to get together and speak with a single strong voice.* Only the Academy is broad enough to embrace the whole of the magnificent, indeed awesome, scientific and technological establishment in Florida.

To minister to individual needs of our scientific subsets and to assuage their differences for the betterment of all is a tall order. But it is an order that must be filled. The urgency of its fulfillment must be impressed upon our scientific and technological community. Each small group holds vigorous dialogues among its members but they are heard outside about as much as an air rifle would be when fired simultaneously with a cannon. Bluntly, and perhaps uncharitably for the exceptions, those who should know seem oblivious to the extent that science and high technology support the well-being of all Floridians. It is about time to pool our strength and our identity as scientists to let the people and government know we exist. It is about time we pulled our several narrowly defined disciplinary heads out of the sand and looked with some unity at the world around us. I'm told that a true Florida Cracker always has sand in his *shoes*—not up his nose. Science in Florida needs to clear its head, see the benefits of broad-ranging cross-communication, and the value of numbers in creating a public image.

State science academies, ours is no exception, seem most often to be the enclave of the professorial scientist with perhaps a little participation from education-linked agencies. Thus, we have failed to embrace the applied scientist, the medical practitioner and the engineer, for instance, who could contribute significantly to expanding the somewhat restricted—yea, often hidebound—outlook of the undergraduate level professor who comprised the majority membership. If such a situation was *ever* defensible, it cannot be now in situations where sophisticated computers and analytical devices make possible attacks on, and resolution of, problems formerly beyond reach of most non-academics. Our recent symposium issue on Solar Energy points up sharply the convergence of so-called "academic" and "applied" science. We have, or should have, a common interest in solutions to the many problems incumbent to this highly diversified, technologically sophisticated, socially stressed, and environmentally fragile State. Given that, lets "get our heads together" to accomplish what must be done.

Academy Sections exist to serve our membership and we can create new Sections to imbricate, and thus serve members in, any specialized discipline or industry within the scope of ARTICLE II of our Charter. Further, should a separate group wish to retain its identity completely, ARTICLE III, *Section 1* of the Bylaws allows us to enter into affiliations with other organizations. We already are empowered by our Charter and Bylaws, let's get on with some affiliating. Send our office the names of likely groups and persons and we'll see what can be done.

THE STATE OF THE JOURNAL—Despite strong efforts to achieve economies, our costs have risen for production and distribution of the FLORIDA SCIENTIST. Occasionally issues have been slightly delayed for lack of an adequate number of acceptable papers in hand. We are receiving a few more papers than in the past, but few papers are submitted in the social sciences, physical sciences, applied sciences or medical sciences. We would like to see more.

Some authors have not been members of the Academy in the past and they have not been excluded from our pages because of it. Non-members have been routinely invited to join with some success. However, manuscripts will be accepted henceforth only from members of the Academy. Processing of nonmember manuscripts received will be delayed until a membership is activated. This decision to require membership is based upon the fact that without members there can be no journal and that most organizations have such a requirement. Further, as a practical matter, authors with recent issues of the journal in hand submit manuscripts in a format consistent with our style. As a side effect, our growing extra-Florida membership may be expanded as more become acquainted with the publication.

Normally, page charges are not assessed for papers of nominal length beyond the extra costs incurred in setting up tables and preparing figures. The editor often arranges figures and tables in configurations designed to keep such charges to a minimum. For most authors, no change will be apparent, but for extraordinarily long papers or a succession of papers derived from sponsored research, the editor will negotiate a subsidy on a current cost basis. In this way, long papers will not preclude publication of the usual number of contributions by our members and the number of pages published can be increased.

None of the changes noted will affect the member in good standing who submits a usual sort of paper from time to time. They will, however, give greater substance to the importance of membership and provide some modest additional revenue which translates into greater membership benefits.

Your Academy Office is to serve you and to give you a place to send your ideas, to volunteer for a project or to be a reviewer, to complain about a problem, to ask a question about the Academy, or to direct others to for assistance. We are here to help you help the Academy achieve its full potential. We're moving in the right direction—you can help keep it going!—*Harvey A. Miller, Executive Secretary.*

Biological Sciences

NOTES ON THE EMBRYONIC PERIOD OF THE PINFISH *LAGODON RHOMBOIDES* (LINNAEUS)[1]

Steven C. Schimmel

U. S. Environmental Protection Agency, Environmental Research Laboratory,
Gulf Breeze, Florida 32561

Abstract: *Adult pinfish,* Lagodon rhomboides, *were collected during September and October, 1974 and 1975. Following a minimum of one wk holding period, females were initially injected with 200 IU human chorionic gonadotropin and injected with 400 IU every second day thereafter until mature ova (0.90-0.93 mm diam.) were produced. Ova were artificially fertilized and the embryonic period (sensu Balon, 1975) described and illustrated. Emergence occurred 48 hr after fertilization at 18°C and eye pigmentation appeared 144 hr after fertilization. Larval total length at emergence was 2.3 mm; at 96 hr post-emergence, 2.7 mm; and at 120 hr post-emergence, 2.5 mm. Decrease in length and death of larvae after 96 hr post-emergence was probably due to malnutrition and subsequent infection.*

---

[1]Contribution No. 281, Environmental Research Laboratory, Gulf Breeze.

PINFISH are abundant along the Atlantic and Gulf coasts of the United States. The life history distribution and ecology are well described (Hildebrand and Cable, 1938; Reid, 1954; Caldwell, 1957; Springer, 1957; Hansen, 1969; Cameron, 1969). Pinfish are believed to spawn in oceanic waters off the Atlantic and Gulf coasts during the autumn and winter months. Although spawning of the pinfish has never been observed, Springer (1957) reported a school containing specimens with ripe gonads in 21 fathoms of water off the Mississippi coast. Ova and recently hatched larvae (< 5 mm) have never been described from nature. I undertook to force pinfish spawning artificially in the laboratory, using human chorionic gonadotrophic hormone as a stimulant, and to describe the embryonic period of the pinfish.

METHODS AND MATERIALS—Adult pinfish (> 100 mm SL) were collected from Santa Rosa Sound, Florida in September and October, 1974 and 1975. They were held in sea water (14-22°C, 16-28° °/₀₀) for at least one week prior to hormonal injection. Fish were fed frozen adult brine shrimp (*Artemia salina*) daily throughout the laboratory tests. Males were distinguished from females on the basis of presence or absence of milt after gentle squeezing of the lateral surfaces of the fish anterior to the vent.

Females were anesthetized with MS-222 and given a 200 IU intraperitoneal injection of human chorionic gonadotrophic hormone (HCG) and 400 IU injections every second day thereafter until mature ova were produced. Mature ova (clear spherical, 0.90-0.93 mm diam) were stripped from the fish by applying gentle pressure to the abdomen anterior to the vent. Ova were mixed with milt in 190 mm × 100 mm finger bowls that contained 2l of sea water (18°C, 28 °/₀₀) and incubated at 18°C for 30 min to permit fertilization to occur. The embryonated ova suspended in the water column were gently removed on fine nylon gauze to other 2l finger bowls. Immature and infertile ova sank to the bottom of the finger bowls. Approximately 100 embryos were placed in each bowl. Finger bowls remained in the incubator at 18°C, except for daily checks on development and removal of dead embryos. A 10 hr daylight: 14 hr darkness photoperiod was maintained throughout the tests. Development during the embryonic and early larval periods was monitored from fertilization until death occurred. Developmental stages photographed ranged from unfertilized ova to protopterygiolarvae 6 days old. Names of periods and phases follow usage of Balon (1975).

Several foods were supplied the pinfish after eye pigmentation was complete. Among these were raw plankton (< 85 μm), ciliate protozoa (*Uronema nigricans*, strain P_c), brine shrimp nauplii, barnacle nauplii (*Balanus* sp.) and rotifers (*Brachionus plicatilis*).

RESULT AND DISCUSSION—Pinfish were highly variable in their response to hormonal injections. No fish given less than 600 IU of HCG hormone produced mature ova. The avg amount required for positive response was 1,000 IU, although many fish produced no mature ova even after 3,000 IU were injected. Those that did produce were not as obviously distended as croakers injected by

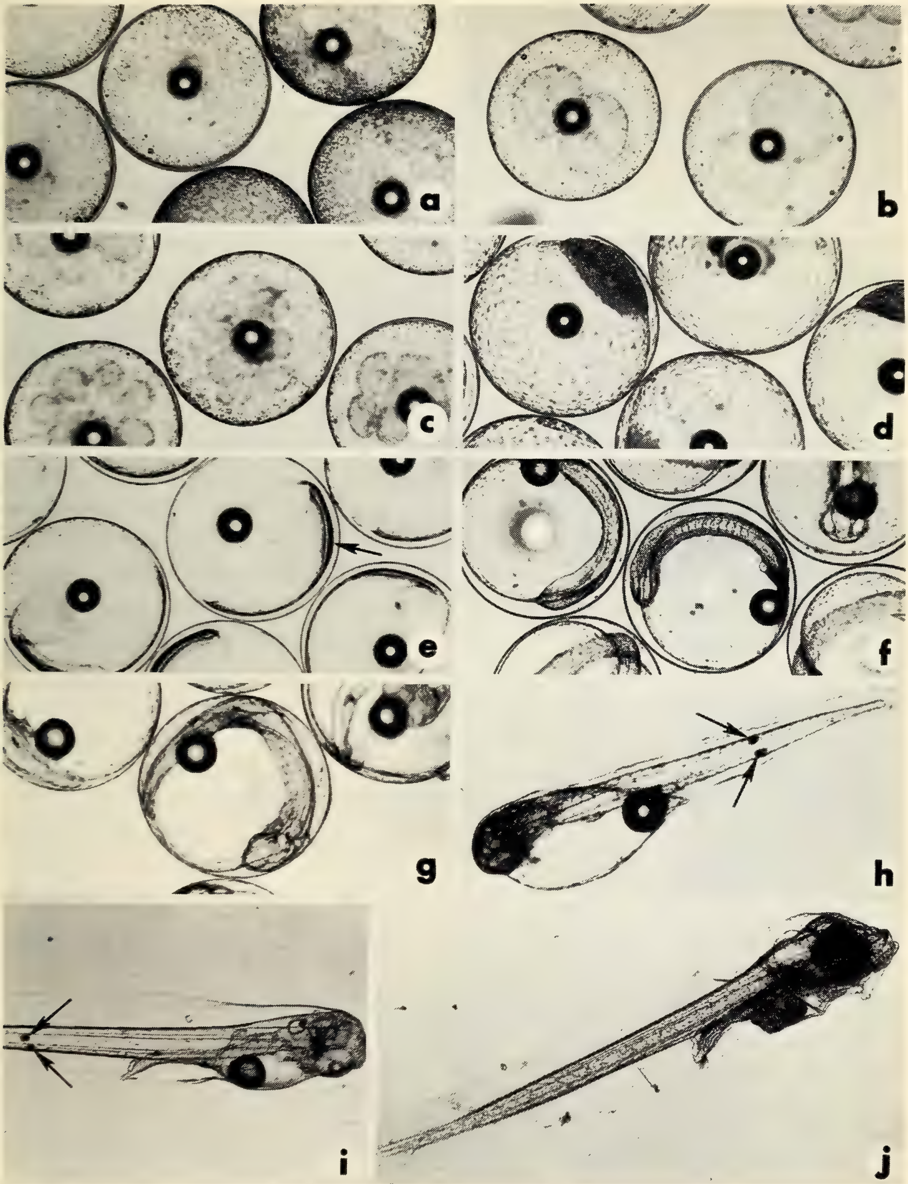


Fig. 1. Cleavage, embryonic, eleutheroembryonic and early protopterygiolarval phases of pinfish (*Lagodon rhomboides*) incubated at 18°C + 1°C. All figures are 35. a. Unfertilized ova with single oil globules. b. Cleavage, 2- and 4-cell stage, 0 hr 45 min. c. Cleavage, 8-cell stage, 1 hr 0 min. d. Late blastula, 8 hr 12 min. e. Gastrulation, 12 hr 45 min. f. Gastrulation complete, formation of brain, somites and eye vesicles, 24 hr 30 min. g. Embryo prior to emergence, 48 hr 05 min. h. Pinfish eleutheroembryo 2 hr after emergence, little eye pigmentation and melanophore on lateral surfaces of tail (arrows). i. Eleutheroembryo phase 24 hr after emergence, greatly reduced yolk sac, melanophore still evident (arrows). j. Protopterygiolarval phase, 96 hr after emergence, fully pigmented eyes and well-developed jaw apparatus; melanophore has disappeared.

Middaugh and Yoakum (1974), but overripe ova were observed from pinfish that were not stripped daily.

Development of the embryo was rapid, emergence occurring after 48 hr incubation at 18 C (Fig. 1 a-j). The emergent eleutheroembryo (2.3 mm total length) was without eye pigmentation, but had a characteristic melanophore on both lateral surfaces approximately 1 mm from the tip of the tail. The melanophore disappeared by the time of eye pigmentation (48 hr post-emergence). During yolk absorption, the larvae grew to approximately 2.7 mm. After yolk absorption, the jaw apparatus developed extensively and the total length of the protopterygiolarva increased to approximately 2.9 mm 96 hr after emergence. Approximately 90% of the larvae died within 120 hr after emergence. The length of individuals surviving beyond 120 hr diminished from 2.9 mm to approximately 2.5 mm. No larvae survived beyond 9 days from emergence.

Although food was supplied and feeding activity was seen, no food was found in the gut. Malnutrition and subsequent infection was believed to be the cause of death. Determination of the nutritional needs and feeding habits of pinfish during the period from yolk sac absorption to the juvenile stage will require a more comprehensive investigation.

Acknowledgment—I thank Steven Foss for help and guidance with photography.

LITERATURE CITED

Balon E. K. 1975. Terminology of intervals in fish development. J. Fish. Res. Board Can. 32:1663-1670.

Caldwell, D. K. 1957. The biology and systematics of the pinfish, *Lagodon rhomboides* (Linnaeus). Bull. Florida St. Mus. 2(6):1-173.

Cameron, J. N. 1969. Growth, respiratory metabolism and seasonal distribution of juvenile pinfish (*Lagodon rhomboides* Linnaeus) in Redfish Bay, Texas. Contrib. Mar. Sci. 14:19-36.

Hansen, D. J. 1969. Food, growth, migration, reproduction, and abundance of pinfish, *Lagodon rhomboides*, and Atlantic croaker, *Micropogon undulatus*, near Pensacola, Florida, 1963-65. U. S. Fish. Wildl. Serv. Fish. Bull. 68:135-146.

Hildebrand, S. F., and L. E. Cable. 1938. Further notes on the development and life history of some teleosts at Beaufort, N. C. Bull. Bur. Fish. 48:504-642.

Middaugh, D. P., and R. L. Yoakum. 1974. The use of chorionic gonadotropin to induce laboratory spawning of the Atlantic croaker, *Micropogon undulatus*, with notes on subsequent embryonic development. Chesapeake Sci. 15:110-114.

Reid, G. K. Jr. 1954. An ecological study of the Gulf of Mexico fishes, in the vicinity of Cedar Key, Florida. Bull. Mar. Sci. 4:1-94.

Springer, S. 1957. Some observations on the behavior of schools of fishes in the Gulf of Mexico and adjacent waters. Ecology 38:166-171.

Florida Sci. 40(1):3-6. 1977.

Biological Sciences

THE FLORIDA SPECIES OF *ILEX* (AQUIFOLIACEAE)

RICHARD P. WUNDERLIN AND JAMES E. POPPLETON

Department of Biology, University of South Florida, Tampa, Florida 33620

ABSTRACT: *Eleven species and three varieties of* Ilex *are recognized for Florida. Keys, brief descriptions, pertinent synonymy, local uses, and distribution maps are provided for each taxon. The new combination* Ilex ambigua *var.* monticola *is proposed.*

ILEX is one of three genera currently recognized in the Aquifoliaceae and the only genus of the family native to Florida. The genus, occurring in both the Old and New World, consists of about 300 species of which approximately 15 are indigenous to North America. Eleven species are recognized for Florida in this treatment. *Nemopanthes*, a second genus of the family consists of 2 species endemic to eastern North America. Clark (1974) treats this genus and discusses its past confusion with *Ilex*. The third genus, *Phelline*, has about 10 species which are endemic to New Caledonia.

Systematists disagree somewhat concerning the exact delimitations and status of certain taxa of *Ilex*. Our treatment is based on synthesis of recent publications and a personal knowledge of the genus, especially the Florida species, through both herbarium and field studies. Since our work is not an in-depth study of the genus outside Florida or the southeastern United States, our conclusions regarding the status of some taxa may be considered as tentative pending further revisionary studies.

Synonymy of several taxa treated here is extensive; for brevity only names considered to be relevant to an understanding of the systematics of the Florida taxa are included in this treatment. The purpose of our work is to present a means to accurately identify the native Florida species of *Ilex* and to describe their distribution and habitat preference.

The distribution maps are based on specimens deposited in the herbaria of the University of South Florida (USF), University of Florida (FLAS), and Florida State University (FSU).

SYSTEMATIC TREATMENT

ILEX L., Sp. Pl. 125. 1753; Gen. Pl. ed. 5. 60. 1754; non Mill., 1754 (Fagaceae).

Prinos L., Sp. Pl. 330. 1753.
Aquifolium Mill., Gard. Dict. Abr. Ed. 4. 1754.
Ageria Adans., Fam. 2: 166. 1763 (Myrsinaceae, p.p.); *non* Raf., 1838.
Macoucoua Aubl., Pl. Guiane 1:88. 1775.
Labatia Scop., Introd. 197. 1777, *nom. rej.*; *non* Sw., 1788 (Celastraceae).

Othera Thunb., Nov. Gen. Pl. 3:56. 1783.
Paltoria Ruiz & Pav., Prodr. 13. 1794.
Winterlia Moench., Meth. 74. 1794; *non* Spreng., 1824 (Lythraceae).
Hexotria Raf., Amer. Monthly Mag. 4:265. 1818.
Chomelia Vell., Fl. Flum. 1:42. 1829; *non* L., 1758 (Rubiaceae); *nec* Jacq., 1760 (Rubiaceae).
Ageria Raf., Sylva Tellur. 56. 1838; *non* Adans., 1763.
Synstima Raf., Sylva Tellur. 48. 1838.
Arinemia Raf., Sylva Tellur. 49. 1838.
Braxylis Raf., Sylva Tellur. 51. 1838.
Ennepta Raf., Sylva Tellur. 52. 1838.
Prinodia Griseb., Abh. Ges. Wiss. Goett. Phys. Cl. 7:224. 1857.
Pileostegia Turcz., Bull. Soc. Nat. Mosc. 32(1):276. 1859; *non* Hook. & Thoms., 1857 (Saxifragaceae).

Trees or shrubs. Leaves simple alternate, petiolate; stipules minute, deciduous. Flowers polygamo-dioecious, hypogynous, small, white or greenish, solitary or cymose in axillary clusters or at nodes below leaves, pistillate with nonfunctional stamens, staminate with rudimentary pistil; calyx minute, 4- to 9-lobed; petals 4-9, slightly connate at base; stamens as many as petals and alternate with them, adnate to corolla tube; ovaries (2-) 4-8 (10) -celled, style usually wanting; stigmas as many as cells, distinct or united. Fruit a berry; seeds (2-) 4-8 (-10), each surrounded by a bony or crustaceous, smooth or ribbed endocarp (pyrenes).

Linnaeus (1753) adopted the Tournefort generic name, *Ilex*, for this group of plants and placed in it 5 species of which only one, *I. cassine*, is native to the United States and Florida. At the same time Linnaeus also adopted the Gronovius name *Prinos* for two species which are now placed in *Ilex*, I. *glabra* and *I. verticillata*. Both these species are native to Florida. Since the proposal of *Ilex* and *Prinos* by Linnaeus, 18 additional generic names have been proposed for parts of this group of plants, resulting in a lengthy synonymy.

Brizicky (1964), following the classification proposed by Gray (see Fernald, 1950) for the northeastern species of *Ilex*, divided the southeastern species into 3 subgenera which include the following Florida species: subgenus Ilex (*I. cassine*, *I. opaca*, and *I. vomitoria*), subgenus Prinos (*I. coriacea*, *I. glabra*, *I. krugiana*, and *I. verticillata*), and subgenus Prinoides (*I. ambigua*, *I. amelanchier*, *I. decidua*, and *I. longipes*). In this treatment of the Florida species, we recognize only two subgenera: subgenus Ilex (including *I. cassine*, *I. coriacea*, *I. glabra*, *I. krugiana*, *I. opaca*, and *I. vomitoria*) and subgenus Prinos (including *I. ambigua*, *I. amelanchier*, *I. decidua*, *I. longipes*, and *I. verticillata*). This arrangement follows that of Lossener (1942) and Hu (1949, 1950). It is felt that this arrangement is more natural than that used by Brizicky. It has more convenient groupings for the taxonomist in that it places all the evergreen species in one subgenus (Ilex) and all the deciduous species in the other subgenus (Prinos). This species separation is usually employed in keys in regional treatments.

KEY TO SPECIES

1. Leaves coriaceous, evergreen 2
1. Leaves chartaceous to subcoriaceous, deciduous 7

2. Leaves crenate throughout their length .... 11. *I. vomitoria*
2. Leaves dentate, serrate, entire, or if crenate, then only toward the apex 3
3. Leaves remotely crenate toward the apex .... 6. *I. glabra*
3. Leaves serrate, dentate, or entire 4
4. Leaves spinulose-dentate or entire; teeth or at least the apex armed with a rigid spine 1 mm long or more .... 9. *I. opaca*
4. Leaves spinulose-serrate or entire; teeth (if present) and the apex unarmed or with a spine less than 1 mm long 5
5. Leaves with minute black punctations below .... 4. *I. coriacea*
5. Leaves without evidence of black punctations below 6
6. Inflorescences pedunculate; fruits red or yellow .... 3. *I. cassine*
6. Inflorescences not pedunculate; fruits black or purple .... 7. *I. krugiana*
7. Leaves crenate, tapering to narrow cuneate base .... 5. *I. decidua*
7. Leaves serrate, rounded or with a broad cuneate base 8
8. Pyrenes with soft, smooth endocarp .... 10. *I. verticillata*
8. Pyrenes with hard, ribbed endocarp 9
9. Undersurface of leaves conspicuously reticulate veined .... 2. *I. amelanchier*
9. Undersurface of leaves only slightly or obscurely reticulate-veined 10
10. Fruiting pedicels 2-8 mm long .... 1. *I. ambigua*
10. Fruiting pedicels 10-23 mm long .... 8. *I. longipes*

1. ILEX AMBIGUA (Michx.) Torr., Fl. New York 2:2. 1843.

Shrub or small tree to 6 m; branches glabrous to densely pubescent. Leaves deciduous, ovate to elliptic, 3-18 cm long, 1.5-7.0 cm wide, acute to acuminate at apex, rounded to broadly cuneate at base, margin serrate or crenate-serrate, lower third frequently entire, variously pubescent or glabrate; petiole 0.3-1.5 cm long. Inflorescences axillary, not pedunculate, pedicels 1-3 mm long, staminate flowers 2-8, pistillate flowers 1-3. Fruit red, subglobose, 4-12 mm; pyrenes 4-8, endocarp bony, deeply furrowed on back.

Key to Infraspecific Taxa

1. Leaves 2-4(-5) cm .... 1a. var. *ambigua*
1. Leaves (5-)6-10 cm .... 2b. var. *monticola*

1a. ILEX AMBIGUA (Michx.) Torr. var. AMBIGUA

Cassine caroliniana Walt., Fl. Carol. 242. 1788; *non* Lam., 1785.
Prinos ambiguus Michx., Fl. Bor.-Amer. 2:236. 1803.
Synstima caroliniana (Walt.) Raf., Sylva Tellur. 49. 1838.
Ilex ambigua (Michx.) Chapm., Fl. SE. U. S. 269. 1860, *nom. superfl.*
Nemopanthes ambigua (Michx.) Wood, Class-book, ed. 2. 467. 1861.
Synstima ambigua (Michx.) Raf. *ex* S. Wats., Bibl. Index N. Amer. Bot. 157. 1878.
Ilex ambigua var. *coriacea* Trel., Trans. St. Louis Acad. Sci. 5:347. 1889.
Ilex caroliniana (Walt.) Trel., Trans. St. Louis Acad. Sci. 5:347. 1889; *non* Mill., 1768.
Ilex buswellii Small, Bull. Torr. Bot. Club 51:382. 1924.
Ilex caroliniana var. *jejuna* McFarlin, Rhodora 34:236. 1932.

Ilex ambigua var. *ambigua*, commonly called the Carolina or Sand Holly, occurs in sandy, upland woods and hammocks from North Carolina south to Florida and west to Arkansas and eastern Texas. In Florida it is found as far south as Lee County (Fig. 1). This taxon can be distinguished from other deciduous species of *Ilex* by the combination short pedicels and ribbed pyrenes. It is distinguished from var. *monticola* primarily on the basis of its smaller leaf. In addition, the fruit of var. *ambigua* is generally 4-7 mm in diam as compared with 8-12 mm in var. *monticola*. However one local race of var. *ambigua*, separated out as *I. buswellii* by some workers, has a larger fruit which falls within the range of that of var. *monticola*, but has much smaller, more coriaceous leaves than those of that variety. Small (1933) recognized *I. buswellii* as a distinct species on the basis of its somewhat more coriaceous leaves, larger fruits, shape of the calyx-lobes of the staminate flowers, and broader stamens. These differences do not appear to be significant and *I. buswellii* is treated here as a local race of the highly polymorphic *I. ambigua*. Long and Lakela (1976) have incorrectly placed *I. buswellii* in synonymy under *I. decidua*. This is probably an oversight. Several other proposed varieties and forms are also placed in synonymy here.

1b. ILEX AMBIGUA var. MONTICOLA (Gray) Wunderlin & Poppleton, comb. nov.

Ilex montana Torr. & Gray *in* Gray, Man. 276. 1848; *non* Griseb., 1861.
Ilex monticola Gray, Man. ed. 2. 264. 1856; *non* Tul., 1857.
Ilex mollis Gray, Man. ed. 5. 306. 1867.
Ilex amelanchier var. *monticola* (Gray) Wood, Amer. Bot. Fl. 208. 1870.
Ilex montana var. *mollis* (Gray) Britt., Bull. Torr. Bot. Club 17:313. 1894.
Ilex monticola var. *mollis* (Gray) Britt., Mem. Torr. Bot. Club 5:217. 1894.
Ilex beadlei Ashe, Bot. Gaz. 24:377. 1897.
Ilex dubia var. *monticola* (Gray) Loes., Nova Acta Acad. Caes. Leop.-Carol. Germ. Nat. Cur. 78:485. 1901.
Ilex dubia var. *mollis* (Gray) Loes., Nova Acta Acad. Caes. Leop.-Carol. Germ. Nat. Cur. 78: 485. 1901.
Ilex dubia var. *mollis* f. *beadlei* (Ashe) Loes., Nova Acta Caes. Leop.-Carol. Germ. Nat. Cur. 78:487. 1901.
Ilex dubia var. *mollis* f. *grayana* Loes., Nova Acta Acad. Caes. Leop.-Carol. Germ. Nat. Cur. 78:487. 1901.
Ilex dubia var. *beadlei* (Ashe) Rehder, Man. Cult. Trees & Shrubs 546. 1927.
Ilex montana var. *beadlei* (Ashe) Fern., Rhodora 41:428. 1939.
Ilex montana f. *rotundifolia* Woods, Rhodora 53:238. 1951.
Ilex ambigua var. *montana* (Torr. & Gray) Ahles, J. Elisha Mitch. Sci. Soc. 80:173. 1964.
Ilex ambigua var. *montana* f. *mollis* (Gray) Ahles, J. Elisha Mitch. Sci. Soc. 80:173. 1964.

Ilex ambigua var. *monticola*, commonly referred to as the Mountain Holly or Mountain Winterberry, occurs in open, mesic woods from Massachusetts south to Florida and west to Tennessee and eastern Texas. In Florida it is found only in the panhandle region (Fig. 2). This taxon can be distinguished from var. *ambigua* by its larger leaf as discussed under that variety. *Ilex ambigua* var. *monticola* has been treated as a species distinct from *I. ambigua* by several authors (e.g. Correll and Johnston, 1970; Fernald, 1950; Gleason, 1952; Kurz and Godfrey, 1962; and Small, 1933). However, in our opinion it does not appear to be specifically distinct and is therefore treated as a variety of *I. ambigua*. Variety *beadlei* (= *I. beadlei*) and var. *mollis* (= *I. mollis*), recognized by some workers, are based on nothing more than variations in leaf shape and pubescence and are not worthy of taxonomic recognition. They are accordingly reduced to synonymy here.

The oldest available epithet at the varietal rank for this taxon is *monticola* (*Ilex amelanchier* var. *monticola* (Gray) Wood, Amer. Bot. Fl. 208. 1870). This has not been previously used in combination with *Ilex ambigua*. Therefore the new combination required is proposed here.

2. ILEX AMELANCHIER M. A. Curtis *in* Chapm., Fl. SE U. S. 270. 1860.

Prinos dubia G. Don, Gen. Syst. 2:20. 1832.
Ilex dubia (G. Don) B.S.P., Prelim. Cat. New York Pl. 11. 1888; *non* Webber, 1851.

Shrub to 2 m; branches puberulent to glabrate. Leaves deciduous, oblong to ovate-lanceolate, (4-) 5-9 cm long, 1.5-4.5 cm wide, apex acute to subacute, base cuneate, margin entire or serrulate, glabrate above, prominently reticulate and puberulent below; petiole 0.6-1.2 cm long. Inflorescences axillary or at nodes below leaf axils, peduncle 5-12 mm long, pedicels 6-20 mm long, staminate flowers 6-9, pistillate flowers 1-3. Fruit dull red, subglobose, 8-10 mm diam; pyrenes 4-8, endocarp bony, 2 deep furrows on back.

Ilex amelanchier, sometimes called Sarvis (Service?) Holly, is a rare species occurring in swamps and wet woods from Louisiana to Georgia and north to southeastern Virginia. In Florida it is known only from Holmes and Santa Rosa Counties (Fig. 3). This species resembles *I. verticillata* and to a lesser extent, *I. ambigua* var. *monticola*, but is easily distinguished from both by its longer pedicels.

3. ILEX CASSINE L., Sp. Pl.125. 1753; *non* Walt., 1788.

Shrub or small tree to 12 m; branches puberulent or glabrate. Leaves evergreen, elliptic to obovate, 3-14 cm long, 2-5 cm wide, bristle-tipped at apex, rounded to cuneate at base, margin entire or with a few spinulose-serrate teeth, teeth (if present) and apex armed with a spine less than 1 mm long, revolute, glabrous above, pubescent to glabrate below; petioles 0.5-1.2 cm long. Inflorescences axillary or at nodes below leaf axils, peduncles 3-8 mm long, pedicels 1-3 mm long, staminate flowers numerous, pistillate flowers 1-9. Fruit red, orange, or yellow, subglobose, 6-9 mm diam; pyrenes 4-8, endocarp bony, furrowed on back.

Key to Infraspecific Taxa

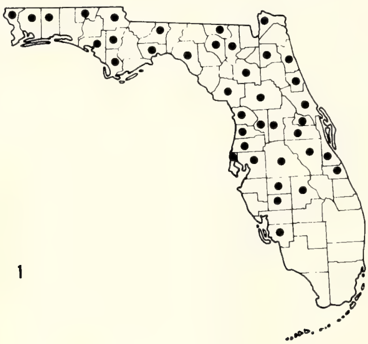
1. Leaves over 1 cm wide; twigs short pilose (occasionally glabrous); secondary branches at an angle of less than 45° from main branch........... 3a. var. *cassine*
1. Leaves less than 1 cm wide; twigs minutely strigose-puberulent; secondary branches at an angle greater than 45° from main branch ....3b. var. *myrtifolia*

3a. ILEX CASSINE L. var. CASSINE

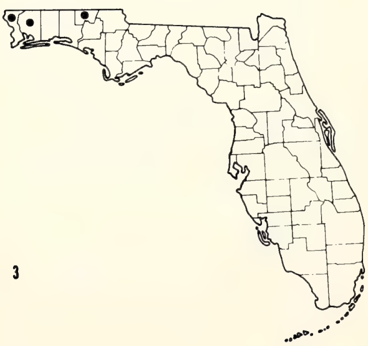
Ilex caroliniana Mill., Gard. Dict. ed. 8. 1768.
Ilex dahoon Walt., Fl. Carol. 241. 1788.
Ilex cassine var. *angustifolia* Ait., Hort. Kew. 1:70. 1789.
Ilex cassine var. *latifolia* Ait., Hort. Kew. 1:170. 1789.
Ilex cassinoides Link, Enum. Pl. Berol. 1:148. 1821; *non* Du Mont de Cour., 1811.
Ilex laurifolia Nutt., Amer. J. Sci. 5:289. 1822.
Ilex dahoon var. *laurifolia* (Nutt.) DC., Prodr. 2:14. 1825.
Ageria palustris Raf., Sylva Tellur. 47. 1838.
Ageria germinata Raf., Sylva Tellur. 48. 1838.
Ageria heterophylla Raf., Sylva Tellur. 48. 1838.

Ageria obovata Raf., Sylva Tellur. 48. 1838.
Ilex dahoon var. *angustifolia* (Ait.) Torr. & Gray *ex* S. Wats., Bibl. Index N. Amer. Bot. 158. 1878.

Ilex cassine var. *cassine*, commonly known as Dahoon, Dahoon Holly, or Christmas Berry, occurs in flatwood depressions and along edges of ponds and swamps from Virginia south to Florida and west to southeastern Texas. It also extends into the Caribbean area to the Bahamas and Cuba. It ranges throughout Florida where suitable habitats are found (Fig. 4). This taxon resembles *I. opaca* in general form except for the conspicuous spinose-dentate leaf margins and apical spine of the latter species. *Ilex cassine* var. *cassine* is variable in leaf shape, size, vestiture, and margins. It is readily separated from the var. *myrtifolia* by the characters given in the key. However var. *cassine* hybridizes with var. *myrtifolia* where the ranges overlap in Florida.


1


2


3

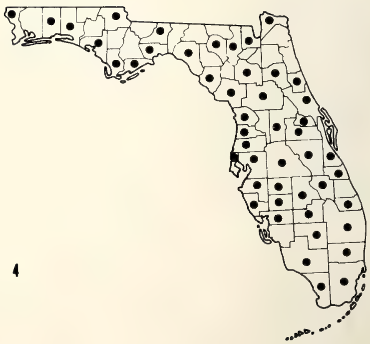

4

Fig. 1. Distribution of *Ilex ambigua* in Florida.
Fig. 2. Distribution of *Ilex ambigua* var. *monticola* in Florida.
Fig. 3. Distribution of *Ilex amelanchier* in Florida.
Fig. 4. Distribution of *Ilex cassine* var. *cassine* in Florida.

From the scatter diagram (Fig. 5) prepared from Florida specimens, it can be seen that the plants determined to be var. *cassine* and var. *myrtifolia* fall into two nearly discrete groups with the reputed hybrids falling between the two. The leaves of var. *cassine* have longer petioles and a somewhat lower length/width ratio than those of var. *myrtifolia*. The vestiture of var. *cassine* is of a longer type or occasionally absent while that of var. *myrtifolia* is shorter. The secondary branches of var. *cassine* have less than a 45° upper angle with the

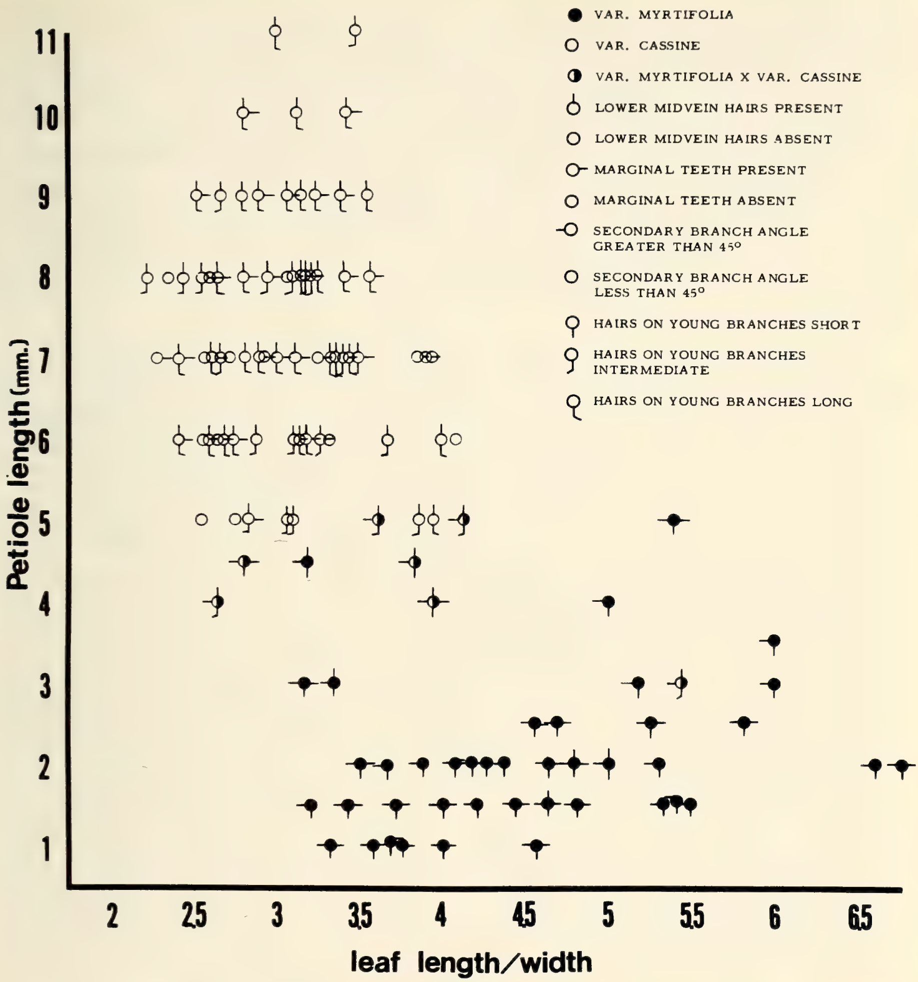


Fig. 5. Analysis of morphological variation of *Ilex cassine* var. *cassine* and var. *myrtifolia* in Florida.

main branches while in var. *myrtifolia*, the angle is greater than 45°. Variety *cassine* has hairs on the midvein on the lower leaf surface while var. *myrtifolia* does not. Exceptions to this are specimens of var. *cassine* which are glabrous on all parts. Finally, it can be seen that the presence or absence of marginal teeth on the leaves is not of taxonomic importance.

The reputed hybrids are intermediate between the two varieties in several characters. In Florida there is a proportionally small and reasonably well marked number of individuals because the varieties are sympatric only in the northern part of the state. However, in other southeastern states where both varieties are commonly encountered, hybridization is more frequent and a high degree of introgression occurs. In Florida, specimens determined as hybrids have been seen from Alachua, Calhoun, Escambia, Franklin, Gulf, Okaloosa, Santa Rosa, St. Johns, and Wakulla Counties.

Because separation of these taxa is based on vegetative characters and they apparently hybridize readily in nature, it is best to consider them as varieties of the same species. No difference in habitat for the two varieties could be ascertained, but rather both grow under very similar if not identical environmental conditions. The fruits of *I. cassine* var. *cassine* are usually red, but occasionally plants with orange or yellow fruits are found. Also, yellow-fruited specimens of var. *myrtifolia* and even of the hybrid have been seen. It does not appear to serve a useful purpose to recognize the yellow color forms in this species. *Ilex cassine* var. *cassine* is occasionally grown as an ornamental. Its evergreen leaves and bright red fruits are frequently used as Christmas decorations, hence the name Christmas Berry.

Ilex × *attenuata* Ashe is reported as a hybrid between *I. cassine* and *I. opaca*. It is reported from northwestern Florida, North Carolina, and South Carolina (Brizicky, 1964), but no specimens have been seen during this study. The few specimens seen and determined as *I.* × *attenuata* have been actually *I. cassine* var. *cassine* × var. *myrtifolia* or narrow leaved *I. cassine* var. *cassine*.

3b. Ilex cassine var. myrtifolia (Walt.) Sarg., Gard. & For. 2:16. 1889.

Ilex myrtifolia Walt., Fl. Carol. 241. 1788; *non* Lam., 1792.
Ilex rosmarinifolia Lam., Tab. Encyc. Meth. 1:346. 1792.
Ilex ligustrifolia G. Don, Gen. Syst. 2:19. 1832.
Ilex dahoon var. *myrtifolia* (Walt.) Chapm., Fl. SE U. S. 269. 1860.
Ilex myrtifolia f. *lowei* Blake, Rhodora 26:231. 1924.

This variety, commonly referred to as Myrtle Dahoon, Myrtle-leaved Holly, or simply Myrtle Holly, occurs from North Carolina south to Florida and west to southwest Texas. Its habitat preference appears to be the same as that of var. *cassine*. In Florida this taxon occurs in the northern counties (Fig. 6). The differences between this variety and var. *cassine* are discussed under the latter taxon. Occurrence of hybrids between these taxa has also been previously discussed and the reasons given why this taxon is best considered a variety of *I. cassine* following Radford, et al. (1964) and West and Arnold (1946) rather than as a distinct species as it has been treated by some authors (e.g., Kurz and Godfrey, 1962; Small, 1933; and Correll and Johnston, 1970).

The fruits of var. *myrtifolia* are usually red, but occasionally plants with orange or yellow (= *I. myrtifolia* var. *lowei*) fruits are found. Variety *myrtifolia* is occasionally found in cultivation as an ornamental plant.

4. Ilex coriacea (Pursh) Chapm., Fl. SE U. S. 270. 1860; *non* Alain, 1960.

Prinos lucidus Ait., Hort. Kew. 1:478. 1789.
Prinos coriaceus Pursh, Fl. Amer. Sept. 1:221. 1813; *non* Benth., 1840.
Prinos atomarius Nutt., Gen. Amer. 1:213. 1818.
Ennepta atomaria (Nutt.) Raf., Sylva Tellur. 52. 1838.
Ennepta coriacea (Pursh) Raf., Sylva Tellur. 52. 1838.
Ilex lucida (Ait.) Torr & Gray *ex* S. Wats., Bibl. Index N. Amer. Bot. 1:159. 1878; *non* Presl, 1844.

Shrub to 3 m; branches puberulent to glabrate. Leaves evergreen, elliptic to obovate, 3.5-7.0 cm long, 1.5-4.0 cm wide, acute to short acuminate at apex, broadly cuneate at base, margin crenate-serrate toward apex or entire, glabrous above, glabrous and with minute black punctations below, petiole 3-8 mm long. Inflorescences axillary, not pedunculate, pedicels 3-9 mm long, staminate flowers numerous, pistillate flowers 1-5. Fruits black, subglobose, 6-10 mm diam; pyrenes 4-8, endocarp bony, smooth.

Ilex coriacea, commonly referred to as Large Gallberry, Sweet Gallberry, or Bay-Gall Bush, occurs in flatwood depressions, edges of swamps, and low hammocks from Virginia south to central Florida and west to southeastern Texas. In Florida, it occurs from Polk County northward (Fig. 7). Toothed forms of this species may be confused with *I. glabra* or *I. cassine* var. *cassine* with which it may occasionally be found growing. It is, however, easily distinguished from these species by the presence of minute black punctations of the lower surface of its leaves.

5. ILEX DECIDUA Walt., Fl. Carol. 241. 1788.

Ilex prinoides Ait., Hort. Kew. 1:169. 1789.
Ilex aestivalis Lam., Encyc. 3:147. 1792.
Ilex tenuifolia Salisb., Prodr. 70. 1796.
Ilex prinonites Willd., Enum. Suppl. 8. 1809.
Prinos deciduus (Walt.) DC., Prodr. 2:16. 1825.
Prinos deciduus var. *aestivalis* (Lam.) DC., Prodr. 2:17. 1825.
Ilex decidua var. *curtissii* Fern., Bot. Gaz. 33:155. 1902.
Ilex curtissii (Fern.) Small, Man. SE U.S. 815. 1933.
Ilex cuthbertii Small, Man. SE U.S. 815. 1933.

Shrub or small tree to 10 m; branches glabrous or pubescent. Leaves deciduous, oblanceolate to spatulate, 2.5-8.0 cm long, 0.8-4.5 cm wide, obtuse to rounded at apex, cuneate at base, margins crenate, glabrous above, pubescent or glabrous below, petiole 2-10 mm long. Inflorescences axillary or at nodes below leaf axils, not pedunculate, pedicels 2-8 mm long, staminate and pistillate flowers 1-3. Fruits red, orange, or yellow, subglobose, 4-9 mm diam; pyrenes 4-8, endocarp bony, faintly furrowed on back.

Ilex decidua commonly called Possum Haw, Winterberry, or simply Deciduous Holly, occurs in upland alluvial woods and thickets from Maryland south to Florida and west to Kansas and Texas. In Florida it ranges south along the west coast to Desoto County (Fig. 8). It apparently is absent from the eastern side of the state. This species is easily recognized as it is the only native species of deciduous *Ilex* with leaves conspicuously crenate their length and which taper to a narrow cuneate base. *Ilex cuthbertii* and *I. curtissii* (= I. *decidua* var. *curtissii*) have been recognized by Small (1933) as distinct species, but in our opinion these are merely variations of *I. decidua* not worthy of taxonomic recognition. Orange- and yellow-fruited forms of this usually red-fruited species are known, but only red-fruited specimens have been seen from Florida. *Ilex decidua* is occasionally found in cultivation as an ornamental plant.

6. ILEX GLABRA (L.) Gray, Man. ed. 2. 264. 1856.

Prinos glaber L., Sp. Pl. 330. 1753.
Winterlia trifolia Moench., Meth. 74. 1794.
Ennerpta myricoides Raf., Sylva Tellur. 52. 1838.
Winterlia glabra (L.) K. Koch, Dendrol. 2(1):225. 1872.
Ilex glabra f. *leucocarpa* F. W. Woods, Rhodora 58:25. 1956.

Shrub to 4 m; branches puberulent. Leaves evergreen, obovate to elliptic, 2-5 cm long, 0.5-3.0 cm wide, acute to obtuse at apex, cuneate at base, margin remotely crenate-serrate in upper third, glabrous on both surfaces; petiole 3-8 mm long. Inflorescences axillary, peduncles 1-5 mm long, pedicels 1-5 mm long, staminate flowers 3-7, pistillate flowers 1-3. Fruits black or rarely white, subglobose, 4-8 mm in diam; pyrenes 4-8, endocarp bony, smooth.

Ilex glabra, commonly known as Inkberry, Bitter Gallberry, or simply Gallberry, occurs in low, mesic woods and pinelands from Maine south to Florida and west to Texas. It also extends into Canada to Nova Scotia. In Florida, it occurs throughout the state (Fig. 9). This species is distinguished from other evergreen *Ilex* species by glabrous leaves which are crenate only at the apex and its black fruits. It is occasionally confused with *I. coriacea*, but is distinguished from that species by its lack of minute black punctations on the lower surface of its leaves. An unusual white-fruited form (f. *leucocarpa*) is known to occur in Jackson County. This species is rarely found in cultivation as an ornamental. On one hand it is sometimes regarded as an undesirable plant in pine woods, but on the other it is considered to be an important honey source.

7. Ilex krugiana Loess., Engl. Bot. Jahrb. 15:317. 1892.

Shrub or small tree to 11 m; branches glabrous. Leaves evergreen, elliptic or ovate, 5-10 cm long, 3-5 cm wide, acuminate at apex, rounded to broadly cuneate at base, margin entire or rarely with a few serrate teeth, glabrous on both surfaces; petiole 0.5-2.0 cm long. Inflorescences axillary, not pedunculate, pedicels 5-8 mm long, staminate and pistillate flowers 1-3. Fruits black or purplish, subglobose, 4-7 mm; pyrenes 4-8, endocarp bony, furrowed on back.

This species, referred to as the Tawnyberry Holly, grows in hammocks and pinelands in south Florida, the Bahamas, and Hispaniola. Although unreported from Cuba, it is likely to be found there. It is one of the rarest Florida species of *Ilex*, being known only from Dade County (Fig. 10). It may also occur in Monroe County, but no specimens have been seen from there. *Ilex krugiana* is distinguished from other species of *Ilex* in south Florida by the combination of its black or purplish fruits and entire, elliptic or obovate leaves.

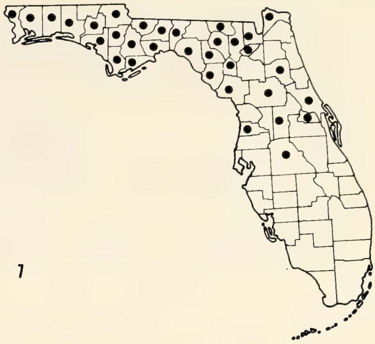
8. Ilex longipes Chapm. *ex* Trel., Trans. St. Louis Acad. Sci. 5:346. 1889.
Ilex decidua var. *longipes* (Chapm. *ex* Trel.) Ahles, J. Elisha Mitch. Sci. Soc. 80:173. 1964.

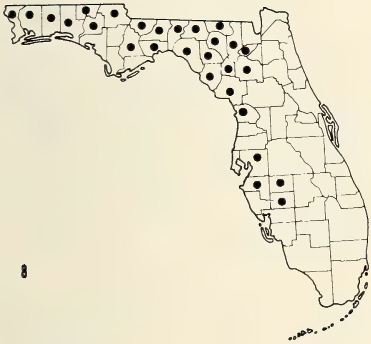
Shrub or small tree to 7 m; branches glabrous. Leaves deciduous, elliptic to obovate, 4-6 cm long, 2-3 cm wide, short acuminate to subobtuse at apex, broadly cuneate at base, margin serrulate, glabrous above, glabrous or short hirtellous below; petiole 3-10 mm long. Inflorescences axillary, not pedunculate, pedicels 1.0-2.3 (-3.0) cm long, staminate and pistillate flowers 1-3. Fruit red, subglobose, 5-8 mm diam; pyrenes 4, endocarp furrowed on back.

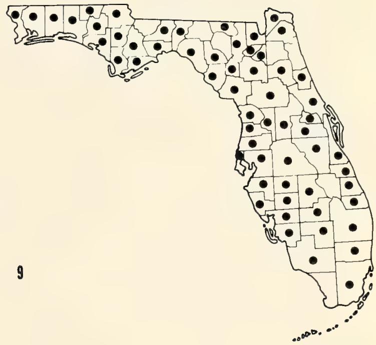
This species, referred to as the Georgia Holly or Chapman's Holly, occurs in upland woods and thickets from West Virginia south to Florida and west to Tennessee and Texas. In Florida it is found only in the panhandle region (Fig. 11). *Ilex longipes* is readily distinguished from the other Florida deciduous *Ilex* species, except *I. amelanchier*, by its long pedicels. It can be distinguished from *I. amelanchier* by its obscurely reticulate-veined lower leaf surfaces.

Some authors have confused *I. collina* Alex with *I. longipes* (see Clark, 1974). Clark's study revealed that *I. collina* is distinct from *I. longipes* and in fact it should be removed to the genus *Nemopanthes* (*N. collinus* (Alex.) Clark). Clark also referred *I. longipes* to synonymy under *I. decidua*. However, these latter two species differ in several characters and this alignment is considered untenable. Therefore, *I. longipes* is best considered as a distinct species. It appears to be more closely related to *I. verticillata* than to *I. decidua*.


6


7


8


9


10

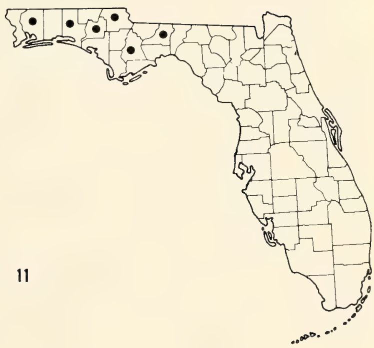

11

Fig. 6. Distribution of *Ilex cassine* var. *myrtifolia* (closed circle) and hybrid between var. *cassine* and var. *myrtifolia* (open circle) in Florida.

Fig. 7. Distribution of *Ilex coriacea* in Florida.

Fig. 8. Distribution of *Ilex decidua* in Florida.

Fig. 9. Distribution of *Ilex glabra* in Florida.

Fig. 10. Distribution of *Ilex krugiana* in Florida.

Fig. 11. Distribution of *Ilex longipes* in Florida.

9. Ilex opaca Ait., Hort. Kew. 1:169. 1789.

Shrub or small tree up to 15 m; branches pubescent to glabrate. Leaves deciduous, ovate, elliptic, to oblanceolate, 3.5-10.0 cm long, 1.5-5.0 cm wide, tipped with stout spine 1 mm long or more at apex, rounded to cuneate at base, margin sinuate-dentate with teeth ending in a stout spine or entire, revolute, glabrate above, sparsely short hirtellous on midvein to glabrate below; petiole about 5 mm long. Inflorescences axillary, peduncle 3-5 mm long, pedicels 3-5 mm long, staminate flowers 3-10, pistillate flowers 1-3. Fruits red, orange, or yellow, subglobose, 7-12 mm diam; pyrenes 4, endocarp bony, irregularly furrowed on back.

Key to Infraspecific Taxa

1. Trees; leaves dark green, 3.5-5.5 cm wide, margins flat or only slightly revolute; mesic woods .... 9a. var. *opaca*
1. Compact shrubs or occasionally small trees; leaves 1.0-2.5 cm wide, margins distinctly revolute; white sand scrub .... 9b. var. *arenicola*

9a. Ilex opaca Ait. var. opaca

Ilex laxiflora Lam., Encycl. 3:147. 1789.
Ilex quercifolia Meerb., Icon. Sel. 2:1798.
Ilex opaca var. *laxiflora* (Lam.) Nutt., Gen. N. Amer. Pl. 1:109. 1818.
Ageria opaca (Ait.) Raf., Sylva Tellur. 27. 1838.
Ilex opaca var. *integra* Wood, Amer. Bot. Flor. 207. 1870.
Ilex opaca var. *acuminata* Beissn. *in* Beissn., Schelle, & Zab., Handb. Laubh. Benen. 290. 1903.
Ilex opaca var. *globosa* Beissn. *in* Beissn., Schelle, & Zab., Handb. Laubh. Benen. 290. 1903.
Ilex opaca var. *latifolia* Beissn. *in* Beissn., Schelle, & Zab., Handb. Laubh. Benen. 290. 1903.
Ilex opaca var. *macrodon* Beissn. *in* Beissn., Schelle, & Zab., Handb. Laubh. Benen. 290. 1903.
Ilex opaca vr. *floribunda* Demck., Mitt. Deutsch. Dendr. Ges. 1904: 155. 1904.
Ilex opaca f. *xanthocarpa* Rehder, Mitt. Deutsch. Dendr. Ges. 1907:73. 1907
Ilex opaca f. *subintegra* Weatherby, Rhodora 23:119. 1921.
Ilex opaca var. *subintegra* Rehder, Man. Cult. Trees Shrubs 543. 1927.

The American Holly occurs in mesic woodlands from Massachusetts south to Florida and west to Oklahoma and Texas. In Florida it occurs south to Hillsborough County (Fig. 12). *Ilex opaca* is easily distinguished from other Florida evergreen *Ilex* species by its spinose-dentate leaves. Entire leaf forms can be distinguished from the similar *I. cassine* by the presence of a conspicuous apical spine over 1 mm long on *I. opaca*. Variety *opaca* is differentiated from var. *arenicola* by its habit, vegetative morphology, and its habitat as given in the above key. *Ilex opaca* var. *opaca* is a highly variable taxon for which numerous infraspecific taxa have been proposed, most of which are probably not worthy of taxonomic recognition. Two commonly recognized forms which are known to occur in Florida are the yellow-fruited form (f. *xanthocarpa*) and the form with leaves entire or nearly so (f. *subintegra*). These are not formally recognized in this treatment. *Ilex opaca* is commonly cultivated as an ornamental tree in eastern North America and Europe. Its foliage and bright red fruits are commonly used as Christmas decorations while its creamy white wood is occasionally used for decorative work.

9b. Ilex opaca var. arenicola (Ashe) Ashe, Charleston Mus. Quart. 1(2):31. 1925.

Ilex arenicola Ashe, J. Elisha Mitch. Sci. Soc. 40:44. 1924.
Ilex cumuliocola Small, Bull. Torr. Bot. Club 51:382. 1924.
Ilex pygmaea McFarlin, Rhodora 34:17. 1932.
Ilex arenicola f. *sebringensis* McFarlin, Rhodora 34:18. 1932.
Ilex arenicola f. *oblanceolata* McFarlin, Rhodora 34:234. 1932.
Ilex arenicola var. *obovata* McFarlin, Rhodora 34:234. 1932.
Ilex arenicola var. *paucidens* McFarlin, Rhodora 34:235. 1932.
Ilex pygmaea var. *subedentata* McFarlin, Rhodora 34:235. 1932.
Ilex arenicola var. *transiens* McFarlin, Rhodora 34:235. 1932.

Ilex opaca var. *arenicola,* referred to as Hummock Holly or Scrub Holly, is endemic to the white sand scrublands of central Florida (Fig. 13). This taxon was originally proposed as a species by Ashe, but later reduced to a variety of *I. opaca.* The flowers and fruits of var. *arenicola* are the identical to those of var. *opaca.* It is differentiated from var. *opaca* by its habit, vegetative morphology, and its habitat as given in the above key. McFarlin (1932a, 1932b) described *I. pygmae* with one segregate variety and five infraspecific taxa of *I. arenicola* which are all best considered synonymous with the variable *I. opaca* var. *arenicola.*

10. ILEX VERTICILLATA (L.) Gray, Man. Bot. ed. 2. 264. 1856.

Prinos verticillata L., Sp. Pl. 330. 1753.
Prinos confertus Moench., Meth. 481. 1794.
Prinos gronovii Michx., Fl. Bor. Amer. 2:236. 1803.
Prinos padifolius Willd., Enum. Hort. Berol. 394. 1809.
Prinos prunifolius Desf., Tabl. ed. 2. 272. 1815.
Prinos verticillatus var. *tenuifolius* Torr., Fl. N. Mid. U. S. 338. 1824.
Ilex verticillata var. *padifolia* (Willd.) Torr. & Gray *ex* S. Wats., Bibl. Index N. Amer. Bot. 1:160. 1878.
Ilex verticillata var. *tenuifolia* (Torr.) S. Wats., Bibl. Index N. Amer. Bot. 1:160. 1878.
Ilex verticillata var. *cyclophylla* Robins., Rhodora 2:105. 1900.
Ilex verticillata f. *chrysocarpa* Robins., Rhodora 2:106. 1900.
Ilex verticillata f. *fructuosa* Loess., Nova Acta Acad. Caes. Leop.-Carol. Germ. Nat. Cur. 78:473. 1901.
Ilex bronxensis Britt., Man. Fl. N. St. Can. 604. 1901.
Ilex fastigiata Bickn., Bull. Torr. Bot. Club 39:426. 1912.
Ilex verticillata var. *fastigiata* (Bickn.) Fern., Rhodora 23:274. 1922.
Ilex verticillata var. *aurantiaca* Moldenke, Rev. Sudam. Bot. 6:39. 1939.
Ilex verticillata f. *aurantiaca* (Moldenke) Rehd., Bibl. Cult. Trees Shrubs 403. 1949.
Ilex verticillata f. *hodgdonii* Seymour, Fl. New Engl. 377. 1969.

Shrub to 5 m; branches pubescent or glabrous. Leaves deciduous, elliptic to obovate, 4-10 cm long, 1.5-5.0 cm wide, acuminate at apex, broadly cuneate at base, margin crenate-serrate, glabrous above, pubescent or glabrous below; petiole 7-17 mm long. Inflorescences axillary, rarely from nodes below leaves, peduncles 1-5 mm long, pedicels 1-5 mm long, staminate flowers 3-numerous, pistillate flowers 1-3. Fruits red, orange or yellow, subglobose, 5-7 mm diam; pyrenes 5-10, endocarp soft, smooth.

Ilex verticillata, called Black Alder or Common Winterberry, occurs in low woods, thickets, and along edges of swamps from Maine south to Florida and west to Minnesota and eastern Texas. It extends into Canada to Newfoundland. It is rare in Florida, occurring in the western panhandle region (Fig. 14). *Ilex verticillata* is similar to *I. ambigua,* but differs in having smooth seeds and pedunculate flowers. This species is highly variable with several named varieties recognized by some authors. These varieties are in our opinion best treated as synonyms since intergradations are common. The fruits of *I. verticillata* are usually red, but occasionally plants with orange (f. *aurantiaca*) and yellow (f. *chrysocarpa*) fruits are found. This species is occasionally found in cultivation as an ornamental plant.

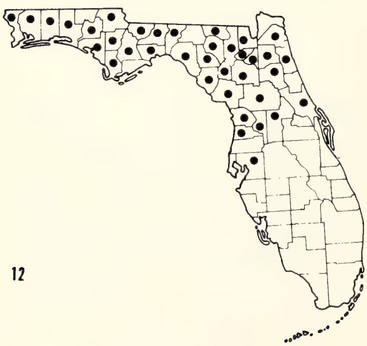
11. ILEX VOMITORIA Ait., Hort. Kew. 1:170. 1789.

Ilex cassine var. *β* L., Sp. Pl. 125. 1753.
Cassine paragua Mill., Gard. Dict. 8. 1768.
Ilex cassine Walt., Fl. Carol. 241. 1788; *non* L., 1753.
Ilex cassena Michx., Fl. Bor.-Amer. 2:229. 1803.

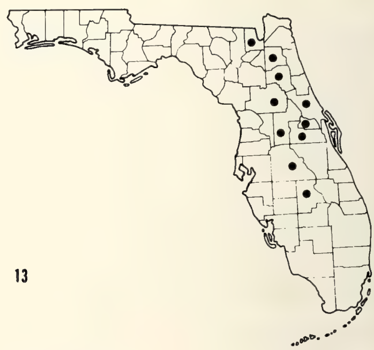
Shrub or small tree to 8 m; branches pubescent. Leaves evergreen, oval to elliptic, 1.0-4.5 cm long, 0.8-2.0 cm wide, obtuse at apex, broadly cuneate at base, margin crenate, revolute, glabrous above, sparsely pubescent to glabrate below; petiole 1-3 mm long. Inflorescences axillary, peduncles up to 3 mm long, pedicels 1-3 mm long, staminate flowers 4-10, short pedunculate, pistillate flowers 1-3, subsessile. Fruits red, subglobose, 5-7 mm diam; pyrenes 4, endocarp bony, furrowed on back.

Ilex vomitoria, commonly referred to as Yaupon, occurs in and around the edge of sandy, upland and maritime woods from Virginia south to Florida and west to Arkansas and Texas. It has been introduced and is now naturalized in Bermuda. It also occurs disjunctly in Chiapas and Veracruz, Mexico (var. *chiapensis* Sharp). In Florida it occurs south to Sarasota County (Fig. 15). This species is one of the easiest recognized as it is the only native evergreen holly with crenate margins their entire length.

The leaves of *Ilex vomitoria* contain a caffeine. Reports of southern Indians using an infusion of the leaves of this species as a ceremonial drink is frequent in the early literature of the southeast coastal areas. Alston and Schultes (1951) give an excellent historical and documented account of this use. Horticulturally this species is commonly grown as an evergreen hedge, being well adapted to severe trimming. The branches with bright red fruits are also occasionally used as Christmas decorations.

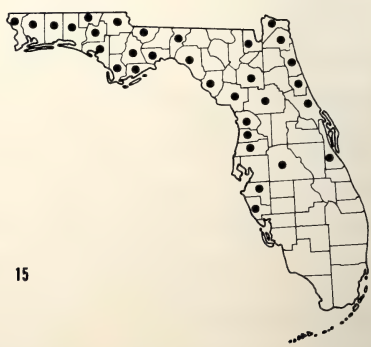


12



13

14



15

Fig. 12. Distribution of *Ilex opaca* var. *opaca* in Florida.

Fig. 13. Distribution of *Ilex opaca* var. *arenicola* in Florida.

Fig. 14. Distribution of *Ilex verticillata* in Florida.

Fig. 15. Distribution of *Ilex vomitoria* in Florida.

ACKNOWLEDGMENTS—Daniel B. Ward, University of Florida, and Loran C. Anderson, Florida State University, Curators, are gratefully acknowledged for loan of herbarium specimens for this study. Appreciation is expressed to Ms. Betty Loraamm for photographic assistance. This work was supported in part by the George R. Cooley Botanical Research Fund, University of South Florida.

LITERATURE CITED

ALSTON, A. H. G. AND R. E. SCHULTES. 1951. Studies of early specimen reports of *Ilex vomitoria*. Rhodora 53:372-379.

BRIZICKY, G. K. 1964. The genera of the Celastrales in the southeastern United States. J. Arnold Arb. 45:206-23.

CLARK, R. C. 1974. *Ilex collina*, a second species of *Nemopanthes* in the southern Appalachians. J. Arnold Arb. 55:435-440.

CORRELL, D. S. AND M. C. JOHNSTON. 1970. Manual of the Vascular Plants of Texas. Texas Research Foundation. Renner.

FERNALD, M. L. 1950. Gray's Manual of Botany. ed. 8. American Book Company. New York.

GLEASON, H. A. 1952. The New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada. 3 vol. New York Botanical Garden. New York.

HU, S. Y. 1949. The genus *Ilex* in China. J. Arnold Arb. 30:233-344, 348-387.

__________ . 1950. The genus *Ilex* in China (continued). J. Arnold Arb. 31:39-80, 214-263.

KURZ, H. AND R. K. GODFREY. 1962. Trees of Northern Florida. Univ. Florida Press. Gainesville.

LINNAEUS, C. 1753. Species Plantarum. Stockholm.

LOESSNER, T. 1942. Aquifoliaceae. Engler U. Prantl Nat. Pflanzenfam. ed. 2. 20b:36-86.

LONG, R. W. AND O. LAKELA. 1976. A Flora of Tropical Florida. 2nd ed. Banyan Books. Miami.

MCFARLIN, J. B. 1932a. Two new evergreen hollies from central Florida. Rhodora 34:16-18.

__________. 1932b. Hollies from central Florida. Rhodora 34:232-236.

RADFORD, A. E., H. E. AHLES AND C. R. BELL. 1964. Manual of the Vascular Flora of the Carolinas. Univ. North Carolina Press. Chapel Hill.

SMALL, J. K. 1933. Manual of the Southeastern Flora. Publ. Author. New York.

WEST, E. AND L. E. ARNOLD. 1946. The Native Trees of Florida. Univ. Florida Press. Gainesville.

Florida Sci. 40(1):7-21. 1977.

ADDITIONS TO THE ACADEMY LIBRARY—In order to assure that publications which are difficult to obtain, especially technical reports for agencies and such things, we urge authors of papers citing such items to deposit copies with the Academy. These copies may be examined in the Academy headquarters or copies will be provided to members at cost if so requested. Members are urged to send comparable items which they prepare to enhance our coverage of knowledge in the state. All will be listed in these pages as received.

Anclote Environmental Project Annual Report, 1970. Marine Science Institute, University of South Florida, St. Petersburg.

Anclote Environmental Project Annual Report, 1971. Marine Science Institute, University of South Florida, St. Petersburg.

Anclote Environmental Project Annual Report, 1972. Marine Science Institute, University of South Florida, St. Petersburg.

Anclote Environmental Project Annual Report, 1973. Marine Science Institute, University of South Florida, St. Petersburg.

Anclote Environmental Project Annual Report, 1974. Marine Science Institute, University of South Florida, St. Petersburg.

Collected Reprints, Volume 8. 1968-71. University of Georgia Marine Institute. Sapelo Island.

Collected Reprints, Volume 9. 1971-74. University of Georgia Marine Institute. Sapelo Island.

Biological Sciences

EVALUATION OF COLORED FLOY ANCHOR TAGS ON WHITE SHRIMP, *PENAEUS SETIFERUS*, TAGGED IN CAPE FEAR RIVER, NORTH CAROLINA 1973-1975

Frank J. Schwartz

Institute of Marine Sciences, University of North Carolina, Morehead City, North Carolina 28557

Abstract: *Variously colored Floy anchor tags were applied to 30,510 adult white shrimp,* Penaeus setiferus, *from the Cape Fear River, North Carolina, to note shrimp movements and distances traveled, and the feasibility, physical effects, color bias, and retention of the tags. Movements were southerly for 575 km to near Jekyll Island, Georgia, during late fall and winter. The tags caused no physical damage or impediment to the shrimp's swimming or burrowing ability; color did not bias the tag returns. Tag retention observations were conducted in the field as well as with aquarium held shrimp. Tag retention was as long as 7 mo and through 2 molts.*

Penaeid shrimps were first tagged in 1934 with Peterson disk tags (Lindner and Anderson, 1956). Since then Atkins (Ruello, 1975), toggle (Penn, 1975), and internal tags (Walker et al., 1975), fluorescene pigments (Klima, 1965), dyes (Dawson, 1957), or combinations of these tags have been used to mark shrimp or prawns in the United States or other countries (Penn, 1975). However, each type of tag presented disadvantages to their use, either by impairing swimming or the burrowing ability of the shrimp (Iverson and Jones, 1961; Lucas et al., 1972), causing physical damage, ulceration, or shedding during subsequent molting. Bearden and McKenzie (1972) were the first to explore the use of the Floy FD-67 anchor tag on white shrimp, *Penaeus setiferus*. Although subject to some of the above problems, they concluded that the anchor tag held promise as a shrimp tag, yet too few shrimp had been tagged to test tag adequacy.

The need for a simple, rapidly applied, and light-weight tag to mark white shrimp induced me to choose the Floy FD-67 anchor tag. Also, the anchor tag in many colors was available and each tag could be serially numbered or coded along with a printed return address reward notice.

Sampling and Tagging Methods—From September 1973 through November 1975, 30,510 white shrimp were tagged in the lower 15 mi (24 km) of the Cape Fear River and adjacent Atlantic Ocean off Oak Island, North Carolina. White shrimp, *Penaeus setiferus* were captured at a variety of localities (Fig. 1) and habitats within this geographic area with 25 (7.6 m) and 40 ft (12.2 m) semi-balloon otter trawls. Tows were of 15 (river) or 30 min (ocean) duration at speeds of 1.5 km/hr with cable/depth ratios of 3:1. A tickler chain preceded each net to help stir up the bottom and shrimp. Immediately after removal from the nets, all shrimp 90-200 mm TL were placed in washtubs filled with river or ocean water from the capture locality.

Tagging proceeded yr-round with the greater number of shrimp tagged during summer or fall months (Table 1). Release of each tagged shrimp was almost immediate depending on how bothersome sea gull predation was on the tagged shrimp thrown overboard. On such occasions, prior to release, the tagged

Fig. 1. Shrimp tagging sites (stars and shaded area) within the Cape Fear River and adjacent Carolina Beach Inlet and Atlantic Ocean area of North Carolina.

shrimp were held less than 15 min until a sizable number were tagged and we outmaneuvered the gulls. Tagging of adult white shrimp (90-to 200-mm TL) proceeded as rapidly as each individual man could insert a tag through the abdominal segments midway between the ventral blood vessel and intestine. On large specimens the tag was inserted nearer the telson than on smaller specimens and did not physically damage the specimen. Upon insertion the lightweight tag projected horizontally perpendicular to the axis of the shrimp's body (Fig. 2). This tag position (Fig. 3) had little apparent effect on their swimming or balancing ability for, upon release the shrimp would readily swim off.

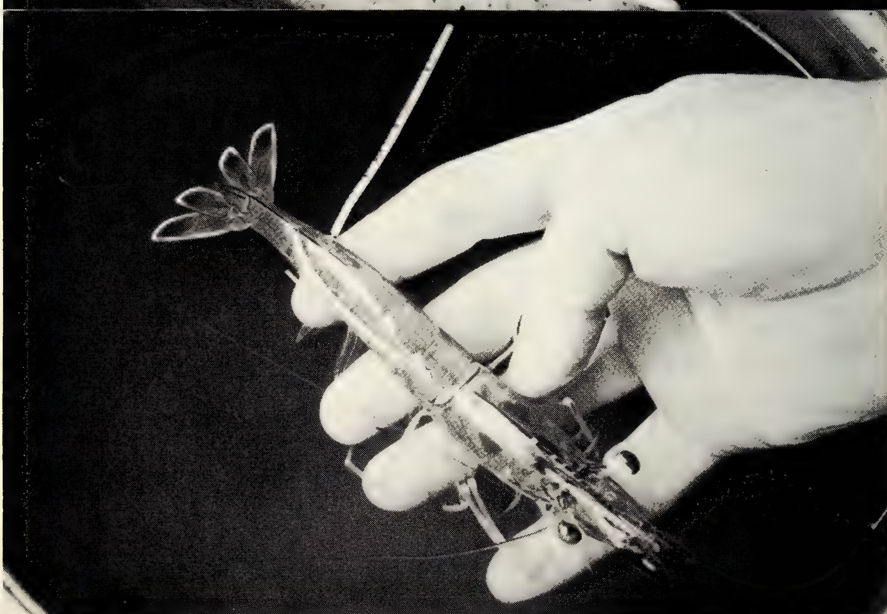


Fig. 2. Tagged white shrimp with Floy anchor tag, dorsal and ventral aspect views.

Fig. 3. Tagged white shrimp prior to release overboard or into temporary holding tank. Note return address and number.

TAG RETURNS: To encourage tag return, a small monetary reward was offered for information on date and place of capture. This return data, compared with the original release data, permitted an improved way of following seasonal movements and individual days at liberty throughout all seasons of the year.

Yellow, red, white, orange, and blue tags were used on a rotating basis during the tagging period. Each color tag was used in lots of 1-2,000 and then changed with the next numbering and color sequence. This prevented use of the same color during spring or fall tagging sessions. Disadvantages of this procedure were that the tag return data (Table 1) may be slightly distorted in that little or no fishing existed for shrimp during the first half of each tag yr. Likewise, the date a color tag was applied in the fall could influence the rate of return for tags of a specific color. For instance, tagged shrimp released in September were subject to fishing pressure for a longer period of time, before the waters cooled or the fishing stopped, than those tagged in October or November.

Red tags were originally believed to be either too dark to be noticed by the fisherman or would resemble the red beard sponge *Microcionia prolifera*; hence, they were discontinued after applying 1,000 to the shrimp tagged in the fall of 1973. Also, reports by South Carolinian fishermen, who caught migrating shrimp tagged in the fall with yellow tags, resembling the sponge *Clionia*, prompted an examination of the tag returns from all areas to see if there were apparent color biases in the returns.

RESULTS—Of the 30,510 shrimp tagged between September 1973 and December 1975, 1,226 have been recaptured as of 1 March 1976 (Table 1). While as many of one color as another were returned by North and South Carolinian fishermen, only the analysis of the fall 1974 and 1975 data is discussed, although the overall results statistically are the same if all seasons are tested.

Analyzing the proportion of the tag returns to tags released for each color in fall 1974 and 1975 with an analysis of variance or chi square test, I found no significant difference in the rate at which each color was returned (Table 1). The variability between color during each season (Table 1) may stem from aspects mentioned above, the color sequence, or some factors yet unaccountable within the fishery. These observations agreed with similar color tests by Penn who applied toggle (a modified Floy) tags to King prawns *Penaeus latisculatus* in Australia.

Aquarium tests in 33,000 gal (124,905 1) outdoor tanks revealed that shrimp retained the Floy anchor tag through as many as two molts before being shed. Contrary to Bearden and McKenzie's observations, little ulceration or infection was experienced by shrimp released into these tanks or by those captured in the field months after release. Our tank tested shrimp experienced a 1% mortality of all sizes between 90 and 200 mm as opposed to the 25% initial mortality experienced in adult Australian prawns (Lucas et al., 1972). Our tank and field tagged shrimp held the Floy tag at least 7 mo. Over-crowding or prolonged retention of shrimp on board can increase handling mortality during the June-July tagging seasons. Shrimp tagged between September and November survived tagging best and yielded the most interesting survival and movement data.

TABLE 1. Number of white shrimp tagged and recaptured between September 1973 and November 1975 with five colors of Floy anchor FD-67 tags. Statistical analyses apply only to fall 1974 and 1975 comparisons, in italics.

SEASON/YR	COLOR					TOTAL
	Yellow	Red	White	Orange	Blue	
1973						
Fall	82/2,000	44/1,000				126/3,000
1974						
Spring			6/670			6/670
Fall	*191/3,000*		*203/3,330*	*80/3,000*	*23/566*	497/9,896
1975						
Spring					14/1,061	14/1,061
Fall	*58/3,000*		*58/3,510*	*291/6,000*	*176/3,373*	583/15,883
TOTALS	331/8,000	44/1,000	267/10,510	371/9,000	213/4,990	1,226/30,510

ANALYSIS OF VARIANCE

	d.f.	sum sq.	mean sq.	
Total	7	.00092		
Years	1	.00038	.00038	f = 4.22 n.s.
Error	6	.00054	.00009	

White shrimp released in the lower Cape Fear River, while subject to an intense commercial and sport fall fishery, moved out of the estuary as waters cooled in the fall. By early December, returns were received from Myrtle Beach, S. C. and by late December shrimp movement seemed to extend southward to the Charleston, S. C. harbor area. By late January, Cape Fear white shrimp had been recaptured just south of Jekyll Island, Ga., about 575 km away. These southerly movements agree with findings of McCoy (1968) for pink and brown shrimp from Pamlico Sound, N. C. and Bearden and McKenzie who released white shrimp caught in Charleston Harbor. The latter moved southward to St. Augustine, Florida. Cape Fear shrimp recapture returns fell just short of the 580 km movements reported for Gulf Coast white shrimp (Lindner and Anderson, 1956) or the 930 km northerly movement of *P. plebejus* off Australia (Ruello, 1975).

CONCLUSIONS—I recommend the Floy anchor tag as a rapid, light-weight means to mass tag and identify white shrimp populations, movements, and individuals. Mortality or damage induced by the tag to adult shrimp is slight. A variety of colors permit specific locality, tag retention, distance traveled, days at liberty, information to be obtained without fear that one color may be more visible than another, thereby distorting the return data. Tag retention is at least 7 mo and the tags apparently do not incumber the white shrimp.

ACKNOWLEDGMENTS—C. Bearden and C. Farmer, South Carolina Wildlife and Marine Resources Department, Charleston, S. C., D. Cargo, Chesapeake Biological Laboratory, Solomons, Md., and Dr. A. B. Williams, Systematics Laboratory, National Marine Fisheries Service, Washington, D. C. reviewed the manuscript. Dr. W. Hogarth, K. MacPherson, and Chris Benedict, CPL, Raleigh, N. C., supplied shrimp returns from the screens of the Brunswick Steam Electric Plant located near Southport, N. C. Funding of the study was by Carolina Power and Light Co., Raleigh, N. C. Dr. D. Hayne, North Carolina State University, Raleigh, N. C. commented on the statistical aspects of the results. G. W. Link assisted with the return tabulations. The shrimp fleets and fishermen of North and South Carolina enthusiastically provided the bulk of the recaptures.

LITERATURE CITED

BEARDEN, C. M., AND M. D. MCKENZIE. 1972. Results of pilot shrimp tagging project using internal anchor tags. Trans. Amer. Fish. Soc. 101:358-362.

DAWSON, C. E. 1957. Studies on the marking of commercial shrimp during marking experiments. U. S. Fish Wildl. Serv. Fish. Bull. 69:247-251.

KLIMA, E. F. 1965. Evaluation of biological stains, inks, and fluorescent projects as marks for shrimp. U. S. Fish Wildl. Serv. Spec. Sci. Rept. Fish. 511:8 p.

IVERSON, E. S., AND A. C JONES. 1961. Growth and migration of the Tortugos pink shrimp *Penaeus duorarum* and changes per unit of effort of the fishery. Florida St. Bd. Cons. Tech. Ser. 34.

LINDNER, M., AND W. S. ANDERSON. 1956. Growth, migration, spawning, and size distribution of shrimp, *Penaeus setiferus*. Fish. Bull. 56:555-645.

LUCAS, C., P. C. YOUNG AND J. K. BRUNDRITT. 1972. Preliminary mortality rates of marked king prawns in laboratory tanks. Australian J. Mar. Freshwater Res. 23:143-149.

MCCOY, E. G. 1968. Migration, growth, and mortality of North Carolina pink and brown Penaeid shrimp. N. C. Div. Comm. Sport Fish. Spec. Sci. Rept. 15:26 p.

PENN, J. W. 1975. Tagging experiments with western King prawn *Penaeus latisculatus* Kishenocye. 1. Survival, growth, and reproduction of tagged prawns. Australian J. Mar. Freshwater Res. 26:197-211.

RUELLO, N. V. 1975. Geographical distribution, growth, and breeding migration of the eastern Australian King prawn *Penaeus plebejus* Hess. Australian J. Mar. Freshwater Res. 26:343-354.

WALKER, B. D., S. H. CLARK, C. T. FONTAINE AND R. C. BENTON. 1975. A comparison of Peterson tags and biological stains used with internal tags as marks for shrimp. Gulf Res. Rept. 5:1-5.

Florida Sci. 40(1):22-27. 1977.

Social Sciences

THE INFLUENCE OF INCORPORATED SYMBOLISM UPON YOUTH VALUE SELECTIVITY

John E. Hodgin

Department of Sociology, Florida Technological University, Orlando, Florida 32816.

Abstract: *Similarity of mother-youth beliefs was compared to the relationship of similarity to youth's feelings of self-estrangement. For 369 mother—youth pairs we attempted to operationalize Cooley's looking-glass model. Data suggest that mother is an historical "mirror" image that influences youth's perception of self and some abstractions that Cooley hypothesized in his model tend to be substantiated.*

Interpretation of the structure of self was described by Cooley (1902) as an evolutionary social process of individual "imaginings" integrated into reality segments. These abstractions were, to Cooley, "the locus of society." In other words, Cooley's self emerged as a social reality through a system of subtle choices based upon: 1) one's imagination of how he appears to another person; 2) one's imagination of how that other person judges his apearance; and 3) "some sort of self-feeling such as pride or mortification." These feelings are the result of abstract imagery that has been communicated through socialization. Thus, an impression of transmitted images between mother and child would provide indicators for Cooley's third criterion.

All three elements of the "looking glass" model present areas for inquiry by social investigators seeking empirical evidence to test this theoretical system. But for the purposes of this study observations were limited to only one aspect (mother-child relations) of the total socialization system. It is unfortunate that Cooley limited himself to intuitive observations of "some imagination" alone. His observations, although theoretically acceptable, do not present valid evidence that his system is functional.

Apparently, Cooley had little concern with the time element of the stages of evolution involved in self-perception (Timasheff, 1965). This lack of specific identification of the historical stages of self formation as a part of the functioning whole presents a weakness in the "looking glass" model that is responsive to empirical testing. Research in this area tends to offer Cooley's model the refinement it needs and deserves (Miyamoto and Dornbusch, 1956; Reeder et al., 1960; Quarantelli and Cooper, 1966). My research focused upon the development of the self (particularly upon beliefs and feelings of estrangement) as a social process that incorporates the historical event (a mother's influence) upon all three elements of Cooley's "looking glass self" while disregarding the other elements of the socialization system. The Cooley model clearly accepts the premise of an imagined "other", and it is thought that the socializing process by such a significant "other" becomes a subset of norms and values (symbols) to which the child refers in his own definition of himself. A consideration of the possible effect of such transmitted symbols upon self-perception could add to the substance of Cooley's theory.

METHODOLOGY—Responses to questionnaires distributed to 384 university students and their mothers provide basic data. The sample was drawn from undergraduate classes of not more than 25 students in engineering, education, psychology, sociology, geography, and business. The questionnaire was administered to these students after the Thanksgiving holiday weekend, and mailed before the following weekend to the mothers using their names and addresses as drawn from the students' questionnaires. Of the sample, 369 (96.3%) of the mothers returned the questionnaires, resulting in 369 student-mother pairs for analysis. Each student responded to a Self-estrangement Scale (Bonjean and Grimes, 1970) and to 48 attitude statements according to conventional 5-point Likert agree-disagree continua. After finishing his response to the 48 items, each student was then asked to respond to the same statements in the way he thought his mother would. The mothers were asked to follow the same procedure, i.e., to fill out the schedule according to her opinions and then to respond in the way she thought her youth would. Included with each questionnaire was the request that there be no collaboration, and telephone spot checks were carried out through the week to determine how many had discussed the questionnaires. We were unable to discover any instances of collaboration between or among the mother-youth pairs.

The attitude statements were constructed in four areas of beliefs somewhat reflective of both Murdock's (1949) four "universal" functions and those family functions listed by Bell and Vogel (1968). The four areas used in this study were: 1) sexuality; 2) child socialization; 3) sense of community; and 4) economics. Twelve items were constructed for each area. This schedule is available upon request from the author. Representative items concerning sexuality were "people who engage in sex before marriage are likely to make better marriage partners" and "it is perfectly all right for a woman to be aggressive in sex and to enjoy it". Items concerning child socialization included "it is desirable for parents to select playmates for their children" and "permissive parents produce spoiled, unruly children." A typical item of the sense of community scale was "if a person has good friends, he doesn't need kinfolks." And finally, the economics area was researched with such items as "a person should spend all that he has and a little more too."

In order to index the extent of the relationship among the variables described, all variables were dichotomized at the median and constructed into 2 × 2 contingency tables to reveal the extent to which each youth correctly predicted his mother's responses, the extent to which each youth *thought* that his mother's responses would be the same as his own, and the extent to which each youth and his mother's responses were exactly the same.

RESULTS—We first examined the relationship to other variables of each youth's ability to predict his mother's responses (Table 1). The greater the ability of the youth to predict his mother's responses, the greater was the tendency to think that his mother held the same beliefs as he did, i.e., 63.6% of the youths who predicted their mother's responses more than 50% of the time thought that their mother's beliefs were more similar to their own, while only 38.2% of the

TABLE 1. Relationship of youth's ability to predict mothers' responses with three selected variables.

Variables	Youth's Prediction of Mother's Responses			
	More often than avg		Less often than avg	
	Number (N = 165)	Percentage	Number (N = 204)	Percentage
Youth think Mother's Beliefs Match Theirs				
More than 50% of time	105	63.6	78	38.2
Less than 50% of time	60	36.4	126	61.8
$\chi^2 = 23.51$	df = 1	$p < .05$	Q = .48	
Mothers Predict Youth's Beliefs				
More than avg	106	64.2	77	37.8
Less than avg	59	35.8	127	62.3
$\chi^2 = 25.57$	df = 1	$p < .05$	Q = .50	
Youth's and Mother's Beliefs Actually Match				
More than avg	119	72.1	66	32.3
Less than avg	46	27.9	138	67.7
$\chi^2 = 57.67$	df = 1	$p < .05$	Q = .69	

youths who predicted their mother's responses less than 50% of the time thought that their mother's beliefs were similar to their own. This relationship was significant beyond the .05 level and of moderate strength ($\chi^2 = 23.51$, Q = .48).

The relationship between the youths' abilities to predict their mother's responses and the mothers' abilities to predict their youth's responses was similar ($\chi^2 = 25.57$, Q = .50). The strongest relationship, however, was between the youths' abilities to predict their mother's responses and the tendency for these youths to hold the same beliefs as their mothers. We found that 72.1% of the youths who predicted their mother's responses more than 50% of the time tended to hold the same beliefs as their mothers; but only 32.3% of the youths who predicted their mother's responses less than 50% of the time held similar beliefs.

The ability of each youth to predict his mother's responses, the youth's tendency to think his mother's responses would be the same as his own, and the tendency for youths and mothers to hold the same beliefs were all significantly and negatively related to youths' feelings of self-estrangement (Table 2). In all three cases, the greater the ability of prediction or agreement between youth and mother, the less the youth's estrangement from self. The strongest relationship was between self-estrangement and the tendency for youth and mother to hold the same beliefs, with 42.2% of the youths who held more similar beliefs to their

TABLE 2. Relationship of self-estrangement with three selected variables.

	Variables			
	Youth's Predictions of Mother's Responses			
	More often than avg		Less often than avg	
	Number (N=165)	Percentage	Number (N=204)	Percentage
Self-estrangement				
More than avg	73	44.2	113	55.4
Less than avg	92	55.8	91	44.6
$\chi^2=4.66$	df=1	p<.05	Q=-0.22	
	Youth Think Mothers' Beliefs Match Theirs			
Self-estrangement	More often than avg (N=183)		Less often than avg (N=186)	
More than avg	80	43.7	106	57.0
Less than avg	103	56.3	80	43.0
$\chi^2=6.49$	df=1	p<.05	Q=-0.26	
	Youth's and Mothers' Beliefs Actually Match			
Self-estrangement	More often than avg (=185)		Less often than avg (N=184)	
More than avg	78	42.2	108	58.7
Less than avg	107	57.8	76	41.3
$\chi^2=10.07$	df=1	p<.05	Q=-0.32	

mothers, compared to 58.7% of the youths who held less similar beliefs, scoring more than 50% on the Self-estrangement Scale.

DISCUSSION—Lacking an adequate body of hypotheses concerned with primary group relationships (cf. Neiman and Hughes, 1951), it has been necessary here to view "self" as an emerging set of options or a series of social choices in order to present the evolutionary nature of self process. The chosen operational method provided data that upheld the premise (that a mother influences a child's socialization and subsequent internalized symbolism, or social perceptions) by presenting evidence that a congruity of beliefs between mother and youth related positively to one aspect of the youth's perception of self—i.e., when youth's and mother's beliefs are more similar, youth is less self-estranged. The data lend credence to the notion that the child is a "carbon copy" of the parent in terms of the finding that when the youth predicted his mother's responses more accurately, the mother's beliefs were more likely to be the same as that of the youth.

Contrary to Winch's (1962) thesis, it seems that the lasting influence of the mother upon the youth is not in terms of identification alone. Rather, the determination of self seems to be a symbolic process involving mutual expectations including historic mirrored images. The data suggest that the mother is an historical social figure that influences social order or disorder. Self-estrangement and belief systems were highly related to the ability of youths to clearly perceive the "other" image of their mothers, i.e., when a youth more accurately predicted his mother's responses (clarity of image) he was more likely to have similar belief-orientations with his mother, and less likely to experience self-estrangement. The youth has used his imagination to form a mirrored image of the symbolic historical mother.

CONCLUSIONS—Self, in Cooley's view, was not only an immediate social reality. He recognized that self-awareness was an historical social event, but he left as abstractions these historical parts to which the study has attempted to relate. The data tend to uphold the validity of his abstractions and suggest that the historical process involved in self-perception functions within immediate social reality and that feelings of self-estrangement are related to the larger value system existing between a youth and his mother.

LITERATURE CITED

BELL, N., AND E. VOGEL. 1968. Toward a framework for functional analysis of family behavior. pp. 1-34. *In* Bell, N. and E. Vogel (eds.) A Modern Introduction to the Family. Free Press. New York.

BONJEAN, C. M., AND M. D. GRIMES. 1970. Bureaucracy and alienation: a dimensional approach. Social Forces 48:365-372.

COOLEY, C. H. 1902. Human Nature and the Social Order. Charles Scribner & Sons. New York.

MIYAMOTO, S. F., AND S. DORNBUSCH. 1956. A test of the symbolic interactionist hypothesis of self-conception. Amer. J. Sociol. 67:399-403.

MURDOCK, G. P. 1949. Social Structure. Macmillan. New York.

NEIMAN, L., AND J. HUGHES. 1951. The problem of the concept of role—a re-survey of the literature. Social Forces 30:141-149.

QUARENTELLI, E. L., AND J. COOPER. 1966. Self conceptions and others: a further test of Meadian hypotheses. Sociol. Quart. 7:281-297.

REEDER, L., G. DONOHUE AND A. BIBLARZ. 1960. Conceptions of self and others. Amer. J. Sociol. 66:153-159.

TIMASHEFF, N. 1965. Sociological Theory, Its Nature and Growth. Random House. New York.

WINCH, R. F. 1962. Identification and its familial determinants. Bobbs-Merrill Co. New York.

Florida Sci. 40(1):28-32. 1977.

Biological Sciences

DISTRIBUTIONAL NOTES ON SOME NORTH FLORIDA FRESHWATER FISHES

George H. Burgess (1), Carter R. Gilbert (1), Vincent Guillory (2), and Donald C. Taphorn (1)

(1) Florida State Museum and Department of Zoology, University of Florida, Gainesville, Florida 32611; and
(2) Florida Game and Fresh Water Fish Commission, 5950 West Colonial Drive, Orlando, Florida 32807

Abstract: *Recent captures of* Notropis cummingsae, Notropis welaka, Ictalurus brunneus, *and* Etheostoma olmstedi *from waters of the St. Johns River drainage are reported, and the disjunct distributions of these species in Florida are discussed. Freshwater distribution of* Lucania parva *in the St. Johns River system is summarized, with a new locality included. Establishment of two exotic fish species.* Xiphophorus variatus *and* Sarotherodon aureus (=Tilapia aurea), *in Gainesville is documented. Known range of* Enneacanthus chaetodon *is extended to Pasco county.*

Extensive field collections were recently made in the St. Johns River system as part of a survey along the proposed route of the Cross-Florida Barge Canal. The object of the survey was to determine the status of five possibly "rare and endangered" fish species, whose occurrence in the drainage is widely disjunct from their next closest populations: *Notropis cummingsae, Notropis welaka, Ictalurus brunneus*, *Enneacanthus chaetodon*, and *Etheostoma olmstedi.* This note is a report on the results of this survey and several unrelated collections in the Gainesville area, and also includes previously unpublished locality records of these species and of *Lucania parva* that were listed by McLane (1955) in his doctoral dissertation.

The tessellated darter, *Etheostoma olmstedi* Storer, is found in eastern United States from eastern Massachusetts and southern New Hampshire to the St. Johns River system in Florida (Cole, 1967). Cole considered the St. Johns population to be the subspecies *maculaticeps.* It is abundant throughout its range, except in the St. Johns drainage. Until our survey only 23 specimens had been collected from this drainage, all from a single locality in the Oklawaha River (Davenport Landing, Marion County), with the last known capture on 2 October 1949. We collected 7 specimens of this species from two tributaries of the Oklawaha River: 6 from Orange Creek at state route 315 bridge, Putnam County (5 October 1975, 23 January 1976 and 22 May 1976); and one from Eaton Creek, Marion County, approximately 0.5 mile south of its junction with the Oklawaha River (31 January 1976). *Etheostoma edwini, E. fusiforme,* and *Percina nigrofasciata* were also collected at both sites; *E. olmstedi* is now known from 30 specimens and 3 localities in the St. Johns system (Fig. 1).

The systematics of the snail bullhead, *Ictalurus brunneus* (Jordan), were recently clarified by Yerger and Relyea (1968). They gave its range from the Cape Fear River in North Carolina southward to the St. Johns River and west-

Fig. 1. Florida distribution of *Etheostoma olmstedi*.

ward into Alabama in the Apalachicola River system. In the St. Johns drainage, *I. brunneus* was reported from 7 localities. Collections of this species at 6 new localities during our recent investigations reveal that it is widespread throughout the system (Fig. 2). New capture data are as follows: Oklawaha River, at state route 19 bridge, Putnam County, 25 February 1975 and 15 June 1975 (1 and 1 specimens); Oklawaha River, 1.5 mi. south of Eureka, Marion County, 26 February 1975 and 20 August 1975 (1 and 1 specimens); Eaton Creek, 0.5 mi. south of junction with Oklawaha River, Marion County, 20 July 1975 and 31 January 1976 (2 and 3 specimens); branch of Oklawaha River, 0.5 mi. north of state route 40 bridge, Marion County, 30 January 1976 (1 specimen); Juniper Springs Run, 0.3 mi. east of state route 19 bridge, Marion County, 21 February 1976 (1 specimen); Wekiva River, 1.8 mi. south of state route 46 bridge, Orange-Seminole counties, 20 February 1976 (1 specimen). In addition, Kenneth Relyea (personal communication) collected this species in the St. Johns River at Green Cove

Fig. 2. Florida distribution of *Ictalurus brunneus*. Proximate localities are often represented by a single dot.

Springs, Clay County. All *I. brunneus* here reported were captured using rotenone, electrofishing gear, or fish traps. Snail bullheads are difficult to collect using seines, since they apparently prefer deep holes in channels (McLane, 1955).

Hubbs and Raney (1951) gave the distribution of the dusky shiner, *Notropis cummingsae* Myers, as from the Neuse River in North Carolina southward to the St. Johns River and westward to the Apalachicola River in western Florida and eastern Alabama. Although *N. cummingsae* has been reported from 6 localities in the St. Johns system, it has been found only rarely in recent yr, last being collected on 2 September 1962. We collected 28 dusky shiners in Little Orange Creek, 0.4 mi. east of state route 21, Putnam County, on 13 February 1976 and 22 May 1976; and Robert B. Juul took 80 individuals from two nearby localities in Little Rice Creek, about 5 mi. west of Palatka, Putnam County, on 5 April

Fig. 3. Florida distribution of *Notropis cummingsae*. Proximate localities are often represented by a single dot.

1976. These localities are shown in Fig. 3. *Notropis hypselopterus* and *N. petersoni* were also taken at the former collection site, and *N. hypselopterus* and *N. chalybaeus* at the latter.

We sampled nearly all localities where the bluenose shiner, *Notropis welaka* Evermann and Kendall, had previously been reported in the St. Johns drainage (Fig. 4), but did not collect this species. However, we have examined six specimens (20.3-29.2 mm SL) of the bluenose shiner collected subsequently by T. J. Timmons and K. J. Foote in Alexander Spring Run on 25 September 1976. These specimens, like nearly all others collected from the St. Johns drainage, are juveniles. This suggests that the bulk of the St. Johns *Notropis welaka* population inhabit deep, often congested backwater areas (as noted by Douglas, 1974), and that the few known captures are based on young individuals straying into the main channels. The Alexander Spring Run collection is the first capture of this species in the St. Johns system since 7 April 1956.

Fig. 4. Florida distribution of *Notropis welaka*. Proximate localities are often represented by a single dot.

The 4 species discussed above are at the southern limits of their ranges in the St. Johns River system. Examination of the Florida distributions of these species (Fig. 1-4) reveals that the St. Johns populations are disjunct relicts that presumably became isolated as a result of Plio-Pleistocene sea level fluctuations described by Alt and Brooks (1965). None of the 4 species is found in the major adjacent river systems (the Suwannee, St. Marys, and Satilla), and only *N. cummingsae* is found in the Aucilla and Ochlocknee rivers.

Parallel distribution patterns are known in other groups of animals, including the mayfly *Baetisca gibberi* (Berner, 1955), and the geminate crayfish species *Procambarus pictus* and *P. youngi* (Hobbs, 1942). Isolation of the *Procambarus* populations has resulted in differentiation to the species level, whereas the mayfly and fish populations have not even reached subspecific levels. These situations do not seem to be exactly comparable to those involving the pugnose minnow (*Notropis emiliae*) and the largemouth bass (*Micropterus salmoides*), both of which have differentiated into well-defined subspecies in peninsular Florida and are widely distributed throughout the southern part of the state (Gilbert and Bailey, 1972; Bailey and Hubbs, 1949). In contrast to the situation involving the 4 fish species being considered, intergrading populations of *Notropis emiliae* and *Micropterus salmoides* occur in the intervening systems, apparently as a result of isolation and subsequent recolonization. The differences in distribution and degree of differentiation suggest that the peninsular populations of the last 2 species became isolated at an earlier time than did those of the other 4 fish species.

The absence of *E. olmstedi*, *N. cummingsae*, and *N. welaka* from numerous seemingly favorable collecting sites, as well as their unexplained absence from areas where they formerly were found, suggest that these species possibly are undergoing natural extirpation in the St. Johns River drainage. In addition, the abundance and distribution of these fish have been influenced by environmental changes resulting from the partial construction of the Cross-Florida Barge Canal. Several localities (e.g. Deep Creek, part of Orange Creek, and parts of the lower Oklawaha River) formerly inhabited by these species have subsequently been flooded. Such major alterations, as well as subtle changes in water quality, siltation, and seasonal flow regimes that accompany flooding, have certainly affected these organisms.

Previous Florida records of the blackbanded sunfish, *Enneacanthus chaetodon* (Baird), have been limited to 8 Marion County localities, mostly within the boundaries of the Ocala National Forest (Bailey, 1941; Chable, 1947; Reid, 1950; McLane, 1955). We may now report this species from 5 additional Florida sites, plus 2 localities in nearby Georgia waters: unnamed pond on Bexley property, approximately 3.5 mi. southwest of Gowers Corner, R18E, T25S, Sec. 29 (SW quarter), Pasco County, 12 May 1973 (3 specimens); unnamed pond, about 8 mi. south of Leesburg, Lake County, May 1956 (10 specimens); Niggertown Lake, 0.25 mi. south of Ocala National Forest, Marion County, 9 October 1954 (1 specimen); North Prairie, 13.4 air mi. ESE of Silver Springs and about 1.0 mi. north of state route 40, Marion County, 9 May 1973 (17 specimens); borrow pit, 2.5 mi. west of Baxter on state route 2, Baker County, March 1968 (1 specimen); Linton Lake, just west of Aucilla River and approximately 1.0 mi. north of the Florida-Georgia state line, Thomas County, Georgia, 9 September 1967 (2 specimens); and a site adjacent to state route 133, about 4.0 mi. north of Florida-Georgia state line, Thomas County, Georgia, 1974 (1 specimen).

Unlike the 4 previously discussed species, the present disjunct distribution of the blackbanded sunfish in Florida apparently does not directly reflect the effects of Plio-Pleistocene sea level fluctuations (Fig. 5). *Enneacanthus chaetodon* characteristically occupies coastal acid-water areas (Bailey, 1941; Smith, 1953) and would seem entirely capable of recolonizing most lowland areas following a lowering in sea level. However, the distribution of the species is very spotty throughout its range (see map in Jenkins et al., 1975), as well as in Florida, which suggests that some unknown ecological factor(s) may be limiting its dis-

Fig. 5. Florida distribution of *Enneacanthus chaetodon*. Proximate localities are often represented by a single dot.

tribution. Although the blackbanded sunfish has been collected from the Aucilla and Suwannee river drainages in Georgia, it has not been recorded from the Florida portions of these drainages, despite recent collecting efforts by personnel from Florida State University. This may be the manifestation of ecological preferences of the species. Until these critical habitat parameters have been more specifically determined, the distribution of *Enneacanthus chaetodon* will remain an enigma.

The rainwater killifish, *Lucania parva* (Baird), is normally found in brackish waters from Massachusetts to northeastern Mexico (Hubbs and Miller, 1965). Freshwater populations of this species were reported from 3 widely separated localities in the upper St. Johns system by Hubbs and Miller (1965). Relyea (1975) also reported it from Alexander Springs and suggested these populations were "possibly isolated." However, McLane (1955), in his unpublished doctoral dissertation, had earlier reported it from 8 other localities in this system, and we have since found it at one additional locality (Okalawaha River, 0.2 mi. north of state route 40 bridge, Marion County). The known freshwater distribution of this species in the St. Johns system now extends from Doctors Lake, near Orange Park, Clay County, south to Lake Poinsett, west of Cocoa, Brevard County. These records suggest that *Lucania parva* probably is distributed throughout much of the St. Johns drainage.

Two species of exotic fishes have recently become established in the Gainesville region. The variable platyfish, *Xiphophorus variatus* (Meek), is now found in several ponds and sinkholes on the University of Florida campus. The Graham Pond population has been reproducing for at least 6 yr, and some individuals have reverted from bright red and yellow to the somewhat drab natural color morph. Courtenay et al. (1974) reported establishment of this common aquarium species in Palm Beach, Brevard, Hillsborough, and Manatee counties. Alachua County may now be added to this list.

The blue tilapia, *Sarotherodon aureus* (Steindachner) (= *Tilapia aurea* of many authors) has been established in Lake Alice, also on the University of Florida campus, at least since 1969. Males defending their distinctive circular nests were observed in late winter and spring. Blue tilapia have the most extensive distribution of all exotic fishes in Florida (Courtenay et al., 1974) but have not been reported in the St. Johns River System until recently. Holcomb (1974, 1975) reported captures of S. *aureus* (as *T. aurea*) from Lake Apopka, Lake and Orange counties. Florida Game and Fresh Water Fish Commission personnel recently collected S. *aureus* from Lake Jessup, Seminole County, and Lake Monroe, Seminole, and Volusia counties (William Johnson, personal communication). Tilapia nests, presumably of S. *aureus*, were observed by one of us (C. R. Gilbert) in Blue Springs, Volusia County, in February 1976. A species of tilapia is reportedly established in the St. Johns River not far from Lake George, Volusia County (Waldner and Courtenay, 1974). The disjunct distribution of blue tilapia created by the Lake Alice population suggests local introduction rather than the natural spread of this species that is occurring farther south in central Florida.

It is significant that both Alachua County introductions have occurred in bodies of water receiving heated water effluents or constant temperature spring water. Establishment of exotics (including S. *aureus*) in such artesian springs as Eureka Springs and those that supply Six Mile Creek, Hillsborough County (Waldner and Courtenay, 1974) further indicates that thermostatic springs in the Gainesville area could act as refuges for exotic species possibly unable to survive north Florida winters.

Acknowledgments—We thank D. Gray Bass, who was instrumental in obtaining support for the project and offered helpful suggestions. Reeve M. Bailey, Mondell Beach, Walter R. Courtenay, Karen J. Foote, Dennis E. Holcomb, William E. Johnson, Robert B. Juul, Kenneth Relyea, Thomas J. Timmons and Ralph W. Yerger kindly shared information. Eugene C. Beckham lent museum specimens for study. This work was supported by U. S. Army Corps of Engineers Contract No. DACW17-75-C-0030 and U. S. Fish and Wildlife Service Contract No. 14-16-0008-950, under the auspices of the Florida Game and Fresh Water Fish Commission.

LITERATURE CITED

ALT, D., AND H. K. BROOKS. 1965. Age of the Florida marine terraces. J. Geology 73:406-411.

BAILEY, R. M. 1941. Geographic variation in *Mesogonistius chaetodon* (Baird), with description of a new subspecies from Georgia and Florida. Occ. Pap. Mus. Zool. Univ. Michigan 454:1-7; 1 pl.

————, AND C. L. HUBBS. 1949. The black basses (*Micropterus*) of Florida with description of a new species. Occ. Pap. Mus. Zool. Univ. Michigan 516:1-40.

BERNER, L. 1955. The southeastern species of *Baetisca* (Ephemeroptera: Baetiscidae). Quart. J. Florida Acad. Sci. 18:1-19.

CHABLE, A. C. 1947. A study of the food habits and ecological relationships of the sunfishes of northern Florida. Master's thesis. Univ. Florida. Gainesville.

COLE, C. F. 1967. A study of the eastern johnny darter, *Etheostoma olmstedi* Storer (Teleostei, Percidae). Chesapeake Sci. 8:28-51.

COURTENAY, W. R., H. F. SAHLMAN, W. W. MILEY AND D. J. HERREMA. 1974. Exotic fishes in fresh and brackish waters of Florida. Biol. Cons. 6:292-302.

DOUGLAS, N. H. 1974. Freshwater Fishes of Louisiana. Claitor's Publ. Div. Baton Rouge.

GILBERT, C. R., AND R. M. BAILEY. 1972. Systematics and zoogeography of the American cyprinid fish *Notropis (Opsopoedus) emiliae.* Occ. Pap. Mus. Zool. Univ. Michigan 664:1-35; 2 pl.

HOBBS, H. H., JR. 1942. The crayfishes of Florida. Univ. Florida Publ. Biol. Sci. Ser. 3(2):1-179.

HOLCOMB, D. E. 1974. Fish population studies. *In* Oklawaha Basin Fisheries Investigations, Florida Game and Fresh Water Fish Comm., First Ann. Perf. Rept., Dingell-Johnson Proj. F-30-1. (Mimeographed). *In FAS Library.*

————. 1975. Fish population studies. *In* Oklawaha Basin Fisheries Investigations, Florida Game and Fresh Water Fish Comm., Second Ann. Perf. Rept., Dingell-Johnson Proj. F-30-2. (Mimeographed). *In FAS Library.*

HUBBS, C. L., AND R. R. MILLER. 1965. Studies of the cyprinodont fishes. XXII. Variation in *Lucania parva*, its establishment in western United States, and description of a new species from an interior basin in Coahuila, Mexico. Misc. Publ. Mus. Zool. Univ. Michigan 127:1-104; 3 pl.

————, AND E. C. RANEY. 1951. Status, subspecies, and variation of *Notropis cummingsae*, a cyprinid fish of the southeastern United States. Occ. Pap. Mus. Zool. Univ. Michigan 535: 1-25; 1 pl.

JENKINS, R. E., L. A. REVELLE, AND T. ZORACH. 1975. Records of the blackbanded sunfish, *Enneacanthus chaetodon*, and comments on the southeastern Virginia ichthyofauna. Virginia J. Sci. 26(3):128-134.

MCLANE, W. M. 1955. The fishes of the St. Johns River system. Ph.D. dissert. Univ. Florida. Gainesville.

REID, G. K. 1950. Notes on the centrarchid fish *Mesogonistius chaetodon elizabethae* in peninsular Florida. Copeia 1950:239-240.

RELYEA, K. 1975. The distribution of the oviparous killifishes of Florida. Sci. of Biol. J. 1(2):49-52.

SMITH, R. F. 1953. Some observations on the distribution of fishes in New Jersey. New Jersey Dept. Conser. Econ. Develop., Div. Fish Game, Fisheries Surv. Rept. 2:165-174.

WALDNER, R. E., AND W. R. COURTENAY. 1974. Correlation of distributions of native and exotic species with oligotrophic and eutropic habitats. *In* Exotic fish investigations, Florida Game and Fresh Water Fish Comm. and Florida Atlantic Univ., Job Final Rept., Dingell-Johnson Proj. F-28. *In FAS Library.*

YERGER, R. W. AND K. RELYEA. 1968. The flat-headed bullheads (Pisces: Ictaluridae) of the southeastern United States, with a new species of *Ictalurus* from the Gulf Coast. Copeia 1968(2): 361-384.

Florida Sci. 40(1):33-41. 1977.

Earth and Planetary Sciences

PROPERTIES OF MAGHEMITE AND HEMATITE

FRANCIS J. LĘCZNAR

6341 S. W. 10th Street, Pompano, Florida 33068

ABSTRACT: *Temperature, time and cooling regimes were established for transformation of soft hematite and iron glance into maghemite in an oxidizing atmosphere; hematite structure seems to aid in retaining magnetic properties in an oxidizing atmosphere.*

FERROMAGNETIC Fe_2O_3 is designated as γ $-Fe_2O_3$ in contrast to non-magnetic or normal α $-Fe_2O_3$. The elemental content is the same as that of hematite but the crystalline structure differs. Hematite appears in trigonal crystals in the form of rhombohedrons and scalenohedrons but γ $-Fe_2O_3$ has a cubic lattice comparable to magnetite (Fe_3O_4). Vervey (1935) reported that γ $-Fe_2O_3$ has a defect lattice comprised, on the avg, of 32 oxygen and 21.3 iron atoms. Gamma-hematite differs from natural hematite in that it is thermodynamically unstable with a higher lattice energy than hematite. With the loss of this energy, the lattice rearranges to stable α $-Fe_2O_3$ (Czerski, 1947). As might be expected, γ $-Fe_2O_3$ occurs rarely in nature and is known only from Gorzyniec, Poland, the Iowa Mountains of California and near Johannesburg, South Africa, where it was named maghemite by P. A. Wagner (Mellor, 1934).

Hilpert (1909) produced maghemite by oxidizing either precipitated magnetite or ferrous hydroxide in soluble oxidizing agents (Gmelin, 1923). Sosman and Posnjak (1925) experimentally produced maghemite by dehydration at 250°-300°C of lepidocrocite which is one of the two crystalline forms of $Fe_2O_3 \cdot H_2O$; the other form, goethite, yields only paramagnetic Fe_2O_3 (Herroun and Wilson, 1928-29). Because temperatures, times and cooling regimes seemed to affect transformations of hematites and their magnetic properties, a series of experiments was undertaken to circumscribe and characterize these changes.

EXPERIMENT WITH SOFT HEMATITE—Soft hematite grains to 0.1 mm diam and iron glance to 0.5 mm were heated and tested for magnetic separation in the field of a 220 V 0.05 A Krupp, Bauart-Ulrich electro-magnetic separator. Soft Hematite spheres 50 mm in diam were placed in a preheated electric furnace, and after 450° was established they were heated for 10 and 20 min respectively. On removal from the furnace, the spheres were slowly cooled to about 60° in 18°C open air. They were cut in half and particles of the spheres were tested along the radius, i.e., to the center of each sphere, to determine magnetic properties. Then 5 g from each sphere kernel was tested in the electro-magnetic separator.

Results: Soft hematite was transformed into magnetic hematite as shown in Table 1. The equation α $-Fe_2O_3 \longrightarrow \gamma$ $-Fe_2O_3 \longrightarrow \alpha$ Fe_2O_3 occurs at temperatures from about 450°C to about 850°C. The maximum amount of magnetic hematite, 95.93%, exists at 750° with a 10 min heating time and then the amount rapidly decreases to 850°C, transforming γ -Fe_2O_3 into α -Fe_2O_3. For spheres heated for 20 min, the maximum magnetic content of 84.46% occurs following a rapid increase approaching its peak at 550° and this then decreases as temperatures are raised to 850°.

EXPERIMENT WITH IRON GLANCE—A small, covered, quartz crucible filled with 5 g of iron glance grains was placed in the center of a soft hematite sphere. Each sphere was put in an electric furnace in 450°C and heated for 10 and 20 min respectively. On removal from the furnace, the spheres were slowly cooled to about 60°C in 18° open air. Iron glance was tested in an electro-magnetic separator.

Results: Iron glance was transformed into magnetic hematite as shown in Table 1. The equation α -$Fe_2O_3 \longrightarrow \gamma$ $Fe_2O_3 \longrightarrow \alpha$ -Fe_2O_3 includes changes from about 450°C to 850°C. The maximum magnetic fraction, 82.2% occurs at 650°C. Spheres heated for 20 min have a maximum magnetic fraction of 76.18% at 550°C with a gradual decrease to about 850°C.

Discussion: The oxidation of magnetite into maghemite takes place at temperatures above 200°C (Baudisch and Albrecht, 1932; Welo and Baudisch, 1925) and one can conduce it to about 850°C (Lęcznar, 1952, 1956). Over 600°C maghemite to hematite transformation begins slowly and at 700°C rapidly transforms into hematite. At 200°C the black magnetite color changes to brown which remains up to about 550°C becoming light brown and then at 750°C it becomes brown again. Above 750°C the color changes progressively into violet reaching its maximum intensity at 850°C.

More than 100 experiments with fine grain hematite did not resolve the conditions for the α -$Fe_2O_3 \longrightarrow \gamma$ Fe_2O_3 transformations. Soft hematite spheres of 20, 30, 40 and 50 mm diam established that when heated in a temperature

TABLE 1. Magnetic fractions of soft hematite and iron glance.

Preheating (min)	Heating (min)	Temp. °C	Magnetic fraction % Soft hemat.	Magnetic fraction % Iron glance
15	10	450	0.00	1.21
15		550	22.92	53.15
15		650	90.28	82.20
18		750	95.93	58.18
22		850	5.64	1.43
13	20	450	0.00	3.27
13		550	83.35	76.18
15		650	86.46	67.53
18		750	41.28	44.20
22		850	0.00	0.51

TABLE 2. Magnetic fraction of soft hematite and iron glance after cooling.

Temp. °C	Heating min	Cooling in min: in furnace to temp.	Time	in open air to temp.	Time	Magnetic fraction %: soft hemat.	iron glance
		450	55		40	19.5	87.1
		400	95		30	11.2	60.5
550	20	350	140	60	30	2.9	68.2
		300	205		25	3.2	60.0
		250	295		20	0.0	73.9
		60	660		0	0.0	52.1
		450	75		40	53.8	76.5
		400	100		30	52.0	62.4
650	10	350	160	60	25	16.7	74.7
		300	250		25	12.5	72.4
		250	315		20	4.4	81.1
		60	660		0	0.0	79.3
750	10	60	675	60	0		68.4

range of 450°-850° maghemite is produced in the sphere center. The larger spheres produced more maghemite which suggested greater production against heat loss. Fast cooling seemed to result in loss of hematite transformation.

MAGNETIC RETENTION EXPERIMENT WITH SOFT HEMATITE—Soft hematite spheres 50 mm in diam were heated in an electric furnace at 550°C for 20 min. Cooling was accomplished by reducing furnace temperatures to 60°C and thence in open air. A 5 g fraction of each sphere center was tested for magnetic properties in a 220 V, 0.05 A electro-magnetic separator. The same procedure was applied to soft hematite spheres heated at 650°C for 10 min. Results of these experiments are summarized in Table 2.

MAGNETIC RETENTION EXPERIMENT WITH IRON GLANCE—A small quartz crucible with iron glance (to 0.5 mm diam) was put into the core of a hematite sphere. It was heated at 550°C for 20 min in an electric furnace. Cooling was accomplished by decreasing furnace temperature to about 60°C and thence in open air. Iron glance was tested for magnetic properties in the 220 V, 0.05 A electro-magnetic separator. The same procedure was applied to soft hematite spheres with iron glance heated to 650°C for 10 min. Results of these experiments are summarized in Table 2.

Discussion: The shortest cooling time of 55 min of the soft hematite heated at 550°C for 20 min produces a smaller (19.5%) magnetic fraction than that resulting from 10 min heating at 650°C which produced 53.8% magnetic fraction.

The longest (295 min) cooling of soft hematite heated in 550°C for 20 min destroyed its magnetic properties. The same thing occurred for soft hematite heated at 650°C for 10 min and cooled to 60°C over 660 min. Soft hematite fast lost its magnetic properties and passed into non-magnetic hematite.

The short, 55 min cooling of soft hematite with iron glance heated at 550°C for 20 min caused an increase in the magnetic fraction to 87.1%. The longest, 660 min cooling time to 60°C decreased the magnetic fraction to 35%.

Iron glance heated at 650°C for 10 min and cooled at various rates from 75 to 660 min retains about the same level of magnetic properties. Iron glance heated at 750°C for 10 min and cooled to 60°C over 675 min retained 68.4% magnetic fraction. The difference in retention of magnetic properties is significant in the structure of both hematites.

Soft hematite spheres 20, 30, 40 and 50 mm in diam were heated at 750°C for 10 min and cooled slowly in open air. The cores were transformed into magnetic hematite in relation to the length of the radius. If cooled quickly in cool air they lost their magnetic properties.

CONCLUSIONS—1) The transformation of iron glance and soft hematite into magnetic forms, $\alpha\ –Fe_2O_3 \longrightarrow \gamma\ –Fe_2O_3 \longrightarrow \alpha\ –Fe_2O_3$ proceeds in an oxidizing atmosphere; 2) the transformation of both hematites occurs between about 450°C and 850°C; 3) longer heating time moves their maxima into lower temperatures; 4) soft hematite looses magnetic properties during extended cooling times in the furnace and in open air by passing into non-magnetic hematite; 5) iron glance retains its magnetic properties for a longer time independently of relative cooling time in the furnaces and open air; and 6) an amorphous or crypto-crystalline structure of soft hematite and a crystalline structure of iron glance may aid in retaining magnetic properties in an oxidizing atmosphere.

ACKNOWLEDGMENTS—Sincere thanks are expressed to Prof. Antoni Gaweł, Chairman of Mineralogy and Petrography at Jagiellonski University.

LITERATURE CITED

BAUDISCH, O., AND W. H. ALBRECHT. 1932. Gamma ferric oxide hydrate. J. Amer. Chem. Soc. 54.

CZERSKI, L. 1947. Topochemistry and technics. Chem. Rev. (Warsaw) 1.

GMELIN, . 1923. Handbuch der Anorganischen Chemie. Verlag Chemie G. M. B. H. Berlin.

HERROUN, E. F., AND E. WILSON. 1928-29. Ferromagnetic ferric oxide. Proc. Phys. Soc. London 41.

HILPERT, S. 1909. Uber Beziehungen zwischen Konstitution und magn. Eigenschaften bei Eisenverbindungen. Ber. Deutsch. Phys. Ges.

LĘCZNAR, F. 1952. Ores Dressing. State Sci. Publ. Wroclaw.

————. 1956. The oxidation of iron oxides. Hutnik (Katowice) 11.

MELLOR, J. W. 1934. A Comprehensive Treatise on Inorganic and Theoretical Chemistry, vol. 13. London.

SOSMAN, R. B., AND E. POSNJAK. 1925. Ferromagnetic ferric oxide, artificial and natural. J. Washington Acad. Sci. 15.

VERWEY, E. J. W. 1935. Incomplete atomic arrangement in crystals. J. Chem.-Phys. 3.

WELO, L. A., AND O. BAUDISCH. 1925. The two stage transformation of magnetite into hematite. Phylos. Mag. London, ser. 6, 50.

Florida Sci. 40(1):42-45. 1977.

Earth and Planetary Sciences

FORAMINIFERAL STUDIES IN TROPICAL CARBONATE ENVIRONMENTS: SOUTH FLORIDA AND BAHAMAS

Don C. Steinker

Department of Geology, Bowling Green State University, Bowling Green, Ohio 43403

Abstract: *Those who seek to understand ancient carbonate rocks must first pursue knowledge of modern carbonate depositional environments. Those who study modern carbonates in tropical areas quickly learn that plants and animals exert significant influences upon the depositional environment, affecting the sedimentary record in a variety of ways. Many geologists and paleontologists, therefore, have entered into studies of modern organisms and their effects upon the carbonate sedimentary framework. The foraminifera are important both as members of the biota and as skeletal constituents of carbonate sediments in areas such as south Florida and the Bahamas. Most studies of modern foraminifers from the south Florida-Bahama region have concentrated on distributions among sediment samples, with living and dead populations distinguished on the basis of rose bengal stain. Rose bengal is found to be an unreliable indicator of living specimens and methods of direct observation are suggested for the recognition of live foraminifers. Generally, a larger living population is found on marine vegetation than in the sediments of these areas. The assemblage among the bottom sediments commonly is sorted by waves and currents and does not necessarily accurately reflect the biocoenosis of an area. Attempts must be made to discriminate between those factors of the environment that influence the distribution of living populations and those that determine the thanatocoenosis in the sediments. More biologically oriented investigations are necessary for a better understanding of the foraminifera in their natural habitats. Such investigations should include both field studies and laboratory cultures.*

With increasing attention being devoted to modern carbonate environments, carbonate geologists have become more and more interested in the various organisms that inhabit such environments, particularly those that may affect the sedimentary record as constructional or destructional agents. It is becoming increasingly evident that an understanding of carbonate rocks depends, to a large extent, upon an understanding of many of the biotic elements in the original faunal and floral assemblage. As a result, a number of geologists have become attracted to the study of modern corals and calcareous algae and various boring and burrowing organisms. Even marine grass beds are receiving a great deal of attention, as are algal mats. The diverse organisms in such habitats include not only those found as fossils, but also those not normally preserved in the rock record but which influence the depositional environment. Geologists have begun to realize that an understanding of the role of these assorted types of organisms in the overall sedimentary framework must be assessed against the background of their ecologic, physiologic, and environmental functions.

Since many of the questions that the geologist might ask about the organisms have not been adequately answered by the biologist who may view the biota in a somewhat different light, it has been expedient for some geologists to transgress into the field of marine biology. In addition, some of us with initial primary interests in both geology and biology, particularly in paleontology, become fascinated by studies of modern carbonate environments because of the intimate relationships and interactions displayed among the various organic and inorganic aspects of these environments, strengthened and reinforced by the pleasantness of shallow tropical seas, where a land dweller can quickly become acclimatized, and by the diversity of habitats and organisms.

The biologically oriented geologist is making important contributions to our knowledge of marine carbonate environments and is amassing information that can be used as a basis for reconstruction of ancient environments and for paleoecological inferences from carbonate rocks and contained fossil assemblages. These biologically oriented contributions include studies of coral reef ecology, growth rates, and the roles of various organisms in sedimentation. Much, though, remains to be done, both in basic research, such as problems of calcification and of productivity, and in the synthesis of pertinently relevant biological and geological studies.

The foraminifera are significant both as biotic elements of faunas and as skeletal constituents of sediments in tropical marine, shallow-water, carbonate depositional environments, in some cases comprising the bulk of the sediments. Although a great deal is known about the taxonomy and distribution of modern foraminifers, the general areas of ecology, physiology, life cycles, and variation have been somewhat neglected. Because of the value of foraminifera in making detailed stratigraphic correlations, geologists have been primarily concerned with the morphology, phylogeny, taxonomy, and stratigraphic ranges of fossil forms. Recognizing also the paleoecologic potential of the group, a number of paleontologists have focused on the environmental distribution of taxa and on correlations between test morphology and environment, concentrating mainly on establishing correlations that may be significant in reconstructing ancient depositional environments but commonly disregarding the potential paleoecological significance of differentiating between factors of the environment affecting the distribution of living foraminiferan populations and those affecting the distribution of total populations (living and dead) in the sediments.

Most distributional and ecological studies of modern foraminifers have mainly treated the distribution of tests in sediment samples, with living and dead specimens being commonly differentiated on the basis of rose bengal stain. Sediments may or may not be the primary habitat of benthonic foraminifera, and the rose bengal staining technique is not necessarily a reliable indicator of living versus dead individuals.

From time to time it is well to review the work that has been done in a particular area, to indicate the status of progress in that field of study, and to suggest additional lines of research. Several studies by me of benthonic foraminifera from tropical carbonate environments of south Florida and the Bahamas, either in progress or recently completed, deal with sampling methods, methods for recognition of living individuals, foraminiferal habitats and ecology, and reef assemblages, as well as culture studies pertaining to the biology of certain species and variation, along with taxonomic implications. Some of this work is here summarized and previous work on the benthonic foraminifera of these areas is reviewed. Excellent descriptions of the sedimentary environments of south Florida and the Bahamas may be found in Bathurst (1975).

In 1959, when I completed a Master's thesis on recent foraminifera from south Florida, there were relatively few published reports on the foraminifers of south Florida and the Bahamas. Since that time, several papers have appeared, primarily on the Florida fauna. Following is a summary review of published reports on the modern benthonic foraminiferal faunas inhabiting the tropical carbonate environments of the Florida-Bahamas region. The list is presented in a chronological order and is not meant to be exhaustive, but does serve to summarize the work in this area.

The shallow-water, benthonic, foraminiferal fauna of this region is well known, as is the areal and environmental distribution of many of its elements. D'Orbigny (1839) first recorded many of these species from Cuba, and Brady (1884) in his "Challenger Report" described additional species from samples taken in the tropical western Atlantic. Cushman (1918-1931) described and illustrated many foraminifers from the Gulf of Mexico and the Caribbean Sea. These works, taken together, serve to block out the general distribution of foraminifers in the western Atlantic region. In addition, Vaughan (1918) published some comparisons between foraminifera found in shallow-water sediment samples from Australia, Florida, and the Bahamas, as did Norton (1930), who recognized a series of zones related to water depth and temperature. Finally, in his textbook, Cushman (1948) divided modern benthonic foraminiferal faunas into cold-water and warm-water faunas, recognizing two cold-water and four warm-water faunas. His West Indian faunal province includes south Florida and the Bahamas, extending northward to Bermuda and southward to Brazil.

Detailed faunal descriptions in this region begin with Cushman's study (1922) of shallow-water foraminifera from the Dry Tortugas, off Key West, Florida. Cushman provided observations on movement, color, and commensal algae in living specimens, and noted the need for studies of developmental stages and variation in modern foraminifers. He collected shallow-water samples from bottom sediments, reef flats, and marine grass, representing a considerable range of environmental conditions. Relatively few species, most with thick tests, occurred among the coarse sediments, whereas many delicate tests were found among the finer-grained bottom sediments. *Homotrema rubrum* was abundant on dead-coral banks, with *Haliphysema advena* present in crevices. An association of living species on the grass included *Iridia diaphana*, *Planorbulina acervalis*, *Discorbis* spp., "*Orbitolites duplex*", and "a peculiar miliolid which spreads over the surface" (probably *Cornuspiramia antillarum*). Cushman reported 147 species and varieties from the Dry Tortugas, providing descriptions of many, along with comments on occurrences. Included are observations on *Iridia diaphana* and *Haliphysema advena*, two species that usually are not observed in sediment washings.

M. A. Illing (1950) studied the mechanical distribution of foraminiferan tests in shallow-water sediments from the southeast corner of the Great Bahama Bank, in the area of Ragged Island. Approximately 100 species were recorded, less than half of which were found to be common. Over most of the area studied the sediments were found to be well sorted with coarser sediments containing few small foraminiferan tests. Small tests were common only in fine-grained sediments from sheltered environments. She concluded: "The principal factor which affects the distribution of the foraminiferal tests is transportation and sorting by marine currents in the same way as grains of sand, and their distribution is thus primarily controlled by their size." And, "The forms that appear in any sample are thus controlled far more by the local current conditions than by the local indigenous foraminiferal fauna."

Illing (1952) expanded her earlier work in a treatment of samples from around New Providence and Great Abaco Islands, as well as from the Ragged Island area. She identified approximately 150 species from bottom samples, noting that most of the species identified by Cushman (1922) from the Dry Tortugas are also present on the Bahama Banks. Generally, different foraminiferal assemblages were found in the outer marginal shelf environment that encircles the Banks between the open ocean and the cays and in the more sheltered inner portion of the Banks. In the outer exposed zone, which is subjected to more wave action and stronger tidal currents, the foraminifera tend to have thicker, stronger tests and fewer species are present. In the inner protected environment smaller forms with delicate tests are more common and species diversity is higher. Environmentally mixed assemblages occur in the vicinity of tidal channels between cays. Samples collected near reefs and from areas with large amounts of marine grass and algae yielded few foraminifers; in fact, few animals.

L. V. Illing (1954), in his study of calcareous sands on the Bahama Banks, summarized the previous work of M. A. Illing (1950, 1952) on the foraminifers. He observed that the distribution of sands is controlled by currents, which also control the distribution of tests among the sediments, thus masking local environmental control on living assemblages.

A rather comprehensive study of south Florida carbonate sediments was published by Ginsburg (1956). Ginsburg recognized two major environments in this area: 1) the reef tract, and 2) Florida Bay. The Florida Bay sediments were found to have a larger proportion of sediments less than 1/8 mm than those of the reef tract. Another difference was in the constituent particle composition of the fraction larger than 1/8 mm. In Florida Bay this fraction consists mainly of molluscan fragments and foraminifera, whereas in the reef tract algal and coral fragments are abundant. In 11 samples from Florida Bay foraminiferan tests constituted on the avg 17 percent of the sediments with grain sizes greater than 1/8 mm. The average for the reef tract was 9%.

Moore (1957) studied 61 grab and dredge bottom samples previously collected by Ginsburg. Most of the samples (39) were taken in Florida Bay; 10 came from the back reef environment, 5 from the outer reef area, and 7 from the fore reef. For the most part, Moore's data were presented in terms of the relative abundance of individuals assigned to each family present. Moore concluded: "The faunas that represent each of the environments . . . are so distinctive that they may be recognized on the basis of the families, and the abundance of individuals assigned to each family, without resorting to the use of genera and species." The dominant foraminiferal families in the Florida Bay samples were found to be the Miliolidae, Peneroplidae, and Nonionidae (*Elphidium*).

Most of the species identified by Moore from Florida Bay also were identified in the back reef environment. The fauna of the 10 samples from the back reef area was dominated by members of the Miliolidae, Peneroplidae, Nonionidae, and Rotaliidae and included more species than the Bay fauna. Moving seaward, the numbers of Miliolidae and Nonionidae decrease, whereas the numbers of Peneroplidae, Amphisteginidae, and Anomalinidae show a definite increase. The back reef fauna is said to be comparable to that described by Cushman (1922) from the Dry Tortugas and to much of the exposed margin to ocean fauna of Illing (1950, 1952). In Moore's sediment samples from the outer reef the Peneroplidae were dominant, and the Amphisteginidae (especially *Asterigerina carinata*) are said to be characteristic of this environment. The Cassidulinidae appear in the fore reef environment, where the Anomalinidae increase somewhat in importance. *Angulogerina*, *Bulimina*, *Uvigerina*, and *Reusella* appear at a depth of approximately 45m. Moore noted that as the sediments become coarser in size the frequency of large tests increases in the sample, whereas finer-grained sediments contain more of an abundance of small tests. A major problem that yet exists is the determination of factors influencing the distribution of empty tests in the sedimentary depositional environment.

Lynts (1962, 1965, 1966, 1971) has reported on the foraminiferal fauna of upper Florida Bay in several papers. Large fluctuations in temperature and salinity occur in this area, and the water remains turbid throughout the year. In the first two studies (1962, 1965) Lynts found that the foraminiferan tests occurring in the calcareous muds are not sorted by waves and currents; instead, it is suggested that sediment size may be an important ecologic factor in determining the local distribution of some species. The other two studies (1966, 1971) deal with foraminiferal standing crops in Buttonwood Sound in the southeastern part of Florida Bay. The standing crop was found to be dominated by porcellaneous species, which comprised over 90% of the populations. Lynts (1971): "No simple linear relationship exists between Buttonwood Sound foraminiferal species and ecological distributions. The distribution of species is controlled by a complex interplay of physico-chemical and biologic factors acting upon the species."

Hofker (1964) included a few Bahamian samples from New Providence, Bimini, and Cat Key in his study of foraminifera from the tidal zone of various West Indian islands. In this faunal study he identified 78 species from the West Indian region. A few of Hofker's observations are herewith summarized. Large numbers of miliolids in combination with *Streblus*, *Elphidiononion*, and peneroplids are indicative of nearshore conditions. The miliolids, with the exception of *Pyrgo*, are mainly found in shallow water. Miliolids with thick tests commonly are found in beach sands, whereas those with thin tests are found in the more sheltered waters of lagoonal environments. *Discorinopsis aguayoi* is frequent in the sediments of mangrove swamps. The peneroplids characteristically occur in clear, shallow waters. *Rotorbinella rosea* is usually absent in areas where the larger Puteolinae are abundant.

Members of the Peneroplidae are conspicuous elements of the south Florida-Bahama foraminiferal fauna. Cole (1965) studied recent and some fossil peneroplids from areas of the Pacific, the Philippines, Africa, the Caribbean, and Florida in a reconsideration of the taxonomy of the group. His interpretations are based upon test morphology. Life history and variation studies in controlled laboratory cultures are still needed to confirm his evidence. Coles' classification and taxonomic assignments of the peneroplids are very different from those of Hofker (1951, 1964).

Howard (1965) identified 66 species from 12 sediment samples taken in the vicinity of Big Pine Key in the lower Florida Keys. Samples from Spanish Harbor, on the Florida Bay side of the Keys, yielded a low-diversity assemblage containing numerous small miliolids. Samples from the ocean side of the Keys contained a more diverse fauna. According to Howard (1965), "Relationships between distribution of dominant species of Foraminifera and physical, chemical, and biologic variations at each locality seem to indicate that turbulence is the major controlling factor of population constituents in the southern Florida Keys."

The geographically widespread occurrence of many recent species of benthonic foraminifera has long been an intriguing problem to foraminiferologists. Bock (1969b) has suggested an apparently effective mode of dispersion for species living on blades of the marine grass, *Thalassia testudinum*. In the Florida Keys this is an important habitat for many species of foraminifera (Bock, 1969b; Grant et al., 1973). During storms, *Thalassia* plants are ripped up from the bottom by storm waves and the blades with their foraminiferan inhabitants may be carried great distances by currents.

The sediments and biota in Coupon Bight, a shallow lagoon at the southern end of Big Pine Key in the lower Florida Keys, were described by Howard, Kissling, and Lineback (1970). Part of their project dealt with the foraminifers taken from sediment samples. Fifty-five species were identified, but individuals assigned to the genera *Archaias* and *Quinqueloculina* are numerically dominant.

Bock (1971) has provided a catalog of 235 species of foraminifera from the south Florida region. A diagnosis is given for each species, most of which are illustrated. Bock recognizes five faunal assemblages in this region: Straits fauna, back-reef fauna, brackish-water fauna, Gulf fauna, and Bay fauna. The presence of *Discorbis rosea, Homotrema rubrum*, and *Pyrgo murrhina* distinguish the back-reef fauna from that of the Bay. The Bay fauna includes a large number of species, of which 66 of the most common are listed by Bock. He suggests that wave and current action may be important in determining the distribution of tests among the bottom sediments of Florida Bay. The Gulf fauna inhabits the area west of Florida Bay. Small bays along the northern margin of the Bay are inhabited by the brackish-water fauna, characterized by *Ammonia beccarii* var. *parkinsoniana* and *Elphidium discoidale*. According to Bock (1971), the Straits and Gulf faunas are controlled by depth, the back-reef and Bay faunas by temperature and salinity, and the brackish-water assemblage primarily by salinity. Secondary control on the Bay fauna is exerted by wave and current action.

The distribution of foraminifers in the southwest portion of Florida Bay is recorded by Smith (1971), based upon 26 sediment samples from which 150 species were identified. *Ammonia beccarii* was found to be the most abundant species. The numbers of Miliolidae and Soritidae were found to increase and of Rotaliidae and Elphidiidae to decrease with distance from shore.

Wright and Hay (1971) studied 53 samples taken from Rodriquez Key to Molasses Reef in the back-reef environment off Key Largo, Florida. At each station both sediments and vegetation were examined for foraminifera, although the authors did not elaborate upon the types of plants examined. The vegetation was sampled by sweeping through it with a fine-mesh net, which I have found to be relatively ineffective for obtaining attached foraminifers. It was found that samples taken from closely adjacent areas contain different proportional representations of species, but widely spaced samples showed even greater differences. More living foraminifera were present on vegetation than in the bottom sediments, and in bare sediment areas few living foraminifers were present. And a direct correlation was observed between the distribution of living specimens and that of empty tests. However, a relationship also was observed between the grain size of sediments and the abundance of tests. The number of tests decreased with an increase in sediment size, which is a function of the dynamics of the environment. Wright and Hay conclude: "The population of foraminiferal tests on the bottom is a death assemblage. The distribution of the bottom population is a function of both the distribution of the living individuals and the factors acting on the tests after death. Transportation by current movement is a significant factor in the final distribution of the tests. Most of the tests have remained in the proximity of their original niche or have been transported shoreward. Selective solution of tests after deposition on the bottom may also affect the distribution and abundance."

Bock and Moore (1971) worked on the foraminifers and micromolluscans from two coral atolls: Hogsty Reef in the southeastern Bahamas and Serrana Bank in the western Caribbean. Ninety-three species were identified from Serrana Bank, 111 from Hogsty Reef; 83 species were common to both atolls. Commonly occurring species included *Asterigerina carinata*, *Homotrema rubrum*, *Archaias angulatus*, *Discorbis rosea*, *Rosalina floridana*, and various miliolids. *Homotrema rubrum* is considered by Bock and Moore to be indicative of a reef environment. At Serrana Bank *Homotrema* only occurred in the reef environment; at Hogsty Reef it was most abundant in the reef sediments but also was found in smaller numbers in the back reef area.

Approximately 20 yr after M. A. Illing's work in the Bahamas, a period during which very few papers appeared concerning Bahamian benthonic foraminifera, Todd and Low (1971) published a study of the foraminifera from the Bahama Bank west of Andros Island. Their study was based on 46 sediment cores ranging from the outer bank, across the central portion of the banks, to the nearshore regions of Andros Island. The fauna was dominated by *Archaias angulatus* and

Peneroplis proteus. Several species were largely restricted to the outer edge of the bank, including *Amphistegina lessonii*, *Asterigerina carinata*, and *Rotalia rosea*. Species largely restricted to nearshore areas included *Discorinopsis aguayoi* and *Parrina bradyi*, along with several others. Various miliolids, elphidiids, and agglutinated forms were common and widely distributed over the banks.

A recent study by Grant, Hoare, Ferrall, and Steinker (1973) attempted to define some habitats of living foraminifera from a small, nearshore area near the mouth of Coupon Bight at Big Pine Key, Florida. *Thalassia testudinum*, *Dasycladus vermicularis*, *Penicillus capitatus*, and *Halimeda* spp. all proved to be important foraminiferal habitats. Diatom growths and associated organic detritus on the plants appeared to provide food and shelter for many of the foraminifers. Few living individuals occurred in the bottom sediments, although almost all species found living on the plants were represented in the sediments by empty tests, but not necessarily in the same proportions. *Archaias angulatus* was the numerically dominant species, constituting 65% of all specimens identified.

Discussion—Although not of particular interest to the micropaleontologist, the allogromiids, with an organic or membranous test, are of considerable interest to the foraminiferal biologist. These usually are either not found or are overlooked in sediment samples. If such samples are processed by washing through sieves, the animals commonly are destroyed. They are most readily obtained through the microscopic examination of vegetation samples. Few papers on the modern foraminifera of south Florida and the Bahamas mention the presence of allogromiids. Bock (1971), for example, lists no allogromiid species in his handbook of the benthonic foraminifera of south Florida. Cushman (1922) reports the occurrence of *Iridia diaphana* from the Dry Tortugas and includes various observations on the living animal. Grant et al. (1973) found numerous specimens of *Allogromia laticollaris* living on *Thalassia* blades and on the green alga *Dasycladus* in Coupon Bight, Big Pine Key, Florida. I suggest that observations on the allogromiids and other foraminiferans with soft, easily destroyed tests would contribute to our understanding of microbiotic communities. In addition, the biologically oriented foraminiferologists have had some success in raising these species in laboratory cultures (Arnold, 1974). The absence of a firm test makes them especially useful for cytological studies which lead to a better understanding of life histories.

Definite need exists for more laboratory culture studies that will add information to our knowledge of the fundamental biological relationships of these protozoans. In addition to modes of reproduction and life histories, studies can be carried out in culture on variation, nutrition, experimental ecology, and symbiotic relationships. The author currently is studying several species of *Rosalina* in culture (Steinker, 1974b, 1975b), including *Rosalina floridana* from the west coast of Florida and south Florida and an as yet unidentified species from Coupon Bight. *Rosalina floridana* is commonly found living on vegetation and has proved to be relatively easy to culture. Laboratory populations so far seem to be apogamic, with no sexual reproductive stage. The temperature tolerance of this species ranges from approximately 13° to 35°C, so that it is quite eurythermal; the optimal thermal range for reproduction is about 18° to 25°C for populations from Sarasota, but has not yet been determined for those from Coupon Bight. The coiling direction is random, with no significant variation with differences in food, temperature, or substratum, nor from generation to generation. Additional observations on the biology, life habits, and morphological variation will be presented in a forthcoming paper. Studies of this type are invaluable to our understanding of the living animal, but they also need to be closely checked against studies made in the natural habitats. The conditions in the laboratory, even in large aquariums, can only very roughly approximate the biological and physical conditions in nature; the conditions of the animal's habitat can never be exactly reproduced in the laboratory.

More field ecology studies of living foraminifera are needed. More efforts are needed to attempt to identify microhabitats and to define communities. So far, few serious attempts have been made to study the role of foraminifers in the microbiotic community. Shallow-water, tropical carbonate environments are ideal situations in which to study living foraminiferal populations because the habitats can be observed directly by wading, by snorkeling, or by SCUBA diving. An underwater magnifying glass can be used for an *in situ* examination, for example, of the microbiota on *Thalassia* blades without disturbing the microhabitat to any significant extent. In such environments the investigator can collect samples knowing the exact nature of the general surroundings, unlike grab samples from murky waters.

The first step in field investigations of foraminiferal ecology, however, is the ability to distinguish between living and dead individuals. The thanatocoenosis found among the sediments is not necessarily strictly representative of the biocoenosis that might be living on the vegetation of that same area, so that the ecologist must work with living populations. The rose bengal stain technique (Walton, 1952) has been found by a number of workers to be unreliable for distinguishing between living and dead individuals (e.g., Green, 1960; Benda and Puri, 1962; Boltovskoy, 1963; Boltovskoy and Lena, 1970; Le Calvez and Cesana, 1972; Martin and Steinker, 1973; and Walker et al., 1974). Martin and Steinker (1973) recently emphasized more direct observational techniques in recognizing living foraminifers. "The only reliable methods known to us for the determination of living individuals involve direct observation in an attempt to recognize signs of life. These methods are tedious and time-consuming, but are more reliable than the staining techniques so far employed" (Martin and Steinker, 1973). Sometimes protoplasmic color serves as an aid, or pseudopodial activity. The test can be broken open to see if it contains protoplasm, or examination of the test under high magnification may reveal protoplasmic streaming within the test. Each test must be treated individually, so that these techniques lack the advantage of rapid determination professed for various staining techniques. There are several disadvantages to the staining techniques tried. One is that tests devoid of foraminiferan protoplasm may be stained because of the presence of bacteria or an internal organic film. Another is that the intensity of the stain varies considerably from specimen to specimen. Finally, for various reasons some living individuals are not stained, sometimes due to a bolus of food material in the apertural region.

Although a number of foraminiferologists have been aware of the problems with the rose bengal technique, most ecological studies over the past 20 yr have relied upon this method. For example, in his recent book summarizing the distribution and ecology of benthonic foraminifera Murray (1973) states: "The study of the distribution of living foraminiferids dates from the introduction in 1952 of Walton's method of staining protoplasm with rose Bengal. During the past twenty years, there has been a steadily increasing volume of published data based on the use of this staining method. In this book I have attempted to summarize and synthesize these data to produce a coherent pattern of foraminiferid distributions."

Once the investigator settles upon a satisfactory method of discriminating between living and dead individuals numerous problems of an ecological nature become available for investigation. The well-known problem of the spotty distribution of foraminifers within a local area, usually inadequately explained on the basis of unknown variations in microhabitats, deserves the attention of the foraminiferal ecologist. Localized reproduction may account for some difference in numbers from spot to spot, but is inadequate to explain all such variation. Detailed observations on foraminiferal biocoenoses in Florida and the Bahamas (Grant et al., 1973; Steinker, 1974a; Steinker and Steinker, 1975), as well as California (Steinker, 1975a) and the Virgin Islands (Steinker, in progress), suggest that the amount of organic detritus present sometimes may be a controlling factor. In the Florida Keys and at Jewfish Cay in the Bahamas a direct correlation has been observed between the presence and abundance of detritus and the number and diversity of foraminifers present. For example, *Thalassia* blades or *Halimeda* plants with a thick covering of diatom growths and associated detritus support many more individuals and species of foraminifera than do nearby plants that are devoid of diatoms and detritus. This material seems to serve both as food for some species and as a protective cover among which many of the smaller species live. The same type of situation has been observed among the sediments. In general, living foraminifers are more abundant among sediments which include detritus than among those which are clean. Current action and the stabilizing influence on the sediments of filamentous algae are important factors influencing the amount of detritus present. I have noted, however, that fine muds containing much decaying detritus usually are inhospitable environments for these protozoans, based upon my observations in south Florida and the Bahamas.

Most distributional and ecological studies have been based upon sediment samples obtained by means of corers, grab samplers, or dredges, which generally seem to miss the bottom vegetation and the foraminifers living thereupon. In shallow, tropical waters the foraminifers in sediment samples usually are represented mainly by empty, frequently broken, and abraded tests. Both the empty tests and the living individuals that may be present commonly show the effects of current sorting. Examination of foraminifers living on benthonic vegetation in the same area may reveal a very different distributional pattern than that exhibited by the assemblage in the sediments. Both juvenile and adult individuals are likely to be represented on the plants, whereas sometimes only adult tests of the larger species are present in the sediments. Individuals belonging to species that attain only a small size as adults may be common on plants but rare or absent among the surrounding sediments. Species with organic tests or with loosely agglutinated tests may be well-represented on marine algae or grasses but absent from adjacent bottom sediments.

It is suggested that sediment samples alone are an inadequate basis for serious ecological studies. In many areas of south Florida and the Bahamas the major part of the biocoenosis inhabits various types of marine vegetation, particularly *Thalassia* blades and certain calcareous codiacean algae (Grant et al., 1973; Steinker and Steinker, 1975). In both areas the following genera of plants have been found to be major habitats for significant numbers of foraminifera: *Thalassia*, *Dasycladus*, *Penicillus*, *Halimeda*, and *Rhipocephalus*. The broad blades of the grass *Thalassia testudinum* commonly are partially coated with a sticky growth of diatoms. The grass bed serves as an effective baffle, slowing the currents and allowing fine-grained material to accumulate in a sheltered environment. Organic detritus is trapped among the diatom growths on the grass blades, creating a favorable habitat for various minute animals which are afforded food and protection. The foraminiferal thanatocoenosis in the sediments of the grass bed represents more of an autochthonous assemblage than in bare sediment areas. There is less transportation and sorting of tests by currents in dense grass beds than in other environments. A large quantity of fine, light brown organic debris commonly accumulates among the cluster of fine branchlets in *Dasycladus*, which grows on rocks in shallow waters. Foraminifers may be common on this plant. In fact, in some sheltered areas in Coupon Bight, lower Florida Keys, these plants frequently are covered with peneroplids. The capitular tufts of *Penicillus* provide excellent shelter for foraminifers, which may live in profusion among the filaments, particularly if detritus is abundant. In *Rhipocephalus* the capitular filaments are united to form blade-like structures. Detritus, diatoms, and foraminifers mainly are limited to the outer portions of the capitulum. In some places the branches of *Halimeda* yield a diversity of species living on the plant among diatom growths and detritus; in other places where the branches are free of extraneous material foraminifers may be scarce. Foraminifers may also be found alive among subtidal filamentous algal mats, and less commonly among intertidal algal mats. In tropical areas desiccation and high diurnal temperatures limit the occurrence of intertidal foraminifers more than in temperate regions. However, few investigations have treated the foraminifera of rocky intertidal zones and more are needed. Marine plants may be washed in seawater to obtain living individuals; however, for accurate determination of foraminiferal assemblages the plants themselves should be examined under the microscope, since some tests are firmly attached to the vegetation and others may be destroyed during the washing process.

It is ecologically and paleoecologically important to discriminate between factors that influence the distribution of living foraminifers and those that determine the distribution of empty tests among the sediments, as was emphasized by Shifflett (1961). Preliminary studies in Coupon Bight indicate that only moderate wave energy is needed to put the smaller tests into suspension and carry them into areas where they are not normally found living. In bare sediment areas, where tests commonly are devoid of protoplasm, a close correspondence usually is noted between the grain-size of the sediments and the size of the tests, indicating wave and current sorting. In the more sheltered environments of the grass beds both the sediments and the tests of living foraminifers show a greater size range than in exposed areas. Because of their sturdy tests, specimens of *Archaias angulatus* frequently are common among the sand-sized sediments in non-vegetated areas; ordinarily few of these tests contain protoplasm.

Another rejected area of research is the foraminiferal fauna associated with modern coral reefs. Very few observations on the foraminiferan reef fauna of south Florida and the Bahamas are available in the literature. Murray (1973) observes: "In the Indo-Pacific and Atlantic Oceans, larger foraminiferids of the genera *Amphistegina*, *Calcarina*, *Baculogypsina*, *Alveolinella*, *Borelis*, *Marginopora*, and *Peneroplis* are commonly present in addition to abundant smaller miliolids and rotaliids." And, "The exact ecological niches occupied need to be known and the role of foraminiferids as reef-builders needs re-evaluation." Wright and Hay (1971) comment: " . . . the distribution and abundance of the living and dead species in reef areas has not been studied. Foraminifers are not reef constructing organisms, although they do occur on the reef proper." Milliman (1973) notes that *Homotrema rubrum* lives mainly on the fore reef and reef flat in the Caribbean reef areas. Bock (1969a) found living *Homotrema rubrum* restricted to coral reefs at St. Croix in the Virgin Islands. The dominant reef species at St. Croix, as given by Bock, are *Homotrema rubrum*, *Amphistegina gibbosa*, and *Rosalina rosea*; *H. rubrum* occurs in low numbers among the sands behind the reef. Howard (1965) found *Archaias angulatus* to be numerically dominant among reef sediments at Looe Key, off Big Pine Key in the lower Florida Keys. *Poroeponides lateralis*, *Amphistegina gibbosa*, and *Asterigerina carinata* were found among the reef sediments but not among those in the back-reef environment. Bock and Moore (1971), studying Hogsty Reef in the southeast Bahamas and Serrana Bank in the western Caribbean, concluded that among the foraminifera encountered *Homotrema rubrum* is the only true indicator of a reef environment. Similarly, MacKenzie et al. (1965), working in Bermuda, found *H. rubrum* living mainly on the outer shoals surrounding the Bermuda Platform. According to both Bock and Moore (1971) and MacKenzie et al. (1965), tests of *H. rubrum* are not transported very far into lagoonal areas. Illing (1950, 1952) found *H. rubrum* and *Rotorbinella rosea* to be conspicuous in occurrence along the edges of the Bahama Banks. However, Cushman (1922) saw abundant specimens of *H. rubrum* living attached to banks of dead coral in the lower portion of the intertidal zone in the Dry Tortugas. And the present author has observed numerous living specimens of this species attached to rocks in the nearshore and intertidal regions at St. Croix and a few attached to conch shells and other hard substrates in the inner portion of the back-reef environment along the Florida Keys.

The foraminiferal faunas of the patch reefs and the outer reef tract off Big Pine Key, Florida, are currently being studied. The results presented here are based upon washed and dried samples and must be considered preliminary. Among the sediments at Looe Key in the outer reef tract, *Archaias angulatus* is most abundant, followed by *Homotrema rubrum* and *Rotorbinella rosea*. *Asterigerina carinata*, *Amphistegina lessonii*, *Borelis pulchra*, and various species of *Quinqueloculina* are locally common. Numerous other species occur only in small numbers among the sediments. Although *Homotrema rubrum* and *Gypsina* sp. grow attached to the surface of dead coral, there are no indications that these encrusting forms contribute significantly to the biological accretion of the reef; *Archaias angulatus* seems to add more to the growth of the reef through the contribution of tests to the sedimentary framework. In the *Thalassia* bed immediately behind the reef at Looe Key *Rosalina candeiana*, *Planorbulina acervalis*, and *Archaias angulatus* are common on the grass blades.

Archaias angulatus and *Rotorbinella rosea* are relatively abundant in dried sediment samples from the patch reefs in the back-reef environment off Big Pine Key. *Clavulina tricarinata*, *Textularia agglutinans*, *Quinqueloculina bradyana*, *Q. lamarckiana*, *Q. seminulum*, *Pyrgo subsphaerica*, *Sorites marginalis*, and *Planorbulina acervalis* locally are fairly common. Whereas most of the tests from the outer reef sediments are broken or abraded, most of those from the patch reefs are unbroken due to the more sheltered environment.

Summary—1. Most faunal studies of modern foraminifera have neglected those species with organic, membranous, and loosely agglutinated tests. Attention to such species results in a more complete knowledge and a better understanding of foraminiferal communities. Many are potentially valuable for purposes of cytological studies.

2. More culture studies are needed to increase our knowledge of the biology of the group. Experimental ecologic investigations will add to the value of the foraminifera in paleoecologic studies. And more investigators should take the time to make detailed observations on living individuals, such as those by Cushman (1922) on some of the Tortugas foraminifera.

3. So far, no satisfactory substitute has been found for the collection of samples by hand in reasonably shallow waters. Core samplers, dredges, and grab samplers bring up mostly sediments, in some cases indiscriminantly mixing surface sediments with those from lower layers. Many or most types of vegetation commonly are missed by these sampling methods. Nets passed among the bottom vegetation may secure a number of foraminifers but will miss more firmly attached forms.

4. None of the staining techniques for the distinction of living versus dead foraminifers that have been tested has proved to be satisfactory. Protoplasmic color, pseudopodial activity, and protoplasmic streaming are more reliable guides for the recognition of living foraminifers.

5. Detailed field studies will lead to a better appreciation of foraminiferan microhabitats. Once habitats are established, problems of niches, communities, and local distributions can be investigated, employing both field and laboratory methods. The paleoecologist will be interested in distinguishing between factors affecting the distribution of living populations and of empty tests.

6. A number of studies have been published on the benthonic foraminiferal fauna of south Florida and the Bahamas, most dealing with the distribution of tests in sediment samples. The general fauna is well known. The warm, clear, shallow waters of these areas invite additional and more detailed investigations, particularly by biologically oriented researchers. The variety and diversity of easily accessible environments is conducive to ecological studies that can be supplemented by experimental work in the laboratory.

ACKNOWLEDGMENTS—Funds for part of the research were provided by grants from the Faculty Research Committee and the National Science Foundation Institutional Grant Committee at Bowling Green State University. The Department of Geology at Bowling Green State University provided supplies, equipment, space for the Marine Science Laboratory, where much of the work was carried out, and a houseboat that served as a field station in the Florida Keys. The Newfound Harbor Marine Institute, Big Pine Key, Florida, provided laboratory space during part of the field work. The facilities of the University of Miami Field Station at Pigeon Key were made available to the author on numerous occasions.

LITERATURE CITED

ARNOLD, Z. M. 1974. Field and Laboratory techniques for the study of living Foraminifera. Pp. 153-206. *In* R. H. HEDLEY AND C. G. ADAMS, eds. Foraminifera. Academic Press. New York.

BATHURST, R. G. C. 1975. Carbonate Sediments and Their Diagenesis. 2nd Ed. Elsevier. New York.

BENDA, W. K., AND H. S. PURI. 1962. The distribution of Foraminifera and Ostracoda off the Gulf Coast of the Cape Romano area, Florida. Gulf Coast Assoc. Geol. Soc. Trans. 12:303-341.

BOCK, W. D. 1969a. Report on the ecology of the benthonic Foraminifera in St. Croix. West Indies Lab. Contr. 3:1-19.

———. 1969b. *Thalassia testudinum*, a habitat and means of dispersal for shallow water benthonic Foraminifera. Gulf Coast Assoc. Geol. Soc. Trans. 19:337-340.

———. 1971. A handbook of the benthonic Foraminifera of Florida Bay and adjacent waters. Miami Geol. Soc. Mem. 1:1-72.

———, AND D. R. MOORE. 1971. The Foraminifera and micromollusks of Hogsty Reef and Serrana Bank and their paleoecological significance. Fifth Carib. Geol. Conf. Trans. Geol. Bull. 5:143-146.

BOLTOVSKOY, E. 1963. The littoral foraminiferal biocoenoses of Puerto Deseado (Patagonia, Argentina). Cushman Found. Foram. Res. Contr. 14:58-70.

———, AND H. LENA. 1970. On the decomposition of the protoplasm and the sinking velocity of planktonic foraminifers. Internat. Rev. Ges. Hydrobiol. 55:787-804.

BRADY, H. B. 1884. Report on the Foraminifera dredged by H. M. S. *Challenger* during the years 1873-1876. Rept. Voyage *Challenger* Zool. 9:1-814.

COLE, W. S. 1965. Structure and classification of some recent and fossil peneroplids. Amer. Paleont. Bull. 49(219):1-37.

CUSHMAN, J. A. 1918-1931. The Foraminifera of the Atlantic Ocean. U. S. Natl. Mus. Bull. 104.

———. 1922. Shallow-water Foraminifera of the Tortugas region. Carnegie Inst. Washington Publ. 311:1-85.

———. 1948. Foraminifera, Their Classification and Economic Use. Harvard Univ. Press. Cambridge.

GINSBURG, R. N. 1956. Environmental relationships of grain size and constituent particles in some south Florida carbonate sediments. Amer. Assoc. Petroleum Geol. Bull. 40:2384-2427.

GRANT, K., T. B. HOARE, K. W. FERRALL, AND D. C. STEINKER. 1973. Some habitats of Foraminifera, Coupon Bight, Florida. Compass 59(4):11-16.

GREEN, K. E. 1960. Ecology of some Arctic Foraminifera. Micropaleontology 6:57-78.

HOFKER, J. 1951. Recent Peneroplidae. Roy. Micros. Soc. J. (Ser. 3) 71:223-239.

__________. 1964. Foraminifera from the tidal zone in the Netherlands Antilles and other West Indian islands. Stud. Fauna Caracao Other Carib. Isl. 21(83):1-119.

HOWARD, J. F. 1965. Shallow-water foraminiferal distribution near Big Pine Key, southern Florida Keys. Compass 42:265-280.

__________, D. L. KISSLING, AND J. A. LINEBACK. 1970. Sedimentary facies and distribution of biota in Coupon Bight, lower Florida Keys. Geol. Soc. Amer. Bull. 81:1929-1946.

ILLING, L. V. 1954. Bahaman calcareous sands. Amer. Assoc. Petrol. Geol. Bull. 38:1-95.

ILLING, M. A. 1950. The mechanical distribution of recent Foraminifera in Bahama Banks sediments. Ann. Mag. Nat. Hist. (Ser. 12) 3:757-761.

__________. 1952. Distribution of certain Foraminifera within the littoral zone of the Bahama Banks. Ann. Mga. Nat. Hist. (Ser. 12) 5:275-285.

LE CALVEZ, Y., AND D. CESANA. 1972. Détection de l'état de vie chez les Foraminifères. Ann. Paléontol. 58:129-134.

LYNTS, G. W. 1962. Distribution of recent Foraminifera in upper Florida Bay and associated sounds. Cushman Found. Foram. Res. Contr. 13:127-144.

__________. 1965. Observations on Some Florida Bay Foraminifera. Cushman Found. Foram. Res. Contr. 16:67-69.

__________. 1966. Variation of foraminiferal standing crop over short lateral distances in Buttonwood Sound, Florida Bay. Limnol. Oceanogr. 11:562-566.

__________. 1971. Distribution and model studies on Foraminifera living in Buttonwood Sound, Florida Bay. Miami Geol. Soc. Mem. 1:73-115.

MACKENZIE, F. T., L. D. KULM, R. L. COOLEY AND J. T. BARNHART. 1965. *Homotrema rubrum* (Lamarck), a sediment transport indicator. J. Sed. Petrol. 35:265-272.

MARTIN, R. E., AND D. C. STEINKER. 1973. Evaluation of techniques for recognition of living Foraminifera. Compass 50(4):26-30.

MILLIMAN, J. D. 1973. Caribbean coral reefs. Pp. 1-50. *In* O. A. JONES AND R. ENDEAN. eds. Biology and Geology of Coral Reefs. Academic Press. New York.

MOORE, W. E. 1957. Ecology of recent Foraminifera in northern Florida Keys. Amer. Assoc. Petrol. Geol. Bull. 41:727-741.

MURRAY, J. W. 1973. Distribution and Ecology of Living Benthic Foraminiferids. Crane, Russak & Co. New York.

NORTON, R. D. 1930. Ecologic relations of some Foraminifera. Scripps Inst. Oceanogr. (Tech. Ser.) 2(9):331-388.

D'ORBIGNY, A. 1839. Foraminiferes. Pp 1-224. *In* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba. Paris.

SHIFFLETT, E. 1961. Living, dead, and total foraminiferal faunas, Heald Bank, Gulf of Mexico. Micropaleontology 7:45-54.

SMITH, S. L. 1971. Distribution of recent Foraminifera in lower Florida Bay. Miami Geol. Soc. Mem. 1:116-120.

STEINKER, D. C. 1974a. Foraminiferal studies in tropical carbonate environments (abstr.). West Indies Lab. Spec. Publ. 6:37-39.

__________. 1974b. Observations on laboratory populations of a rosalinid foraminifer (abstr.). Geol. Soc. Amer. Abstr. Progr. 6(7):970.

__________. 1975a. Foraminifera of the rocky intertidal zone, central California coast (abstr.). Benthonics '75, Abstr. 46-47.

__________. 1975b. Observations on laboratory populations of rosalinid foraminifers (abstr.). Geol. Soc. Amer. Abstr. Prog. 7(6):863-864.

STEINKER, P. J., AND D. C. STEINKER. 1975. Shallow-water Foraminifera, Jewfish Cay, Bahamas (abstr.). Benthonics '75, Abstr. 47.

TODD, R., AND D. LOW. 1971. Foraminifera from the Bahama Bank west of Andros Island. U. S. Geol. Surv. Prof. Pap. 683-C:1-22.

VAUGHAN, T. W. 1918. Some shoal-water bottom samples from Murray Island, Australia, and comparisons of them with samples from Florida and the Bahamas. Carnegie Inst. Washington Publ. 213:235-288.

Walker, D. A., A. E. Linton, and C. T. Schafer. 1974. Sudan black B: A superior stain to rose bengal for distinguishing living from non-living Foraminifera. J. Foram. Res. 4:205-215.
Walton, W. R. 1952. Techniques for recognition of living Foraminifera. Cushman Found. Foram. Res. Contr. 3:56-60.
Wright, R. C., and W. W. Hay. 1971. The abundance and distribution of foraminifers in a back-reef environment, Molasses Reef, Florida. Miami Geol. Soc. Mem. 1:121-174.

Florida Sci. 40(1):46-61. 1977.

Earth and Planetary Sciences

CALCULATED X-RAY POWDER DIFFRACTION PATTERNS FOR BARITE, CELESTITE, AND ANGLESITE

Frank N. Blanchard

Department of Geology, University of Florida, Gainesville, Florida 32611

Abstract: *Calculated x-ray powder diffraction patterns from refined crystal structure data indicate that, although the JCPDS data for barite, celestite and anglesite in the Powder Diffraction File are of high reliability, there are several errors in indexing the reflections. Calculated standard scale factors are given for these three minerals.*

Computer-simulated diffractometer charts and calculated d-spacings and relative intensities have been obtained for the barite group minerals (barite, celestite, and anglesite), using the FORTRAN IV program for calculating x-ray powder diffraction patterns—version 5 (Clark, Smith and Johnson, 1973) and refined crystal structure data from recent literature. Comparison of the results with the JCPDS (Joint Committee on Powder Diffraction Standards, 1974) file card for each of these minerals indicates that there are minor omissions and minor errors in indexing on the file cards. In addition to evaluating the quality of existing powder diffraction data the results may be applied to quantitative analysis by using the calculated standard scale factors.

Figure 1 shows computer-simulated diffractometer charts based on CuKα radiation, a Cauchy line profile, and a half-width at 40° 2θ of 0.1°. Table 1 consists of input data for minerals of the barite group and Table 2 gives d-spacings and relative intensities compared with those in the powder diffraction file. The calculated standard scale factors are 0.224×10^{-3} (barite), 0.398×10^{-3} (celestite), and 0.426×10^{-3} (anglesite).[1]

In general there is a close correlation between the powder diffraction data on the file cards for these three minerals and the powder diffraction data calculated from the crystal structure, suggesting that both the powder data and the crystal structure data are of high reliability. Some of the minor descrepancies

[1]For definition and discussion of the standard scale factor, see Hubbard et al., 1976.

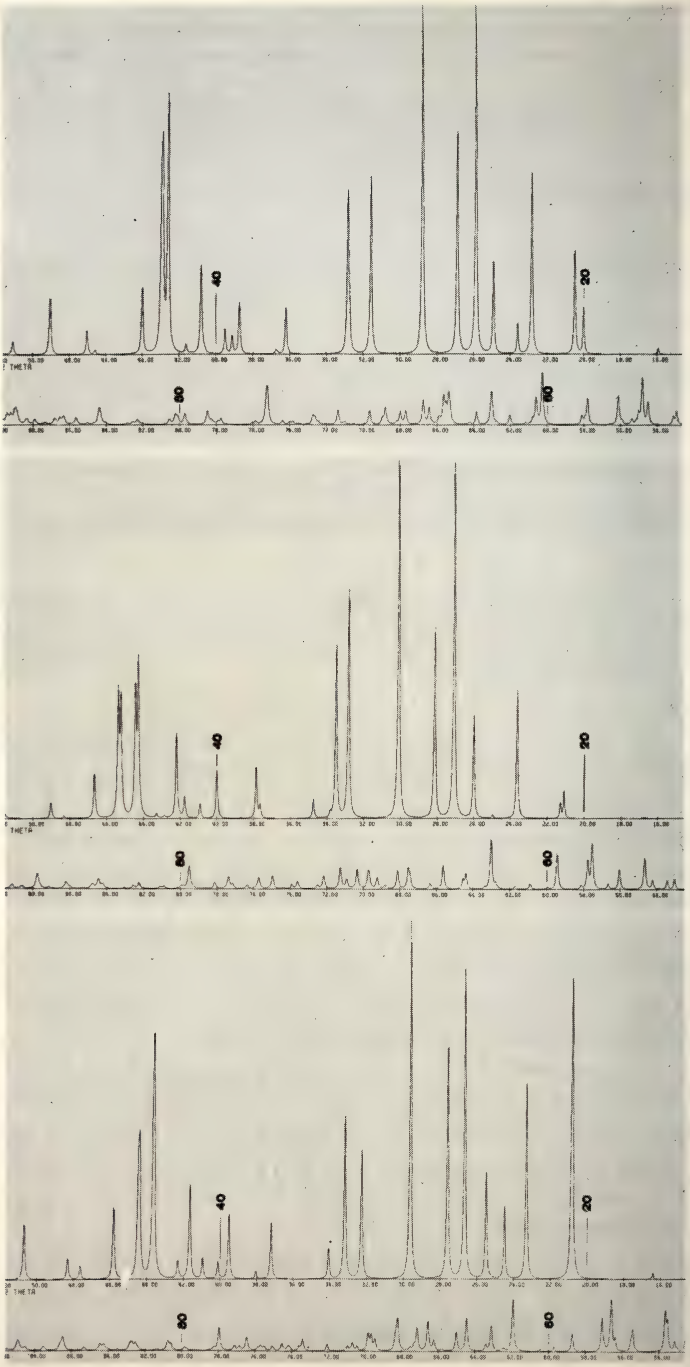


Fig. 1. Computer-simulated diffractometer scans for barite (top), celestite (center), and anglesite (bottom) from 16° 2θ to 90° 2θ (2θ angle increasing from right to left). The patterns are for CuKα radiation, a Cauchy line profile, and a half-width at 40° 2θ of 0.1°.

TABLE 1. Crystal structure data for barite, celestite and anglesite—partial input data for the computer program.

	Barite	Celestite	Anglesite
System	orthorhombic	orthorhombic	orthorhombic
Space Group	Pnma	Pnma	Pnma
Unit Cell Content	4	4	4
Density	4.468	3.960	6.267
a	8.884	8.3600	8.516
b	5.458	5.3520	5.399
c	7.153	6.8580	6.989
Source of Positional and *Thermal Parameters*	Coville and Staudhammer (1967)	Hawthorne and Ferguson (1975)	Sahl (1963)

in relative intensities may be due to preferred orientation. In addition there are several minor errors in indexing which appear on the JCPDS file cards.

A comparison of the calculated pattern for barite with the data on file card #5-448 indicates that the reflection at d = 2.12 (indexed as 113) is actually a doublet and should be indexed as 113,401. Similarly, the reflection at d = 2.104 (indexed as 312) should be indexed as 122,312, the reflection at 1.754 (indexed as 313) should be 313,104, the reflection d = 1.526 (indexed as 512) should be 512,232 and the reflection at d = 1.474 (indexed as 124) should be 124,314. There are also sixteen lines of low intensity which are not listed.

For celestite (card #5-593) the reflection at d = 4.23 (indexed as 011) should be indexed as 011,200. The reflection at d = 2.006 (indexed as 203) is an unresolved doublet and should be indexed as 312,203 (92% of the intensity is from the 312 reflection). The reflection at d = 1.691 is indexed as 412,131; the 412 might best be deleted as its contribution is negligible. The reflection at d = 1.679 (indexed as 313) should be indexed as 313,104. Finally, there are nine reflections of low intensity which are not listed on the file card.

For anglesite (card #5-577) the reflection at d = 4.26 should be indexed as 011,200 (rather than as 011), the reflection at d = 1.716 should be 104,412+ (rather than 412) and the reflection at d = 1.703 should be 313,131+ (rather than 322). There are also eleven lines of low intensity which are not listed on the card.

ACKNOWLEDGMENTS—Calculation of the powder diffraction patterns was done with facilities of the Northeast Regional Data Center of the State University System of Florida. R. A. Wicker adapted the program written by Clark, Smith, and Johnson to the NRDC computer and wrote the plot routine. N. K. Olsen assisted in keypunching.

LITERATURE CITED

CLARK, C. M., D. K. SMITH, AND G. G. JOHNSON. 1973. A FORTRAN IV program for calculating x-ray powder diffraction patterns—version 5. Pennsylvania State Univ. University Park.

COVILLE, A. A., AND K. SLAUDHAMMER. 1967. A refinement of the structure of barite. Amer. Mineral. 52:1877-1880.

TABLE 2. Powder diffraction data for barite, celestite, and anglesite.

BARITE					
Calculated			Card #5-448		
d A	I/I_o	hkl	d A	I/I_o	hkl
5.5715	2	101			
4.4420	13	200	4.44	17	200
4.3391	28	011	4.34	36	011
3.8989	50	111	3.90	57	111
3.7736	8	201	3.77	12	201
3.5765	25	002	3.576	31	002
3.4452	99	210	3.442	100	210
3.3177	64	102	3.317	67	102
3.1040	100	211	3.101	97	211
2.8351	52	112	2.834	53	112
2.7361	10	301	2.734	16	301
2.7290	46	020	2.726	47	020
2.4813	14	212	2.481	14	212
2.4508	1	121			
2.4460	1	311	2.444	2	311
2.3252	16	220	2.322	15	220
2.3028	6	103	2.303	6	103
2.2809	8	302	2.281	7	302
2.2210	1	400			
2.2113	28	221	2.209	27	221
2.1696	3	022			
2.1217	47	113	2.120	80	113
2.1211	36	401			
2.1076	52	122			
2.1046	42	312	2.104	76	312
2.1008	2	203			
2.0572	21	410	2.056	23	410
1.9495	1	222	1.947	<1	222
1.9322	8	321	1.930	7	321
1.8572	20	303	1.857	16	303
1.7883	4	004	1.787	3	004
1.7632	6	031	1.760	9	031
1.7582	6	313	1.754	9	313
1.7531	5	104			
1.7501	1	322			
1.7295	5	131	1.726	5	131
1.7244	3	501	1.723	6	501
1.6836	8	230	1.681	7	230
1.6747	17	421	1.673	14	421
1.6691	4	114	1.669	10	114
1.6589	2	204			
1.6443	1	511			
1.6388	11	231	1.636	8	231
1.6252	0	403			
1.5952	10	132	1.593	8	132
1.5913	2	502	1.590	7	502
1.5872	3	214			
1.5354	20	323	1.534	18	323
1.5308	0	304			
1.5277	10	512	1.526	11	512
1.5233	2	232			
1.5150	1	331			
1.4957	4	024	1.495	3	024
1.4807	1	600			
1.4750	10	124	1.474	10	124
1.4739	4	314			
1.4578	5	521	1.457	3	521
1.4500	1	601			
1.4290	5	610	1.426	8	610, 133
1.4276	10	133			
1.4247	5	503			
1.4223	10	332			

CELESTITE					
Calculated			Card #5-593		
d A	I/I_o	hkl	d A	I/I_o	hkl
4.2192	4	011	4.23	11	011
4.1800	4	200			
3.7667	33	111	3.77	35	111
3.5693	1	201	3.57	2	201
3.4290	27	002	3.433	30	002
3.2943	95	210	3.295	98	210
3.1725	53	102	3.177	59	102
2.9695	100	211	2.972	100	211
2.7291	64	112	2.731	63	112
2.6760	48	020	2.674	49	020
2.6511	1	202			
2.5817	6	301	2.582	6	301
2.3890	4	121	2.388	7	121
2.3756	15	212	2.377	17	212
2.2537	14	220	2.253	18	220
2.2051	5	103	2.208	5	103
2.1626	7	302	2.164	7	302
2.1411	26	221	2.141	25	221
2.1096	1	022			
2.0900	1	400			
2.0455	46	122	2.045	55	122
2.0388	39	113	2.041	57	113
2.0057	3	203	2.006	40	203
2.0051	33	312			
1.9992	37	401	1.999	48	401
1.9468	14	410	1.947	15	410
1.8834	1	222			
1.8580	5	321	1.857	7	321
1.7674	17	303	1.769	17	303
1.7265	3	031	1.728	2	031
1.7145	3	004	1.715	3	004
1.6909	3	131	1.691	3	412,131
1.6795	4	104			
1.6783	8	313	1.679	9	313
1.6409	7	230	1.640	5	230
1.6244	2	501	1.625	2	501
1.6049	1	223	1.604	7	223, 114
1.6025	4	114			
1.6016	12	421	1.601	15	421
1.5958	9	231	1.569	10	231
1.5862	1	204			
1.5550	11	132	1.555	11	132, 511
1.5544	2	511			
1.5425	1	403			
1.5209	2	214	1.521	1	214
1.5029	1	502			
1.4801	2	252			
1.4748	19	323	1.475	16	323
1.4469	6	512	1.447	6	512
1.4436	3	024	1.444	5	024
1.4226	9	124	1.424	6	124
1.4088	2	314	1.410	3	314
1.3886	4	521	1.388	9	521
1.3869	7	133			
1.3762	7	332			
1.3645	1	224			
1.3569	4	430			
1.3496	4	503			
1.3484	5	610			
1.3380	8	040			
1.3287	4	015			
1.3231	9	611			

ANGLESITE					
Calculated			Card #5-577		
d A	I/I_o	hkl	d A	I/I_o	hkl
5.4025	2	101	5.381	3	101
4.2726	72	011	4.26	98	011
4.2580	28	200			
3.8189	53	111	3.813	57	111
3.6363	19	201	3.622	23	201
3.4945	29	002	3.479	33	002
3.3433	83	210	3.333	86	210
3.2329	66	102	3.220	71	102
3.0160	100	211	3.001	100	211
2.7737	37	112	2.773	35	112
2.7013	2	202			
2.6995	45	020	2.699	46	020
2.6300	9	301	2.618	8	301
2.4158	17	212	2.406	17	212
2.3644	2	311	2.355	<1	311
2.2799	20	220	2.276	20	220
2.2471	5	103	2.235	5	103
2.2033	7	302	2.193	7	302
2.1675	29	221	2.164	26	221
2.1363	5	022	2.133	5	022
2.0746	52	113	2.067	76	113, 112
2.0721	46	112			
2.0400	36	312	2.031	34	312
2.0366	32	401	2.028	48	401
1.9806	23	410	1.973	21	410
1.9095	4	222	1.905	3	222
1.8838	7	321	1.879	6	321
1.8009	19	303	1.793	15	303
1.7473	2	004	1.741	8	004, 031
1.7428	9	031			
1.7271	1	123			
1.7231	3	412	1.716	3	412
1.7116	9	104			
1.7083	5	313			
1.7074	5	131			
1.7069	2	322	1.703	16	322
1.6577	7	230	1.656	7	230
1.6548	3	501	1.648	3	501
1.6316	4	114			
1.6258	19	421	1.621	19	421
1.6165	1	204			
1.6129	12	231	1.611	10	231
1.5821	1	511			
1.5724	6	132	1.571	6	132
1.5716	1	403			
1.5485	2	214	1.542+	2	214
1.5310	1	502	1.525+	1	502
1.4981	19	323	1.493	15	323
1.4977	3	232			
1.4880	1	304			
1.4852	1	331			
1.4730	10	512	1.467	7	512
1.4668	2	024			
1.4455	13	124	1.441	8	124
1.4345	7	314			
1.4193	1	600			
1.4108	4	521	1.406	3	521
1.4047	12	133			
1.3938	9	332			
1.3909	2	601			
1.3868	1	224			
1.3749	6	503			
1.3744	7	430			
1.3727	5	610			
1.3532	5	015			

HAWTHORNE, F. C., AND R. B. FERGUSON. 1975. Anhydrous sulfates. 1: Refinement of the crystal structure of celestite with an appendix on the structure of thenardite. Canad. Mineral. 13: 181-187.

HUBBARD, C. R., E. H. EVANS, AND D. K. SMITH. 1976. The reference intensity ratio, I/I_c, for computer simulated powder patterns. J. Appl. Crystallogr. 9:169-174.

SAHL, K. 1963. Die verfeinerung der kristallstrukturen von $PbCl_2$ (cotunnit), $BaCl_2$, $PbSO_4$ (anglesite) und $BaSO_4$ (baryt). Beitr. Min. Petr. 9:111-132.

Florida Sci. 40(1):61-64. 1977.

Conservation

NESTING WADING BIRD POPULATIONS IN SOUTHERN FLORIDA

James A. Kushlan and Deborah A. White
U. S. National Park Service, Everglades National Park, Homestead, Florida 33030

Abstract: *Wading birds, including ibises, herons, and storks, which once nested in southern Florida by the millions have decreased because of habitat destruction. A 1974-1975 survey located 41 colonies and 129,800 wading birds nesting in southern Florida. White Ibis and Cattle Egret were most abundant; populations of Great Egrets, Little Blue Herons, Louisiana Herons and Snowy Egrets were lower than expected. Wading birds nested year round but individual species had more circumscribed nesting seasons which differed seasonally and between inland and coastal colonies.*

Fifteen species of herons, storks and ibises nest in southern Florida. As many as 2.5 million wading birds are estimated to have nested in this area under the pristine, natural conditions of the 1800's (Robertson, 1965). The subsequent decline caused by plume hunting and recovery after the end of that era are well known chapters in the story of American conservation (Robertson and Kushlan, 1974). Since that time, progressive degradation of the southern Florida environment has led to a second period of population decline from the 1930's to present. Study of the recent decline and its causes has been pursued by the National Park Service and National Audubon Society which preserve many of the traditional nesting sites from disturbance. The occurrence of population declines despite protection of their colony sites shows that preservation of the vitally important feeding habitat has been less successful. Monitoring the population levels of 15 species over the vast marshes, swamps and marine habitats of southern Florida has proved to be a difficult undertaking because of the time and resources required. Nonetheless, such data are crucial in order to understand the current status and to provide for future preservation of these possibly diminishing populations.

During a one year study we attempted to determine, at least roughly, the number of wading birds nesting in southern Florida. We collected information from September 1974 through August 1975. Active colony sites were located and abundance was estimated for some of the most abundant species. Deficiencies exist in the data base because, for instance, some colonies in the Big Cypress Swamp were only estimated by aerial survey. Some early nesting individuals and Great Blue Herons that nested in scattered inland sites were not censused. Black-crown Night Herons *(Nycticorax nycticorax)*, Yellow-crown Night Herons *(Nyctinassa violacea)*, Green Herons *(Butorides striatus)*, Reddish Egrets *(Dichromanassa rufescens)*, and Least Bitterns *(Ixobrychus exilis)*, because of the dispersed nature of their nesting sites, were too inadequately censused to be included in the summary. We do provide estimates of colony and population totals for the most abundant species as a step towards achieving a complete picture of wading bird nesting in southern Florida.

Southern Florida is bordered by the Caloosahatchee and St. Lucie Rivers, including Lake Okeechobee, and extends south to the southern boundary of Everglades National Park in Florida Bay (Fig. 1). This does not include the lower Florida Keys. Initial estimates of colony size were made by aerial observation. For all but 6 sites, aerial surveys were followed by one or more censuses from the ground. Wading birds censused were the White Ibis (*Eudocimus albus*), Roseate Spoonbill (*Ajaia ajaja*), Wood Stork (*Mycteria americana*), Great Blue Heron (*Ardea herodias*), Great Egret (*Casmerodius alba*), Snowy Egret (*Egretta thula*), Little Blue Heron (*Florida caerulea*), Louisiana Heron (*Hydranassa tricolor*), and Cattle Egret (*Bubulcus ibis*). Locations where Black-crown Night Herons, Yellow-crown Night Herons and Reddish Egrets nested are included. Data on colony associates, the Brown Pelican (*Pelicanus occidentalus*), Double-crested Cormorant (*Phalacrocorax auritus*) and Anhinga (*Anhinga anhinga*), are also included where available. There was no count of Glossy Ibis (*Plegadus falcinellus*) nesting in southern Florida this year, although the species has nested in the area in the past (Kushlan and Schortemeyer, 1974) and some evidence suggests it may have nested at Okaloacoochee in Fall of 1974 (J. C. Ogden, personal communication).

Results—Forty-two colony sites active in 1974-75 are listed on Table 1. The location of each colony is given in the table and shown on Figure 1. The number of nests of each species includes all birds nesting at the site during a complete year's cycle of nesting. In some cases this includes more than one wave of nesting and approximate dates when nesting began are included. In addition, Great Blue Herons (including Great White Herons) that nested on some islands in Florida Bay and in the 10,000 Islands along the west coast are combined in the table. Where the totals are known to underestimate several species, this is noted.

The largest colony of about 40,600 wading birds was a late summer and autumn nesting in the Okaloacoochee Slough in the Big Cypress Swamp. A nearby colony at Sunniland Grade consisted of about another 600 birds. These colonies were the first known to occur in this area, although previous coverage was not extensive. The Big Cypress nesting was the largest nesting episode of the year.

The levee-surrounded water conservation areas north of Everglades National Park held three sizable colonies during the usual spring nesting season. These colonies accounted for about 32,700 nesting wading birds. Large, successful wading bird colonies were first found in Water Conservation Area 3 in 1972 (Kushlan, 1973), although they may have existed previously and at least one colony was found in 1967 (Ogden). Wading birds have formed large colonies at various sites in the conservation areas each year from 1972 through 1975. Kings Bar, the primary nesting colony in Lake Okeechobee, had about 14,400 nesting wading birds during the spring. A mid-summer 1974 nesting apparently also occurred there, before the present census began (Ogden).

Fig. 1. Number of wading birds at the colony sites active in 1974-75. Colony numbers are keyed to names listed in Table 1.

The largest colonies in Everglades National Park were at Rodgers River Bay, Lane River, Frank Key and Taylor Slough. The Rodgers River Bay colony was active from fall through late summer of 1975 with several successive waves of nesting beginning with Great Egrets, followed by Snowy Egrets, then Louisiana Herons, and finally White Ibis. Lane River is the principal Wood Stork colony in the park. This year four other species nested there, including 6 Roseate Spoonbills (Ogden) which represent one of the few inland nesting records of this species in southern Florida. Frank Key contained 10 species of wading birds in-

Table 1. Colony sites and number of wading bird nests in southern Florida, September 1974 to August 1975.

Colony Site	Colony Location[1]	Month of Nesting[2]	White Ibis	Roseate Spoonbill	Wood Stork	Great Blue Heron	Great Egret	Snowy Egret	Little Blue Heron	Louisiana Heron	Cattle Egret	Other Wading Bird Species[5]	Brown Pelican	Double-Crested Cormorant	Anhinga
1. Kings Bar	Lake Okeechobee	III[3]	3000			8	65	80	50	20	4000				10
2. Sadie Cypress	Big Cypress Swamp	XII[3]			27										
3. Corkscrew	Big Cypress Swamp	XII[3]			3000		150								
4. Tarpon Bay	Sanibel Island	V				1							2	14	
5. Estero Bay	Estero	III				1	2	8	2	27	12	B	139	35	1
6. Sunniland Grade	Big Cypress Swamp	IX[3]					300								
7. Okaloacoochee	Big Cypress Swamp	IX[3]	12000				125	150	25		8000				40
8. Big Marco Pass	Marco Island	I,III,VI					28	29	7	278	274		108	17	3
9. Chokoloskee	Everglades Nat'l Park	III,VI					252			416	3		150	108	
10. Alligator Alley West	Conservation Area 3a	IX,I	1			19	950	400				B			10
11. Alligator Alley East	Conservation Area 3a	III[3]	11000			15	1000	1500		590	1	B			8
12. L-67-A	Conservation Area 3a	III				2	40	412	72	728		B			8
13. Seawall	St. Lucie Inlet	II,III	27			4	41	19	4	26	162	B			
14. Fisherman's Island	West Palm Beach	II,III					57	226		113	881				
15. Executive Airport	Fort Lauderdale	II					20				147				3
16. Power Company	Fort Lauderdale	XII,III					25		22	4	5	Y			
17. Greynolds	North Miami	IV	41				2	1	13	13	581	B,Y		14	34
18. Cutler	Biscayne Bay	II												350	
19. Arsenicker Keys	Biscayne Nat'l Mnt.	XII,III	106			13	19	2	19	25	879			120	2
20. Rookery Keys	Biscayne Bay	II												250	
21. Hole-in-Donut	Everglades Nat'l Park	VI									630				
22. Taylor Slough	Everglades Nat'l Park	VII					2		6	30	1000				4
23. Rookery Branch	Everglades Nat'l Park	XII				1	9								25
24. Rodgers River Bay	Everglades Nat'l Park	IX,I,V	923				443	1330		588					9
25. Lane River	Everglades Nat'l Park	XII,III		3	1100		200	577		842					11

26. East River	Everglades Nat'l Park	XII,I			110		90	9		117					2
27. Cuthbert	Everglades Nat'l Park	XII,III					65	96		6				15	
28. Madiera	Everglades Nat'l Park	XII			125		100	150							30
29. Porjoe Key	Everglades Nat'l Park	XI,IV	15	15			1	38	3	49					
30. Nest Key	Everglades Nat'l Park	II					4						40		
31. Tern Key	Everglades Nat'l Park	IX,XI,V	15	315		2	3	6	1	610		R			
32. Palm Key	Everglades Nat'l Park	I				8	48							80	
33. Frank Key	Everglades Nat'l Park	XII,VI	841	24		19	350	42	32	101	12	B,R	140	328	
34. Oyster Key	Everglades Nat'l Park	XII		57		3	30	22				B,R	62	85	
35. Catfish Key	Everglades Nat'l Park	XII				16	3								
36. Sandy Key	Everglades Nat'l Park	I,III				11	53	20	1	259				91	
37. Upper Arsnicker Key	Everglades Nat'l Park	II,III				13	60						50	390	
38. Green Mangrove Key	Everglades Nat'l Park	II				3								80	
39. Buchanan Keys	Everglades Nat'l Park	IX,V	4	8[4]		11	20	34		19			50	117	
40. Cowpens Keys	Everglades Nat'l Park	IX,III	10	25		9	30	14		43				14	100
41. Bottle Key	Everglades Nat'l Park	XII		13		2									
42. Stake Key	Everglades Nat'l Park	XII		20		10									
Florida Bay other Keys	Everglades Nat'l Park			20		321									120
10,000 Islands	Everglades Nat'l Park					14[4]									20[4]
Totals															
	Everglades Nat'l Park		1800	500	1330	440	1760	2340	40	3070	1640				
	South Florida		28000	500[4]	4360	500[4]	4590	5190	260[4]	4900	16640				

[1]See Figure 1 for precise location.
[2]Month between September (IX) 1974 and August (VIII) 1975 when wave of wading bird nesting began. IX indicates nesting underway when study year began.
[3]Data from airplane estimates only.
[4]Indicates datum known to be underestimate.
[5]B = Black-crown Night Heron, Y = Yellow-crown Night Heron, R = Reddish Egret.

cluding the first Cattle Egrets known to nest in northwest Florida Bay. Taylor Slough is primarily a summer Cattle Egret colony.

Corkscrew was the largest southern Florida stork colony with 6,300 nesting birds. Storks also nested at Madeira, East River, Lane River and Sadie Cypress. Of the 8,700 Wood Storks that nested in southern Florida in 1974-75, 30% nested in Everglades National Park and the rest in the Big Cypress Swamp. Rookery Branch, the location of the traditional Everglades nesting colonies that in the 1930's numbered in the hundreds of thousands of birds, was nearly inactive for the third year in a row with only 20 herons and 30 Anhingas nesting. Cuthbert and East River, two other famous park colony sites of the 1950's and early 1960's, contained only 330 and 750 birds respectively.

The following list summarizes available data on the nesting population of various species in 1974-75:

White Ibis	56,000
Roseate Spoonbill	1,000
Wood Stork	8,700
Great Blue Heron	1,000
Great Egret	9,200
Snowy Egret	10,300
Little Blue Heron	500
Louisiana Heron	9,800
Cattle Egret	33,300
Total	129,800

The most numerous wading bird species in southern Florida was the White Ibis, 56,000 of which nested at 13 sites during the study period. The Cattle Egret, with 33,300 nesting birds was the next most abundant species. Together these two species accounted for 69% of the wading birds nesting in southern Florida in 1974-75. Censused nesting populations of the Snowy Egret (10,300 birds), Louisiana Herons (9,800 birds) and Great Egrets (9,200 birds) were relatively small. The nests of about 1,000 Great Blue and Great White Herons were counted but at least a couple hundred more nesting birds were not included. At least 1,000 Roseate Spoonbills nested in Florida Bay.

One interesting aspect of wading bird nesting in southern Florida, contrasted with the rest of North America, is the long duration of the nesting season. Wading birds were nesting somewhere in southern Florida during every month in 1974-75 (Fig. 2). Colonies along the east coast generally began in winter and continued through the largest peaks in summer. Florida Bay colonies began earlier than those along the east coast. Most inland nesting occurred during the winter and spring dry season, but nesting by some species, particularly White Ibis, Cattle Egrets and Great Egrets, perhaps in response to localized water conditions, may result in year round nesting. Generally however, November is the low point of nesting. Various species tend to show more seasonality in their nesting cycle (Fig. 2). In 1974-75, White Ibis and Cattle Egrets nested in both fall and spring, while Great Egrets nested year yound. Other species tended to be circumscribed.

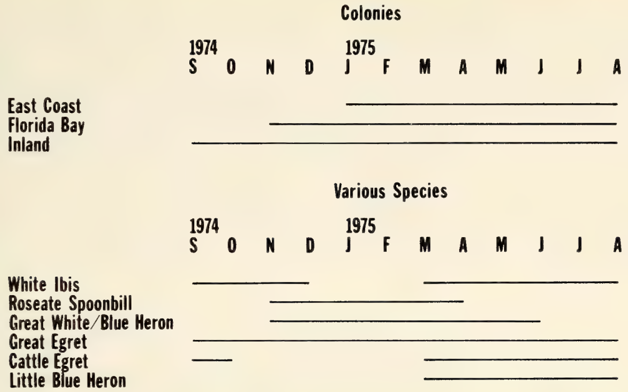


Fig. 2. Timing of nesting at wading bird colonies and nesting season of various species in southern Florida, 1974-75.

Discussion—Robertson estimated wading bird numbers in southern Florida to have been 2,500,000 in 1800's, 500,000 in 1920's, 1,200,000 in 1930, 300,000 in 1960 and 150,000 in 1970 (Robertson and Kushlan, 1974). The 1975 population level is estimated to be 129,800 birds. This compares well with the 128,000 birds estimated to have nested in this area in 1972, based on aerial surveys of the National Audubon Society (Sprunt, 1973), and the National Park Service (Robertson and Kushlan, 1974). The present estimate represents a 95% decrease in population since the 1800's, and 89% decrease since the 1930's, and a 13% decrease since 1970. The estimates of 1972 and of 1975 are essentially identical. The differences between them are within the error associated with either census.

Of considerable concern is the low percentage of the total population nesting in Everglades National Park. During the 1930's the largest colonies in Florida, and perhaps in the United States, were located in what is now Everglades National Park. Rookery Branch of the Shark River, the site of the largest colonies, supported only 20 nesting wading birds in 1975. Furthermore, birds nested there in numbers only twice since 1967. The largest colonies are now located north of the Park. Only 20% of southern Florida wading bird population, 25,900 birds, nested in the Park in 1975. Although a greater percentage may nest there in some years, the situation is still very different than in the 1930's. Since Park colony sites are protected, this means that the feeding habitat that the Everglades marsh in the Park once supplied for hundreds of thousands of wading birds is now sufficiently altered to preclude nesting of a large percentage of the South Florida population in most years. These changes suggest strongly that some aspects of the natural ecological processes are no longer functioning in the southern Everglades of Everglades National Park.

Two species of special concern, the Wood Stork and Roseate Spoonbill, both nested successfully in 1974-75. Ogden (1971, 1972, 1973) has summarized recent history of Wood Stork nesting in Florida. In 1975, Wood Storks produced 8,000 young. The Spoonbills produced about 1,000 young. Also on the positive side is population total of 56,000 nesting White Ibis. This species nests in irregular numbers often at different locations each year, but the count for 1975 is similar in magnitude to the fairly precise 1972 and 1973 censuses of 60,300 and 40,200 birds (Robertson and Kushlan, 1974). Both White Ibis and Cattle Egrets appear to be maintaining substantial and probably biologically viable populations. Both, it might also be noted, appear to be capable of taking advantage of suitable foraging conditions by establishing colonies in areas where such opportunities present themselves. This was shown by the Big Cypress nesting of 1974. Despite the optimistic outlook for these species, it should be kept in mind that the 1975 southern Florida nesting population of White Ibis is probably about 10% of what it was in the 1930's.

The Snowy Egret, Great Egret and Louisiana Heron each have about 9,000-10,000 birds nesting in southern Florida. According to our data, only 500 Little Blue Herons nested during the year. This is almost certainly an underestimate, but very little is known about this species. All totals are surprisingly low and are considerably below the 40,000-50,000 birds that Robertson and Kushlan (1974) estimated to be the combined population of these four species. More attention needs to be given to study of the population levels and biology of these species of egrets and herons.

Acknowledgements—This study was funded by the U. S. Fish and Wildlife Service, and supported by the U. S. National Park Service and National Audubon Society. John C. Ogden and William B. Robertson, Jr. contributed much information. We thank the many persons and organizations who also contributed information or in other ways assisted with the survey: J. Anderson, M. Kushlan, R. Miele, A. Lussier, R. Cooley, T. Schmidt, F. Whitehead of Everglades National Park; J. Brooks of the Fort Pierce Audubon Society; T. Custer of the U. S. Fish and Wildlife Service; H. Kale of the Florida Audubon Society; J. King of Dade County Parks; J. Layne and F. Lohrer of Archbold Biological Station; S. Nesbitt of the Florida Game and Fresh Water Fish Commission; O. Owre of the University of Miami; K. Rist of Broward County Audubon Society; R. Roberts of the Florida Department of Natural Resources; A. Sprunt IV of the National Audubon Society; C. Stone and K. Washington of Florida Power and Light Co.; J. Tilmant of Biscayne National Monument; and C. Singletary and T. Below.

LITERATURE CITED

Kushlan, J. A. 1973. White Ibis nesting in the Florida Everglades. Wilson Bull. 85:230-231.

———, and J. L. Schortemeyer. 1974. Glossy Ibis nesting in southern Florida. Florida Field Natur. 2:13-14.

Ogden, J. C. 1971. Florida Region. Amer. Birds 25:846-851.

——— 1972. Florida Region. Amer. Birds 26:847-852.

——— 1973. Florida Region. Amer. Birds 27:859-863.

Robertson, W. B., Jr. 1965. Inside the Everglades. Aud. Mag. 67:274-279.

———, and J. A. Kushlan. 1974. The southern Florida avifauna. Miami Geol. Soc. Mem. 2:414-452.

Sprunt, A., IV. 1973. Status of colonies of large wading birds in south Florida. Rept. Res. Dep. National Audubon Society.

Florida Sci. 40(1):65-72. 1977.

Physics and Astronomy

DOUBLE MINIMUM BENDING POTENTIALS FOR AB_2-TYPE MOLECULES IN THE CNDO APPROXIMATION

SUHEIL F. ABDULNUR AND JOHN R. SABIN

Quantum Theory Project, Department of Physics, University of Florida, Gainesville, Florida 32611

ABSTRACT: *The CNDO method has been applied to a variety of AB_2*-type molecules in order to test the reliability of the method at geometries removed from equilibrium. In particular, the method was found to predict double minima in the bending potential of such molecules in a qualitatively correct manner. Some features of such CNDO determined potential curves are discussed.

THE Complete Neglect of Differential Overlap (CNDO) approximation (Pople and Beveridge, 1970) is known to give reasonable predictions of molecular geometry when used near the equilibrium configuration. This is especially true for calculation of bond angles in small molecules when experimental bond lengths are used. If both distance and angle are varied, the quality of the results is not as high, but is still reasonable. Little has been done, however, to test the reliability of the method at geometries significantly removed from equilibrium. In order to test the reliability of this method at such non-equilibrium geometries, we have carried out calculations on a number of AB_2-type molecules, which have been proposed to have double minima in their bending potentials (Hoffman, 1971; Peyerimhoff and Buenker, 1967).

Calculations were carried out using a modified version of the Dobosh CNDO program (Dobosh, 1970) incorporating the Santry second row parameters (Sabin et. al., 1972).

The O_3 molecule was selected as a test case, as extensive ab initio calculations (Peyerimhoff and Buenker, 1967) on it are available for comparison. The bending potential for O_3 at the experimental bond length, 1.278 Å (Sutton, 1958), is presented in Figure 1. It can be seen that there is indeed a double minimum in the potential with minima at 114° and 58°, in reasonable agreement with ab initio results (P. Lindner and C. Edmiston, personal communication, 1972). The inner (58°) minimum is of considerably lower energy. It should be noted that the curve is discontinuous at nearly 83°. In addition, Walsh type diagrams show the individual orbital energies to be discontinuous at nearly the same bond angle. Separate minimization of the energy with respect to the O-O bond distance at the two minimum energy angles gives qualitatively the same result, with the lower minimum at $R = 1.237$ Å and $\theta = 60°$, and the higher minimum at $R = 1.17$ Å and $\theta = 119°$.

Although the existence of a double minimum in this system with a lower small angle minimum agrees with more sophisticated calculations by Lindner and Edmiston, the discontinuities in the potential and Walsh diagrams seem to be a result of the CNDO method itself. From accurate ab initio calculations on O_3 (Peyerimhoff and Buenker, 1967), one obtains a variety of $^1A_1$ states arising

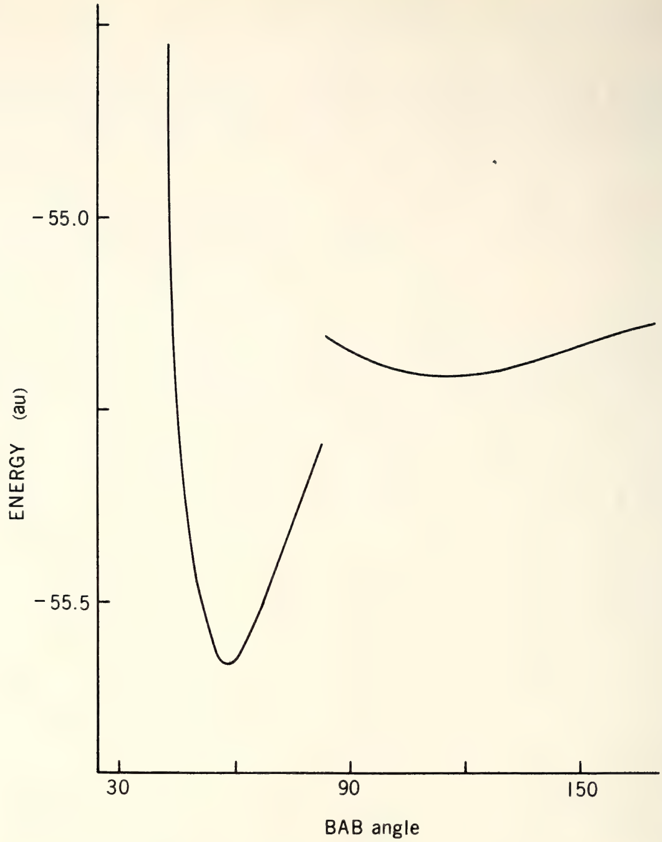


Fig. 1. CNDO bending potential for 0_3 at $R_{oo} = 1.278$ Å.

from different orbital occupations. In particular, the state resulting from the $(2b_1)^2$ configuration has a minimum at 118.5°, while the state corresponding to the $(4b_2)^2$ configuration has a minimum near 70°. The curves for these two states apparently cross at about 90°. Similarly, the plots of orbital energy sums for the two $^1A_1$ states cross, but at about 98°. Since the CNDO method occupies orbitals such that the orbital energy sum is minimum (i.e. the lowest energy N/2 molecular orbitals will be filled), it is to be expected that as the O-O-O angle is decreased, the total energy will follow the curve corresponding to $(2b_1)^2$ occupation until 98°, when it will switch to the curve corresponding to $(4b_2)^2$ occupation. As the total energy and orbital energy sum curves for the two states do not cross at the same place, this will lead to a discontinuity in the CNDO calculated total energy, as is found in this work. The orbital occupancy changes at the discontinuity in the total energy curve, leading to the observed discontinuities at the same point in the Walsh diagram.

Calculations on a variety of other AB_2 molecules were also carried out, and the results obtained are presented in Table 1. Here it can be seen that in all cases two minima were observed, but the energy relation between the two minima depended strongly on the particular case in question.

TABLE 1. Summary of identifying features of potential energy curves with bond angle variation for a number of AB_2-type molecules.

Molecule	Location of Discontinuity	Large angle minimum	Small angle minimum	Bond length[7]	Valence electrons
BO_2	83°-86°	180°	62°	1.25 Å	15
CO_2	94°-97°	180°	67°	1.162	16
N_3^-	100°-120°	180°	~80°	1.12	16
NO_2	100°-110°	~135°	~63°[a]	1.20	17
SO_2	70°-72°	120°	51°[a]	1.432	18
S_3	82°-83°	~115°	~62°	2.06	18
CF_2	58°-59°	~105°	51°	1.32	18
NO_2^-	70°-80°	~115°	~60°[a]	1.236	18
O_3^-	82°-84°	114°	58°[a]	1.278	18
O_3^-	82°-84°	119°[b]	~68°[a]	1.20[b]	19
S_3^-	80°-100°	~115°	~65°[a]	2.06	19

[a]Identifies the cases where the second minimum has a lower (more negative total energy than the first.
[b]Refers to values obtained by simultaneously minimizing both the angle and the bond distance.

The results presented here are in qualitative agreement with the little theoretical and experimental evidence available (e.g., Hays and Pfeiffer, 1968). It appears that CNDO correctly predicts two minima in the bending potential curves for AB_2-type molecules. The magnitude of the energy difference between the higher and lower minima is probably not quantitatively correct, but the ordering, at least in the case of O_3, agrees with Lindner and Edmiston's more sophisticated ab initio SCF calculations. A more thorough corroboration of these results is indicated by more recent sophisticated SCF and configuration interaction (CI) calculations (Wright, 1972; Hay and Goddard, 1972; Wadt and Goddard, 1974; Grinbert and Devoquet, 1974; Shih, Buenker, and Peyerimhoff, 1974), but awaits experimental corroboration.

The authors are grateful to the National Science Foundation for support of this work, and to the Computer Center of the University of Florida for a grant of computer time.

LITERATURE CITED

DOBOSH, P. A. 1973. Program CNINDO, #141 from the Quantum Theory Program Exchange.

GRIMBERT, P., AND A. DEVOQUET. 1974. Strongly bent excited states of ozone. Mol. Phys. 27:831-836.

HAY, P. J., AND W. A. GODDARD. 1972. Theoretical results for the excited states of ozone. Chem. Phys. Letters 14:46-48.

HAYS, E. F., AND G. V. PFEIFFER. 1968. On the possible existence of double minima in potential energy surfaces of AB_2-type molecules. J. Amer. Chem. Soc. 90:4773-4777.

HOFFMAN, R. 1971. Paper presented at the 23rd International Congress of Pure and Applied Chemistry in Boston. August, 1971.

PEYERIMHOFF, S. D., AND R. J. BUENKER. 1967. Geometry of ozone and azide ion in ground and certain excited states. J. Chem. Phys. 47:1953-1966.

———, AND ———. 1968. Theoretical study of the geometry and spectrum of nitrous oxide. J. Chem. Phys. 49:2473-2487.

POPLE, J. A., AND D. L. BEVERIDGE. 1970. Approximate Molecular Orbital Theory. McGraw Hill. New York.

Sabin, J. R., D. P. Santry and K. Weiss. 1972. CNDO molecular orbital calculations: on the invariance of methods for second row elements. J. Amer. Chem. Soc. 94:6651-6652.

Shih, S., R. J. Buenker and S. Peyerimhoff. 1974. Theoretical investigation of the cyclic conformer of ozone. Chem. Phys. Letters 28:463-470.

Sutton, L. E., ed. 1958. Tables of Interatomic Distances. Spec. Publ. No. 11. The Chemical Society. London.

Wadt, W. R., and W. A. Goddard. 1974. Comparison of INDO and ab initio methods for the correlated wave functions of the ground and excited states of ozone. J. Amer. Chem. Soc. 96(6): 1689-1693.

Wright, J. S. 1973. Theoretical evidence for a stable form of cyclic ozone and its chemical consequences. Canad. J. Chem. 51:139-146.

Florida Sci. 40(1):73-76. 1977.

Biological Sciences

REPRODUCTIVE PATTERNS OF SOME SMALL MAMMALS IN SOUTH CAROLINA

Michael J. O'Farrell[1], Donald W. Kaufman[2], John B. Gentry and Michael H. Smith

Savannah River Ecology Laboratory, Drawer E, Aiken, South Carolina 29801

Abstract: *Reproductive cycles of the shrew,* Blarina brevicauda, *and three rodents,* Peromyscus gossypinus, Ochrotomys nuttalli *and* Sigmodon hispidus, *were examined from lands of the ERDA Savannah River Plant near Aiken, South Carolina. The information was collected from 1955 to 1973 and all species demonstrated bimodal reproductive cycles with peaks of activity in the spring and fall.* Sigmodon hispidus *and* P. gossypinus *had an equal intensity of effort during both seasons while* B. brevicauda *had a greater spring effort and* O. nuttalli *a greater fall effort.*

Golley (1966) summarized reproductive information on small mammals in South Carolina, but most reproductive cycles of small mammals are unknown. The Savannah River Ecology Laboratory has maintained an active trapping program from 1955 to 1973 on the lands of the Energy Research and Development Administration (formerly Atomic Energy Commission) Savannah River Plant (SRP) near Aiken, South Carolina, and we have been able to accumulate reproductive information on *Blarina brevicauda*, *Peromyscus gossypinus*, *Ochrotomys nuttalli* and *Sigmodon hispidus*. Their seasonal reproductive trends, litter size and relative recruitment rate of young into the population were determined. Secondarily, reproductive cycles were compared interspecifically for sympatric species and intraspecifically on a regional and latitudinal basis.

Materials and Methods—Specimens captured in snap traps, live traps and pit-falls were autopsied for reproductive information. For females, condition

[1]Present address: Department of Biological Sciences, University of Nevada, Las Vegas, Nevada 89109.

[2]Present address: Department of Biological Sciences, State University of New York, Binghamton, New York 13901.

of vulva, presence of embryos, crown-rump measurements of embryos, and lactation or indication of having lactated were recorded. For males, position, length and width of testes and, starting in 1969, sperm smears were taken. Fresh body wt and standard measurement were taken for both sexes. Although the data herein were collected over a period of several yr, each mo mean usually represents an adequate sampling throughout.

Results and Discussion—*Blarina brevicauda*: Short-tailed shrews were captured from 1967 to 1973 with the majority of data gathered from 1968 and 1969. Most captures occurred in the lowland hardwood forest, the preferred habitat for this species in the southeast (Golley, 1966; Gentry, Golley and Smith, 1971).

Monthly trends in reproductive activity of *B. brevicauda* are shown in Fig. 1A. Testicular activity, based on length, shows a distinct bimodal trend contrary to the observation of continuous summer breeding found for this species from the more northerly latitudes of Pennsylvania to Massachusetts (Pearson, 1944). The ratio of individuals with sperm present follows this trend. The summer low of mean testis length probably represents the influx of juvenile males following the spring breeding season. Adult males did not exhibit regressed testes in the summer, which supports this conclusion, and would therefore follow the active summer pattern in the north (Pearson, 1944).

The female cycle, as expected, follows that of males with a lag of about 1 mo in peak activity (Fig. 1A). The general pattern observed follows that described by Pearson but differs in several ways. Pregnant females began appearing in March or about 1 mo earlier than for northern *Blarina*. Also, the latest pregnancy encountered by Pearson was in early September while in South Carolina, *B. brevicauda* can be found pregnant through November. The extremely low percentage of pregnant females in our sample (Table 1) may reflect a strong trap bias against pregnant shrews. However, the seasonal trends still appear applicable.

The prolonged period of pregnancy in the spring would easily allow for 2 and possibly 3 litters based on the gestation period of 18-20 da. Likewise the autumn period would allow for 1-2 litters. This high number of litters would be further augmented as postpartum estrus occurs (Hamilton, 1949). Pearson found that males reached reproductive maturity by 83 da while females became receptive by da 47. From this is can be concluded that young born in the spring contribute to the fall production of young. Litter size in South Carolina ranged from 2-6 with a mean of 4 (Table 1). This figure is low compared to the mean of 5.7 and mode of 7 given by Pearson.

Peromyscus gossypinus: Cotton mice were captured on the SRP from 1955 through 1973 with the majority of captures occurring in 1968 and 1969. Most captures occurred in mesic wooded areas, although *P. gossypinus* was found in a variety of habitats including late seral stages of old-fields (Golley et al., 1965).

Monthly trends in reproductive activity for this species are shown in Fig. 1B. The pattern for males does not include juveniles (wt < 20.0 g). Even so, there is no clear-cut pattern of testicular activity. Sperm smears indicate that the

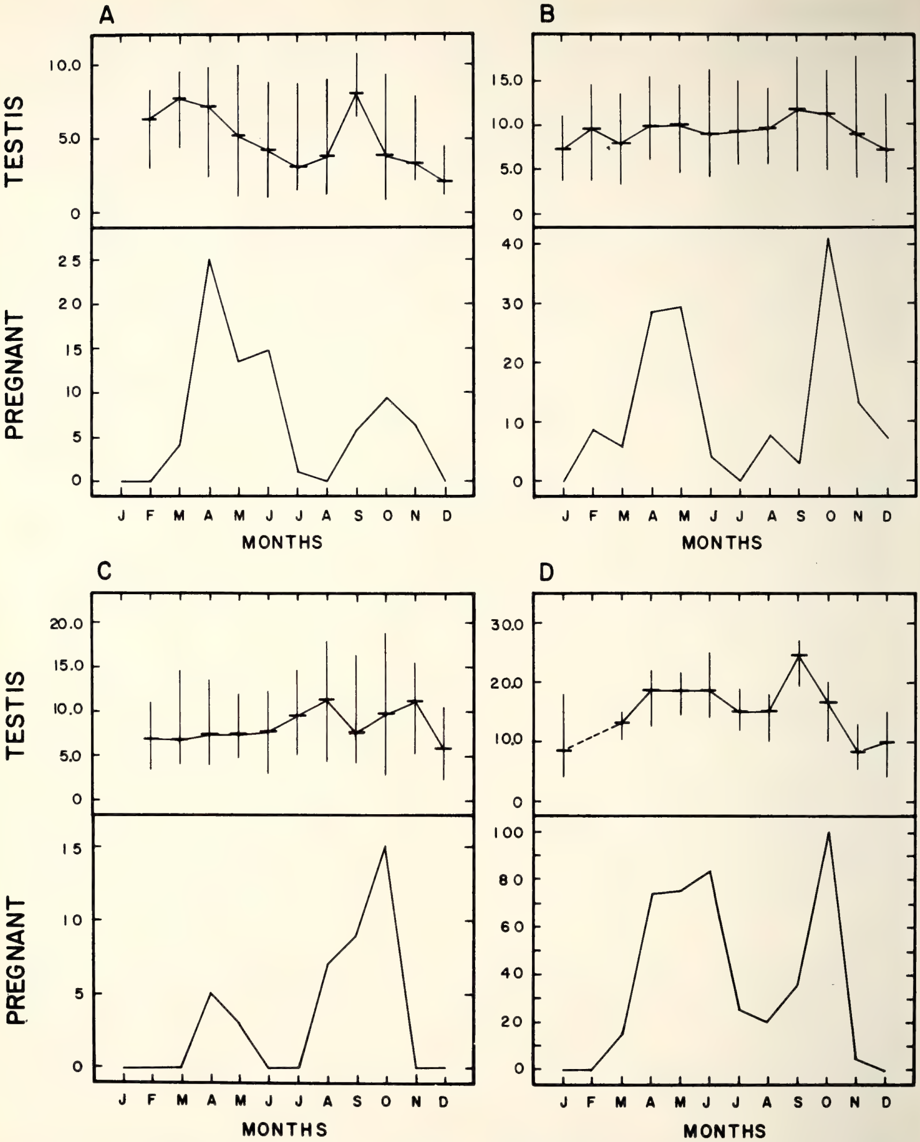


Fig. 1. Composite annual pattern of changes in testis length and percent females pregnant for (A) *Blarina brevicauda*, (B) *Peromyscus gossypinus*, (C) *Ochrotomys nuttalli*, and (D) *Sigmodon hispidus*. Mean and range are given for testis length. Sample sizes are given in Table 1.

largest proportion of active males occurs from April through May and September through November. Pournelle (1952) noted *P. gossypinus* males in breeding condition in all mo of the yr in Florida but less than 10% were active from May through July. He found that this decline in testicular activity was directly affected by high ambient temperatures.

The female cycle was more pronounced than that for males (Fig. 1B). A definite bimodal pattern was evident with little or no breeding activity in summer and winter. In contrast, Pournelle (1952) found high percentages of breeding females in Florida throughout the yr except for the summer mo. In the more southerly latitudes, *P. gossypinus* exhibits a prolonged breeding period. Postpartum estrus was evident for this species (Pournelle, 1952).

Based on a gestation period of 23-30 da (Pournelle, 1952), an avg of 3 litters per yr could be expected in South Carolina. Overall litter size ranged from 2-6 with a mean of 3.6 (Table 1). Spring litter size of 3.1 was significantly smaller than the fall litter size of 4.3. Litter size agrees with that of Florida cotton mice (Pournelle, 1952) but no seasonal differences were found between the two studies. However, reproductive potential of Florida cotton mice seems greater due to a prolonged breeding period with the ability to produce up to 6 litters per yr.

In an attempt to determine recruitment and the role of juveniles and young adults in the population, we plotted the percentage of selected wt classes by mo (Fig. 2A). The recruitment of juveniles was slight in late spring and early summer but comprised about 40% of the population in late fall and early winter. Many individuals apparently overwinter with little gain in wt until spring. The increase in the highest wt category fits the time of pregnancy and lactation.

Ochrotomys nuttalli: Golden mice were captured from 1967 to 1973 with the majority of captures occurring in 1968 and 1969. This species was found mainly in the mesic lowland hardwood forest. Due to a propensity for arboreal existence, *O. nuttalli* was not taken in significant numbers until long-term re-

TABLE 1. Summary of litter size for 10 species of small mammals from South Carolina. Indicated are the number of litters examined (N) and range, mean ($\bar{X}$) and 2 standard errors ($2S_{\bar{x}}$) of litter size. Total number of adult females examined is given in parentheses.

		Litter Size		
SPECIES	N	Range	$\bar{X}$	$2S_{\bar{x}}$
Sorex longirostris	6 (43)	2 - 4	3.00	0.52
Blarina brevicauda[1]	41 (623)	2 - 6	3.95	0.26
Spring, March-July	24 (257)	2 - 6	3.75	0.37
Fall, September-November	17 (210)	3 - 5	4.24	0.32
Cryptotis parva	3 (43)	2 - 3	2.67	0.67
Oryzomys palustris	10 (45)	3 - 5	3.60	0.44
Reithrodontomys humulis	2 (30)	2 - 3	2.50	1.00
Peromyscus gossypinus[1]	32 (286)	2 - 6	3.62	0.39
Spring, February-June	17 (127)	2 - 5	3.06	0.32
Fall, August-November	15 (107)	2 - 6	4.27	0.60
Ochrotomys nuttalli	12 (317)	2 - 4	2.42	0.39
Sigmodon hispidus[1]	139 (451)	2 - 8	4.47	0.22
Spring, April-July	83 (158)	2 - 8	4.66	0.31
Fall, August-November	56 (213)	2 - 6	4.22	0.26
Microtus pinetorum	4 (15)	1 - 3	2.00	0.82
Mus musculus	11 (35)	4 - 7	5.09	0.50

[1]There was a positive correlation between litter size and body length in *Sigmodon hispidus* ($F = 7.51$ and $P = 0.007$) but not in *Peromyscus gossypinus* ($F = 0.81$ and $P = 0.37$) or *Blarina brevicauda* ($F = 0.76$ and $P = 0.39$). This relationship was not tested for other species because of inadeqate sample size.

moval trapping and placement of traps in trees was initiated (Gentry, Golley and Smith, 1968).

Mean testis length peaked in August and again in November (Fig. 1C). The overall result is a bimodal pattern with spring and fall peaks. Although sperm were present in some individuals in late winter through spring, less than 40% of the males were found active through these mo. The percentage increased through summer and began to decline through the fall. This indicates that the major focus of breeding activity occurs in late summer and fall.

A greater proportion of the females were pregnant during April and again in October (Fig. 1C). The bimodal pattern is evident with a larger proportion of breeding females occurring from August through October. Only a small percentage of breeding females were captured in any mo which might reflect low trapability during pregnancy. The breeding season for *O. nuttalli* has been reported for various geographical areas; breeding occurs from March through October in Kentucky (Goodpaster and Hoffmeister, 1954), Florida (Layne, 1960) and Tennessee (Linzey, 1966). McCarley (1958), however, reported that in Texas, breeding occurred from fall through spring with almost total cessation through the summer months.

In summarizing length of gestation for *O. nuttalli*, Linzey (1966) reported gestation in *Ochrotomys* to range from 25-29 da for lactating females with shorter gestation periods for non-lactating females. Although successful postpartum breeding can occur (Goodpaster and Hoffmeister, 1954) it is not necessarily the rule (Linzey, 1966). Also, Goodpaster and Hoffmeister (1954) hypothesized the production of 7-8 litters per yr. On the basis of the known gestation period, *O. nuttalli* in South Carolina would be capable of producing 3-5 litters per yr.

An examination of the monthly wt class distribution follows the general trend exhibited by *P. gossypinus* (Fig. 2A). Recruitment of light, young individuals, however, occurred in late spring-early summer and the largest peak occurred in mid-winter. This supports the idea that the major breeding period occurs in the fall. The gradual increase of heavy, older individuals through the yr also reflects the magnitude of fall breeding.

Litter size for *O. nuttalli* ranged from 2-4 with a mean of 2.4 (Table 1). These data agree with other values in the literature (Goodpaster and Hoffmeister, 1954; McCarley, 1958; Layne, 1960; Linzey, 1966).

Sigmodon hispidus: Cotton rats were captured from 1955 through 1973 with the majority of captures occurring in 1960 and 1972. This species was trapped in a variety of habitats but was most prevalent in seral old-field communities.

The monthly trends of reproductive activity are shown in Fig. 1D. Males exhibited a bimodal pattern with peaks in testicular size occurring in spring and early fall. The values presented are for adults only (70.0 g), thus eliminating bias introduced by reproductively inactive juveniles. The distribution of males with sperm present shows that all adult males are reproductively active throughout summer. Thus the decrease in testis length at this time only represents a partial physical not functional decline. The general trend in males agrees closely with data presented by Goertz (1965) for cotton rats in Oklahoma.

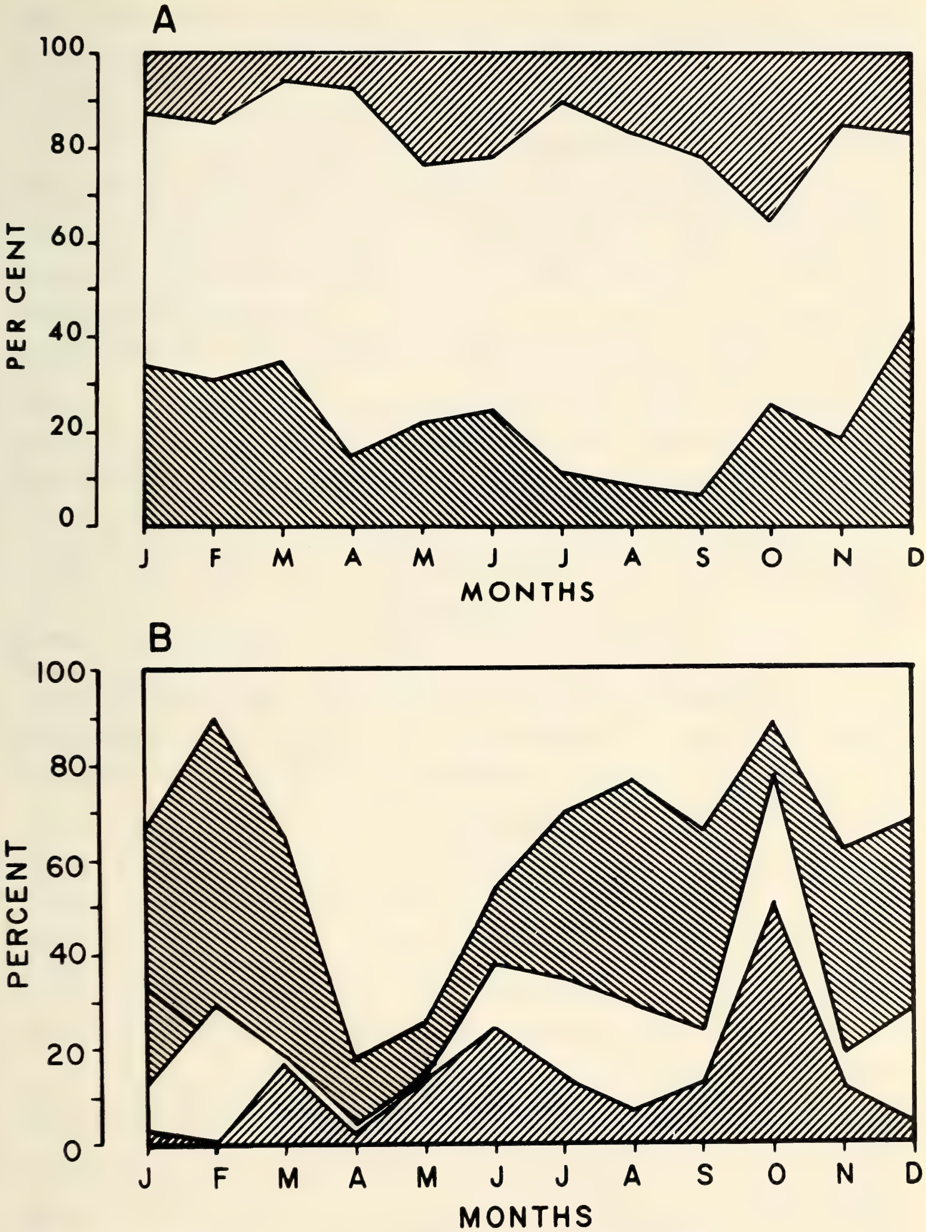


Fig. 2. Composite annual changes in wt class distribution of (A) *Peromyscus gossypinus*, and (B) *Sigmodon hispidus*. For *P. gossypinus the wt classes are from top to bottom:* >30 *g; 21-29 g;* <20 *g. For S. hispidus* the wt classes are from top to bottom: >100 g; 81-99 g; 61-80 g; <60 g.

The female cycle is definitely bimodal, demonstrating a prolonged spring period of reproduction and a short fall period (Fig. 1D). At least 20% of the population continues to breed through the summer mo. Goertz (1965) summarized reproductive trends in cotton rats from a variety of geographic areas and noted that the low breeding activity in the summer and winter was correlated with temperature extremes and secondarily related to density pressures. This may partially explain the lack of breeding in winter on the SRP. Since our data are a composite of many yr the effect of extreme winter temperatures and high density stress would tend to be eliminated.

Cotton rats have a high reproductive potential. Meyer and Meyer (1944) found that litters could be produced every 27 da with up to 9 litters per yr. Average litter size ranges between 5.0 and 6.0 (Meyer and Meyer, 1944; Goertz, 1965). Based on Fig. 1D it appears that in South Carolina 4-6 litters would be possible. Mean litter size in the present study was 4.6 and positively correlated with body length (Table 1). We found no significant difference between spring and fall litter sizes in contrast to the findings of Goertz (1965).

The mo wt class distribution (Fig. 2B) gives good indication of recruitment of young into the population. Based on the percent of individuals < 60 g, 3 major age cohorts are produced each yr. The large number of *S. hispidus* > 100 g in April appear to be from the fall cohort of the previous yr. Fleharty and Choate (1973) found a different age-weight composition for cotton rats in Kansas; peak percentage of adults (> 100 g) occurred in early summer and only low numbers of juveniles (< 60 g) from February through March.

Other species: Sample sizes for the shrews *Sorex longirostris* and *Cryptotis parva* were small (Table 1). *Sorex longirostris* has a litter size of 4-5 young (Asdell, 1964) with up to 6 for *C. parva* (Hamilton, 1944). Hamilton (1944) noted *C. parva* breeding from March to November at northern latitudes and speculated that it might be reproductively active throughout the yr in Florida. All *C. parva* examined on the SRP during the winter were in non-breeding condition.

Oryzomys palustris were found with relatively small litters (Table 1). Negus, Gould and Chipman (1961) reported similar values for this species during a period of high density but mean litter size of 6.0 during a period of low density.

Kay (1961) in North Carolina and Dunaway (1968) in Tennessee reported mean litter size for *Reithrodontomys humulis* of 3.2. Layne (1959) reported a mean litter size of 2.2 for *R. humulis* from Florida. Although our data are few (Table 1) there appears to be a trend for decreasing litter size at the southern latitudes for this species.

Litter size in *Microtus pinetorum* (Table 1) was small but corresponds exactly with that found by Horsfall (1963) and Gentry (1968). Litter size for wild *Mus musculus* agrees closely for that listed by Asdell (1964) for a wide variety of geographic localities.

We have found a general trend of decreasing litter size at the more southern latitudes similar to that described by Smith and McGinnis (1968) and Spencer and Steinhoff (1968). It appears that as the length of extreme weather conditions decrease at southern latitudes the breeding season is lengthened. With an increase in breeding season a concomitant decrease in litter size occurs. Exceptions to this trend may include *S. hispidus* and definitely *P. polionotus* (Smith and McGinis, 1968).

General Comparisons—In the mesic lowland hardwood forest the three major species of small mammals are *B. brevicauda*, *O. nuttalli* and *P. gossypinus*. All three exhibit similar reproductive trends with major peaks in breeding in the spring and fall. The cycles vary, however, in intensity of breeding effort during these times. The focus of breeding in *O. nuttalli* is in the late summer and fall while in *B. brevicauda* reproductive intensity is highest in spring and early summer. In contrast, *P. gossypinus* does not show a seasonal difference. From the mo wt class distribution, it appears that *O. nuttalli* and *P. gossypinus* juveniles overwinter with little change in body wt. This is probably a reflection of reduced resource availability which would account for the lack of winter reproductive activity in these species.

Sigmodon hispidus and *P. polionotus* are the primary species found in seral old-fields. Davenport (1964) described a 5-yr composite breeding cycle of *P. polionotus* on the SRP. It was found to breed in all mo but a decline in percent pregnant occurred from November through January. No summer decline, as was found for *S. hispidus*, occurred indicating little or no effect due to warm weather extremes. This is in contrast to the summer decline in reproduction of Florida *P. polionotus* found by Smith (1966).

An examination of wt class distribution for *S. hispidus* indicates that most juveniles continue to gain wt throughout the winter. This continued development may account for the high percentage of breeding individuals during the spring. In fact, cotton rats demonstrate a much higher percentage of pregnant individuals during peak times of the yr than do any of the other species examined. From all indications *S. hispidus* has the highest reproductive potential of any small mammal examined on the SRP.

LITERATURE CITED

ASDELL, S. A. 1964. Patterns of mammalian Reproduction. 2nd ed. Cornell University Press. Ithaca

DAVENPORT, L. B. 1964. Structure of two *Peromyscus polionotus* populations in old-field ecosystems at the AEC Savannah River Plant. J. Mammal. 45:95-113.

DUNAWAY, P. B. 1968. Life history and populational aspects of the eastern harvest mouse. Amer. Midl. Nat. 79:48-67.

FLEHARTY, E. D., AND J. R. CHOATE. 1973. Bioenergetic strategies of the cotton rat, *Sigmodon hispidus*. J. Mammal. 54:680-692.

GENTRY, J. B. 1968. Dynamics of an enclosed population of pine mice, *Microtus pinetorum*. Res. Popul. Ecol. 10:21-30.

———, F. B. GOLLEY AND M. H. SMITH. 1968. An evaluation of the octagon census method for estimating small mammal populations. Acta Theriol. 10:149-159.

———, ——— ———. 1971. Yearly fluctuations in small mammal populations in a southeastern United States hardwood forest. Acta Theriol. 16:179-190.

GOERTZ J. W. 1965. Reproductive variation in cotton rats. Amer. Midl. Nat. 74:329-340.

GOLLEY, F. B. 1966. South Carolina Mammals. Contrib. Charleston Museum 15. Charleston, S. C.

———, J. B. GENTRY, L. CALDWELL AND L. DAVENPORT, JR. 1965. Numbers and variety of small mammals on the AEC Savannah River Plant. J. Mammal. 46:1-18.

GOODPASTER, W. W., AND D. F. HOFFMEISTER. 1954. Life history of the golden mouse, *Peromyscus nuttalli*, in Kentucky. J. Mammal. 35:16-27.

HAMILTON, W. J., JR. 1944. The biology of the little short-tailed shrew, *Cryptotis parva*. J. Mammal. 25:1-7.

———. 1949. The reproductive rates of some small mammals. J. Mammal. 30:257-260.

HORSFALL, F., JR. 1963. Observations on fluctuating pregnancy rate of pine mice and mouse feed potential in Virginia orchards. Proc. Amer. Soc. Hort. Sci. 83:276-279.

KAYE, S. V. 1961. Laboratory life history of the eastern harvest mouse. Amer. Midl. Nat. 66:439-451.

LAYNE, J. N. 1959. Growth and development of the eastern harvest mouse, *Reithrodontomys humulis.* Bull. Florida St. Mus. Biol. Sci. 4:61-82.

———. 1960. The growth and development of young golden mice, *Ochrotomys nuttalli.* Quart. J. Florida Acad. Sci. 23:36-58.

LINZEY, D. W. 1966. The life history, ecology and behavior of the golden mouse, *Ochrotomys n. nuttalli,* in the Great Smoky Mountains National Park. Ph.D. Dissert. Cornell Univ. Ithaca.

MCCARLEY, H. 1958. Ecology, behavior and population dynamics of *Peromyscus nuttalli* in eastern Texas. Texas J. Sci. 10:147-171.

MEYER, B. J., AND R. K. MEYER. 1944. Growth and reproduction of the cotton rat, *Sigmodon hispidus hispidus,* under laboratory conditions. J. Mammal. 25:107-129.

NEGUS, N. C., E. GOULD AND R. K. CHIPMAN. 1961. Ecology of the rice rat, *Oryzomys palustris* (Harlan), on Breton Island, Gulf of Mexico, with a critique of the social stress theory. Tulane Stud. Zool. 8:94-123.

PEARSON, O. P. 1944. Reproduction in the shrew (*Blarina brevicauda* Say). Amer. J. Anat. 75:39-83.

POURNELLE, G. H. 1952. Reproduction and early post-natal development of the cotton mouse, *Peromyscus gossypinus gossypinus.* J. Mammal. 33:1-20.

SMITH, M. H. 1966. The evolutionary significance of certain behavioral, physiological, and morphological adaptations of the old-field mouse, *Peromyscus polionotus.* Ph.D. Dissert. Univ. Florida. Gainesville.

———, AND J. T. MCGINNIS. 1968. Relationships of latitude, attitude, and body size to litter size and mean annual production of offspring in *Peromyscus.* Res. Popul. Ecol. 10:115-126.

SPENCER, A. W. AND H. W. STEINHOFF. 1968. An explanation of geographic variation in litter size. J. Mammal. 49:281-286.

Florida Sci. 40(1):76-84. 1977.

MIDDORSAL SPINES IN STINGRAYS (*DASYATIS*) OF THE GEORGIA COAST

—*Michael D. Dahlberg,* Ecological Sciences Division, NUS Corporation, 1910 Cochran Road, Pittsburgh, Pennsylvania 15220

ABSTRACT: *A proposed procedure for counting middorsal spines provides for a reliable separation of the Atlantic stingray (*Dasyatis sabina*) from other sympatric species (*D. sayi, D. americana, D. centroura*) on the U. S. Atlantic coast. Middorsal spines were apparent when* D. sabina *reached 149 to 170 mm disc width and increased with body size. Rate of spine development decreased when disc width reached 250 mm. Rate of spine development was similar in both sexes of* D. sabina *although females reached a much larger size.*

POSITIVE identification of the smaller stingrays along the U. S. Atlantic coast is often difficult using standard proportions and angles, especially with damaged specimens. The number of middorsal spines appeared to be a useful meristic characteristic and was investigated in *D. sabina* and small *D. sayi* and *D. americana* collected on the Georgia coast during 1967-1969. All specimens were discarded. For the latter two species, counts were also taken from four specimens depicted in Bigelow and Schroeder (1953), Bohlke and Chaplin (1968), and Randall (1968).

Standard counting methods have been described for skates (Hubbs and Ishiyama, 1968) but not rays. The purposes of this note are to propose a standard counting procedure for middorsal spines, describe the variability of this characteristic in *D. sabina* and evaluate its taxonomic value.

The middorsal spine series includes all spines along the dorsal midline of the body and tail between the nuchal region and large tail spine (Fig. 1). Scapular spines located to the sides of the midline are not counted. The counts are plotted against disc width. This count is useful for small stingrays up to 400 mm disc

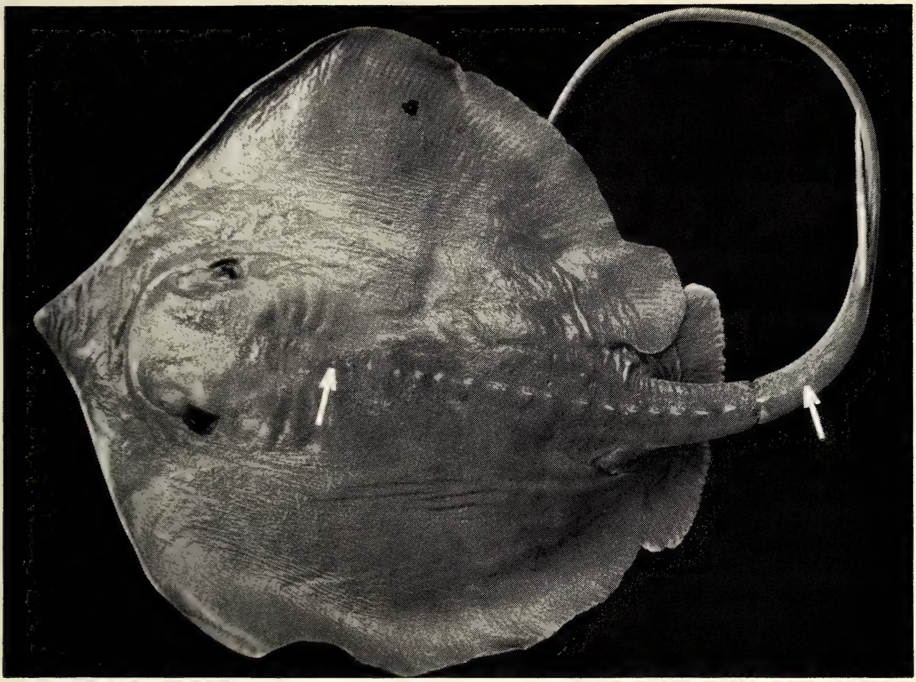


Fig. 1. Distribution of middorsal spines in *Dasyatis sabina*. Arrows show anterior and posterior spines.

width, but is of limited use for large *D. sayi* (over 615 mm) which develop 2-3 irregular rows of small tubercles anterior to the pectoral girdle and mature *D. centroura* (over 450 mm) which have 1-3 irregular rows of bucklers between the nuchal region and tail spine (Bigelow and Schroeder 1953).

All species of *Dasyatis* are born without spines except for the large tail spine which is soft at birth. In *D. sabina*, middorsal spines were lacking in 88 to 138 mm (disc width) embryos and 126 to 160 mm young (Fig. 1). The smallest specimens with one or two spines were 149 to 170 mm; *D. sayi* and *D. americana* are smooth up to 225 mm and *D. centroura* up to at least 450 mm disc width (Bigelow and Schroeder, 1953).

The rate of spine development decreased in larger *D. sabina*. Linear regression lines were calculated separately for smaller rays (less than 17 spines) and larger rays (over 16 spines). Rates of spine development and points of inflection (approximately 250 mm) were similar in males and females although the females grow faster (Sage et al., 1974) and reached a much greater size. In contrast, a reduction to two middorsal spines has been reported for large, female *D. sayi* (Bigelow and Schroeder, 1953).

The middorsal spine count is useful to separate *D. sabina* from other small rays up to 400 mm disc width (Fig. 2). *D. sayi* and *D. americana* overlap widely.

Clinal variation was not examined since all *D. sabina* were collected on the Georgia coast. Clinal variation is unlikely because the distribution of *D. sabina* in the Atlantic Ocean is relatively limited. This ray is abundant in the coastal

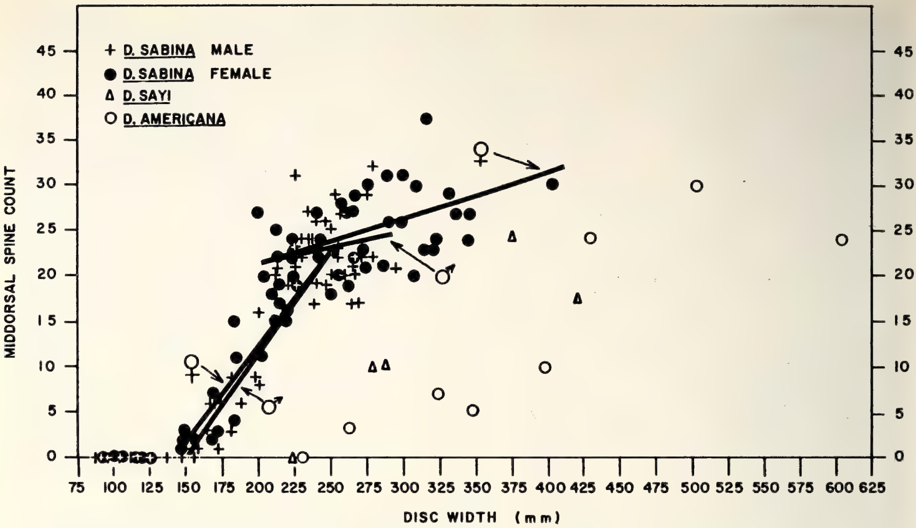


Fig. 2. Number of middorsal spines plotted against disc width in three species of *Dasyatis*.

habitat (to 10 fathoms) off Georgia and South Carolina (Struhsaker, 1969, Anderson, 1968), is common near shore from Georgia to North Carolina during warmer months (Dahlberg, 1975; Anderson, 1968; Bigelow and Schroeder, 1953) and ranges north to Chesapeake Bay only during the summer (Bigelow and Schroeder, 1953).

Little quantitative information is available for larger stingrays. Bigelow and Schroeder (1953) reported a reduction to two spines in large *D. sayi* (maximum size=914 mm), 60 spines in a 1058 mm specimen which "may have been" *D. americana*, and about 65 irregular bucklers in a 1415 mm male *D. centroura*.

ACKNOWLEDGMENTS—Dr. F. J. Schwartz reviewed the manuscript; Sue Douglas of NUS Corporation drafted the figure.

LITERATURE CITED

ANDERSON, W. W. 1968. Fishes taken during shrimp trawling along the south Atlantic coast of the United States. U. S. Fish Wildl. Serv. Spec. Sci. Rept. Fish. 570:1-60.

BIGELOW, H. B., AND W. C. SCHROEDER. 1953. Sawfishes, guitarfishes, skates and rays. *In* Fishes of the Western North Atlantic. Mem. Sears Found. Mar. Res. 1(2):i-iv; 1-514.

BOHLKE, J. E., AND C. C. G. CHAPLIN. 1968. Fishes of the Bahamas and Adjacent Tropical Waters. Livingston Publ. Co. Wynnewood, Pa.

DAHLBERG, M. D. 1975. Guide to Coastal Fishes of Georgia and Nearby States. Univ. Georgia Press. Athens.

HUBBS, C. L., AND R. ISHIYAMA. 1968. Methods for the taxonomic study and description of skates (Rajidae). Copeia 1968:483-491.

RANDALL, J. E. 1968. Caribbean Reef Fishes. T. F. H. Publ. Jersey City.

SAGE, M., R. G. JACKSON, W. L. KLESCH AND V. L. DE VLAMING. 1972. Growth and seasonal distribution of the elasmobranch *Dasyatis sabina*. Contr. Mar. Sci. 16:71-74.

STRUHSAKER, P. 1969. Demersal fish resources: Composition, distribution, and commercial potential of the continental shelf stocks off southeastern United States. Fish. Industr. Res. 4:261-300.

Florida Sci. 40(1):84-86. 1977.

Biological Sciences

NEW RECORDS OF THE INTRODUCED SNAIL, *MELANOIDES TUBERCULATA* (MOLLUSCA: THIARIDAE) IN SOUTH FLORIDA

M. A. Roessler, G. L. Beardsley and D. C. Tabb

Tropical BioIndustries Development Company, 9000 Southwest 87 Court, Miami, Florida 33176

Abstract: *New populations of the introduced thiarid snail,* Melanoides tuberculata, *were found in fresh water canals of Dade and Collier counties and in the saline mangrove areas adjacent to Biscayne Bay in the Matheson Hammock-Snapper Creek area of Coral Gables. No trematode larvae were discovered in specimens examined but the extension of the snail into brackish and marine waters increases the possibility of spread of avian trematode infection because of increased numbers of potential intermediate crustacean hosts available in the mangrove habitat.*

Abbott (1950, 1952) reported that approximately 50 species of exotic land and fresh water mollusks have been established in North America in the past 100 yr. Despite the hazards to native vegetation, native mollusks, and the potential introduction of parasites via the mollusks, little ecological work has been published on the introductions. Ingram (1948, 1959) and Ingram, Keuf and Henderson (1964) studied the introduction, distribution and impact of the Asian clam, *Corbicula manilensis* (=*Corbicula fluminea*). Hunt (1958) and Hale (1964) described the impact of the ampullariid snail, *Marisia cornuarietis*, on the Everglades populations of apple snail, *Pomacea paludosa*, and the consequences to the feeding of the rare Everglades kite, *Rostrhamus sociabilis*. Lachner, Robins and Courtney (1970) reviewed the data on the introduction of the large herbivorous snail, *Achatina fulica*.

Lachner et al. (1970) and Courtenay and Robins (1973) have reviewed the methods of introduction and the potential dangers involved, including habitat destruction, replacement of native species, and the introduction of parasites and disease. Dundee (1974) has catalogued introduced mollusks of eastern North America.

Recent discovery of large populations of the melaniid snail, *Melanoides tuberculata*, in mangrove swamps of South Florida has prompted us to 1) review the introduction and spread of melaniids; 2) discuss the density, size distribution and ecological requirements of the species; and 3) examine specimens from the Miami area for trematode larvae.

Origin and Distribution—The first record of introduced Oriental melaniid snails, *Tarebia granifera*, was reported by Abbott (1952). Apparently the introduction of *T. granifera* was via an aquarium dealer in San Francisco, California. The dealer sent specimens to the U. S. National Museum on 23 March 1935. Although the location of the native habitat has not been determined, he concluded that this probably was the sole introduction of the species. In 1937 a Tampa, Florida aquatic plant and fish dealer acquired specimens in California and began distributing the snail as the "Philippine horn of plenty". In 1947 specimens from Lithia Springs, Hillsborough County, Florida were sent to Dr. Abbott, who examined these specimens plus additional material in the Lithia Springs region and commented on their ecology. Abbott (1952) also reported seeing specimens in Silver Springs, Maryland, in home aquaria which had been obtained from Washington, D. C. dealers. Murray (1964) reported *Tarebia* from San Antonio, Bexter County, and New Braunfels, Comal County, Texas. Murray (1971) also states that the 1964 catalog of the Carolina Biological Supply Company, Burlington, North Carolina, listed *Tarebia* for sale. These specimens were from Florida and probably the distribution was widespread through this source.

Although the exact route and agent of introduction of *Melanoides tuberculata* is not known, it is probable that these snails were intentionally or accidentally introduced from the Orient by aquarium dealers.

Murray (1964) reported *Melanoides tuberculata* from the San Antonio River, Bexter County, Texas and from Landa Park, New Braunfels, Comal County, Texas. Murray (1971) cites Dwight Taylor as having observed *Melanoides* from Harney County, Oregon, and Phoenix, Arizona. Apparently floods in 1965-66 destroyed the Phoenix population. Clench (1969) reported these snails from Lake Osceola in Coral Gables, Greynolds Park in North Miami and Hillsborough State Park, Florida. Dundee (1974) summarized the known occurrence of *M. tuberculata* in the U. S. as of 1974. Russo (1974) reported additional specimens from Pompano Canal and Middle River in Broward County. We have obtained additional specimens from Snapper Creek; lakes on the Baptist Hospital grounds on North Kendall Drive in South Miami; Fairchild Tropical Gardens; Matheson Hammock; Lake Osceola; Miami Lakes; in a canal east of the Palmetto Expressway; at the intersection of L 29 and the Tamiami Canal 4.2 km north of 40-mile Bend, all in Dade County; and from the Tamiami Canal at bridge 78, Ochopee, in Collier County.

Several distinct morphological forms were found but, according to Joseph Rosewater, Curator, Department of Invertebrate Zoology (Mollusca) USNM, these are all local strains of *Melanoides tuberculata* (Muller).

HABITAT AND DENSITY—*Tarebia* was reported by Abbott (1952) to prefer shallow riffles of fast-flowing freshwater streams. Murray (1971) reported that the geographical distribution of thiarid snails in the U. S. appears ecologically restricted to springs having a temperature range of 18-25°C with a pH from 7.0 to 7.5. Russo (1974) reported *Melanoides* from fresh water habitat with an avg chloride concentration of 40 mg/1 (0.1 ppt salinity) and from an estuarine site with chloride concentrations between 230 and 2200 mg/1 (0.4-4.0 ppt salinity).

Our samples indicate *Melanoides* can flourish in brackish water with salinity ranging between 0 and 30 ppt (Table 1). Sampling in hypersaline (40-42 ppt) areas produced no snails. The occurrence of *Melanoides* in near-seawater conditions indicates they can spread throughout farm and mosquito ditches of the coastal mangrove fringes of South Florida, at least in the rainy summer season when salinity in these ditches is generally below 20 ppt and occasionally reaches 0.

TABLE 1. Physico-chemical data associated with collections of *Melanoides tuberculata*.

Sample	Location	Temp °C	Sal ppt	D.O. ppm	Apparent color[a]	Turbidity JTU's	pH
SNAPPER CREEK							
Site A—high tide		25.2	26.5	-	39	12	7.40
Site A—low tide		28.4	28.0	1.8	58	15	7.50
Site B		26.4	28.0	1.3	70	20	7.30
Site C		26.3	30.0	1.2	82	12	7.30
Site D		-	30.0	-			
Site E		-	40.0	-			
Site F		No Water					
Site F			42.0				
Site G			40.0				
FAIRCHILD TROPICAL GARDENS							
FC 1 Sunken garden pond			0.0		42	17	7.44
FC 2 Overlook pool			0.0		28	19	8.24
FC 3 Amphitheater pond			0.0		30	3	7.42
FC 4 Amphitheater lake			0.0		48	5	7.38
FC 5 East end of moat			4.0		29	135	8.78
MATHESON HAMMOCK							
M 1 Brackish picnic lake			2.0		10	3	7.80
OCHOPEE							
Tamiami Canal		26.0	0.0	4.7	30	7	7.50

[a]Apparent color in APHA Platinum-cobalt standard units.

The site where we first noted *Melanoides* was in a portion of the old channel of Snapper Creek. The area was characterized by large red (*Rhizophora mangle*) and white (*Laguncularia racemosa*) mangroves. Occasional rubber vine (*Rhabdadenia biflora*) and mangrove mallow (*Pavonia spicata*) were also present. In one 100 sq m quadrat we measured mangrove densities as follows: 13.4 red mangrove seedlings/m^2; 8.3 white mangrove seedlings /m^2, .05 black mangrove seedlings/m^2, .12 mature red mangroves/m^2, .01 mature white mangroves/m^2, and .02 mature black mangroves, *Avicennia germinans*,/m^2. The tree canopy was 18-22 m high and avg diam breast height (DBH) was 13.5 cm for reds, 33 cm for whites and 2 cm for blacks. The soil was comprised of mangrove peat. *Melanoides* concentrated in leaf debris along a small stream at the tidal interface. A 1 sq m sample produced 1103 *M. tuberculata* but these were concentrated in about 100 cm^2 at the bank-water interface in an area of dense mangrove rootlets located immediately below the sediment surface.

In March 1975 a series of 75 cm^2 plug samples were taken near Snapper Creek and in several locations in Fairchild Tropical Gardens. In April, collections were made in Matheson Hammock, Dade County Park, Lake Osceola, in Miami Lakes and along the Tamiami Canal near 40-mile Bend. Two specimens

(15 and 28 mm) were collected from the Tamiami Canal at Bridge 78, 3.5 km west of Carnestown near Ochopee in Collier County.

In the Snapper Creek area 7 sampling transects were established to ascertain population size and other biological parameters. Each transect contained several plug samples taken at 0.5 m intervals starting at the stream bank and moving up-gradient away from the water's edge. At Site A 11 plug samples (A1—A11) were taken and the abundance of *M. tuberculata* varied from 23,000/m^2 at the stream bank edge (A1) down to 0/m^2 5.5 m inland. Table 2 shows the distribution of abundance, size range and biomass of snails at each sampling site. A second peak of abundance, at site A7, was comprised of small snails with an avg wet whole wt of 0.03 g. It appears that the young (2-5 mm) snails are concentrated on slightly higher ground than the adult (15-20 mm) snails.

Transect B consisted of 4 plugs. Abundance at plugs B1-B3, taken at 0.5 m intervals, varied from 6667/m^2 at the stream edge (B1) to 1067 snails/m^2 at the landward plug (B3). Again larger snails (.12-.13 g) were found near the channel and smaller (.06 g) snails were found back from the stream edge. One sample (B-4), chosen where abundance looked greatest, produced 37,500 snails/m^2.

Transect C was comprised of 9 plugs (C1-C9). Abundance varied from about 24,000 at the stream edge to a low of 933 4m back from the stream edge. The size was relatively uniform along the transect.

Transect D contained a single plug (D1). Abundance here was 8133 snails/m^2. The snails were between 6.3 and 20 mm. Associated snail species included *Melampus coffeus* and *Neritina virginica*. The snails in the original sampling of this station avg 17 mm long and 0.24 g/snail.

Twelve sites were examined in the Fairchild Tropical Garden lake and ornamental pond system. *Melanoides* were found in 5 sites: the sunken garden pond, the amphitheater pond, the amphitheater lake, the overlook pool, and the moat. Samples collected in areas where snails were aggregated produced densities of about 7000/m^2. The snails varied from 6 to 27 mm high and had an avg whole wet wt of 0.42 g/individual.

The brackish water ponds in Matheson Hammock, of the Dade County Park System, produced large numbers of both adult and juvenile specimens of *Melanoides*. The size ranged between 10.7 and 22.0 mm and these had an avg wt of 0.9 g.

Examination of the shore in Lake Osceola on the campus of the University of Miami in Coral Gables confirmed the presence of a substantial population of *Melanoides* there. These are probably descendents of the specimens reported by Clench (1969).

The densities observed in our studies were greater than the 4300 *Tarebia*/m^2 reported by Abbott (1952) in Lithia Springs, and much greater than the 130 *Melanoides*/m^2 in Pompano Canal and 216/m^2 in Middle River reported by Russo (1974), but less than the 51,650 *Tarebia* and *Melanoides* larger than 5 mm/m^2 from San Antonio, Texas reported by Murray and Wopschall (1965).

Murray and Wopschall (1965) have measured snails above 5 mm high and state that most of the population is between 5 and 15 mm. They state that *M.*

TABLE 2. Numbers and weights of *Melanoides tuberculata* at sampling stations at Snapper Creek and Fairchild Garden, Florida.

Station	Total	Total wt (gm)	Size Range (cm)	No./m²	Wt Snail (gm)	Wt./m² (gm)
SNAPPER CREEK						
A-1	173	18.39	.21-2.27	23,066	.11	2537
A-2	160	20.25	.30-2.21	21,333	.13	2773
A-3	69	13.92	.64-2.25	9,200	.20	1840
A-4	65	14.61	.25-2.46	8,666	.22	1907
A-5	32	3.75	.36-2.09	4,267	.12	512
A-6	1	.31	2.19	133	.31	41
A-7	127	4.26	.30-1.90	16,932	.03	508
A-8	7	.20	.43-1.16	933	.03	28
A-9	10	.42	.23-2.03	1,333	.04	53
A-10	0	0	0	0	0	0
A-11	2	.02	.47-.49	267	.01	3
B-1	50	5.90	.54-2.40	6,667	.12	800
B-2	9	1.19	.54-2.20	1,200	.13	156
B-3	8	.48	.70-1.57	1,067	.06	171
B-4	281	-	.59-2.33	37,465	-	-
C-1	180	28.56	.20-2.19	23,999	.16	3840
C-2	81	12.84	.53-2.38	10,800	.16	1728
C-3	21	3.46	.61-2.18	2,800	.16	448
C-4	54	8.55	.44-2.41	7,200	.16	1152
C-5	43	8.60	.36-2.23	5,733	.20	1147
C-6	24	3.05	.30-2.15	3,200	.13	416
C-7	20	5.20	.35-2.38	2,666	.26	693
C-8	7	1.12	.60-1.90	933	.16	149
C-9	12	1.72	.35-1.99	1,600	.14	224
D-1	61	-	.63-2.00	8,133	-	-
FAIRCHILD GARDEN						
FC-1	56[a]	22.23	.61-2.66		.40	
FC-2	2[a]	.15	1.34-1.35		.08	
FC-3	3[a]	.36	1.22-1.58		.12	
FC-4	29[a]	13.70	1.42-2.98		.47	
FC-5	52[a]	13.56	.62-2.64		.26	

[a]Random non-quantitative sample.

tuberculata maintains a stable population as to total number of individuals of any one size and as to total number of snails over a 9 mo period.

Our short term investigation indicated two size classes were present with mean sizes of 7 and 13 mm and modes at 7 mm and 18 mm (Fig. 1). The first age group (A) was comprised of 45 specimens, the second (B) of 55 specimens. The overall mean size was 13 mm for the 100 snail sample. The occurrence of 3 mm snails indicates successful breeding in the Snapper Creek and Fairchild Garden populations. Since the species is parthenogenetic and adaptable it seems likely that small introductions to other areas could produce populations in most waters of South Florida.

PARASITES—Murray (1971) reported that *M. tuberculatus* is a known intermediate host for the trematodes *Paragonimus westermani* (Oriental lung fluke)

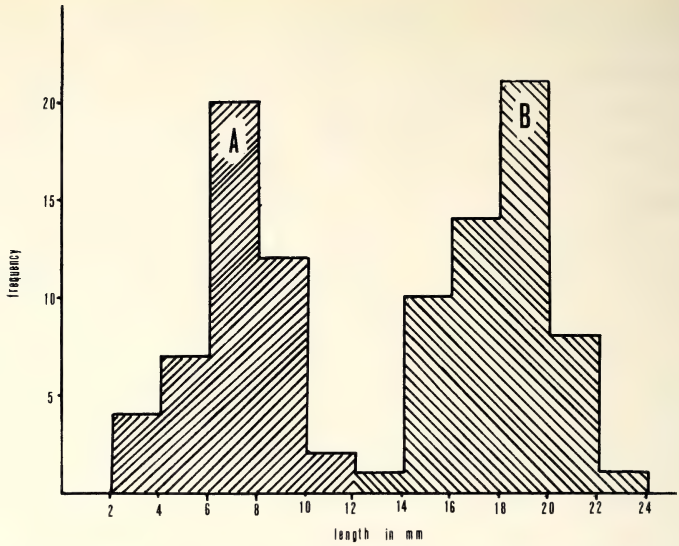


Fig. 1. Size frequency of 100 *Melanoides tuberculata* from Snapper Creek, Florida.

and *Clonorchis sinensis* (liver fluke) also from the Orient. Rediae of these species have not been detected within the United States. However, Murray and Stewart (1968) and Murray (1971) reported trematode rediae, with mature cercariae, from *Melanoides* and *Tarebia* from Texas. Murray and Haines (1969) found additional larvae and adults in the nictitating membrane of ducks. The trematode involved in this cycle was identified as *Philophthalmus megalurus* (Murray, 1971) and the final hosts include large numbers of species of water fowl. Other *philophthalmids* have been reported from native snails such as *Goniobasis* sp. (West and Fisher, 1959) and *Batillaria minima*, infected by *P. hegeneri*. In Hawaii *P. gralli* have been recorded from *Tarebia granifera mauiensis* by Alicata (1962). Russo (1974) reports two cases of human infestation by *Philophthalmus* sp.

Because a second intermediate host, generally a crustacean, is needed by the metacercarian larvae, and these must be eaten raw if the fluke is to infest man, the chance of human infection is small. With the previous data on salinity tolerance, crayfish and *Macrobrachium* shrimp might be logical vectors to man in the state, but the present data indicating salt tolerance increases the potential vectors to include "blue crabs" (*Callinectes sapidus* and *ornatus*), spiny lobster (*Panulirus argus*), shrimp (*Penaeus* spp.), stone crabs (*Menippe mercenaria*) and land crabs (*Cardisoma guanhumi*), as well as other estuarine crustacea occasionally eaten by man. It is more likely that these snails will be fed upon by crustacea such as *Aratus pisonii*, *Uca* spp. and *Rithropanopeus* sp., which in turn are preyed upon by local populations of ibis, heron and ducks, thereby increasing the potential of a closed life cycle for avian trematodes.

An examination of specimens from salt and freshwater habitats by Dr. E. S. Iversen of the University of Miami Rosenstiel School of Marine and Atmospheric

Science has failed to detect larvae of any trematodes in the South Florida population of *Melanoides tuberculata*.

Discussion—Damage to the ecology of an area from introductions of exotic species can result when the introduced species interferes with the food source of endemic species. In the Snapper Creek habitats, where we encountered thiarid snails, the dominant mollusks are generally *Melampus coffeus*, *Littorina angulifera*, *Neritina virginea*, and sometimes *Batillaria minima* and *Cerithium variable*, when sea grasses occur in channels or ditches. In our collections only the first three were common. *Melampus* feeds on fallen mangrove leaf tissue; *Littorina* is restricted to tree trunks where it grazes algae and lichens. There is little competition from thiarids for food. The thiarids apparently are grazers of microalgae and hence compete with *Neritina virginea* for the microalgal food supply. The widespread range of the native species does not indicate a danger of exclusion of an endemic species as noted by Murray (1970) where *Goniobasis comalensis* has become extremely rare after the invasion of thiarids at its type locality in New Braunfels, Texas.

Because the thiarids appears to be microalgal grazers they do not pose the threat of the giant herbivore *Achatina fulica*, nor is it so different from the native cerithids as to provide feeding difficulties to native birds as is the case with *Marisa cornuarietis*. Thus, the primary danger associated with the introduction of thiarids appears to be linked with the function of the snail as a host for trematode parasites not yet found in Florida, with crustacean intermediate and avian definitive hosts.

The invasion of Fairchild Garden and adjacent Snapper Creek is probably associated with the import of exotic aquatic vegetation in Fairchild Garden, but may be a spread from Lake Osceola and the Coral Gables Waterway located 4.8 km north of the present site. The other widespread populations observed in South Florida indicate most of the canals and brackish areas will probably be colonized in time.

LITERATURE CITED

Abbott, R. T. 1950. Snail invaders. Natur. Hist. 59:80-85.

———. 1952. A study of the intermediate snail host (*Thiara granifera*) of the oriental lung fluke (*Paragonimus*). Proc. U. S. Nat. Mus. 102:71-116.

Alicata, J. E. 1962. Life cycle and developmental stages of *Philophthalmus gralli* in the intermediate and final hosts. J. Parasit. 48:47-54.

Clench, W. J. 1969. *Melanoides tuberculata* (Muller) in Florida. Nautilus 83:72.

Courtenay, W. R., Jr., and C. R. Robins. 1973. Exotic aquatic organisms in Florida with emphasis on fishes: A review and recommendations. Trans. Amer. Fish. Soc. 102:1-12.

Dundee, D. S. 1974. Catalog of introduced molluscs of eastern North America (north of Mexico). Sterkiana 55:1-37.

Hale, M. C. 1964. The ecology and distribution of the introduced snail, *Marisa cornuarietis* (Ampullariidae) in South Florida. Ph.D. dissert. Univ. Miami. Coral Gables.

Hunt, B. P. 1958. Introduction of *Marisa* into Florida. Nautilus 72:53-55.

Ingram, W. M. 1948. The larger fresh-water clams of California, Oregon, and Washington. J. Entomol. Zool. 40:72-92.

———. 1959. Asiatic clams as potential pests in California water supplies. J. Amer. Water Works Assoc. 51:363-370.

———, L. Keuf and C. Henderson. 1964. Asiatic clams at Parker, Arizona. Nautilus 77:121-124.

Lachner, E. A., C. R. Robins and W. R. Courtenay, Jr. 1970. Exotic fishes and other aquatic organisms introduced into North America. Smithson. Contr. Zool. 59:i-iv;1-29.

Murray, H. D. 1964. *Tarebia granifera* and *Melanoides tuberculata* in Texas. Ann. Rept. Amer. Malacol. Union 1964:15-16.

__________. 1971. The introduction and spread of thiarids in the United States. The Biologist 53: 133-135.

__________, and D. Haines. 1969. *Philophthalmus* sp. (Trematoda) in *Tarebia granifera* and *Melanoides tuberculatus* in South Texas. Ann. Rept. Amer. Malacol. Union 1969:44-45.

__________, and A. J. Stewart. 1968. Establishment of a trematodes cycle in *Tarebia granifera* (Lamarck) in Texas. Ann. Rept. Amer. Malacol. Union 1968:17-18.

__________, and L. J. Wopschall. 1965. Ecology of *Melanoides tuberculata* (Muller) and *Tarebia granifera* (Lamarck) in South Texas. Ann. Rept. Amer. Malacol. Union 1965:25-26.

Russo, T. N. 1974. Discovery of the gastropod snail *Melanoides (Thiara) tuberculata* (Muller) in Florida. Florida Sci. 36:212-213.

West, A. F., and F. M. Fisher. 1959. The life history of a species of *Philophthalmus* (Trematoda: Philophthalmidae). J. Parasit. 45:60.

Florida Sci. 40(1):87-94. 1977.

SOME EFFECTS OF CHEMICAL CONTROL OF AQUATIC PLANTS ON ORGANIC MATTER ACCUMULATION IN SEDIMENTS[1] — *R. S. Hestand, C. C. Carter and H. E. Royals*, Florida Game and Fresh Water Fish Commission, Eustis Fisheries Research Laboratory, Eustis, Florida 32726

Abstract: *Three salt formulations of endothall (7 oxabicyclo* [*2.2.1*] *heptane—2,3-dicarboxylic acid) and a combination of diquat (6,7-dihydrodipyrido* [*1,2—∝; 2′, 1′-c*] *pyrazinodiium ion) and chelated copper were placed in test ponds; dihydroxy aluminum salt of endothall and mono (dimathytridecylamine) oxide of endothall resulted in a significant difference in the amount of organic sediment deposited on the bottom.*

Effects of herbicidal control of aquatic plants on lake bottoms remain little known. Therefore, a study was undertaken to determine if chemical treatment of aquatic plants resulted in significant increases in organic sediments. A literature review revealed that further investigations of this type should be initiated because similar analyses were not to be found.

Methods and Materials—Fifteen cm of washed building sand were placed in 45 plastic pools (0.91 m × 3.66 m) and 8 samples from each pool were taken for analysis in July 1973. The pools were planted with *Chara* sp., *Ceratophyllum demersum* L., *Vallisneria americana* Michx., *Najas quadalupensis* (Sprengel) Magnus, *Hydrilla verticillata* Royle, and *Myriophyllum spicatum* L. These plants were allowed to establish at 100% (approximately 1 yr). The pools were treated in August, 1974, with the following herbicides; Mono (dimethytridecylamine) oxide 7-oxabicyclo (2.2.1) heptane-2, 3 dicarboxylic acid equivalent (TD-1874), a coded experimental compound made by Pennwalt Corp.; Mono (N, N-dimethylalkylamine-7 oxabicyclo (2.2.1) heptane 2, 3 dicarboxylic acid equivalent (Hydrothol 191); Dihydroxyaluminum salt of 7 oxabicyclo (2.2.1) heptane 2, 3 dicarboxylic acid equivalent (System E); and 6.7 dihydrodipyrido (1, 2—∝;2′,

[1]Paper Number 29 of the Eustis Fisheries Research Laboratory, Florida Game and Fresh Water Fish Commission, P. O. Box 1903, Eustis, Florida 32726.

TABLE 1. A comparison of treatment means (percent organic matter). Values with different letters are significantly different at the 5% level according to Tukey's Multiple Range Test.

Control	Diquat and Cutrine Plus	Hydrothol 191	System E	TD-1874
0.20a	0.20a	0.22ab	0.26b	0.32c

1′-c) pyrazinediium dibromide (Diquat); plus triethanolamine complex of copper sulfate (Cutrine Plus). Nine months following treatment, the pools were drained and soil samples were taken for analysis. Two soil samples were taken at random per treatment from different pools and analyzed for organic content by the Walkley-Black method (Jackson, 1958). A one-way analysis of variance was conducted to test for significant differences between treated and untreated pools. Treatment means were compared with the control using Tukey's Test (Table 1).

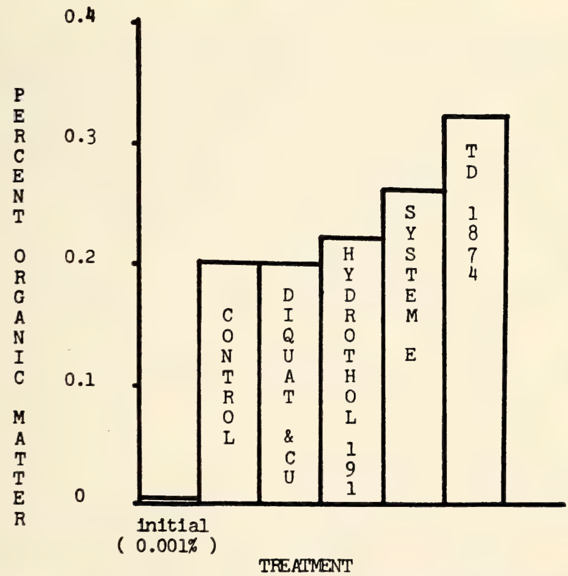


Fig. 1 Comparison of organic matter accumulation in pools nine months following treatment.

RESULTS AND DISCUSSION—As expected, the organic content of the substrate initially was less than 0.001%.

Jewell (1970) found that when plants are killed or die at 18°C, they decay at a rate of about 9% per day, depending on the nature of the plant. Assuming this to be true, there should have been very little difference. Two years after the initial planting and 9 months following chemical treatment, there was a significant increase in organic matter (using Student's test) in all pools (Fig. 1).

TD-1874 and System E had a significant increase in organic sediment compared to the other treatments (Table 1). This difference may be due to several uncontrollable factors such as species composition and differences in biomass at the time of treatment, and plant regrowth.

LITERATURE CITED

JACKSON, M. L. 1958. The Walkley-Black Method. pp. 219-222 *In* Soil Chemical Analysis. Prentice Hall. Engelwood Cliffs, New Jersey.

JEWELL, W. J. 1970. Aquatic Weed Decay: dissolved oxygen utilization and nitrogen and phosphorus regeneration. Ann. Conf. Water Poll. Contr. Fed. 43:1457-1467.

Florida Sci. 40(1):94-96. 1977.

REVIEW

VOSS, GILBERT L. *Seashore Life of Florida and the Caribbean.* E. A. Seeman Publishing Co., P. O. Box K, Miami, Florida 33156. February, 1977. 168 pp. Clothbound. $9.95

THIS excellent little book is the first general guide to the identification of the larger or more conspicuous shallow-water invertebrates of the West Indian Marine Province. The book is designed for informed laymen and scientists who want to identify such marine invertebrates without extraordinary effort. Because it concentrates on relatively obvious and easily recognized identifiable characteristics for each of the species, taxonomic nit-picking and keying are reduced to a minimum. In addition, significant taxonomic characteristics are well illustrated in the line drawings of each species discussed. The book is especially noteworthy because of its scope. It excludes shelled gastropods and bivalves, which, as the author points out, are covered well in other books. In all, 280 species of less familiar animals are covered, including at least one common representative each of the Protozoa, Numertinea, Ctenophora, Sipunculida, and Bryozoa. Thankfully, the book deals with eleven species of marine tunicates, a group generally omitted from ordinary field guides, covering either invertebrates or vertebrates; and it also discusses fifteen common corals. The author has arranged the taxa in ascending systematic order for easy location of descriptions and illustrations of each organism discussed. Descriptions include the common name, correct scientific name, a line drawing and brief observations on natural history. A distinct strength of the book is found in the bibliography which lists advanced reference books for each of the phyla discussed, thereby allowing the serious student to get into the scientific literature on a particular group of animals easily. The sections on the preservation and narcotization of various marine specimens will be useful for science teachers and others. A full length glossary of all technical terms used will assist the non-specialist user. The only shortcoming of the book is the absence of an indication of the approximate range of each species. This is especially desirable because the book covers a wide geographic area, and many locally abundant taxa have relatively limited ranges. In spite of this, the book is a very welcome addition to the library of those of us who go to the shores of the Gulf and Caribbean and want to be able to quickly and accurately identify the creatures we see.—*Mark E. Sinclair,* Educational Director, John Young Museum and Planetarium, Orlando, Florida 32803.

INSTRUCTIONS TO AUTHORS

Rapid, efficient, and economical transmission of knowledge by means of the printed word requires full cooperation between author and editor. Revise copy before submission to insure logical order, conciseness, and clarity.

MANUSCRIPTS should be typed double-space throughout, on one side of numbered sheets 8½ by 11 inch, smooth, bond paper.

A CARBON COPY will facilitate review by referees.

MARGINS should be 1½ inches all around.

FOOTNOTES should be avoided. Give ACKNOWLEDGMENTS in the text.

ADDRESS should be given following the author's name.

ABSTRACTS should be typed double-spaced immediately following the address.

LITERATURE CITED follows the text. Double-space every line and follow the form in the current volume.

TABLES are charged to authors at $25.00 per page or fraction. Titles must be short, but explanatory matter may be given. Type each table on a separate sheet, double-space, unruled, to fit normal width of page, and place after Literature Cited.

LEGENDS for illustrations should be grouped on a sheet, double-spaced, in the form used in the current volume, and placed after Tables. Titles must be short but may be followed by explanatory matter.

ILLUSTRATIONS are charged to authors ($20.00 per page or fraction). Drawings should be in India ink, on good board or drafting paper, and lettered by lettering guide or equivalent. Plan linework and lettering for reduction, so that final width is 4 5/8 inches, and final length does not exceed 7 inches. Do not submit illustrations needing reduction by more than one-half. Photographs should be of good contrast, on glossy paper. Do not write heavily on the backs of photographs.

PROOF must be returned promptly. Leave a forwarding address in case of extended absence.

REPRINTS may be ordered when the author returns corrected proof.

FLORIDA ACADEMY OF SCIENCES

INSTITUTIONAL MEMBERS FOR 1976

Archbold Expeditions
Barry College
Eckerd College
Edison Community College
Florida Atlantic University
Florida Institute of Technology
Florida Southern College
Florida State University
Florida Technological University
Gulf Breeze Laboratory
Jacksonville University
John Young Museum and Planetarium
Manatee Junior College
Miami-Dade Community College
Stetson University
University of Florida
University of Miami
University of South Florida
University of Tampa
University of West Florida

Membership applications, subscriptions, renewals, changes of address, and orders for back numbers should be addressed to the Executive Secretary, Florida Academy of Sciences, 810 East Rollins Street, Orlando, Florida 32803.

Florida Scientist

Volume 40 Spring, 1977 No. 2

CONTENTS

(Continued on back)

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

FLORIDA SCIENTIST
QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Editor: Harvey A. Miller
Department of Biological Sciences
Florida Technological University
Orlando, Florida 32816

The FLORIDA SCIENTIST is published quarterly by the Florida Academy of Sciences, Inc., a non-profit scientific and educational association. Membership is open to individuals or institutions interested in supporting science in its broadest sense. Applications may be obtained from the Treasurer. Both individual and institutional members receive a subscription to the FLORIDA SCIENTIST. Direct subscription is available at $13.00 per calendar year.

Original articles containing new knowledge, or new interpretation of knowledge, are welcomed in any field of Science as represented by the sections of the Academy, viz., Biological Sciences, Conservation, Earth and Planetary Sciences, Medical Sciences, Physical Sciences, Science Teaching, and Social Sciences. Also, contributions will be considered which present new applications of scientific knowledge to practical problems within fields of interest to the Academy. Articles must not duplicate in any substantial way material that is published elsewhere. Contributions from members of the Academy may be given priority. Instructions for preparation of manuscripts are inside the back cover.

Published by the Florida Academy of Sciences
810 East Rollins Street
Orlando, Florida 32803

Printed by the Storter Printing Company
Gainesville, Florida

Florida Scientist

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Harvey A. Miller, *Editor* Walter K. Taylor, *Associate Editor*

Volume 40 Spring, 1977 No. 2

Environmental Sciences

THE MARCO ISLAND ESTUARY: A SUMMARY OF PHYSICOCHEMICAL AND BIOLOGICAL PARAMETERS

Michael P. Weinstein (1), Charles M. Courtney (2) and James C. Kinch (2)

Lawler, Matuskey and Skelly Engineers, 415 Route 303, Tappan, New York 10983 (1); and Marco Applied Marine Ecology Station, North Barfield Drive, Marco Island, Florida 33937 (2)

Abstract: *Marco Island estuary has undergone intensive study during a 4-yr period from July 1971 through July 1975. A general summary of the area's physical, chemical and biological makeup is presented here with emphasis on water chemistry and analyses of macroinvertebrate and fish communities. The estuary may be characterized as seasonally hypersaline with low concentrations of dissolved nutrients. Diversity of animal communities is high with elements of both the West Indian and Carolinian Provinces present. Maximum diversity for epibenthic invertebrates and fishes was associated with seagrass meadows and for the benthic infauna with predominantly coarser substrates (100-500 μm). In addition, several species of invertebrates and fishes exhibited distinct seasonality, becoming scarce during the cooler months. A comparison is also made between artificial waterways and natural mangrove tidal creeks and open bays. The results demonstrate that for the infaunal community considerable differences occur between the two areas. Less pronounced differences, however, are apparent in the canal fish community which most closely resembles that of the unvegetated open bay area.**

Intensive development on Marco Island has prompted widespread interest in the future of the surrounding ecosystem. During the past five years personnel of the Marco Ecology Station, Marco Island, Florida, have studied this area with the goal of obtaining baseline data on climatology, hydrology, water quality and community biology. Here we present a summary of the work conducted during the interval July 1971 through 1975, emphasizing the fish and invertebrate communities associated with seagrass meadows, tidal creeks and artificial waterways.

The study area (Fig. 1) is located at the juncture (25°57′ N Latitude, 81°43′ W Longitude) of the Carolinian and West Indian faunal provinces (Andrews, 1971; Briggs, 1974) and constitutes the approximate northern limit of the extensive mangrove forests of the Ten Thousand Islands (Carter et al., 1973). The Big Cypress Swamp borders the region to the north and east and extends downward to the Gulf of Mexico at Fahka Union and Fahkahatchee Bays. In its western

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

Fig. 1. Map of study area. N = nutrient station; T = trawl station; I = infaunal core station. Unit 24 insert is shown in Fig. 2; canal insert in Fig. 3.

portion sheet flow normally moves to the south and southwest; however, recently constructed inland canals now drain most water southward to Fahka Union and Rookery Bays and westward to Naples Bay and the Cocohatchee River (Carter et al., 1973). The northern sector of the study area consists largely of red mangrove (*Rhizophora mangle*) islets and meandering tidal creeks. The interior mainland forests contain pure and mixed stands of black (*Avicennia nitida*) and white (*Laguncularia racemosa*) mangroves along with buttonwood (*Conocarpus erectus*) at higher elevations. Other plant species including the saltwort (*Batis maritima*), glasswort (*Salicornia virginica*) and marsh samphire (*Philoxerus vermicularis*) comprise the understory. Species composition and zonation reflect the associations commonly described for mangrove communities (Heald, 1975).

MATERIAL AND METHODS—Precipitation was continuously monitored on a recording rain-gauge (Belfort Instrument Co.). Additional data for the mainland were provided by the Division of Forestry, State of Florida. Temperature and salinity were recorded as either surface or near-bottom values utilizing a Beckman (Model RS5-3) Salinometer ($\pm$0.05) and a temperature compensated refractometer (American Optical Co.). The former instrument was precalibrated by titration (APHA, 1971) and prior to field use recalibrated with a 40 ohm resistor ($\pm$5%). Surface and near-bottom dissolved oxygen levels were analyzed by the modified Winkler procedure (EPA, 1971). Acidity was determined with a buffer calibrated Orion (Model 401) Specific Ion meter and a Corning combination pH electrode. Turbidities were read in Jackson Turbidity Units (J.T.U.) on a Hach (Model 1860A) laboratory turbidimeter ($\pm$2% of scale).

Monthly nutrient determinations were carried out with a Beckman (Model 24) spectrophotometer during the period September 1974 to August 1975. All samples were stored on ice and upon return to the laboratory 1.0 l aliquots were filtered through 0.45 μm membrane filters (Millipore Corp., Type HA). Orthophosphate (inorganic, soluble, reactive) was measured by the Murphy and Riley method (Strickland and Parsons, 1972) and total phosphate (unfiltered samples) by the procedures described by the EPA (1974). Nitrate was determined by a modified Morris and Riley method (Strickland and Parsons, 1972) while nitrite was measured by the Bendscheider-Robinson technique (Strickland and Parsons, 1972). A modified Solorzano (1969) method was used for ammonia (Strickland and Parsons, 1972).

Reactive silicate was measured according to the modified Mullin-Riley method (Strickland and Parsons, 1972). Chlorophyll-*a* and phaeophytin analyses were carried out in low illumination (Strickland and Parsons, 1972).

Macroinvertebrates and fishes were collected by several methods. A 3 m otter trawl with a 1.75 inch (4.45 cm) stretched mesh body and a 0.5 inch (1.25 cm) liner was towed at 50 m/min for 2 min over 11 stations in natural and artificial waterways (Fig. 1-3). Seven replicates were taken at each site and stations were selected on the basis of habitat types: mud/*Thalassia*, mud/*Halodule*, muddy-sand/*Halodule*, muddy sand, soft mud (including ooze), and shelly-sand. Stations in manmade canals were selected on the basis of canal length, age and complexity (Fig. 2). With the exception of the canal stations (sampled by one 100 m tow during daylight) all samples were obtained two nights before the new moon of each month.

Benthic infauna were collected with a 1/64 m^2 plug sampler and a 0.7 mm sieve. Forty-six stations of varying substratum type were chosen in natural and dredged areas; however, only those stations used in the community analyses are shown in Fig. 2 and 3. Samples at these sites consisted of the pooled contents of

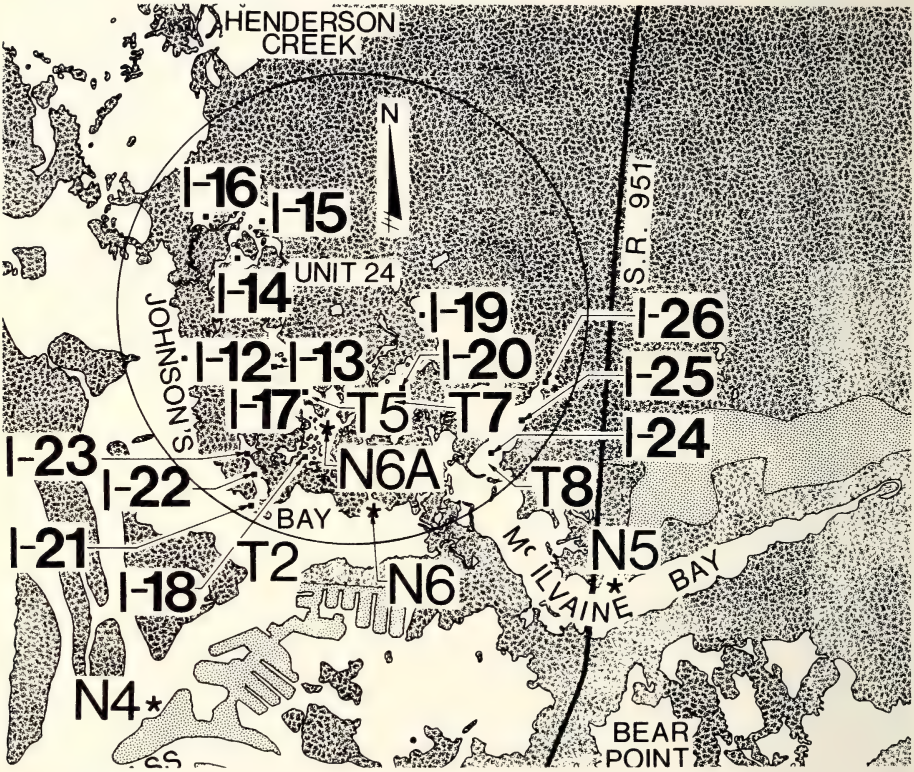


Fig. 2. Sampling sites in Unit 24. Station designations follow the same format as Fig. 1.

four replicates. Temperature, salinity and dissolved oxygen were recorded during each sampling period. Animals were preserved in the field with 10% formalin and transferred for storage into 70% alcohol. All samples were sorted at the laboratory and the wet weight recorded.

Species diversity of macroinvertebrate communities was assessed with the Shannon-Weaver index (Shannon and Weaver, 1963):

$$H' = -\sum_{i}^{s} p_i \log p_i$$

where p_i = the proportion of individuals in the ith species. The degree of similarity between sites was tested with the Jaccard (1908) coefficient used for species occurrences:

$$\frac{C}{N_1 + N_2 - C}$$

where N_1 = Number of occurrences at site 1
N_2 = Number of occurrences at site 2
C = Number of co-occurrences at sites 1 and 2.

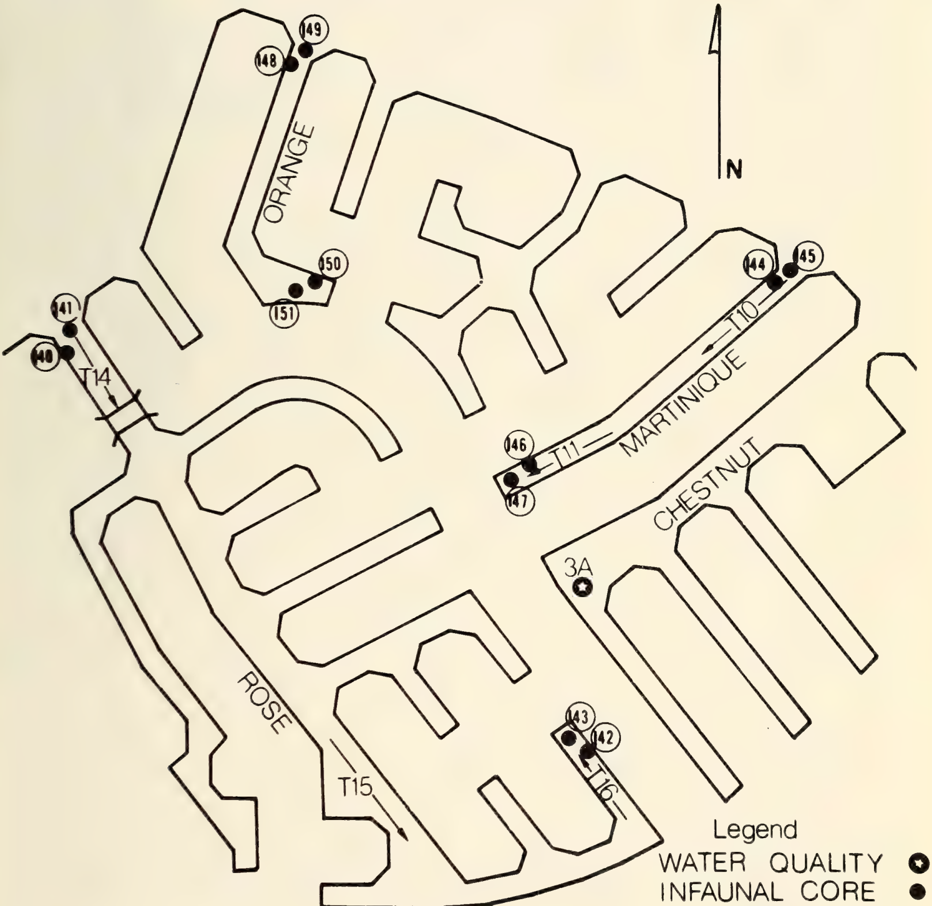


Fig. 3. Sampling sites in artificial waterways. Station designations follow the same format as Fig. 1.

Species represented by only one individual among all samples were eliminated from the analysis because they do not, by definition of the index, contribute to interstation similarity. This index is useful in analysis of binary (presence/absence) ecological data and is used here to compare species composition at selected infaunal stations. Separate matrices were constructed on the basis of station and species affinities (recurring species groups) and clustered by the un-

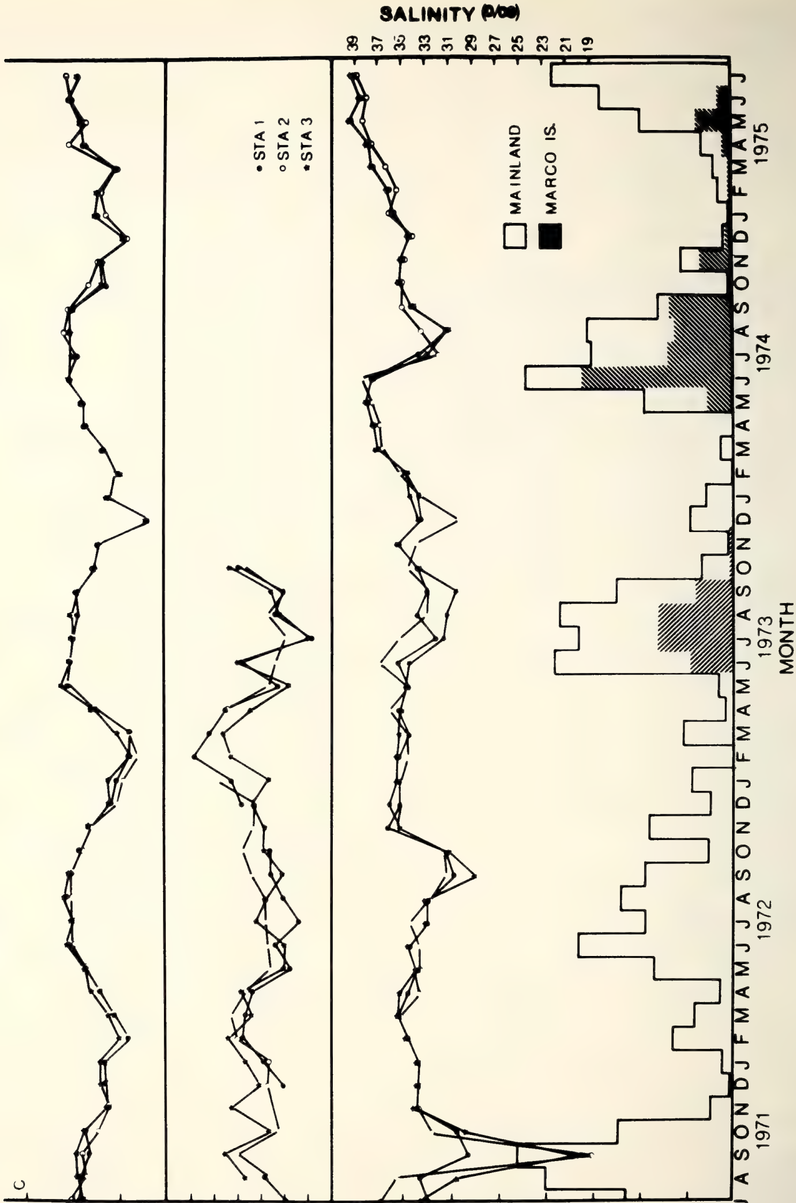


Fig. 4. Physiochemical data at three selected stations; T1, T2, T3.

weighted pair-group avg method (Sneath and Sokal, 1973). For each of these comparisons dendrograms were drawn and the results compared by methods described in Clifford and Stephenson (1975).

Results and Discussion—*Physiochemical Parameters*: Although physiochemical parameters in the Marco Island study area were generally similar to those recorded for other Florida estuaries, several differences were observed. Rainfall data (Fig. 4), for example, indicated a pattern similar to that of the Fahkahatchee Strand and the western coast of Florida, in general (Carter et al., 1973). Total precipitation on Marco Island during the wet season, however, appeared to be significantly lower (Fig. 4) than that of the mainland. Rainfall during the period June 1973 to June 1974, for example, totaled 93.8 cm (mo avg 7.21 cm), nearly all of it falling from May to September (60.4 cm). No measurable precipitation was recorded from January to April 1974. Five comparable sites on the mainland produced an avg of 230.6 cm with a monthly mean of 17.7 cm. Data collected after June 1974 displayed similar values, indicating that this pattern was consistent. The combination of low rainfall and rapid evaporation resulted in seasonally hypersaline conditions in the Marco vicinity. Additional relationships between precipitation and salinity are shown in Fig. 4. In 1973, 1974 and 1975, a lag of about 1 mo followed the onset of the wet season before salinity values began to decrease. This phenomenon seemed to coincide with a gradual movement of land-derived runoff into the area. We believe that the abrupt drop in salinities at all stations in 1971 resulted from rainfall in the immediate vicinity; however, this is only conjecture since local precipitation data are not available. An alternative explanation may relate to the actual sampling time relative to the period during the month when most rain fell.

A westerly salinity gradient was also observed in the Big Marco River (Fig. 1). Sheet flow from the Big Cypress Swamp entered Gullivan Bay to the east of State Road 92 (a barrier to continual westward movement of runoff) in larger volumes than to the west of this road. Salinities at Goodland during the wet season were lower than at the State Road 951 bridge and westward, resulting in enhanced westerly flow in the Big Marco River (Van de Kreeke, 1975).

Except during 1971, a relatively small annual range of salinities was realized (Fig. 4). In addition, the shallow depths encountered over most of the study area effectively eliminated stratification.

Water quality data obtained for total and soluble phosphate, nitrate, nitrite, ammonia, silica and chlorophyll are summarized in Table 1. We believe that the nine stations selected were representative of various conditions within the area. For example, Stations 2, 3, and 3A (Fig. 1 and 2) are either within or immediately adjacent to canals, reflecting the influence of development. Station H.C. (Henderson Creek) is affected by freshwater runoff and during the surveys consistently displayed the lowest salinity values around Marco Island. The remaining stations (1, 5, 6, 6A, and 8) are considered "natural" and encompass backwater bays, tidal creeks and the Big Marco River.

Nutrient concentrations observed at these sites were well within the limits encountered in other Florida estuaries (Bader and Roessler, 1971; Carter et al., 1973; Livingston et al., 1974; Roessler and Beardsley, 1974; Taylor, 1974), and in fact, mean values were generally lower. Thus, the waters of Marco Island may be considered "nutrient-poor" relative to surrounding regions. Our data also indicate that canals (Station 3A) and other developed areas (Stations 2, 3) were usually lower in phosphate and nitrogen than undisturbed sites; however, cer-

TABLE 1. Summary of chemical parameters in waters adjacent to Marco Island. See Figures 1 and 2 for station locations. [1]Total PO_4, [2]Soluble PO_4.

STA. 1	Mean	0.040	0.013	0.006	0.001	0.006	0.964	11.45
	Range	0.014-0.169	0.003-0.019	0.001-0.028	0.000-0.002	0.000-0.034	0.025-1.957	5.87-16.55
STA. 2	Mean	0.025	0.017	0.006	0.000	0.002	0.637	8.30
	Range	0.012-0.043	0.005-0.027	0.001-0.014	0.000-0.002	0.000-0.013	0.073-1.282	3.20-10.68
STA. 3	Mean	0.028	0.018	0.007	0.000	0.005	0.649	8.42
	Range	0.016-0.037	0.010-0.028	0.002-0.019	0.000-0.002	0.000-0.021	0.308-1.196	4.27-16.00
STA. 3A	Mean	0.025	0.014	0.011	0.001	0.002	0.707	13.18
	Range	0.009-0.036	0.000-0.029	0.000-0.029	0.000-0.002	0.000-0.011	0.134-1.576	9.08-28.84
STA. 5	Mean	0.032	0.016	0.009	0.001	0.007	0.836	5.93
	Range	0.010-0.082	0.000-0.030	0.000-0.039	0.000-0.002	0.000-0.021	0.605-1.350	0.53-10.15
STA. 6	Mean	0.036	0.018	0.013	0.001	0.014	0.829	6.29
	Range	0.020-0.086	0.000-0.032	0.004-0.052	0.000-0.003	0.000-0.035	0.336-1.355	3.20-12.82
STA. 6A	Mean	0.030	0.021	0.014	0.001	0.012	1.000	4.94
	Range	0.019-0.041	0.003-0.032	0.006-0.030	0.001-0.003	0.000-0.030	0.692-1.288	3.20- 8.54
STA. 8	Mean	0.040	0.021	0.017	0.002	0.024	1.518	7.89
	Range	0.026-0.052	0.010-0.034	0.006-0.052	0.001-0.004	0.003-0.056	0.966-2.086	1.60-15.49
STA. H.C.	Mean	0.040	0.016	0.017	0.001	0.038	1.690	10.42
	Range	0.017-0.111	0.009-0.020	0.002-0.067	0.000-0.002	0.000-0.107	1.344-2.024	2.67-16.02

tain artificial waterways (e.g., Landmark Waterway) may have been acting as nutrient sinks, periodically releasing these substances to the water column as a result of wind-induced upwellings. In the past this laboratory has reported temporary, localized "blooms" under such circumstances (Appleby, 1974).

Maximum nutrient values were consistently recorded at Henderson Creek, where they were attributed primarily to runoff, carrying nutrients from natural as well as man-induced sources (McNulty et al., 1972). With the exception of Henderson Creek (a point source of pollution) and Station 1 in Gullivan Bay, maximum chlorophyll-*a* values were observed in the canal environ. This observation is in agreement with previous studies (Carpenter, 1973) which indicated that a phytoplankton-based food chain was present. Furthermore, reduced tidal velocities and efficient wind protection resulted in lower turbidities and light penetration to greater depths, with a net effect of increasing phytoplankton populations. The highest mean turbidities were recorded at Henderson Creek, a combined result of runoff and the influence of the nearby trailer parks.

By contrast, color did not display any simple relationship in our data, and values changed both temporally and spatially without any consistent pattern. Local influences, such as maintenance dredging and resultant leachate from mangrove peat, may have been partially responsible for values obtained in the canals and nearby sites; however, conditions within the natural waters were not so easily explained. Perhaps spring tides, penetrating more deeply into mangrove areas, or periods of heavy rainfall at upland sites, or a combination of these factors were associated with the observed changes.

Levels of pH were within the range described for estuarine environs, the major pattern being one of lower values associated with freshwater influence. Henderson Creek displayed slightly lower pH values, as did Stations 6A and 8, which were located at heads of bays, closest to freshwater sources (Fig. 1). Dissolved oxygen concentrations, however, varied widely during the course of this study. The lowest levels were frequently observed in the early morning hours at the heads of certain canals and natural sites associated with shallow, wind protected "backwater" areas of bays and tidal creeks. The combination of high summertime temperatures, poor circulation and large inputs of mangrove detritus often resulted in oxygen levels well below the State of Florida standard (4.0 ppm). These factors, including seasonal hypersalinity, probably induce severe periodic stress on local communities and have been an important limiting factor affecting presence, abundance and distribution of certain species.

Biota: INVERTEBRATES—Over 500,000 individuals comprising 300 taxa of macroinvertebrates were collected. Because of taxonomic difficulties, groups such as the poriferans, polychaetes, amphipods, isopods and tunicates were treated superficially. Those taxa constituting at least 0.5% of the total number of individuals captured are ranked in decreasing order of abundance in Table 2, and include polychaetes, sponges and tunicates but exclude the less easily quantified amphipods and isopods. Representatives of both the West Indian (e.g., *Littorina angulifera, Bulla straita, Aratus pisonii*) and Carolinian (e.g., *Pagurus longicarpus, Leptogorgia virgulata*) Provinces (Andrews, 1971; Briggs, 1974) were

TABLE 2. Invertebrate taxa constituting at least 0.5% of the total catch ranked for each collection method in decreasing order of abundance. [1]Numbers of individuals in parentheses.

TRAWL-EPIBENTHOS (Natural Stations)	CORING-INFAUNA
Leptosynapta parvipatina[1] (219,122)	*Tellina versacolor* (540)
Periclimenes americanus (107,914)	*Amphioplus abditus* (533)
P. longicaudatus (82,530)	*Tellina mera* (413)
Penaeus duorarum (53,763)	Molgulidae (344)
Hippolyte pleuracanthus (23,094)	*Parastarte triquetra* (272)
Tozeuma carolinense (19,994)	Cirratulidae (249)
Bulla striata (16,501)	Sipunculida (240)
Neopanope texana (14,722)	*Branciostoma* sp. (221)
Alpheus heterochaelis (14,389)	Sabellidae (216)
Modulus modulus (11,502)	*Tellina tampaensis* (209)
Anadara transversa (9,636)	Oligochaete (168)
Callinectes ornatus (7,932)	*Marginella apicina* (167)
Palaemonetes vulgaris (7,740)	*Anomalocardia auberiana* (165)
Alpheus normanni (5,776)	*Lyonsia hyalina floridana* (163)
Thor floridanus (5,212)	*Bittium varium* (160)
Marginella apicina (4,376)	*Macoma tenta* (156)
Echinaster spinulosis (4,131)	*Acteocina canaliculata* (145)
Bursatella leachii pleii (4,102)	*Bulla striata* (131)
Trachypenaeus constrictus (4,096)	*Eucratopsis crassimanus* (124)
Bittium varium (3,030)	*Abra aequalis* (121)
	Codakia orbiculata (114)
	Ophiophragmus filograneus (106)
	Corbula caribaea (101)
	Haminoea elegans (80)
	Tagelus divisus (75)
	Tubonilla dalli (70)
	Lumbrinereidae (68)
	Pentacta pygmaea (52)
	Ampharaetidae (51)
	Olivella pusilla (51)
	Granulina ovuliformes (46)
	Hyalina veliei (46)
	Lucina nassula (46)
	Neopanope texana (41)
	Alpheus heterochaelis (37)
	Mitrella lunata (36)

collected. Some members of the Carolinian fauna such as the decapod crustaceans dominated in the catches (see also Tabb et al., 1962), while others such as several asteroids appeared to be at the limits of their range.

A number of species also exhibited distinct seasonality (Fig. 5 and 6). Of the three dominating commercially valuable forms, only the pink shrimp *Penaeus duorarum*, was found in significant numbers in the study area where it was most abundant in grass beds. Our data show a net movement of these shrimp from the inland bay system beginning in October, and in addition, a general influx of recruits beginning in April, and peaking in July. These data coincide with the work of others on the lower Gulf coast (Eldred et al., 1961; Tabb et al., 1962; Yokel, 1975).

Two of the most abundant caridean shrimp in the trawl catches, *Periclimenes longicaudatus* and *P. americanus*, exhibited a seasonal pattern of abundance (Fig.

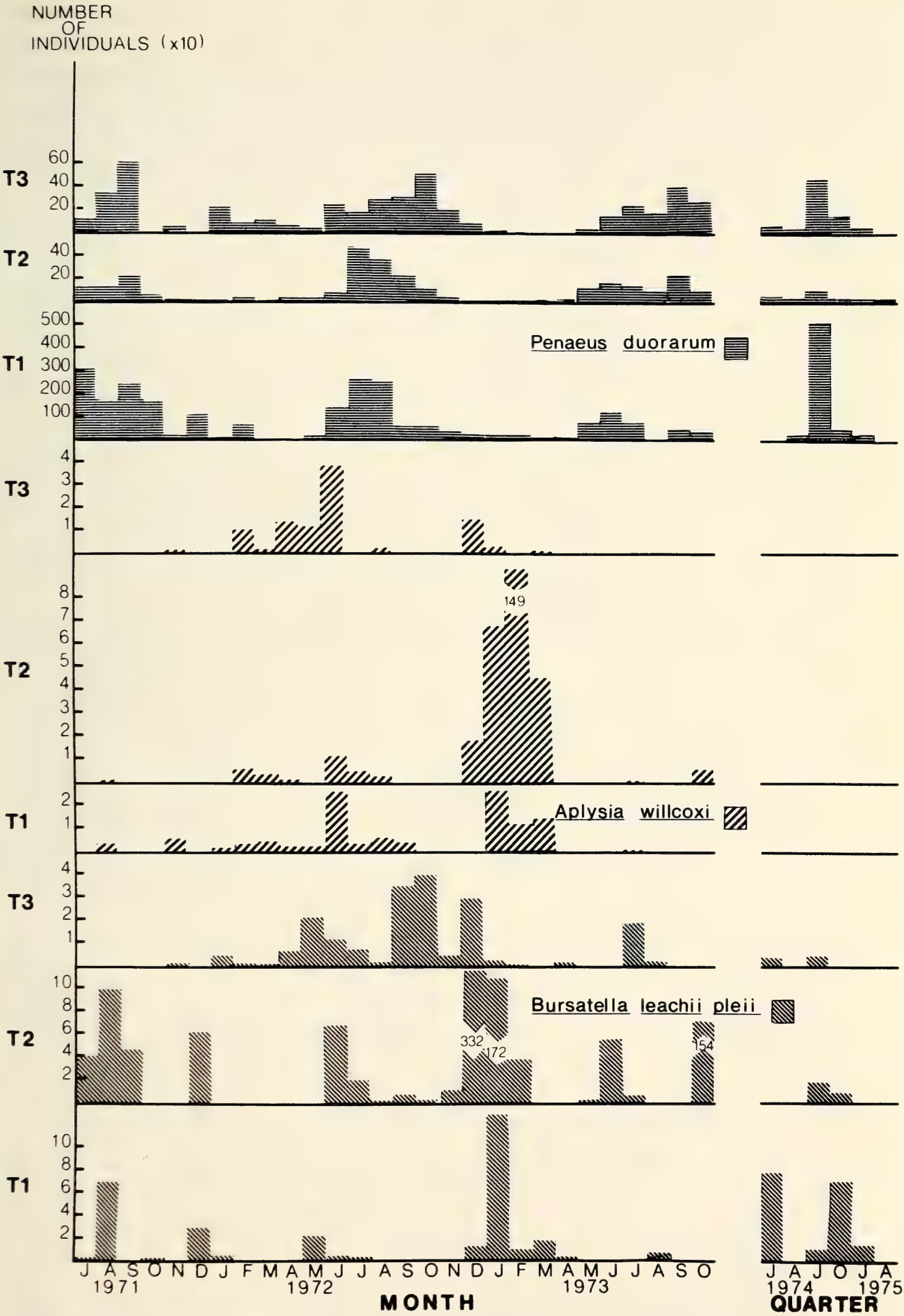


Fig. 5. Seasonality of selected invertebrates at three trawling sites; T1, T2, T3.

6), with peaks also occurring from October to January. Both species declined in numbers from April through August, coincident with increasing abundance of two predators of small crustaceans, *Lagodon rhomboides* and *Orthopristis chrysoptera* (Hansen, 1969: Carr and Adams, 1973). Other invertebrate species occasionally appeared in abundance. *Anadara transversa* (Fig. 6) increased in numbers in late winter and early spring, their densities apparently responsive to

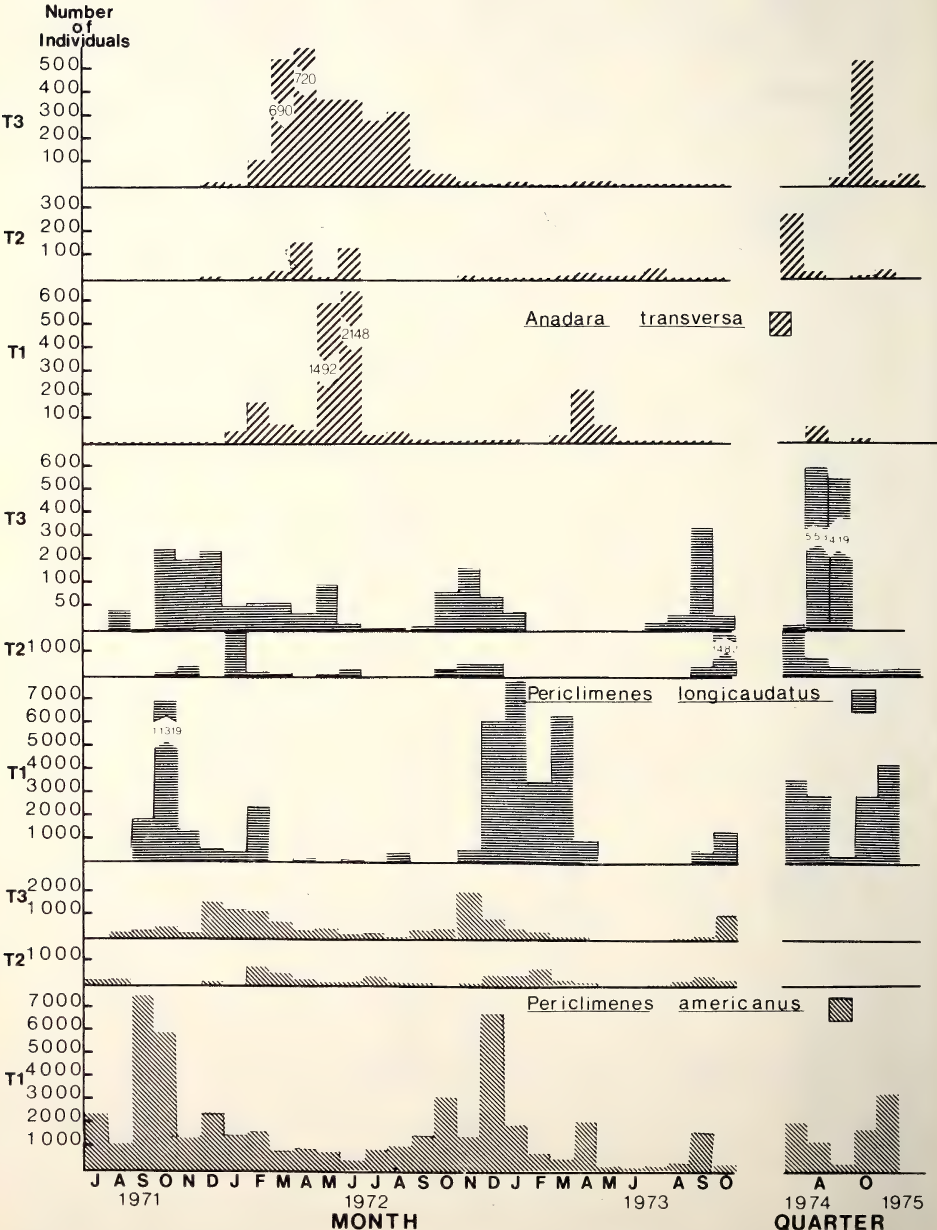


Fig. 6. Seasonality of selected invertebrates at three trawling sites; T1, T2, T3.

success or failure of reproduction. *Bursatella leachii pleii* (Fig. 5) was usually abundant in shallow waters in spring and early summer but was also observed in large numbers in December and January, and concentrations of copulating pairs were noted in October. *Aplysia willcoxi* was abundant only in the collections of December 1972 to February 1973 (Fig. 5), when it may have been undertaking a spawning migration (L. Stephens, personal commun.).

Since microhabitat specificity plays an important part in the distribution of most benthic macroinvertebrates (Hedgepeth, 1975; Odum, 1971; Collard and D'Asaro, 1973; Parker, 1975), a wide variety of substrata were investigated. The greatest avg number of infaunal species were found in predominantly coarser (100-500 μm) substrates. Sea grasses (*Thalassia testudinum* or *Halodule wrightii*) and to a slightly lesser extent, unattached algae, had the greatest influence on the biomass of the epibenthos collected. The Marco vicinity does not appear to be conducive to extensive *Thalassia* colonization and the few beds that were present were restricted largely to sills on the borders of high velocity tidal channels or to the centers of a few large shallow bays (McNulty et al., 1972). In the Marco ecosystem, turbidity seemed to be the chief limiting factor since growth of these plants was limited to depths less than 1 m. Our observations indicated that *Halodule wrightii* was more successful at colonization in this area and predominates in the shallow back-bays of the mangrove complex, where it appears to be limited to depths of about 0.9 m (MHW). Humm (1973) lists this species as the most tolerant of varying environmental conditions including turbidity.

Many of the invertebrate species collected including some of those presented in Table 3, exhibited broad preferences among habitats. *Penaeus duorarum*, for instance, was collected at every trawl station and was the numerically dominant macroinvertebrate in the deep troughs of artificial waterways. Several species, on the other hand, were restricted largely to a particular habitat. Deposit feeders such as *Macoma tenta, Tellidora cristata,* and *Nuculana concentrica* were found exclusively in the unvegetated soft muds of open bay central channels, as were the predators *Ophiolepis elegans, Ophioderma brevispinum,* and *Luidia senegalensis. Ogyrides limnicola* was limited to this habitat as were *Synalpheus fritzmuelleri* and *S. townsendi,* which occurred jointly with sponges. *Anomalocardia auberiana* occurred only at infaunal Station 16, a shallow (0.3-0.9 m) open bay station where deep soft muds predominate. This station is in an area that is apparently unstable with respect to tidal flow and Van de Kreeke (1972) had described it as the point where tidal waves entering from Caxambas and Coon Key passes meet. *Hyalina veliei, Thor floridanus* and *Pitho anisodon* were taken almost exclusively in *Thalassia testudinum* and *Modulus modulus* exclusively in *Halodule wrightii* while *Carditamera floridana, Toxeuma carolinese,* and *Hippolyte pleuracanthus* were "grass" inhabitants, but did not seem to prefer one species of grass over the other. The burrowing suspension feeder *Upogebia affinis* was restricted largely to infaunal Station I44, located in an area of decreasing current activity near the entrance of an artificial waterway. *Heterocrypta granulata,* a shell fragment mimic, was found exclusively on scoured tidal channel bottoms.

TABLE 3. The conspicuous or most common invertebrate inhabitants of the major inshore habitats in the Marco area.

THALASSIA	DIPLANTHERA	SCOURED TIDAL PASS	OPEN BAYS (SOFT MUD)	INSHORE SAND BARS
Crepidula maculosa	*Modulus modulus*	*Erato mangeriae*	*Polinices duplicatus*	*Epitonium humphreysi*
Anachis semiplicata	*Cerithium muscarum*	*Anachis semiplicata*	*Anachis sparsa*	*Busycon contrarium*
Mitrella lunata	*Crepidula convexa*	*Mitrella lunata*	*A. obesa*	*Parvilucina multilineata*
Nassorius uibex	*Marginella apicina*	*Musculus lateralis*	*Melongena corona*	*Codakia orbiculata*
Fasciolaria lilium hunteria	*Crassispira leucocyma*	*Lima pellucida*	*Aplysia willcoxi*	*Lyonsia hyalina floridana*
Marginella spicina	*Turbonilla dalli*	*Argopecten gibbus*	*Bursatella leachii pleii*	*Brachiostoma* sp.
Hyalina veliei	*Bulla striata*	*Trachypenacus constrictus*	*Barbata candida*	*Tellina lineata*
Crassispira leucocyma	*Haminoea succinea*	*Lysmata wurdemanni*	*Anadara transversa*	*Parastarte triquetra*
Bulla straita	*Musculus lateralis*	*Latreutes fucorum*	*Tellina lineata*	
Haminoea elegans	*Lucina nassula*	*L. parvulus*	*T. versicolor*	
Bursatella leachii pleii	*Diastoma varium*	*Sicyonia laevigata*	*T. mera*	
Andara traversa	*Carditamera floridana*	*S. typica*	*Macoma tenta*	
Musculus lateralis	*Penaeus duorarum*	*Ambidexter symetricus*	*Abra acqualis*	
Lima pellucida	*Tozeuma carolinense*	*Panopeus occidentalis*	*Codakia orbiculata*	
Codakia orbiculata	*Hippolyte pleuracanthus*	*Libinia dubia*	*Squilla empusa*	
Carditamera floridana	*Ophiophragmus filograneus*	*Branchistoma* sp.	*Penaeus duorarum*	
Penaeus duorarum	*Ophioderma brevispinum*	*Eucratopsis crassimanus*	*Trachypenaeus constrictus*	
Palaemonetes vulgarus		*Heterocrypta granulata*	*Alpheus normanni*	
Periclimenes longicaudatus			*A. heterochaelis*	
P. americanus			*Ogyrides limnicola*	
Alpheus normanni			*Ambidexter symetricus*	
A. heterochaelis			*Upogebia affinis*	
Thor floridanus			*Persophona aquilonaris*	
Tozeuma carolinense			*Portunus gibbesi*	
Hippolyte pleuracanthus			*Eucratopsis crassimanus*	
Portunus gibbesi			*Luidia senegalensis*	
Callinectes sapidus			*Ophiolepsis elegans*	
Neopanope texana			*Ophioderma brevispinum*	
N. packardii			*Amphioplus abditus*	
Pagurus longicarpus			*Callinectes sapidus*	
Libinia dubia			*Neopanope packardii*	
Pitho anisodon			*Menippe mercenaria*	
Echinaster spinulosis			*Ophiophragmus filograneus*	
Thyone briarius				
Pentacta pygmaea				
Leptosynapta parvipatins				

Salinity also seemed to play a limiting role in several instances. Species characteristic of lower salinity regimes, such as *Mulinia lateralis* (Taylor et al., 1970) *Palaemonetas intermedius* and *Mytilopsis leucophaeta* were totally absent from this seasonally hypersaline estuary.

Species diversity of macroinvertebrate communities was assessed with the Shannon-Weaver index (Shannon and Weaver, 1949). This function is often correlated with stability and tends to be low in ecosystems which are subjected to strong physiochemical limiting factors (Bechtel and Copeland, 1970; Copeland and Bechtel, 1971; Odum, 1971; Livingston, 1975). Despite recent criticism of its value (Hurlburt, 1971; Goodman, 1975) the index of diversity is still useful in comparing patterns which exist in local communities. Thus, trawl and infaunal stations (where uniform sampling effort was applied) were ranked in Table 4 by decreasing diversity. Several salient points are developed in the table: 1) diversity was generally lower in canals than in undisturbed areas; 2) epibenthic diversity decreased with increasing artificial waterway length and complexity of design (Fig. 3); 3) infaunal diversities decreased in a similar manner with increasing dis-

TABLE 4. Invertebrate collections from trawl and infaunal station ranked by decreasing order of diversity. T = trough and B = berm for canal stations.

Infaunal Stations		H′		Trawl Stations	H′
Natural	I3	2.0124	Natural	T3	2.4905
	I21	1.8141		T6	2.3810
	I22	1.7565		T1	2.3036
	I6	1.7475		T5	2.1909
	I18	1.6324		T2	2.1745
	I19	1.3267		T7	2.0680
	I13	1.3052	Canal	T11	1.8645
	I25	1.2319		T10	1.8553
	I10	1.2188		T14	1.5075
	I12	1.1938		T15	1.4500
	I24	1.1829		T16	0.7726
	I20	1.0042			
	I14	0.9910			
	I23	0.9203			
	I26	0.9191			
	I17	0.9092			
	I16	0.8193			
	I15	0.6568			
Canal	I44B	1.6392			
	I48B	1.3186			
	I40B	1.1432			
	I49T(entrance)	0.9627			
	I42B	0.8925			
	I50B	0.7800			
	I41T(entrance)	0.6550			
	I45T(entrance)	0.5881			
	I46B	0.3662			
	I47T(head)	0.1155			
	I51T(head)	0.0260			
	I43T(head)	0.0000			

tance, but were greater on the shallow canal berms than in the deep central trough; 4) infaunal diversities also decreased with distance into the intricate mangrove-lined back-bay complexes of natural areas (Fig. 2). Several authors have documented animal-sediment relationships for infauna (Bader, 1954; Bloom et al., 1972; Parker, 1975; Sykes and Hall, 1970; Thorson, 1965), and Carriker (1967) observed from the works of others that faunally rich "muddy sand" substrata occur in certain parts of estuaries which "support greater densities of megabenthic populations than either clean, coarse unstable sands and gravels at the mouths or slurry muds in the quiet sheltered reaches."

An increase in the $< 40\ \mu m$ sediment fraction with distance into both natural and artificial waterways was discussed by Wanless (1974); however, the artificial waterways contained a significantly greater proportion of this fraction. Furthermore, we have observed that the more diverse assemblages are associated either with increased avg substratum particle size (Stations I18, I44, I21, I48, and I22) or with the presence of grasses (Stations I19, T6, T5, T1 and I3), while lowest diversities were produced at stations devoid of grass cover where a significant proportion (40-97%) of the substratum was composed of particles less than $< 40\ \mu m$ (Wanless, 1974); these stations were usually located in upper reaches (Stations I15, T16, T7, I16, I41, I43, I47, I23, and I26).

An additional attempt was made to quantify the relationship between infaunal assemblages in artificial and natural waterways by using the Jaccard coefficient. Values obtained from interstation and species comparisons were clustered with the unweighted pair-group avg method (Sneath and Sokal, 1973) and the results are presented in Fig. 7 and Table 5. Although similarity (Jaccard) values were generally low due to the presence of many rare species, a clear pattern still emerges. At the 10% level for the station associations five diffuse clusters are discernible; (A) a group of stations in natural tidal creeks: I13, I16, I23, I17, I18, I21, I24, I15, I26 and I19 (Fig. 1); (B) a group of canal entrance (with one exception) stations: I40, I48, I49, I50, I41, I44, I45; (C) a pair of canal head end stations: I42 and I46; and two "outlying" canal groups, (D) consisting of head end stations I47 and I41 and (E) head and station I43 the least similar of all stations. Within each of the major clusters several distinct subgroups may be recognized. In natural areas we have defined stations as either "entrance" or "head" on the basis of location and concomitant substratum type. Thus, stations at the entrance to the mangrove complex (e.g., I21) or within scoured tidal channels (e.g., I24, I13, I17) were generally characterized by firm muddy-sand bottoms, while stations in sheltered, low-flow areas were characterized by soft substrata rich in organic deposits. This was done in order to facilitate comparisons with canal environs which display an increase in the "fine" ($<40\ \mu m$) sediment fraction toward their heads (Wanless, 1974). Further examination of Fig. 7 indicates that Stations I15, I26, and I19 are the least similar natural stations. All are found well back in the mangrove complex where large quantities of detritus, high BOD and consequently low dissolved oxygen concentrations (Van de Kreeke and Roessler, 1975) produce a unique environment. Interestingly, Station I23, a "head" station that did not have extensive organic deposits, was more similar

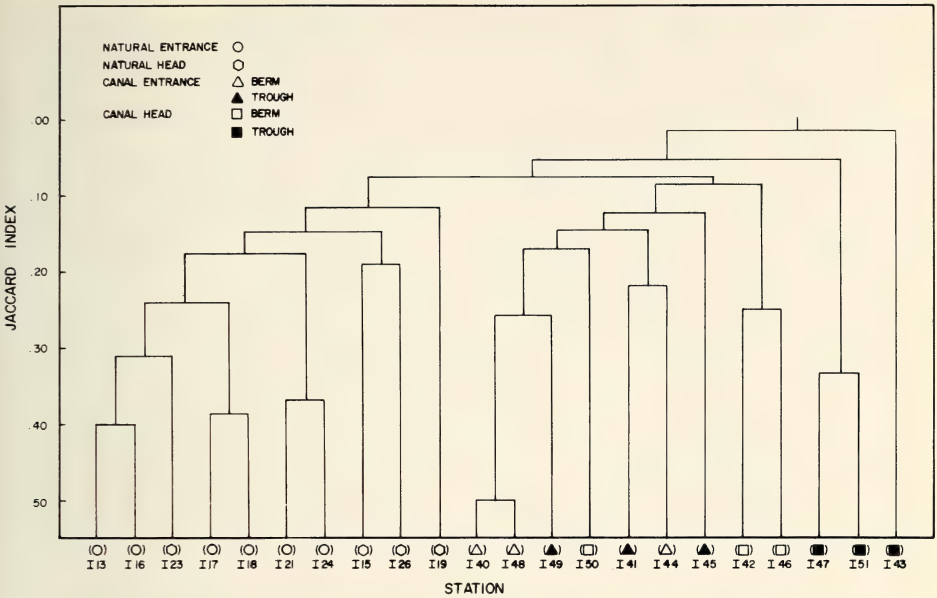


Fig. 7. Dendrogram generated from Jaccard matrix of infaunal station comparisons.

to stations with scoured bottom (although it was less similar to I21, the closest entrance site) than to the soft substratum sites.

Among the artificial waterways several notable patterns emerge. The largest cluster consists of entrance stations on either the berm (I40, I48, I44) or in the deeper trough (I49, I41, I45). Since sediment characteristics are similar in the canal mouths (Wanless, 1974) it is not surprising that the fauna of these sites are the most alike in the canal system. The single exception, Station I50, is a canal head (berm) station in Orange Waterway, the newest and shortest of the canals. The fact that species composition at this station differs from that of other similar localities may relate to canal age and length.

Because of their sediment characteristics, including large quantities of the fine organic fraction, the troughs at the heads of the canals form a group apart from other canal localities. In the case of Rose Waterway, extreme length and improper design (the bottom sloping downward toward the head end) result in oxygen concentrations near zero at the bottom (Van de Kreeke and Roessler, 1975). Thus, Station I43 yielded only a single species in all of the cores collected, making it the strongest "outlyer" of the entire group.

The species composition at all stations is shown in Table 5. The eight groups resulting from the analysis of species associations (Clifford and Stephenson, 1975) are defined by those clusters appearing at the 15% (Jaccard value of .15) level. In the table species groups are cross-referenced with the five clusters described above for station associations. In this way, species groups characteristic of each of the station clusters are readily visualized. The most striking feature on the table is the difference between natural and canal station associations. Infaunal species groups I, V, VI, VII and VIII are associated primarily with the mangrove habitat, while groups II, III and IV are most often associated with canals. Furthermore there is little overlap among species in the two habitats, and we therefore define distinct infaunal assemblages for each.

The species characteristic of the canal environ include: *Macoma tenta*, a fragile deposit feeder that was found chiefly in the soft muds of the canal troughs; *Anachis obesa*, a columbellid which has been associated with hydroid colonies of canal seawalls (Perry and Schwengel, 1955); *Upogebia affinis*, a callianasid that feeds on strained organic matter and which is known to inhabit "muddy stations in the estuaries where salinities are fairly high" (Williams, 1965); two marine oligochaetes of the families Naididae and Tubificidae which are generally known to browse on very small organic particles and which assume important roles in oxygen depleted habitats (Cook and Brinkhurst, 1973); *Tagelus divisus*, a solecurtid clam which takes in loose sediments and suspended material on or just above the surface of the substrate (Fraser, 1967), this species was found exclusively on canal berms and is termed a reliable indicator for high salinity bays by Parker (1975); *Tellina versicolor*, a deposit feeder most frequently found on canal berms; and an unidentified gammarid collected only in Orange Waterway.

The assemblage characteristic of the mangrove habitat includes: *Modulus modulus, Acteocina caniculata, Turbonilla dalli, Marginella apicina, Haminoea elegans, Bulla striata, Vermicularia knorri, Conus floridanus, Codakia orbiculata, Lucina nassula, Parastarte triquetra, Semele purpurascens*, three unidentified cirratulid polychaetes and one hesionid polychaete, *Amphioplus abditus, Ophiophragmus filograneus*, a sipunculid and a colonial ascidian. This assemblage is trophically more diverse than the canal infaunal assemblage with not only suspension and deposit feeding species present (e.g., *Codakia, Lucina, Semele*), but also with scavengers (e.g., *Marginella*), herbivores (e.g., *Retussa*), and predators (*Conus*).

More detailed examination of Table 5 also gives an indication of differences within habitats. For example, natural "head" end stations (I15, I19 and I26) are characterized by low diversity (as described previously) and have fewer species present. In addition, fewer species are shared in common with other natural sites, thus the lower Jaccard values. Species unique to this habitat include cirratulid and syllid polychaetes and an unidentified gammarid. Among the species unique to the entrances of the mangrove-lined channels are *Marginella apicina, Lucina nassula, Pectinaria gouldi, Conus floridanus, Haminoea elegans* and unidentified chaetopterid and lumbrinereid polychaetes. Much of the "uniqueness" of the mangrove assemblage then derives from the entrance stations.

In the canals, the stations with low Jaccard associations (head end Stations I42, I46, I47, I51 and I43) were characterized mainly by the absence of many species and less frequently by unique species. Diversity was generally low and species groups II and III, characteristic of canal stations in general, were underrepresented.

TABLE 1. (facing page) Two-way coincidence table showing species and station group associations for infauna. An asterisk (*) indicates that the species was collected at that site.

STATION GROUPS

E	D		C		B							A											
143	151	147	146	142	145	144	141	150	149	148	140	119	126	115	124	121	118	117	123	116	113		SPECIES GROUPS
													*									Syllidae	I
													*									Gammarus sp. E	
														*								Parastarte triquetra	
				*									*	*			*					Nereidae	
						*																Laevicardium mortoni	II
					*	*	*						*						*			Macoma sp.	
				*	*	*																Macoma tenta	
							*				*	*										Arthropod parts	
						*	*															Anachis obesa	III
				*		*																Upogebia affinis	
		*				*														*		Penaeus duorarum	
				*				*	*													Dosinia elegans	
										*	*											Branchiobdellida sp.	IV
							*			*	*											Bugula neritina	
*								*		*	*											Tubificidae	
								*		*	*											Naididae	
								*		*												Eunicidae	
	*							*		*	*				*	*						Branchiostoma sp.	
								*	*	*												Gammarus sp. C	
			*			*				*	*											Tagelus divisus	
						*				*												Sabellidae sp. C	
					*	*			*	*	*						*					Tellina versicolor	
						*			*	*						*	*					Alpheus normanni	
						*	*		*	*	*					*		*				Abra aequalis	
					*	*			*							*					*	Corbula caribaea	
		*	*		*	*		*	*	*					*	*						Eucratopsis crassimanus	
												*		*			*	*				Modulus modulus	V
												*		*								Cirratulidae sp. B	
														*		*					*	Hesionidae	
														*					*			Acteocina caniculata	
									*					*			*		*		*	Lyonsia hyalina	
														*						*		Ascidia sp.	
																					*	Chaetopterus sp.	
														*							*	Sphaeroma terebrans	
						*															*	Periclimenes longicaudatus	
									*			*									*	Neopanope texana	
															*					*		Turbonilla dalli	VI
															*							Gammarus sp. B	
			*					*					*		*							Gammarus sp. A	
												*			*	*			*		*	Cirratulidae sp. B	VII
					*							*			*	*			*			Amphioplus abditus	
												*	*		*	*	*	*	*	*	*	Marginella apicina	
				*									*		*	*				*	*	Ophiophragmus filograneus	
						*									*					*		Molgula sp. A	
					*										*			*	*	*	*	Cirratulidae unid.	
																		*	*	*	*	Tellina mera	
																	*	*	*	*	*	Cirratulidae sp. A	
				*									*		*		*		*	*	*	Haminoea succinea	
					*	*	*				*		*	*			*		*	*	*	Tellina tampaensis	
										*	*			*			*			*	*	Sabellidae unid.	
	*	*		*		*		*				*	*	*		*	*			*	*	Gammarus sp.	
															*			*				Cerithium muscarum	
																		*				Hyalina pallida	
																*						Ophioderma brevispinum	
															*	*	*	*				Lucina nassula	
				*											*	*	*	*				Haminoea elegans	
			*					*	*						*	*	*	*				Lumbrinereidae	
											*						*	*				Hesionidae	
														*	*	*		*				Codakia orbiculata	
														*		*		*				Chaetoperidae unid.	
					*									*	*		*	*		*		Bulla striata	
			*	*							*					*						Chione cancellata	VIII
																*						Portunus gibbesi	
																*						Vermicularia knorri	
																*						Semele pupurascens	
												*				*						Polychaeta D	
																*						Trachypenaeus constrictus	
						*										*						Echinaster spinulosis	
						*									*	*						Crassispira leucocyma	
									*						*	*						Cyathura sp.	
															*	*						Periclimenes americanus	
																*					*	Codakia orbicularis	
						*										*			*		*	Pectinaria gouldi	
															*	*					*	Conus floridanus	

FISHES—A total of 30,051 fishes representing 95 species and 36 families were collected from various habitats in the Marco vicinity. The major sampling effort (from July 1971 through January 1975) involved simultaneous collections over three major habitat types: 1) a shallow *Thalassia/Halodule* grass flat (T1); 2) a tidal channel generally free of vegetation and with a sand-shell substrate (T2); and 3) a shallow bay bottom composed of mud with little attached vegetation and algae (T3). From these localities a total of 16,836 fishes comprising 82 species and 37 families, were captured. The 25 most common species constituted 96.7% of the total (Table 6) and the silver jenny (*Eucinostomus gula*), pinfish (*Lagodon rhomboides*) and pigfish (*Orthopristis chrysoptera*) accounted for 68.8% of this figure.

Eucinostomus gula proved to be the most abundant species in our samples. Individuals were captured throughout the study area, peaks of abundance usually coincided with maximum salinity and water temperatures. We consider this species a permanent "resident" of the Marco ecosystem since it did not exhibit any seasonal migration into the open Gulf. Larger fishes (>86 mm) dominated the samples in winter and early spring and smaller individuals (11-15 mm) were prominent during late spring and early fall (October). These data indicate a fall

TABLE 6. Relative abundance of fishes collected by trawl at Marco Stations T_1, T_2 and T_3, July 1971—January 1975.

	TOTAL	%
Eucinostomus gula, silver jenny	4469	26.5
Lagodon rhomboides, pinfish	3711	22.0
Orthopristis chrysoptera, pigfish	3420	20.3
Eucinostomus argenteus, spotfin mojarra	901	5.4
Lutjanus synagris, lane snapper	598	3.6
Gobiosoma robustum, code goby	427	2.5
Sygnathus scovelli, Gulf pipefish	355	2.1
Bairdiella chrysura, silver perch	344	2.0
Symphurus plagiusa, black-cheeked tonguefish	312	1.9
Monacanthus hispidus, planehead filefish	289	1.7
Haemulon plumieri, white grunt	201	1.2
Chilomycterus schoepfi, striped burrfish	184	1.1
Achirus lineatus, lined sole	161	1.0
Chaetodipterus faber, Atlantic spadefish	134	0.8
Anchoa mitchilli, bay anchovy	106	0.6
Sygnathus louisianae, chain pipefish	102	0.6
Etropus crossotus, fringed founder	82	0.5
Anchoa cubana, Cuban anchovy	72	0.4
Diplectrum formosum, sand perch	69	0.4
Lutjanus griseus, gray snapper	67	0.4
Elops saurus, ladyfish	64	0.4
Prionotus scitulus, leopard searobin	57	0.4
Lactophrys quadricornus, scrawled cowfish	53	0.3
Hippocampus zosterae, dwarf seahorse	46	0.3
Sphoeroides nephalus, southern puffer	43	0.3
		96.7%

spawning cycle, beginning with the onset of the dry season and continuing until water temperatures begin to lower markedly. The silver jenny showed a preference for a grassy habitat, with nearly 57.6% of the total captured at T1.

Similar temporal and spatial distributions for this species have been reported previously (Reid, 1954, Springer and Woodburn, 1960; Gunter and Hall, 1965), and Yokel (1975) noted significant differences in the catches between vegetated and sand/shell substrate. Wang and Raney (1971) linked this species' distribution to dense algal concentrations in Charlotte Harbor, Florida.

A closely related species, the spotfin mojarra *(Eucinostomus argenteus)* was taken consistently with *E. gula*. The smaller size classes (< 30 mm) are extremely similar and considerable overlap in identifying characters exists. We note this similarity because *E. argenteus* was fourth in abundance and it is probable that a portion of the smaller fishes identified as *E. gula* were actually *E. argenteus*. The ecological separation described by Springer and Woodburn (1960) and Yokel (1975) was not as distinct in the Marco data.

The pinfish (*Lagodon rhomboides)* was recorded at all stations and ranked second in total abundance. Seasonality was clearly evident in this species as demonstrated by relative abundance values and length frequency distributions (Table 7). Peak numbers were recorded during the January-July period when the size mode increased from 11-15 mm to 46-55 mm. These data clearly reflect the utilization of the inshore habitat as a nursery and rearing area for the pinfish. All stations were dominated by the 0-yr class and nearly 87.5% of the fish were collected from T1, indicating a strong preference for seagrass, probably because this habitat provided food and the ample cover for smaller fish. Hansen (1969) noted that vegetation constituted a large part of the summer and fall diet of pinfish. During late fall and winter these fishes (below 76 mm standard length) tended to become carnivorous, feeding predominantly on polychaetes and crustaceans. Odum (1971), on the other hand, stated that stomachs of south Florida fishes contained animal matter (particularly molluscs) almost exclusively. The discrepancy is partially explained by Carr and Adams (1973) who described three distinct stages in ontogenetic food selection by pinfish. Young individuals were primarily planktivorous and larger size classes passed from a carnivorous to herbivorous mode of feeding. The dependence on benthic vegetation and associated fauna would, therefore, necessitate a close relationship between *L. rhomboides* and the resources of the grassflat.

Pinfish remained abundant in the Marco samples until the late fall (October and November) when few were captured, the time of scarcity coinciding with a period of offshore spawning (Hansen, 1969; Moe, 1972). Yokel (1974) noted similar patterns in the catches from Rookery Bay and Wang and Raney (1971) observed that pinfish dominated the Charlotte Harbor epibenthic fauna, with larger fish prevalent in the catches in the latter part of the year.

Ranking third in overall abundance, the pigfish (*Orthopristis chrysoptera*) also preferred the seagrass habitat, with nearly 80% of the total collected at Station T1. A distinct seasonal pattern in abundance and growth was evident (Table 8). The smallest size class (11-15 mm) first appeared in the December samples

Table 7. Length frequency distribution of *Lagodon rhomboides* taken by the three meter trawl at stations adjacent to Marco Island, Florida July 1971—January 1975.

STANDARD LENGTH (mm)	1971						1972												1973									
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O
86+	28	34	21	11	17	12							2	1														1
81-85	26	13	20	11								1	3													3		
76-80	37	8	21	3							1			6				1							6	2	1	
71-75	33	5	18	3									11	15	4								1	1	1			
66-70	40	9	10								2	12	21	23									1	5	5	1	1	
61-65	28	4	2							2	9	13	35	13									3	1	5	2		
56-60	50		2							1	10	14	52	7									1	3	2			
51-55	64							4		2	8	25	44	2									7	13	1			
46-50	25							15	2	2	3	24	40	2									16	2	3			
41-45	5							20	3	1	11	28	35	2									20	14	1			
36-40							10	30	6	4	17	27	22	1								1	24	7	1			
31-35							21	58	2	5	75	31	3									14	36	7				
26-30							9	53	6	8	72	14								1	2	18	5	1				
21-25							31	52	4	21	58	1		1					13	3	22	32	3			3		
16-20							58	47	89	47	32							3	73	16	54	41				1		
10-15							52	12	145	33	1			1				15	87	35	76	21						
Total	336	73	94	28	17	12	181	291	257	126	299	190	268	74	4	0	0	19	173	55	154	127	117	54	25	12	2	1

TABLE 8. Length frequency distribution of *Orthopristis chrysoptera* taken by the three meter trawl at stations adjacent to Marco Island, Florida July 1971—January 1975.

STANDARD LENGTH (mm)	1971						1972												1973									
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O
86+			3	9									1															
81-85			1																									
76-80			1	3					1			2	3	1											1			
71-75				1							4	1	2												3			
66-70										3	14	7	1												2			
61-65				1						11	39	4	1					1					5	2	4			
56-60			1						2	15	27	8						1					5	9	5			
51-55	1		1						3	23	16	4	1										19	5	3			
46-50		1		1			3		2	57	22	4	1										20	7	1			
41-45	3						4		9	67	15	2										6	22	14	2			
36-40							17		25	51	4	3								1		6	48	7				
31-35							17		55	33	2	2										37	20	8				
26-30		2				1	13	4	42	25		1							1		3	40	13					
21-25	3	5				3	11	16	25	12	1								4	2	12	73	11					
16-20	4					4	37	58	18	17	4							7	55	38	9	120	7					
10-15	2				1	3	51	81	25	4	1							78	123	42	39	134	6					
Total	13	8	7	15	1	11	153	159	207	318	149	38	10	1	0	0	0	87	183	83	63	416	176	52	21	0	0	0

and recruitment remained consistent throughout March. Larger specimens were collected in July and lowest catches were recorded between August and November. As with *L. rhomboides,* the preference for a seagrass habitat is based on trophic requirements. Two separate feeding stages for the pigfish have been recognized by Carr and Adams (1973): a planktivorous stage for individuals 10-30 mm in length, and a carnivorous stage for larger fishes >30 mm, which feed primarily on shrimps, benthic crustaceans and polychaetes. Yokel (1974) noted a similar distribution of pigfish in Rookery Bay and the studies of Springer and Woodburn (1960) and Wang and Raney (1971) have indicated a narrow range of temperature and salinity tolerances for this species.

Additional trawl collections in our area (T5, 6, 7, 8, 9; Fig. 1) permitted further observations on the local ichthyofauna. Two vegetated, inner bay stations (T5 and T7) seemed to serve a particularly strong nursery function since fishes collected from these sites rarely exceeded 40 mm. The rainwater killifish, *Lucania parva* dominated the catches, constituting over 75% of the total. This species is considered a permanent resident of the area since relative abundance was not observed to vary throughout the year. Although *L. parva* was not collected elsewhere in our survey, it is noteworthy that the total taken at these two locations ranked this species fourth in overall abundance. They apparently display strong habitat preference, particularly for shallow, vegetated areas (Springer and Woodburn, 1960; Gunther and Hall, 1965).

The open tidal channel habitat (T8 and T9) produced the lowest yield in our trawl effort. Station T8 was characterized by low species diversity and was dominated by the silver jenny (*E. gula*) and pinfish (*L. rhomboides*) attracted from the adjacent mangroves. Station T9 produced the lowest total yield of the survey and did not reflect dominance by any particular species.

Artificial waterways of Marco Island produced an assemblage of fishes similar overall to the pattern at the shallow bay bottom at Station T3. The physical characteristics of the canals align them with Stations T8 and T9; however, lack of strong tidal currents and presence of cover along the seawalls (oyster community) permit greater utilization by smaller fishes. *E. gula, E. argenteus* and the silver perch (*Bairdiella chrysura*) dominated in our collections while both *L. rhomboides* and *O. chrysoptera* were notably absent in the canal habitat.

Kinch (personal observations) has previously noted decreases in species diversity along the major axis of canals towards their head, where dissolved oxygen levels are often lower. In addition, decreased abundance of the benthos in these areas (Table 5) may be an indication of limited forage for the bottom-feeding species which dominated the trawl catch. Reduced faunal diversity and abundance proceeding from mouth to head in artificial systems have been described in other studies (Trent et al., 1972; Lindall et al., 1973).

In order to quantify our data further, importance value curves for the fishes (Whittaker, 1972) were constructed for each of the three trawl stations. Their slopes (Fig. 8) indicate a greater degree of dominance in the grass bed habitat, as the remaining stations exhibited a more equitable distribution of species. Considerable similarity exists in the slopes of the respective curves after the fifth ranked species, indicating an even distribution among the less common forms.

Shannon-Weaver (1949) diversity values were also calculated for trawl stations where a uniform sampling effort had been applied. Maximum values were recorded at the seagrass station (T1) which produced a total of 65 species; 52 species were collected at all other habitats and a total of 36 species were taken in common at all stations. In addition, Station T1 proved to be the most productive, yielding 66.2% of the total catch.

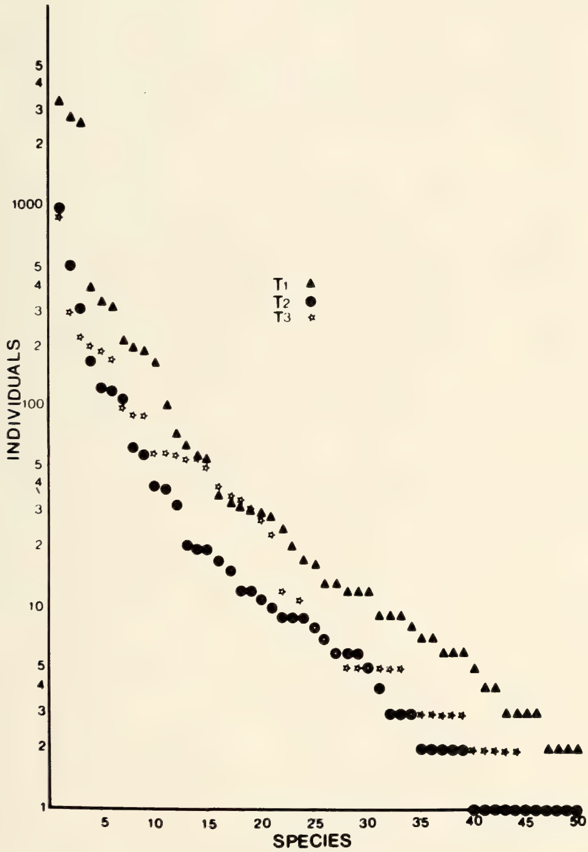


Fig. 8. Importance Value curves for fishes collected at trawl stations T1, T2, T3.

SUMMARY—The waters surrounding Marco Island may be characterized in several ways. First, seasonally hypersaline conditions predominate. Secondly, concentrations of dissolved nutrients are generally low, although recorded values do not differ significantly from other estuaries, and are of the same order of magnitude in artificial waterway as in natural systems. Thirdly, hydrological studies (Van de Kreeke, 1975) indicate a net east-to-west flow through the entire system. This flow flushes the major channels in about one week and is the major controlling influence on hydrographic parameters in the area.

Studies of the Marco biota have also resulted in several pertinent observations. Community composition of inshore macroinvertebrates includes representatives of both the Carolinian and West Indian faunal provinces, with the presence or absence of seagrasses exerting the greatest influence on the biomass of the epibenthos. Several species, particularly the decapod crustaceans and a number of fishes, exhibit clear seasonality. Within infaunal communities, maximum diversity is related to either coarse-grained substrata or the presence of seagrasses.

Several additional generalities may be drawn. A clear distinction occurred between infaunal assemblages in natural and artificial waterways with infaunal diversity decreasing toward the head waters of both systems. This latter observation, however, only applied to the troughs of the canals since the shallow sandy berms were considerably more diverse. Diversity-limiting factors probably include dissolved oxygen concentration and the sediment particle fraction less than 40 μm in diameter.

We classify the ichthyofauna of Marco Island as predominantly marine with distribution and abundance influenced primarily by the presence or absence of vegetation. Seasonal distributions of estuarine fishes are commonly related to the combined influence of salinity and temperature (Reid, 1954; Springer and Woodburn, 1960; Gunther and Hall, 1965; Wang and Raney, 1971; and Carter et al., 1974), although salinity fluctuations in the Marco area are well within the tolerance limits of the majority of dominant species. Temperature, therefore, seems to control the annual distribution of many species since the heavily vegetated, shallow stations are more susceptible to abrupt changes during the winter.

Acknowledgments—A number of associates have contributed a great deal of their time in both the data gathering and analyses used in this paper. We thank the present and past staff members of our laboratory for field and laboratory assistance. Mr. Bernard J. Yokel helped in the original selection of stations and collection methods, and continued to assist in specimen identification through the facilities of the Rosenstiel School of Marine and Atmospheric Studies (RSMAS). Other RSMAS faculty members who assisted by making the results of their research available to us include Dr. James Carpenter, Dr. J. Van de Kreeke and Dr. Harold Wanless. Dr. Kenneth Heck, Jr. of the Philadelphia Academy of Sciences programmed the infaunal data used in the classification analysis.

LITERATURE CITED

Editor's Note: All unpublished reports for the Deltona Corporation have been provided to the Florida Academy of Sciences where they are available for F.A.S. member consultation or copying for *bona fide* scientific research on a cost basis upon request. We invite other Florida organizations to deposit such reports with the Academy.

Andrews, J. 1971. Sea shells of the Texas coast. The Elma Dill Russell Spencer Foundation Ser. 5:17. (Univ. Texas Press. Austin)

APHA, 1971. Standard methods for the examination of water and wastewater. 13th ed. Amer. Publ. Health Assoc. Washington D.C.

Appleby, B. J. 1974. Unpublished report (no title) to the Deltona Corp. Miami, Florida.

Bader, R. G. 1954. The role of organic matter in determining the distribution of pelecypods in marine sediments. J. Mar. Res. 13:32-47.

_________, AND M. A. ROESSLER (eds.). 1971. An ecological study of South Biscayne Bay and Card Sound, Florida. Rosenstiel School of Marine and Atmospheric Science, Rept. to U.S. Atomic Energy Comm. (At-(40-1)-3801-3) 378 p. + 201 Appendix p. (mimeographed).

BECHTEL, T. J., AND B. J. COPELAND. 1970. Fish species diversity indices as indicators of pollution in Galveston Bay, Texas. Contrib. Mar. Sci. 15:103-132.

BLOOM, S. A., J. L. SIMON AND V. D. HUNTER. 1972. Animal-sediment relations and community analysis of a Florida estuary. Mar. Biol. 13:44-55.

BRIGGS, J. C. 1974. Marine Zoogeography. McGraw-Hill Book Co. New York.

CARPENTER, J. H. 1973. Progress report. Chemical observations of waters in the Marco Island and Naples areas. Unpublished report to the Deltona Corp. Miami, Florida. 40p. (mimeographed)

CARR, W. E., AND C. A. ADAMS. 1972. Food habits of juvenile marine fishes: evidence of the cleaning habit in the leatherjacket, *Oligoplites saurus*, and the spottail pinfish, *Diplodus holbrooki*. Fish. Bull. 70:1111-1120.

CARRIKER, M. R. 1967. Ecology of estuarine benthic invertebrates: a perspective. p. 442-487. *In* G. H. LAUFF (ed.). Estuaries. Amer. Assoc. Adv. Sci. Publ. 83. Washington D.C.

CARTER, M. R., ET AL. 1973. Ecosystems analysis of the Big Cypress Swamp and estuaries. p. V-7. *In* South Florida Ecological Study. U.S.E.P.A. Region IV, Surveillance and Analysis Div. Athens, Ga. 327 p. + Appendix p.

CLIFFORD, H. T., AND W. STEPHENSON. 1975. An Introduction to Numerical Classification. Academic Press. New York.

COLLARD, S. B., AND C. N. D'ASARO. 1973. Benthic invertebrates of the eastern Gulf of Mexico. p. III-G-1 - III-G-28. *In* J. D. JONES ET AL. (eds.). A Summary of Knowledge of the Eastern Gulf of Mexico. State Univ. Syst. Florida Inst. Oceanogr. St. Petersburg, Florida.

COOK, D. G., AND R. D. BRINKHURST. 1973. Marine flora and fauna of the northeastern United States. Annelida: Oligochaeta. NOAA Tech. Rept. NMFS Circ. 374:1-23.

COPELAND, B. J., AND T. J. BECHTEL. 1971. Species diversity and water quality in Galveston Bay, Texas. Water, Air Soil Pollut. 1:89-105.

ELDRED, B., R. M. INGLE, K. D. WOODBURN, R. F. HUTTON, AND H. JONES. 1961. Biological observations on the commercial shrimp, *Penaeus duorarum* Burkenroad, in Florida waters. Florida Bd. Conserv. Prof. Pap. Ser. 3:1-139.

ENVIRONMENTAL PROTECTION AGENCY. 1971. Methods for Chemical Analysis of Water and Wastes. National Environ. Res. Center, Analytical Qual. Control Lab. Cincinnati, Ohio.

FRASER, T. H. 1967. Contributions to the biology of *Tagelus divisus* (Tellinacea: Pelecypoda) in Biscayne Bay, Florida. Bull. Mar. Sci. 17:111-132.

GOODMAN, D. 1975. The theory of diversity-stability relationships in ecology. Quart. Rev. Biol. 50:237-266.

GUNTHER, G., AND G. E. HALL. 1965. A biological investigation of the Caloosahatchee estuary of Florida. Gulf Res. Rept. 2:1-72.

HANSEN, D. J. 1969. Food, growth, migration, reproduction and abundance of pinfish, *Lagodon rhomboides*, and Atlantic croaker, *Micropogon undulatus*, near Pensacola, Florida, 1963-65. Fish. Bull. 68:135-146.

HEALD, E. J. 1975. A review of Florida mangrove communities. Unpublished report to the Deltona Corp. Miami, Florida. 164p.

HEDGEPETH, J. W. (ed.). 1957. Treatise on Marine Ecology and Paleoecology. Vol. 1. Ecology. Geol. Soc. Amer. Mem. 67:1296p.

HUMM, H. J. 1973. Seagrasses. p. IIIC-1 - IIIC-10. *In* J. I. JONES ET AL. (eds.). A summary of knowledge of the eastern Gulf of Mexico. State Univ. Syst. Florida Inst. Oceanogr. St. Petersburg, Florida.

HURLBURT, S. H. 1971. The non-concept of species diversity: A critique and alternative parameters. Ecology 52:577-586.

JACCARD, P. 1908. Nouvelles recherches sur la distribution florale. Bull. Soc. Vaud. Sci. Nat. 44:223-270.

LINDALL, W. N., J. R. HALL, AND C. H. SALOMAN. 1973. Fishes, macroinvertebrates and hydrological conditions of upland canals in Tampa Bay, Florida. Fish. Bull. 71:155-163.

LIVINGSTON, R. J. 1975. Input of kraft pulp mill effluents on estuarine and coastal fishes in Apalachee Bay, Florida, USA. Mar. Biol. 32:19-48.

LIVINGSTON, R. J., R. L. IVERSON, R. H. ESTABROOK, V. E. KEYS, AND J. TAYLOR, JR. 1974. Major features of Apalachicola Bay system: physiography, biota and resource management. Florida Sci. 37:245-270.

McNulty, J. K., J. Kneeland, W. N. Lindall, and J. E. Sykes. 1972. Cooperative Gulf of Mexico estuarine inventory and study, Florida: Phase I area description. NOAA Tech. Rept. NMFS Circ. 368:48-52.

Moe, M. A. 1972. Movement and migration of south Florida fishes. Florida Dept. Nat. Res. Mar. Res. Lab. Tech. Ser. 69:1-25.

Odum, W. E. 1971. Pathways of energy flow in a south Florida estuary. Univ. Miami Sea Grant Tech. Bull. 7:1-162.

Parker, R. H. 1975. The Study of Benthic Communities. A Model and a Review. Elsevier Scientific Publishing Co. New York.

Perry, L. M., and J. S. Schwengel. 1955. Marine Shells of the Western Coast of Florida. Paleont. Res. Instit. Ithaca, N.Y.

Reid, G. K., Jr. 1954. An ecological study of the Gulf of Mexico fishes in the vicinity of Cedar Key, Florida. Bull. Mar. Sci. Gulf. Carib. 4:1-94.

Roessler, M. A., and G. L. Beardsley. 1974. Biscayne Bay: Its environment and problems. Florida Sci. 37:186-204.

Shannon, C. E., and W. Weaver. 1949. The Mathematical Theory of Communication. Univ. Illinois Press. Urbana.

Sneath, P. H. A., and R. S. Sokal. 1973. Numerical Taxonomy. W. H. Freeman Co. San Francisco.

Solorzano, L. 1969. Determination of ammonia in natural waters by the phenolhypochlorite method. Limnol. Oceanogr. 14:799-801.

Springer, V. G., and K. D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Florida Bd. Conserv. Prof. Pap. Ser. 1:1-104.

Strickland, J. D. H., and T. R. Parsons. 1972. A practical handbook of seawater analysis. Fish. Res. Bd. Canada Bull. 167:1-310.

Sykes, J. E., and J. R. Hall. 1970. Comparative distribution of mollusks in dredged and undredged portions of an estuary, with a systematic list of species. Fish. Bull. 68:299-306.

Tabb, D. C., D. Dubrow, and R. Manning. 1962. Ecology of northern Florida Bay and adjacent estuaries. Florida Bd. Conserv. Tech. Serv. 39:1-79.

Taylor, J. L. 1974. The Charlotte Harbor estuarine system. Florida Sci. 37:205-216.

__________, J. R. Hall, and C. H. Saloman. 1970. Mollusks and benthic environments in Hillsborough Bay, Florida. Fish. Bull. 68:191-202.

Thorson, G. 1956. Marine level-bottom communities of recent seas, their temperature adaptation and their "balance" between predators and food animals. Trans. N.Y. Acad. Sci., Sect. 2, 18:693-700.

Trent, W. L., E. J. Pullen, and D. Moore. 1972. Waterfront housing developments: their effect on the ecology of a Texas estuarine area. Nat. Mar. Fish. Ser. Biol. Lab, Galveston, Contrib. 311:1-6.

Van de Kreeke, J. 1972. A hydrographic study of the Barfield Bay—Blue Hill Bay—Big Key area. Unpublished report to the Deltona Corp. Miami, Florida.

__________. 1975. Mass transport and mean water level. Proc. 3rd Conf. Civil Engineering in the Oceans. Amer. Soc. Civil Eng. New York, N.Y.

__________, and M. Roessler. 1975. A statistical comparison of daily oxygen minima in artificial and natural waterways, Marco Island, Florida. Unpublished report to the Deltona Corp., Miami, Florida.

Wang, J. C. S., and E. C. Raney. 1971. Distribution and fluctuations in the fish fauna of the Charlotte Harbor estuary, Florida. Charlotte Harbor Estuarine Studies. Mote Marine Lab. Sarasota, Florida.

Wanless, H. R. 1974. Sediments in natural and artificial waterways, Marco Island area, Fla. Unpubl. report to the Deltona Corp., Miami, Florida.

Whittaker, R. H. 1972. Evolution and the measurement of species diversity. Taxon 21:213-251.

Williams, A. B. 1965. Marine decapod crustaceans of the Carolinas. Fish. Bull. 65:1-298.

Yokel, B. J. 1974. Annual abundance and distribution from various habitats in the Rookery Bay Sanctuary. Study 5. Conserv. Foundation. Washington, D.C.

__________. 1975. A comparison of animal abundance and distribution in similar habitats in Rookery Bay, Marco Island, and Fahkahatchee on the southwest coast of Florida. Preliminary Rept. from Rosenstiel School of Mar. and Atmos. Sci. to the Deltona Corp. Miami, Florida.

Florida Sci. 40(2):97-124. 1977.

Biological Sciences

SPAWNING OF YEAR CLASS ZERO LARGEMOUTH BASS IN HATCHERY PONDS[1]

Joe E. Crumpton, Stephen L. Smith and Edwin J. Moyer[2]

Florida Game and Fresh Water Fish Commission Laboratory,
Post Office Box 1903, Eustis, Florida 32726

Abstract: *Largemouth bass fry hatched in mid-February 1974 were stocked into 7 central Florida hatchery ponds. At 9 and 10 mo bass were observed sweeping nests in 6 of 7 ponds. At 11 mo nests building and spawning activity was observed in all ponds. Bass in a single pond were allowed to remain 12 mo, at which time three distinct size classes of fry were collected. At drawdown 87% of the fish dissected were in, or had passed, reproductive condition. Lengths of males with mature gonads ranged from 120 mm to 320 mm and females from 122 mm to 352 mm.*[a]

Factors affecting sexual maturity in the largemouth bass, *Micropterus salmoides,* have been a source of disagreement for many years. Most biologists tend to agree that sexual maturity is based on an age and size relationship. Size especially tends to be a "bone of contention." Wilbur (1968) indicated that sexual maturity for other centrarchids such as redear, *Lepomis microlophus,* was dependent on size rather than age. Smith (1971) believed it to be an age-size relationship. Dineen (1968) believed maturity to be size oriented and reported one year old bass averaging 303 mm spawning in a south Florida rock pit. Swingle and Smith (1950) observed bass spawning at 10 to 12 mo, but not under 156 gm. Chew (1974) stated that female largemouth bass less than 275 mm long did not reach sexual maturity until age 2, while males generally spawned at an earlier age and smaller size. Bennett (1948) and Moorman (1957) reported maturity at 225 mm and 2 yr of age for northern largemouth.

Materials and Methods—Bass fry used in the experiment were derived artificially from selected parents which had been injected with Human Chorionic Gonadotropin (HCG) to stimulate gonadal crudescense. Fry were held in aerated hatching pans until reaching the "swim-up" stage and 75 of the surviving fry from each pan were stocked into 0.04 hectare (0.1 acre) fertilized ponds. As the bass reached 50 to 75 mm, each pond was stocked with forage.

Growth and reproductive characteristics were observed bi-weekly. Upon drawdown fish were checked for growth and reproductive condition. Measurements for total length were affected on a millimeter measuring board and for weight on a balance beam gram scale. Reproductive condition was visually observed for each fish by hand squeezing, tubing and dissection.

---

[a]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

[1]Contribution from Federal Aid in Restoration Funds under Dingell-Johnson Project F-24, State of Florida. Publication Number 22, Fisheries Research Laboratory.

[2]Present address: Florida Game & Fresh Water Fish Comm., Rt. 7, Box 102, Lake City, Florida 32055.

RESULTS—In mid-February 1974, 5 da old largemouth bass fry were stocked into hatchery ponds. Bi-weekly observations revealed that by age 1 mo, fry had attained estimated lengths of 50 to 75 mm and were feeding on existing forage species (mollies and mosquito fish).

A sub-sample of 15 bass (age 6 mo) was taken from the ponds by hook and line in mid-July 1974. The mean total length of the fish was 148 mm.

Nesting activities were observed in late November and December 1974 in six of seven ponds. During December bass on three nests appeared to be guarding eggs, but no eggs were found. Nest building and nesting activity was again observed in mid and late January 1975 in all seven ponds.

Six of the seven ponds were drawn down in mid-January 1975. The remaining pond was left in order to confirm spawning success. Measurements for growth and reproductive condition were recorded for each fish. Mean growth and reproductive condition are compared in Table 1. Of the 187 surviving bass, 88 males and 99 females were in a "squeeze ripe" condition. Nineteen of the squeeze ripe bass were less than 150 mm long (examples of squeeze ripe bass are indicated in Fig. 1 and 2). The smallest male in reproductive condition was 120 mm and weighed 152 gm and the smallest female was 126 mm and weighed 137 gm.

On January 20, 1975, two schools of fry were observed in Pond 7, and a sample of each school (dip net) revealed them to be largemouth bass. On Febru-

TABLE 1. Growth comparisons and reproductive condition for largemouth bass in seven hatchery ponds.

Pond	Sex	No.	Total Length (mm) Range	Mean	% Ripe	Weight (gm) Range	Mean	Age of Fish
1	M	15	220-286	246	87	116-272	175	11 mo
	F	15	227-277	240	80	122-282	173	
2	M	23	131-270	225	96	140-247	167	11 mo
	F	31	122-268	227	77	123-327	159	
3	M	15	273-320	289	87	255-512	339	11 mo
	F	11	277-313	297	91	287-475	380	
4	M	3	307-320	314	100	507-542	529	11 mo
	F	9	275-352	327	56	433-802	616	
5	M	7	275-308	296	100	317-412	370	11 mo
	F	7	293-320	309	100	348-530	451	
6	M	25	120-271	201	100	104-232	155	11 mo
	F	26	126-317	213	77	70-363	159	
Subtotal		187			87			
7	M	28	170-248	213	100	53-193	136	12 mo
	F	37	196-259	218	73	95-237	139	
Subtotal		65			97			
Total		252						

ary 5, 1975, six separate schools of bass fry were observed around the pond's perimeter. Upon drawdown in early February 1975, three size classes of fry were collected and 21 nests were counted over the pond bottom, two still containing eggs, and one with fry. Figures 3 and 4 are examples of nests found over the pond bottom.

Growth and reproductive condition for bass in Pond 7 is indicated at the bottom of Table 1. Of the 65 surviving bass, 28 males and 35 females were in a

Fig. 1. (upper) Developing females from spawning ponds.

Fig. 2. (lower) Developing female which had spawned one; the vent is distended and the tail area is in the process of healing; the egg sac is convoluted and the membrane tough.

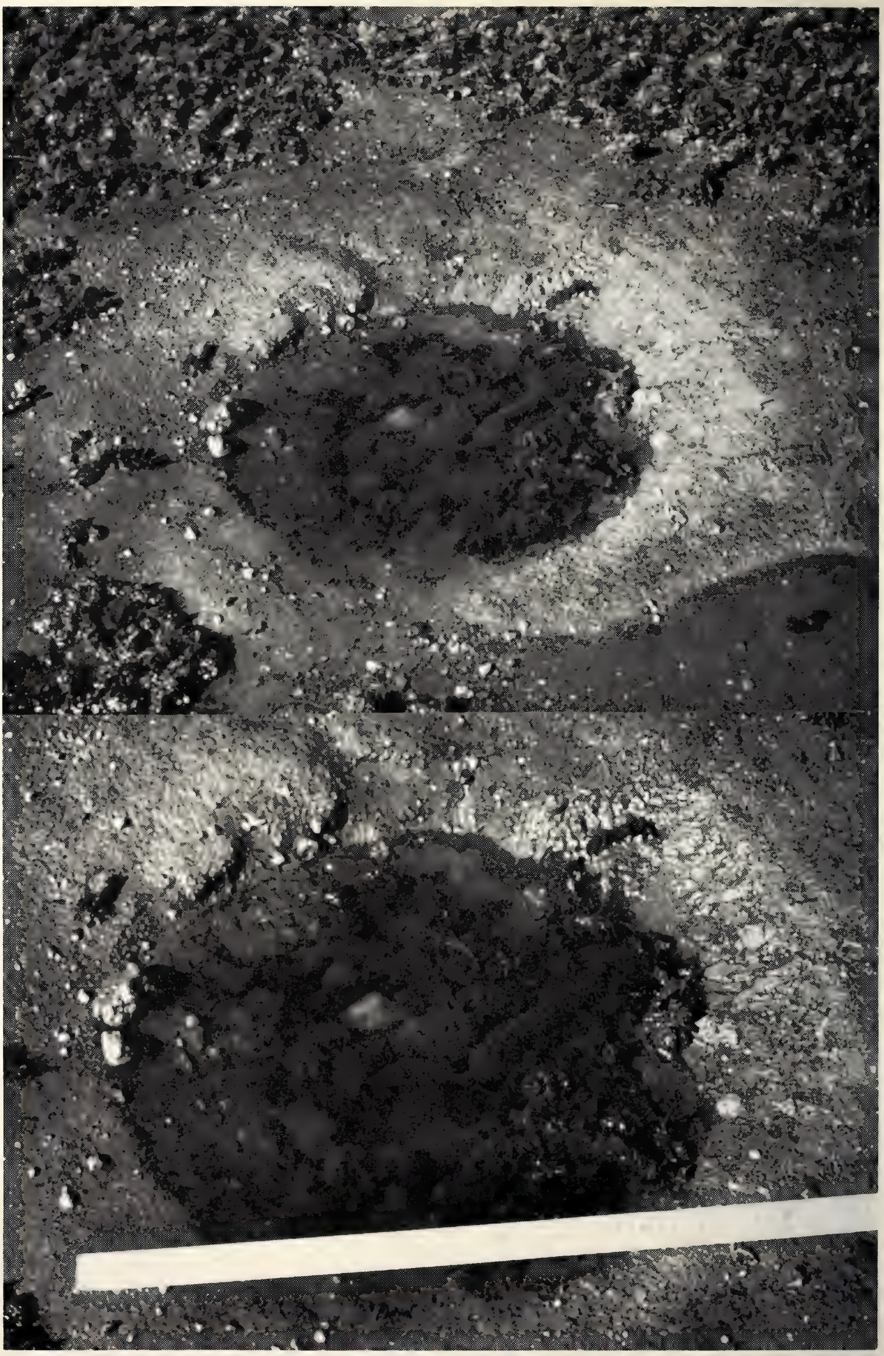


Fig. 3. (upper) Swept spawning bed after drawdown.
Fig. 4. (lower) Closeup of the bed showing eggs attached to the vegetation on the lower right side.

"squeeze ripe" condition or had already spawned. Dissection later revealed that seven of those females were in a "spent" condition. The smallest male in reproductive condition was 170 mm and weighed 56 gm, and the smallest female was 196 mm and weighed 103 gm. The smallest female in a "spent" condition was 203 mm and weighed 122 gm.

Discussion—Literature reviewed indicated that in rare cases largemouth bass spawned at 11 or 12 mo, but for the most part indicated spawning at age 2 yr. Nesting activities were first observed in hatchery ponds when bass were 9 mo old and again at 10 and 11 mo. Six of seven study ponds were drained when the bass were 11 mo old, and 87% were squeeze ripe. Earlier studies indicated that largemouth bass usually spawned only after attaining lengths of 225 to 305 mm. Twelve percent of the bass observed in spawning condition were under 150 mm long, the smallest male being 120 mm and the smallest female 126 mm.

Bass in one of the seven ponds (no. 7) were allowed to complete the spawning cycle. The number of size classes of fry recovered (3) and the number of nests (21) indicated several bass had spawned at least once. Upon drawdown these fish were approximately 1 mo older than the fish first evaluated, however, the avg total length for the population was nearly the same (226 mm) as ponds with similar survival rates. Ninety-seven percent of these bass were squeeze ripe or had already spawned. The smallest male was 170 mm long and the smallest female 196 mm. Other studies have indicated that largemouth bass never spawned smaller than 156 gm (Swingle and Smith, 1950). The smallest male and female in reproductive condition weighed 56 gm and 102 gm, respectively, and the smallest female in a "spent" condition weighed 122 gm.

There is little doubt that maturation of largemouth bass is size-weight oriented, but the importance of these factors in natural populations, in many cases, may not be the limiting factors that many believe them to be. Other factors such as population structure, competition for spawning sites, and presence of older experienced individuals may be more important than size or age in determining reproductive maturity.

LITERATURE CITED

Bennett, G. W. 1948. The bass-bluegill combination in a small, artificial lake. Bull. Illinois Nat. Hist. Surv. 24:377-412.

Chew, R. L. 1974. Early life history of the Florida largemouth bass. Florida Game & Fresh Water Fish Comm., Bull. 7:76 pp.

Dineen, J. W. 1968. Completion Report for F-16-R, Investigation Project. Segment job completion reports 1-B, 1-C and 1-E. Florida Game & Fresh Water Fish Comm. Eustis, Florida.

Moorman, R. B. 1957. Reproduction and growth of fishes in Marion County, Iowa farm ponds. Iowa St. Coll. J. Sci. 32:71-83.

Smith, W. B. 1971. The biology of the Roanoke bass, *Ambloplites cauifrons* Cope, in North Carolina. Proc. 25th Ann. Conf. S.E. Assoc. Game & Fish Comm. pp. 10-20.

Swingle, H. S., and E. V. Smith. 1950. Factors affecting the reproduction of bluegill, bream and largemouth bass in ponds. Agr. Exp. St. Alabama Polytechnic Inst. Circ. 87:8 pp.

Wilbur, R. L. 1968. Annual Progress Report (1967-68) for F-26-R. Florida Game & Fresh Water Fish Comm. Eustis, Florida. 108 pp.

Florida Sci. 40(2):125-129. 1977.

Conservation

A FRESH WATER WASTE RECYCLING-AQUACULTURE SYSTEM

J. H. Ryther, L. D. Williams, and D. C. Kneale

Harbor Branch Foundation, Inc., P. O. Box 196, RFD No. 1, Ft. Pierce, Florida 33450

Abstract: *A system is described in which the nutrients in treated wastewater are removed by passing the effluent through a culture of aquatic weeds. The incremental growth of the weeds is fed to a culture of grass carp and fresh water shrimp* (Macrobrachium). *Projections are made for large-scale nutrient removal efficiencies and the accompanying aquaculture yields in the commercial application of such a system.**

Eutrophication is one of Florida's most pressing environmental problems. Its fresh water lakes, rivers, and canals are being enriched from domestic, agricultural, livestock, food processing, and other kinds of organic wastes. Such waters often become choked with vegetation which makes them unsightly, impassible, and almost useless or valueless for commercial or recreational purposes. The pattern can be reversed only by the removal of plant nutrients (nitrogen, phosphorus) from these wastewaters prior to their discharge or drainage into natural receiving waters. The existing physical and/or chemical methods of nitrogen and phosphorus removal are costly, both in terms of monetary considerations and energy demand. They often are not very effective (Antonucci and Schaunburg, 1975). Biological nutrient removal systems, although not well developed, give promise not only of being more economical to operate but of producing potential valuable crops of plants or animals as a by-product (Ryther et al., 1972). A waste recycling-marine aquaculture system has been developed, tested, and evaluated on a pilot scale by the senior author at Woods Hole, Mass. (Ryther, 1977). The principles of that system would appear to be applicable to fresh water environments, where the need for a satisfactory solution is more critical than in the marine environment.

A joint project was initiated in 1975 with the Florida Game and Fresh Water Fish Commission to develop a fresh water waste recycling-aquaculture system at the Harbor Branch Foundation aquaculture facility. The plan was to pass secondary sewage effluent through ponds containing macroscopic fresh water algae or higher plants (i.e., "aquatic weeds") at concentrations and rates that would enable the vegetation to remove the inorganic nutrients from the effluent. The effluent could then be discharged to the receiving waters and not cause eutrophication.

Nutrient removal by the aquatic vegetation is not, however, the complete answer, since it would not differ from the eutrophication of natural waters. The new growth of the aquatic plants must be removed. One possibility is to use an aquaculture system, feeding the plants to an appropriate aquatic herbivore.

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

The grass carp or white amur (*Ctenopharyngodon idella*) feeds upon macroscopic aquatic vegetation. An exotic species, its general introduction into Florida is restricted. Any research with grass carp in the State must be performed under the supervision of the Florida Game and Fresh Water Fish Commission. The grass carp is a voracious feeder upon a wide variety of aquatic plants (Michewica, Sutton, and Blackburn, 1972). When it was introduced in reservoirs and impoundments in Arkansas, it was highly efficient in removing and controlling vegetation (Bailey, 1975). It should therefore be suited for a fresh water waste-recycling-aquaculture system as proposed above. One disadvantage is that it does not now have market value as human food in the United States and might be useful only as a source of fish meal. It could be argued that its role in a waste recycling system to prevent or reverse eutrophication of Florida's waters is important enough that additional value of the product of the system is inconsequential or simply a bonus. However, in view of the rising price of fish meal, its value for that purpose could also be significant. Also, the species may not always be unpopular as a food fish.

The experiments were performed in two 11 × 4 × 0.6 m (25,000 l) PVC-lined earthen ponds, which were filled with fresh (well) water. One pond was inoculated with the fresh water macroscopic alga *Chara* sp. Undiluted secondary effluent from the Harbor Branch Foundation's activated sludge waste treatment plant was passed through the pond at a rate of 500 l/day, providing a turnover rate of 2% of the pond vol per da.

The experiment was initiated on March 3, 1975 and was terminated on August 29, 1975. During that period, the concentrations of nitrogen, measured as ammonium, nitrite, and nitrate, and of phosphate-phosphorus were measured in the pond influent (i.e., the secondary sewage effluent from the treatment plant) and in the pond effluent. Ammonia was measured by the method of Solorzano (1969), nitrite and nitrate by the method of Wood et al. (1967), and phosphate by the method of Murphy and Riley (1962).

The mean concentrations of total inorganic nitrogen (ammonia, nitrite, and nitrate) and phosphorus entering the pond were 2889 μmoles/l (40 ppm) and 187 μmoles/l (6.2 ppm) respectively. The mean concentrations of these nutrients in the water leaving the pond were 498 μmoles N/l (6.9 ppm) and 25 μmoles P/l (0.8 ppm) giving an efficiency of nitrogen and phosphorus removal of 83 and 87% respectively (Table 1). The ratio, by atoms, of nitrogen to phosphorus in the wastewater entering the pond was 15:1, very close to that present in most algae, which accounts for the similarity in the removal efficiency of both nitrogen and phosphorus. In purely domestic sewage effluent (in contrast to that of the laboratory complex at Harbor Branch Foundation), the N:P ratio is typically 5-7:1 by atoms due to the phosphorus contributed by household detergents (Ferguson, 1968). Aquatic plants can remove the nitrogen from domestic sewage effluent but they will leave one-third to one-half of the phosphorus. Since nitrogen is limiting, the lack of N is an effective deterrent to further plant growth in the environment (Ryther and Dunstan, 1971, Goldman et al., 1974).

Based on the results of the preliminary experiment described above, an area

TABLE 1. Nutrient removal efficiency in *Chara* pond.

	$NH_4^+ + NO_2^- - NO_3^- - N$ (μmoles/liter)	$PO_4^{\equiv}-P$
Influent	2889	187
Effluent	498	25
% removal	83	87

of 60 acres of *Chara* pond culture would be needed to perform tertiary sewage treatment (nutrient removal) at the efficiencies observed (83-89%) on a wastewater loading of one million gallons per da (1 MGD), the avg output of a community of 10,000 people. It is, however, unrealistic to extrapolate the results of one small preliminary experiment to fullscale operation. Choice of the pond size, sewage flow rates, and other operating parameters was purely empirical and did not necessarily reflect the optimal performance efficiencies.

In an adjacent pond of the same size and construction as the *Chara* pond, 28 juvenile (20 g) grass carp (Fig. 1) were stocked on April 8, 1975. These fish were fed the harvest (growth) of the *Chara* at a rate of 1-2 kg *Chara* per da. One of the difficulties encountered in the experiment was that the *Chara* could not be routinely removed from the pond and weighed. Handling apparently damages the fragile alga and seriously depresses its growth for a period of one or more wk. Thus, growth of *Chara* and removal of incremental growth for feeding to the grass carp had to be estimated.

During a period of 161 da (4/8-9/3), the grass carp were fed 170 kg of *Chara* and increased in size from 21 to 180 gm/fish, a total biomass increase of 4.5 kg, a conversion efficiency of only 2.6%. The latter is not impressive since efficiencies of 10-20% (wet wt food:wet wt fish) are not uncommon in fish culture, but it may not be unusual in a voracious herbivore such as grass carp that consumes vast quantities of vegetation. A large fraction of the food eaten is rejected as undigested organic wastes (Stanley, 1974). This phenomenon is, in fact, the basis for the highly successful polyculture practice in mainland China, in which organic wastes from the grass carp serve, directly or indirectly, as food for several other fish species grown together in the same pond (Bardach, Ryther, and McLarney, 1972).

In cognizance of the potential food value of the wastes from the inefficient grass carp, approximately 75 juvenile fresh water shrimp (*Macrobrachium rosenbergi*) were stocked in the grass carp pond on April 23, 1975. In the ensuing 146 days (4/23-9/15) these crustacea grew from 1.7 gm to 19.7 gm/shrimp. At the end of the test period 66 individuals were recovered for a survival of 88% and a biomass increase of 1.2 kg. By that time, the shrimp had reached adult, marketable, size and sexual maturity, gravid females being noted in the population.

The combined yield of 5.0 kg of grass carp and 1.3 kg of *Macrobrachium* per 33 m² pond is equivalent to a production of 1,700 lbs/acre for 6 mo or 1.7 tons/

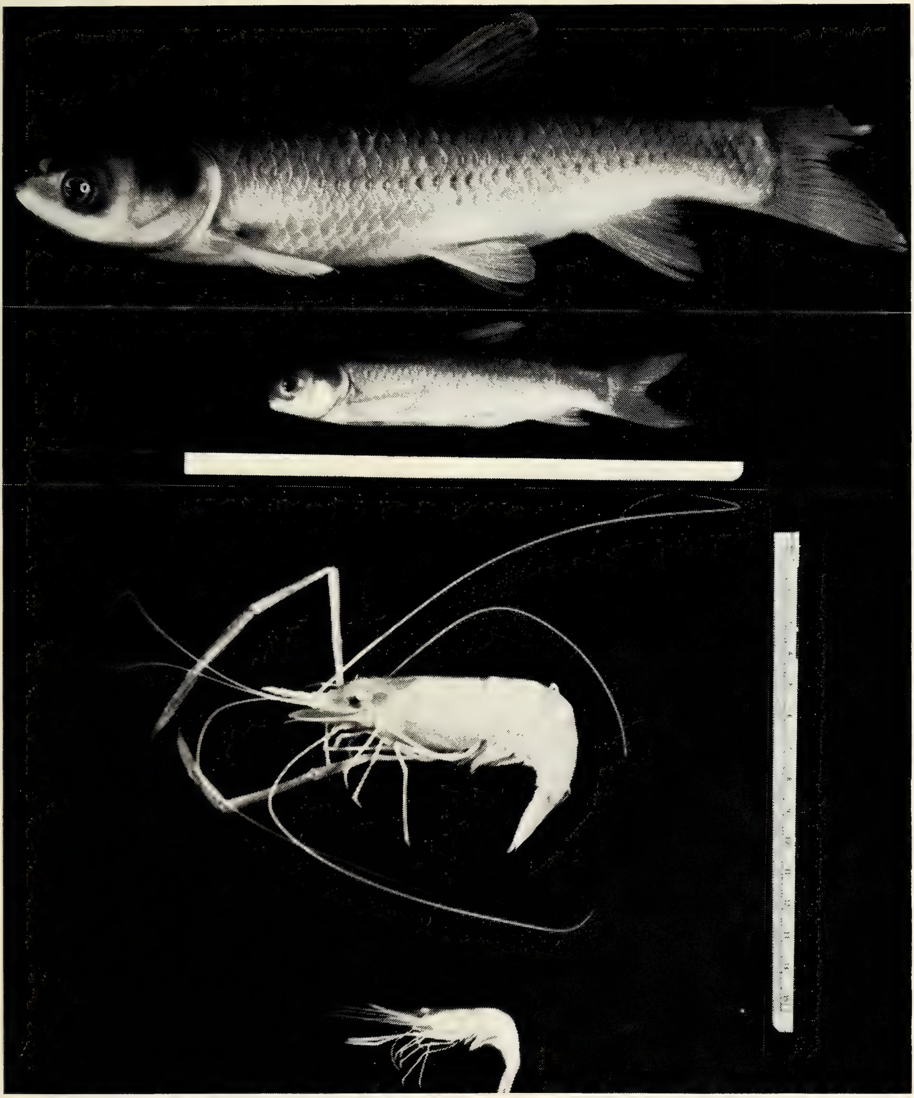


Fig. 1. Growth of grass carp (*Ctenopharyngodon idella*) in 161 days and freshwater shrimp (*Macrobrachium rosenbergi*) in 146 days in pond fed *Chara* harvest.

acre/yr (assuming year-round production at essentially the same rate), an extremely high yield for an aquaculture system based on natural food. More properly, however, the area required for the food production (the *Chara* pond) should also be included, making the production equivalent to 1,700 lbs/acre/yr, which is still an impressive figure.

Problems encountered with the fresh water system include the difficulty in maintaining and handling the alga *Chara* without retarding its growth. The plant has a natural tendency to fragment into small pieces that do not survive or grow in the culture. Since the grass carp apparently feed and grow equally well on a wide variety of plant species it is probable that one or more other species of algae or higher plants would be more successful in the culture system. A new experiment has recently been initiated using the common water weed *Egeria (Elodea) densa,* a plant which appears to be somewhat more hardy and more easily handled than *Chara* and is equally well accepted by the grass carp (Stanley, 1974a, b).

Another problem in our experiment was the development of dense phytoplankton blooms in the *Chara* culture. Discharge of effluent from the pond containing a dense population of phytoplankton would violate suspended solid standards and defeat the objectives of tertiary treatment, as mentioned above. In addition, the phytoplankton shaded and may have reduced the growth of the *Chara.* In the current experiment involving *Egeria,* this problem has been corrected by diluting the sewage effluent 50:1 with well water so as to provide a pond turnover rate of 1 vol per da, a rate of exchange too rapid to permit the establishment of a phytoplankton bloom. How this increased dilution and turnover rate will affect the efficiency of nutrient removal and the economics of the operation remain to be demonstrated.

Another approach to the same problem, not yet investigated, is the use of a filter-feeding herbivore in the plant culture to suppress the growth of phytoplankton. Possible candidates for this role are fresh water clams or mussels, the water flea (*Daphnia*) or other microcrustacea, or a phytoplankton-feeding species of finfish such as the silver carp (*Hypophthalmichthys molitrix*). Introduction of the latter, an exotic species, into Florida would present a problem.

The grass carp-*Macrobrachium* pond did not have any exchange of water during the 6-mo experiment. Aeration was provided to insure an adequate supply of dissolved oxygen, and nutrients were monitored to make sure that dangerous levels of ammonia did not accumulate. Surprisingly, the nutrient concentration did not increase in the pond for reasons that are not understood. However, a dense load of light brown particulate matter did accumulate in suspension in the pond. The origin and nature of the suspended matter, presumably related in some way to the excreted or defecated wastes of the animals, is now being investigated.

Harbor Branch Foundation, Inc. Contribution no. 65.

LITERATURE CITED

Antonucci, D. C., and F. D. Schaunburg. 1975. Environmental effects of advanced wastewater treatment at South Lake Tahoe. J. Water Poll. Cont. Fed. 47:2694-2701.

Bailey, W. M. 1975. Operational experience with the white amur in weed control programs. Proc. Symp. Water Quality Management Through Biological Control, Gainesville, Florida, January 29-31, 1975. U. Florida Dept. Eng. Sci. Rept. No. Env. 07-75-1:75-84.

Bardach, J. E., J. H. Ryther, and W. O. McLarney. 1972. Aquaculture. Wiley-Intersci. Publ. New York.

Ferguson, F. A. 1968. A nonmyopic approach to the problem of excess algal growths. Environ. Sci. Technol. 2:188-193.

Goldman, J. C., K. R. Tenore, and H. I. Stanley. 1974. Inorganic nitrogen removal in a combined tertiary treatment-marine aquaculture system. II. Algal bioassays. Water Res. 8:55-59.

Michewica, J. E., D. L. Sutton, and R. D. Blackburn. 1972. The white amur for aquatic weed control. Weed Sci. 20:106-110.

Murphy, J., and J. P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta 26:31-36.

Ryther, J. H. 1977. Preliminary results with a pilot-plant waste recycling-marine aquaculture system. Pp. 89-132. *In* D'Itri, Ed. Wastewater Renovation and Reuse. Marcel Dekker, Inc. New York.

———, and W. M. Dunstan. 1971. Nitrogen, phosphorus, and eutrophication in the coastal marine environment. Sci. 171:1008-1013.

———, ———, K. R. Tenore, and J. E. Huguenin. 1972. Controlled eutrophication. Increasing food production from the sea by recycling human wastes. BioScience 22:144-152.

Solorzano, L. 1969. Determination of ammonia in natural waters by the phenolhypochlorite method. Limnol. Oceanogr. 14:799-801.

Stanley, J. G. 1974a. Energy balance of white amur fed *Egeria*. Hyacinth Contr. J. 12:62-66.

———. 1974b. Nitrogen and phosphorus balance of grass carp, *Ctenopharyngodon idella* fed *Elodea, Egeria densa*. Trans. Amer. Fish. Soc. 103:587-592.

Wood, E. D., F. A. J. Armstrong, and F. A. Richards. 1967. Determination of nitrate in seawater by cadmium-copper reduction to nitrite. J. Mar. Biol. Assn. U.K. 47:23-31.

Florida Sci. 40(2):130-135. 1977.

Earth Science

THE NUMBER OF LIVING ANIMAL SPECIES LIKELY TO BE FOSSILIZED

David Nicol

Department of Geology, University of Florida, Gainesville, Florida 32611

Abstract: *Of the more than 1.2 million living animal species, only about 100,000, or 8%, are likely to be preserved as fossils.**

A careful estimate of the number of living animal species will provide a basis to estimate the number of species that will likely be fossilized. A study of this sort was made by Teichert (1956), but his estimate of the number of living animal species that are likely to be fossilized seemed too high. He assumed that all living species of vertebrates could appear in the fossil record, but one has only to look at the fossil record of the fish and birds to see that this is a fallacy. Likewise, he considered all species of Sarcodina to be capable of fossilization.

Raup and Stanley (1971) introduce the topic of fossilization in the first chapter of their book with these statements: "The fossil record—far from being complete—represents only a small sample of past life. Furthermore, this is not a random sample but is highly distorted and biased by a variety of biologic and geologic factors."

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

"Not all plants and animals have an equal chance of being preserved as fossils, and not all geological environments are equally favorable for preservation."

On page 6 Raup and Stanley make this further statement: "If overall preservation of fossils were even reasonably good, we would expect the number of fossil species to outnumber by far the number of living species."

I have used Blackwelder's (1963) *Classification of the Animal Kingdom* as my basis for the animal phyla, both extant and extinct. Some conservative taxonomists would lump several of the phyla in Blackwelder's classification, but any classification at this high level is somewhat arbitrary, and Blackwelder's work is particularly useful because he lists the synonyms of the phyla that have them. I have also followed his spellings of the names of the phyla.

Estimates of the number of species in the animal phyla and other animal groups are given in many biology and paleontology books. The main sources I have used are: Hyman (1940, 1951a, 1951b, 1955, 1959); Barnes (1974); Kaestner (1967); Curtis (1975); Weisz (1971); Mayr (1969); MacGinitie and MacGinitie (1949); Stephens and North (1974); Shrock and Twenhofel (1953); and Easton (1960). Of all of these references listed, I found the works of Hyman and Barnes most helpful for many details. *The Fossil Record* (Harland et al., 1967) proved to be a useful guide to the groups with a good fossil record.

In Table 1 are listed 26 animal phyla that have species that are all soft-bodied and have little or no fossil record. These animal phyla have almost no chance of being fossilized. The remaining 10 animal phyla (shown in Table 2) have an extensive or a reasonably good fossil record.

When one compares the animal phyla in Table 1 with those in Table 2, one is immediately struck by the fact that most of the phyla in Table 1 are small, having less than 1,000 species, whereas those in Table 2 are large, having more than 1,000 species. The percentage of small animal phyla in Table 1 is 85%, whereas the percentage of small animal phyla in Table 2 is only 10%. The average size of the phyla in Table 1 is only 2,686 species, whereas the average size of the phyla in Table 2 is 116,930 species. It appears, then, that as a general rule, those phyla that have some or most of their species that have skeletons or shells are more diverse and have undergone a much greater amount of adaptive radiation than those animal phyla that have no species with hard parts.

The Monoblastozoa listed in Table 1 is the name of a phylum with a single species formally proposed by Blackwelder (1963) for *Salinella*. Hyman (1940) believed that this animal is structurally so unique that it cannot be placed in any of the living phyla of animals. At the other extreme is the phylum Nematoda, which I have conservatively estimated as having at least 50,000 living species. Although only about 12,000 living species have thus far been described, Curtis (1975) points out that estimates as high as 400,000 to 500,000 living species exist. The nematodes are generally tiny animals, many are parasites, and most of them are still undescribed. Small, soft-bodied animals are much less well known than animals with hard parts as, for example, most of the Mollusca, and it is likely that the number of described soft-bodied animal species will increase much more rapidly than those with hard parts. The total number of species in Table 1

(69,829) is probably considerably lower than the actual existing number of soft-bodied animal species.

TABLE 1. Animal phyla whose species are all soft-bodied.

Phyla	No. of species
1. Nematoda	50,000
2. Platyhelminthes	13,000
3. Tunicata	1,600
4. Rotifera	1,500
5. Rhynchocoela	750
6. Acanthocephala	600
7. Gastrotricha	350
8. Tardigrada	350
9. Sipunculoidea	330
10. Gordiacea	230
11. Echiuroidea	150
12. Myzostomida	150
13. Ctenophora	100
14. Enteropneusta	100
15. Pogonophora	100
16. Kinorhyncha	100
17. Onychophora	75
18. Chaetognatha	75
19. Pentastomida	70
20. Calyssozoa	60
21. Mesozoa	50
22. Cephalochordata	30
23. Pterobranchia	25
24. Phoronida	25
25. Priapuloidea	8
26. Monoblastozoa	1
Total	69,829

Some of the smaller phyla listed in Table 1 are probably relicts. This certainly seems true of the Onychophora with its disjunct distributions of families and genera (Barnes, 1974). Most likely the number of onychophoran species was much larger in the past, and it appears that the onychophorans were originally marine animals because of their preservation in the marine Cambrian Burgess Shale. The Pterobranchia are probably a mere remnant of a once more diverse phylum because the few species known are mostly found in deep water, and most species are limited to the Southern Hemisphere. In other words, the Pterobranchia seem to have mainly an endemic distribution. A careful study of the geographic distributions of some of the other small phyla listed in Table 1 would likely suggest that they, too, are relicts. Furthermore, there are some relict groups that have a good fossil record such as the nautiloids and xiphosurans. The possibility that several phyla of soft-bodied animals have become extinct without leaving a fossil record is almost a certainty. This should not be surprising because there are extinct phyla of animals with good fossil records as, for example, the archaeocyathids and the graptolites.

Table 2 contains the 10 living animal phyla with an excellent to fair fossil record. These are the basic phyla of living animals covered in almost all general paleontology texts. The 26 phyla in Table 1 are mainly not mentioned at all or some are briefly mentioned in paleontology texts because they are believed to be related to phyla with a good fossil record. Of these 10 phyla, only the Brachiopoda are considered to have all species capable of being fossilized, and they are assumed to have been considerably more diverse in the past. The Mollusca have the greatest number of species that appear to be capable of fossilization, but many soft-bodied gastropods, all aplacophorans, and most cephalopods have little or no chance of fossilization. Animals with the hard parts that are not fused to form a solid skeleton are mainly eliminated as incapable of leaving readily identifiable fossils. This would include many sponges, some coelenterates, and certainly many echinoderms. Some groups of animals have such a thin chitinous cuticle that their chance of preservation as fossils is almost nil. So those animals with sturdy, fused skeletons of inorganic compounds have the only good chance of fossilization. Those animals living in shallow seas have a better chance of getting into the fossil record than those animals living on land or in fresh water because rapid deposition of sediments is most likely to take place in a shallow-water marine environment.

TABLE 2. Animal phyla whose species may either be soft-bodied or have hard parts.

Phyla	Species unlikely to be fossilized	Species likely to be fossilized	Total
1. Arthropoda	983,000	17,000	1,000,000
2. Mollusca	7,000	51,000	58,000
3. Vertebrata	30,200	11,500	41,700
4. Protozoa	26,000	9,000	35,000
5. Coelenterata	5,500	4,500	10,000
6. Annelida	9,000	300	9,300
7. Echinodermata	4,300	1,700	6,000
8. Porifera	3,500	1,500	5,000
9. Bryozoa	1,000	3,000	4,000
10. Brachiopoda	0	300	300
Totals of Table 2	1,069,500	99,800	1,169,300
Totals of all species	69,829		1,239,129

Of the approximately million species of living arthropods, the vast majority have little chance of fossilization. This would include almost all of the insects, all of the arachnids, all of the diplopods, and all of the chilopods. Probably only about 100,000 of the estimated 1,239,129 living species of animals have a good chance of fossil preservation. This means that only 8% of the living species of animals have a likelihood of being preserved in sedimentary rocks as fossils.

Stanley (1976, p. 73) states that skeletonization was an important adaptive breakthrough for many groups of animals during the Late Precambrian, Cambrian, and Ordovician. This is true for some phyla and classes, but many living animal phyla and classes have never developed skeletons. Those animals that have remained small, or become parasites, or are pelagic, or that burrow into soft sediments have commonly remained without a skeleton or have perhaps secondarily had it reduced or lost. The secondary reduction or loss of a skeleton is found in many gastropods, cephalopods, and arthropods. A general evolutionary trend in the cephalopods since the Late Cambrian has been in a reduction of the skeleton. Dr. Fred Thompson pointed out to me (personal communication) the fact that land slugs have a marked advantage over land gastropods with external shells because the slugs can creep into crevices and thus escape a predator, which the shelled land gastropods are incapable of doing. Perhaps there is a higher percentage of living animals with no skeleton than there was at the end of the Ordovician when the adaptive breakthrough of the major groups that developed skeletons was essentially completed.

Acknowledgments—I am particularly indebted to the following people for help in this research: Dr. Robert D. Barnes of the Biology Department at Gettysburg College for additional information on numbers of species in various animal phyla; Dr. Fred G. Thompson of the Florida State Museum for the estimated number of land slugs; Dr. Carter R. Gilbert of the Florida State Museum for an estimate on the number of living species of fish; and Mr. Michael K. Frazier of the Florida State Museum for his opinion on the likelihood of fossilization of living species of vertebrates.

LITERATURE CITED

Barnes, R. D. 1974. Invertebrate Zoology. 3rd ed. W. B. Saunders Co. Philadelphia.

Blackwelder, R. E. 1963. Classification of the Animal Kingdom. Southern Illinois Univ. Press. Carbondale.

Curtis, H. 1975. Biology. 2nd ed. Worth Publ. New York.

Easton, W. H. 1960. Invertebrate Paleontology. Harper and Brothers. New York.

Harland, W. B., C. H. Holland, M. R. House, N. F. Hughes, A. B. Reynolds, M. J. S. Rudwick, G. E. Satterthwaite, L. B. H. Tarlo, and E. C. Willey (Eds.). 1967. The Fossil Record. Geol. Soc. London. Burlington House. London.

Hyman, L. H. 1940-1959. The Invertebrates. Vol. I, 1940; Vol. II, 1951a; Vol. III, 1951b; Vol. IV, 1955; Vol. V, 1959. McGraw-Hill. New York.

Kaestner, A. 1967. Invertebrate Zoology. Vol. 1. Interscience Publ. New York.

MacGinitie, G. E., and N. MacGinitie. 1949. Natural History of Marine Animals. McGraw-Hill. New York.

Mayr, E. 1969. Principles of Systematic Zoology. McGraw-Hill. New York.

Raup, D. M., and S. M. Stanley. 1971. Principles of Paleontology. W. H. Freeman and Co. San Francisco.

Shrock, R. R., and W. H. Twenhofel. 1953. Principles of Invertebrate Paleontology. 2nd ed. McGraw-Hill. New York.

Stanley, S. M. 1976. Fossil data and the Precambrian—Cambrian evolutionary transition. Amer. J. Sci. 276:56-76.

Stephens, G. C., and B. B. North. 1974. Biology. John Wiley and Sons. New York.

Teichert, C. 1956. How many fossil species? J. Paleont. 30:967-969.

Weisz, P. B. 1971. The Science of Biology. 4th ed. McGraw-Hill. New York.

Florida Sci. 40(2):135-139. 1977.

Biological Sciences

FISHES OF A FLORIDA OXBOW LAKE AND ITS PARENT RIVER

HAL A. BEECHER (1), W. CARROLL HIXSON (2), AND THOMAS S. HOPKINS (1)

Department of Biology, University of West Florida, Pensacola, Florida 32504 (1);
Bream Fishermen Association, 1333 N. Spring St., Pensacola, Florida 32501 (2)

ABSTRACT: *An electrofishing and seining survey of a 70-80 yr old oxbow lake and an adjacent section of the Escambia River in northwest Florida yielded 29 species of fishes in the lake and 58 species in the adjacent river. Electrofishing results indicated different abundances of individuals of species common to both areas. A decrease in number of species corresponds to a decrease in habitat diversity in the oxbow lake.**

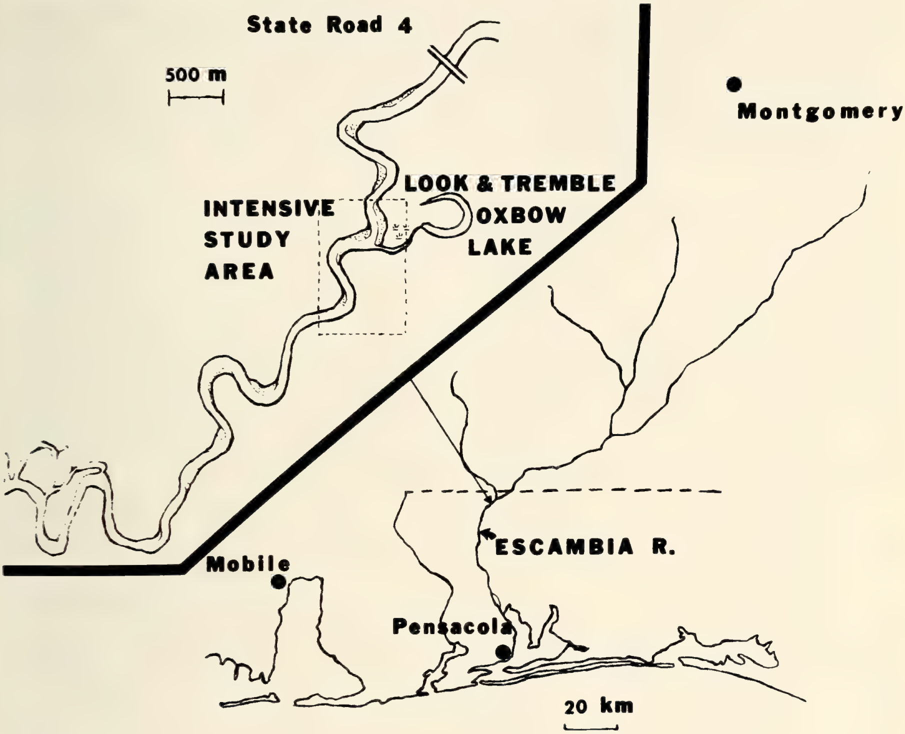
OXBOW LAKES are common along coastal floodplain rivers where they are often the only natural lakes. However, little literature is devoted to the ichthyofauna of oxbow lakes. Ward (1972) discussed the invertebrate fauna of an incipient oxbow lake on the lower Escambia River in northwest Florida, and reviewed the literature on oxbow lakes. Lambou (1959, 1961) discussed fish populations of oxbow lakes along the lower Mississippi River in Louisiana. Shipp and Hemphill (1974) studied fish populations in 3-yr old artificially created oxbow lakes in the Alabama River system. An oxbow lake is derived from its associated river when the parent river changes course; therefore, we can assume that the lake's fish fauna must be derived from that of the parent river. We examined the fish fauna of an oxbow lake isolated from the Escambia River. Fishes of this river system have been extensively studied by Bailey, Winn, and Smith (1954). Their station no. 14 corresponds to our river study area.

DESCRIPTION OF THE STUDY AREA—Our river study area, near the Alabama-Florida border, extends downstream about 5 km from the bridge on State Road 4 between Jay and Century, Florida, at 30°57′54″N, 87°14′03″W. The lake is approximately 1 km south of the bridge and about 400 m east of the river (Fig. 1). During high water the lake and the river are sometimes connected through a hardwood swamp in which beavers were active. A narrow channel between the lake and river has been dug, and is maintained, by local fishermen. This channel is navigable only at high water, but is completely blocked by a beaver dam at low water.

The river study area is 1070 m long. During low water the river is 70 to 80 m wide, and our low water area covered 7.8 hectares. At high water the river spreads out into the surrounding swamp, particularly on the east shore, and the surface area is greatly increased. Inundation of sandbars alone adds 3.6 hectares to the river study area, which includes the channel between the lake and the river west of the beaver dam (Fig. 1). The study area is 84 km upstream from the mouth of the Escambia River, at an elevation of 8.67 m above mean sea level. The Es-

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

cambia River in the study area is an Order 6 or Order 7 stream (U.S. Army Corps of Engineers, Mobile Office, pers. comm.; Kuehne, 1970).



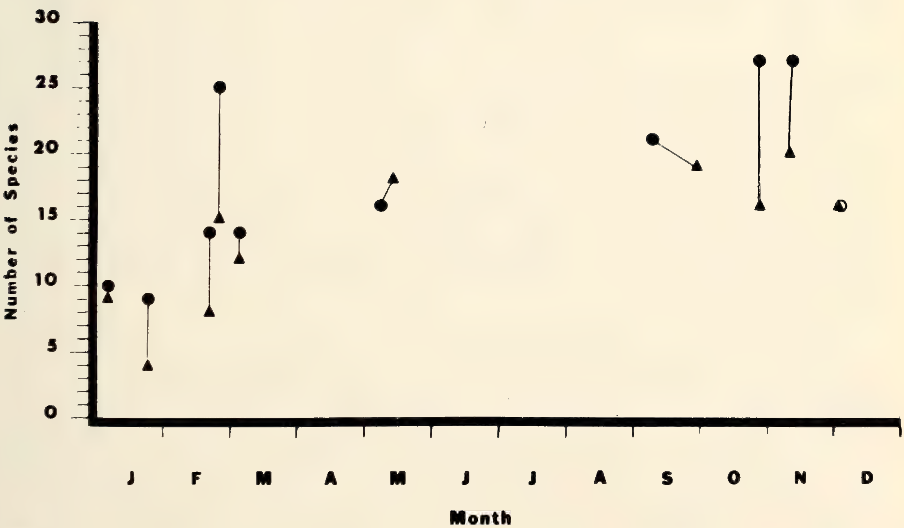


Fig. 1. (upper) Location map of the study area. Inset at left shows vicinity of study area in more detail.

Fig. 2. (lower) Number of fish species per collection in paired river (circles) and oxbow lake (triangles) collections.

The outer sides (cut-banks) of the bends in the river are steep sand-clay banks often overhung by fallen trees. The river reaches its maximum depth near the outsides of bends, being more than 2 m at low water to over 6 m at the highest water levels. The inner sides (slip banks) of the bends are broad sand beaches extending gradually into the channel. Gravel (1-2 cm diam) occurs at some bends where small riffles extend part way across the river. The downstream ends of these sandbars often partly enclose a backwater with no current and a bottom of soft clay-mud.

A map published in the mid-nineteenth century (LaTourette, 1835) shows the oxbow lake as a part of the river, forming the eastern channel, while the present channel formed the western channel, with an island between. The lake is locally known as Look-and-Tremble Lake, because it once formed a sharp bend in the river where a strong current was a hazard to log booms. The peak of logging activity for northwest Florida, with a center at Pensacola, was the last decade or two of the nineteenth century. Therefore, the lake may have been part of the river as recently as 70-80 yr ago. Today there is no perceptible current in the lake, even when it is connected to the river during high water.

The oxbow lake, being an old bend in the river, is similar in form to other bends of the river. The inside of the bend is shallow and covered with a thick layer of decomposing leaf litter. Cypress trees (*Taxodium distichum*) and other swamp vegetation have encroached upon what had been the old sandbar. The outside of the bend remains a steep bank where the lake reaches its maximum depth of 3 m at low water to over 6 m at high water. At low water the oxbow lake has an area of 3.4 hectares. High water increased the area greatly by inundating some of the surrounding swamp. In both the lake and the river the turbidity remains quite high, with visibility rarely reaching 1 m.

The river study area has greater diversity in terms of current velocity and bottom type than the oxbow lake. Both areas have similar morphometry and numerous submerged logs. Aquatic vegetation, other than a seasonal growth of filamentous green algae in the river, is absent from both the river and the lake. Current velocity in the river grades from nil to moderate (regular current readings were not taken, but a single reading in an area of strong current was 1.1 m/sec). Bottom types in the river included gravel, mixed sand and gravel, loose sand, hard-packed sand, sand covered with a thin layer of clay and silt, clay, and clay covered with leaf litter.

METHODS—Collections were made at irregular intervals from November 1971 to December 1972. We made river collections at least once a mo, but low water levels prevented sampling in the oxbow lake during April, June, July, and August. Low water continued into early December. Sampling was begun in December 1971 in the oxbow lake and in January 1972 in the river. A preliminary survey was made throughout the entire river study area during November and December 1971.

Each sampling run took up to 2 hr. The time spent in each run was recorded to the nearest 5 min. We made 36 runs in 68 hr of electrofishing in the river from

January to December, 1972. In the oxbow lake we made 11 runs in 22 hr from December 1971 to December 1972.

We collected fish with a 220V 60Hz AC electric shocker (3-8 amps, once 1-1.5 amps immediately after heavy rains) mounted on the front of an outboard motor boat. Two netters used long-handled dip-nets to place stunned fish in a holding tank in the middle of the boat.

At the termination of a run, each fish was identified, weighed, measured (standard length, SL), tagged with a dart-type tag (if 10 cm SL or more), and released. Unidentified fish (with the exception of *Micropterus* spp) were preserved in 10% formalin and labeled with appropriate station data for later examination.

Additional collections were made by seining. Seine lengths ranged from 4.6 m to 30.5 m, with a 1 cm stretch mesh, but the longer size was not practical. Few seine collections were made in the oxbow lake because of many submerged snags. Fish collected in seine hauls were preserved in 10% formalin and labeled.

We measured the water level at the State Road 4 bridge from highest water in March 1972 through December 1972 (Fig. 5).

Results and Discussion—The species of fish collected in the river and the lake are listed in Table 1. We collected 58 species in the river and 29 species in the oxbow lake. Thirty-one species collected in the river were not taken in the lake, and 3 species from the lake were not taken in the river. Twenty-six species were common to both areas.

The number of fish species per collection for paired river and oxbow lake collections is shown in Fig. 2. Ten of 11 oxbow lake collections are paired with the nearest (in time) 10 of 36 river collections. In 8 of the 10 pairs we collected more species in the river than in the lake. In only one of the 10 pairs were there fewer species in the river than in the lake. There are significantly ($P < 0.05$) more species in the river than in the oxbow lake.

As a result of the formation of the lake, the most noticeable change has been the decrease in the number of species. The change in number of species has occurred in two groups of species, the current dwelling and the euryhaline forms.

The darters (Percidae) were represented by 9 species in the river study area, but were not collected in the oxbow lake. Although the lake appeared to be suitable habitat for the swamp darter (*Etheostoma fusiforme*), none were obtained in a collection made after the study. As a group, the darters are typical of flowing waters.

Such euryhaline species as southern flounder (*Paralichthys lethostigma*), hogchoker (*Trinectes maculatus*), Alabama shad (*Alosa alabamae*), and Atlantic needlefish (*Strongylura marina*) were also absent from the oxbow lake. A single specimen of the skipjack herring (*Alosa chrysochloris*) was collected in a gill-net in the river after the termination of the study. However, the euryhaline group was not totally excluded, as shown by the presence of threadfin shad (*Dorosoma petenense*), gizzard shad (*D. cepedianum*), American eel (*Anguilla rostrata*), and a single striped mullet (*Mugil cephalus*) in the oxbow lake.

Three species, the taillight shiner (*Notropis maculatus*), brown bullhead (*Ictalurus nebulosus*), and Everglades pygmy sunfish (*Elassoma evergladei*), were

TABLE 1. Occurrence of fish species in oxbow lake and river study area. Numbers indicate total number of specimens and number collected by shocking (in parentheses). The catch rate in number of fish captured per hour of electrofishing is shown.

Species	Oxbow Lake Number	Oxbow Lake Fish/Hr	River Number	River Fish/Hr
Acipenser oxyrhynchus	-	-	1(1)[1]	-
Lepisosteus oculatus	10(10)	0.45	5(5)	0.07
L. osseus	5(5)	0.23	47(47)	0.69
L. spatula	-	-	1(1)[1]	0.01
Amia calva	40(40)	1.82	29(29)	0.43
Anguilla rostrata	5(5)	0.23	10(10)	0.15
Alosa alabamae	-	-	9(8)	0.12
A. chrysochloris	-	-	1(0)[2]	-
Dorosoma cepedianum	77(77)	3.50	83(79)	1.16
D. petenense	16(16)	0.73	45(37)	0.54
Esox niger	26(26)	1.18	14(14)	0.21
Ericymba buccata	-	-	132(30)	0.44
Hybognathus hayi	22(22)	1.00	16(9)	0.13
Hybopsis aestivalis	-	-	31(1)	0.01
H. amblops	-	-	91(66)	0.97
Notemigonus crysoleucas	-	-	4(1)	0.01
Notropis chalybaeus	-	-	4(2)	0.03
N. emiliae	24(23)	1.04	11(8)	0.12
Notropis longirostris	-	-	476(87)	1.27
N. maculatus	9(8)	0.36	-	-
N. texanus	2(2)	0.09	707(319)	4.60
N. venustus	5(5)	0.23	1271(363)	5.34
Carpiodes cyprinus	-	-	52(26)	0.38
C. velifer	2(2)	0.09	169(122)	1.79
Erimyzon tenuis	7(7)	0.32	5(5)	0.07
Minytrema melanops	33(33)	1.50	34(34)	0.50
Moxostoma carinatum	-	-	3(3)	0.04
M. poecilurum	35(35)	1.59	244(244)	3.59
Ictalurus natalis	-	-	3(3)	0.04
I. nebulosus	1(1)	0.05	-	-
I. punctatus	-	-	16(13)	0.19
Noturus leptacanthus	-	-	8(8)	0.12
Aphredoderus sayanus	-	-	1(1)[3]	-
Strongylura marina	-	-	4(3)	0.04
Fundulus notti	-	-	1(1)	0.01
F. olivaceus	2(2)	0.09	17+(6)	0.09
Gambusia affinis	1(0)[4]	-	++(0)[4]	-
Labidesthes sicculus	106(60)	2.73	26(11)	0.16
Ambloplites rupestris	-	-	7(7)	0.10
Centrarchus macropterus	-	-	3(3)	0.04
Elassoma evergladei	1(0)[5]	-	-	-
Lepomis gulosus	25(25)	1.14	26(26)	0.38
L. macrochirus	850(846)	38.61	303+(303)	4.45
L. megalotis	29(29)	1.32	269+(269)	3.95
L. microlophus	144(144)	6.55	87(87)	1.28
L. punctatus	2(2)	0.09	1(1)	0.01
Micropterus punctulatus *M. salmoides*	75(75)[5]	3.41	95(89)[5]	1.31
Pomoxis nigromaculatus	26(26)	1.18	26(26)	0.38
Ammocrypta asprella	-	-	1(1)	0.01

TABLE 1. (continued)

Species	Oxbow Lake		River	
	Number	Fish/Hr	Number	Fish/Hr
A. bifascia	-	-	27(6)	0.09
Etheostoma davisoni	-	-	7(0)	-
E. swaini	-	-	4(0)	-
E. histrio	-	-	1(1)	0.01
E. (Ulocentra) sp.	-	-	4(2)	0.03
Percina caprodes	-	-	37(36)	0.53
P. nigrofasciata	-	-	16(16)	0.24
P. uranidea	-	-	31(2)	0.03
Mugil cephalus	1(1)	0.05	136(136)	2.00
Paralichthys lethostigma	-	-	9(9)	0.13
Trinectes maculatus	-	-	45(35)	0.51

[1]Single specimens of Atlantic sturgeon (*Acipenser oxyrhynchus*) and alligator gar (*Lepisosteus spatula*) were shocked, but they were too big to net. The sturgeon was shocked during a non-timed shocking run within the study period but not part of the study.

[2]A single specimen of *Alosa chrysochloris* was gill-netted after the study in July 1975.

[3]A single specimen of the pirate perch (*Aphredoderus sayanus*) was collected during the preliminary survey in November 1971.

[4]A single specimen of mosquitofish (*Gambusia affinis*) was seined in the oxbow lake after the study in June 1975. *Gambusia* was usually uncommon in the river, but during winter high water we collected large numbers in flooded areas.

[5]See text.

collected in the lake but not in the river. Only single specimens of *I. nebulosus* and *E. evergladei* were collected in shallow water in the lake. *Notropis maculatus* was common. *Notropis maculatus* is probably a resident in backwater lakes and ponds of the Escambia River swamp (Bailey et al., 1954). This fish could disperse without entering the river because the swamp lakes and ponds are sometimes interconnected during periods of high water.

The single specimen of *I. nebulosus* was not necessarily representative of the abundance of this species. All our catfish collections may have under-represented these species because of our use of AC rather than DC, which is selective for catfish (Edwards and Higgins, 1973). Immediately after one river collection in which we collected no catfish, trotline fishermen took a number of channel catfish (*I. punctatus*) in the same area.

Elassoma evergladei was collected only after the study during an attempt to collect swamp darters. Pygmy sunfishes, because of their small size and habitat preference, are probably inadequately sampled by shocking. They appear to be uncommon in the oxbow lake. None were collected in the river.

The decrease in species in the lake was accompanied by changes in the relative abundances of the remaining species. Those fish normally found in quiet areas of the river increased in abundance in the lake, while other river species decreased. Among the species which were more abundant in the lake, as indicated by electrofishing yield (Table 1), were bowfin (*Amia calva*), gizzard shad (*Dorosoma cepedianum*), chain pickerel (*Esox niger*), pugnose minnow (*Notropis emiliae*), spotted sucker (*Minytrema melanops*), brook silverside (*Labidesthes sicculus*), warmouth (*Lepomis gulosus*), bluegill (*L. macrochirus*), redear sunfish (*L.

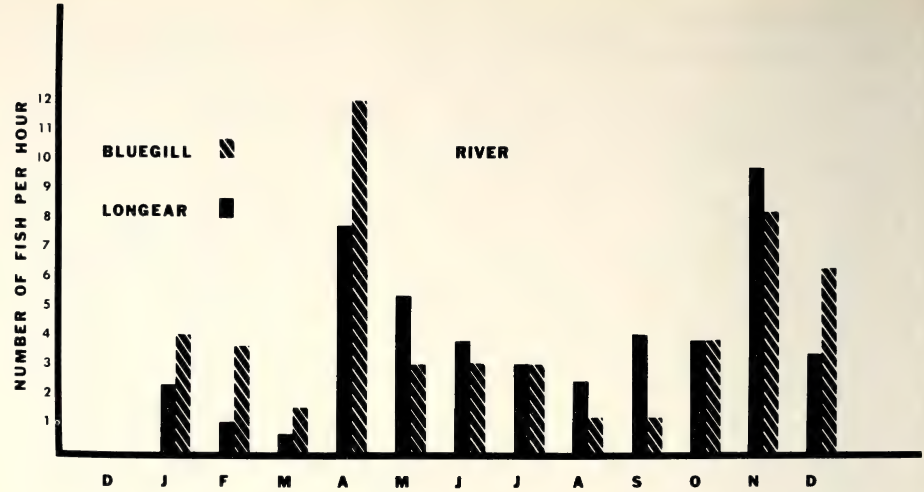


Fig. 3. (upper) Monthly electrofishing yields of bluegill (*Lepomis macrochirus*) and longear sunfish (*L. megalotis*) in the river study area.

Fig. 4. (lower) Monthly electrofishing yields of bluegill (*Lepomis macrochirus*) and longear sunfish (*L. megalotis*) in the oxbow lake.

microlophus), bass (*Micropterus* spp), and black crappie (*Pomoxis nigromaculatus*). Those species which were more abundant in the river included longnose gar (*Lepisosteus osseus*), weed shiner (*Notropis texanus*), blacktail shiner (*N. venustus*), blacktail redhorse (*Moxostoma poecilurum*), highfin carpsucker (*Carpiodes velifer*), longear sunfish (*Lepomis megalotis*), and striped mullet (*Mugil cephalus*).

The changes in relative numbers of centrarchids were of particular interest. The bluegill was the most numerous species in both areas, but it was more abundant in the oxbow lake. In the river, longear sunfish were nearly as abundant as bluegills, and in some months longear sunfish exceeded bluegills in abundance (Fig. 3). In the lake, longear sunfish were relatively scarce (Fig. 4), and in some months they were totally absent from our collections. Both species showed a decrease in mean length and weight from the river to the lake. The mean weight of bluegill dropped from 48 g to 32 g (33.3% reduction), while that of longears dropped from 17 g to 4 g (76% reduction). The mean length of bluegills decreased from 9.6 cm in the river to 8.5 cm in the lake, while that of longears dropped from 7.2 cm to 5.1 cm. During most of the spawning season there was no dispersal route between the two areas. The changes in length and weight are probably not a result of emigration. Longear sunfish did not appear to be competing successfully with bluegills in the lake, although both species appeared to be about equally successful (in terms of numbers) in the river. Presence or absence of a current was probably not a factor by itself; longear sunfish were abundant in quiet areas of the river as well as in areas of strong current.

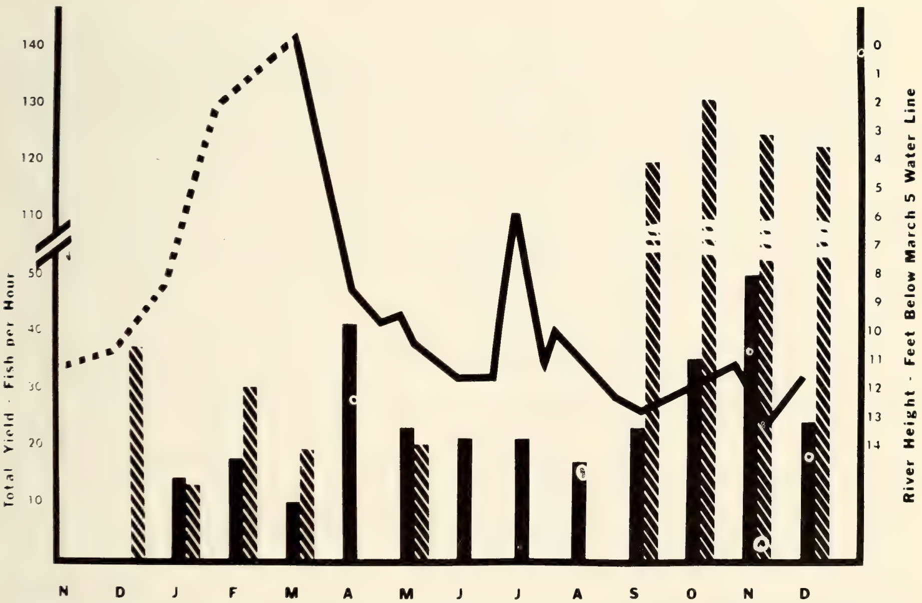


Fig. 5. Monthly total electrofishing yields based on fish per hr in the river study area (solid bars) and in the oxbow lake (cross-hatched bars).

The river gave a more constant yield of fish per hr of electrofishing than did the oxbow lake (Fig. 5). During winter high water, the yields of the two areas were similar, but during fall low water the fish in the oxbow lake were concentrated without an exit. The river yield did not show this dependence upon the water level as clearly. Yields at low water in the oxbow lake suggested a very high biomass. Unfortunately, although we tagged 517 fish in the lake and 907 in the river, our returns of tagged fish (10 in the lake and 32 in the river) were too low to allow a precise estimate of the population (but see Beecher et al., 1976). Our tag returns did not indicate any movement between the river and the lake.

Elimination of current through the lake has resulted in decreased habitat diversity and a corresponding decrease in fish diversity. This process may be continuing with a further decrease in fish species probable in the future.

ACKNOWLEDGMENTS—This study was supported, in part, by a grant from Humble Oil and Refining Company to Thomas S. Hopkins. We could not have carried out this study without the dedicated help of the Bream Fishermen Association. Dr. Ralph W. Yerger (Florida State University) provided valuable assistance with identification of fishes and reviewed the manuscript. Brooke Beecher, John R. Stowe, and Karen Brockman aided in follow-up studies. Dr. Robert L. Shipp (University of South Alabama), Thomas C. Lewis, and Gordon Cherr (Florida State University) provided constructive criticism of the manuscript.

LITERATURE CITED

BAILEY, R. M., H. E. WINN, AND C. L. SMITH. 1954. Fishes from the Escambia River, Alabama and Florida, with ecologic and taxonomic notes. Proc. Acad. Nat. Sci. Philadelphia 106:109-164.

BEECHER, H. A., W. C. HIXSON, AND T. S. HOPKINS. 1976. Studies of *Moxostoma poecilurum* (Pisces: Catostomidae) in two west Florida rivers. A.S.B. Bull. 23(2):42. (Abstract)

EDWARDS, J. L., AND J. D. HIGGINS. 1973. The effects of electric currents on fish. Final Technical Report, Projects B-397, B-400, and E-200-301, Engineering Experiment Station, Georgia Inst. Tech., Atlanta. 75 p.

KUEHNE, R. A. 1970. Applications of the Horton stream classification to evaluate faunal studies. Pp. 367-370. *In* Bioresources of Shallow Water Environments. Amer. Water Resources Assoc. Proc. Ser. 8 (Hydrobiology). Urbana, Illinois.

LAMBOU, V. W. 1959. Fish populations of backwater lakes in Louisiana. Trans. Amer. Fish. Soc. 88:7-15.

————. 1961. Fish populations of Mississippi River oxbow lakes in Louisiana. Proc. Louisiana Acad. Sci. 23:52-64.

LATOURETTE, J. 1835. An accurate map of the state of Alabama and West Florida. Surveyor's Office, Florence, Alabama, October 14, 1835.

SHIPP, R. L., AND A. F. HEMPHILL. 1974. Effects of canalization on fish populations of the lower Alabama River. A.S.B. Bull. 21(2):83. (Abstract)

WARD, G. M. 1972. Limnological aspects of an incipient oxbow lake with notes on the Chironomidae (Insecta: Diptera). M.S. Thesis. Univ. West Florida. Pensacola. 79 p.

Florida Sci. 40(2):140-148. 1977.

Earth Science

A BOUGUER GRAVITY ANOMALY MAP OF ALACHUA COUNTY, FLORIDA

DOUGLAS L. SMITH AND GEORGE J. TAYLOR

Department of Geology, University of Florida, Gainesville, Florida 32611

ABSTRACT: *A detailed gravimetric survey of Alachua County, Florida, consisting of over 250 occupied stations, reveals Bouguer anomaly values ranging from –17 milligals to +5 milligals. Two gravity base stations were located on the University of Florida campus in Gainesville and near the town of Archer. Anomaly patterns, based on one milligal contours, contribute additional fine structure to the existing statewide gravity anomaly map and demonstrate a large gradient leading to a low anomaly in northwestern Alachua County. In contrast, the eastern half is characterized by broadly spaced rambling contours progressing to a high anomaly. The general trend of the anomalies is northeast-southwest, which is congruous with the dominant large-scale Bouguer anomaly pattern for north peninsular Florida.**

RECENT compilations of gravity data for Florida have established a certain prominence for that discipline among comprehensive geophysical studies in the state. Oglesby and his colleagues (Oglesby and Ball, 1971; Chaki and Oglesby, 1972; and Oglesby et al., 1973) have improved an initial gravity anomaly map (Lyons, 1950), and provided a foundation for subsurface structural interpretations.

Oglesby et al. (1973) presented a Bouguer anomaly map of peninsular Florida and the adjoining continental shelves with a contour interval of 4 milligals (4×10^{-5} m/sec^2). The maximum and minimum anomalies are +42 milligals and –26 milligals, respectively, and the general trend of the anomalies is northwest-southeast in the southern part of the peninsula and northeast-southwest in the northern part of the peninsula. Contour values in Alachua County range from –14 milligals in the northwestern corner to +6 milligals in the eastern part of the county.

The statewide survey of Oglesby et al. (1973) depicts only regional anomaly patterns because of station spacing and the resulting contour interval. More detailed surveys on a local scale have been conducted in the Ocala National Forest (Wolansky, 1973; Wolansky and Spangler, 1975) and the Sarasota-Charlotte Counties (Johns, 1976) area. This paper presents the results of a detailed gravimetric survey consisting of 257 stations recorded in Alachua County during the autumn of 1974. The research was initiated to augment and provide additional detail to the existing statewide gravity anomaly maps. Preliminary interpretations were reported by Smith and Taylor (1975) and a detailed account of the data is given by Taylor (1975).

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

Procedures and Data—The survey was conducted with a Worden gravity meter (Prospector model) provided by the Florida Bureau of Geology. In general, the survey entailed (1) the establishment of two base stations in Alachua County (none existed previously), (2) the subsequent occupation of field stations as closed loops from a base station, and (3) application of the appropriate corrections as outlined by Dobrin (1976). Field observation stations coincided with marked locations for recorded elevation determinations by the U. S. Coast and Geodetic Survey (USCGS) and the state of Florida (Gunter, 1948), thereby providing precise elevation values to facilitate data reduction.

Utilizing a previously established gravity base station 1.4 mi southwest of Bronson, Levy County (BM W-12 1932 USCGS; g=979288.50; W. R. Oglesby, personal communication, 1974), a new base station was established at BM C-13 USCGS on State Highway 24 about 1.9 mi NE of Archer (Fig. 1). The procedure involved recording alternate sets of readings at Bronson and Archer until identically (within 0.01 milligals) reproducible values were obtained. The elapsed time between reading sets was only 30-40 min which minimized the effects of instrument drift. As with all stations, individual values were recorded only after

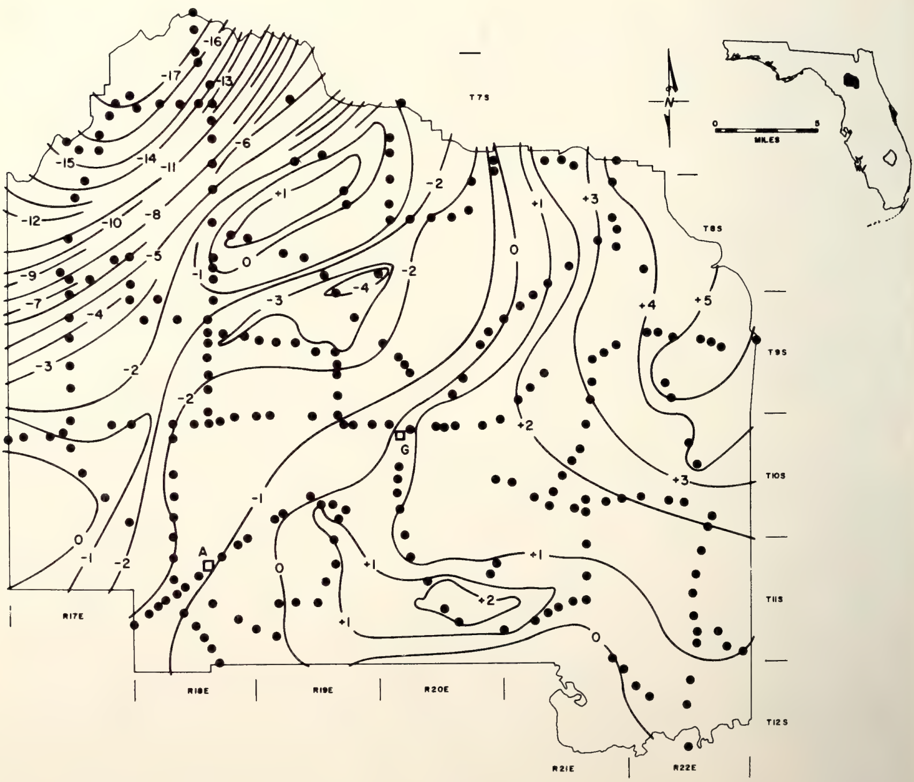


Fig. 1. Bouguer anomaly map of Alachua County, Florida. Contours in milligals. Closed circles represent measurement stations. Open squares A and G designate the base stations at Archer and Gainesville, respectively.

they were reproducible upon offsetting and releveling the instrument. The same procedure was followed from Archer to establish a second base station at BM C-268-A USCGS on the University of Florida campus in Gainesville (Fig. 1). Table 1 summarizes the new base station values.

TABLE 1. Base station values.

Station	Location	Elev.(ft.)	g_{obs}(mgals)
Archer	29°33′10″ N.Lat. 82°29′42″ W. Long.	86.0	979295.98
Gainesville	29°38′45″ N.Lat. 82°20′22″ W. Long.	124.2	979302.39

	Elev. Corr. (mgals)	g_{theor}(mgals)	Bouguer Anom. (mgals)
Archer	+5.93	979301.52	+0.39
Gainesville	+8.57	979310.34	+0.62

All field observations were recorded as relative differences from one of the two base stations. Daily loops of up to 4 hr to occupy observation stations began and ended with measurements at a base station to evaluate and correct for drift. The actual drift determined was a composite of inherent instrumental drift, tidal-induced drift, and temperature-induced drift. The difference in initial and final loop readings at a base station represented the total drift which was divided by the elapsed time to yield an assumed linear drift rate. This rate (usually less than 0.1 mgal/hr) was then applied to the observed station values to determine corrected observed values.

In order to effectively reduce all stations to a uniform reference plane (sea level), an elevation correction, including a free air correction and a Bouguer correction was applied to the observed values. The free air correction was added to the observed values and consisted of

$$\Delta g_{F.A.} = 2g_o \ h/R \cong 0.094 \ \frac{\text{mgal}}{\text{ft}} \times \ h$$

where g_o is the gravity value at sea level, R is the radius of the earth, and h is the elevation above sea level. The Bouguer correction (Δg_B), subtracted from the observed value, accounts for the gravitational attraction of that part of the earth above sea level. The correction is based on the attraction of an infinite plane slab h ft in thickness and, following the example of Oglesby et al. (1973), with a density of 2.0 gm/cm^3 so that

$$\Delta g_{B.} = 2\pi G\sigma h = 0.025 \ \frac{\text{mgal}}{\text{ft}} \times \ h$$

where σ is density and G is the gravitational constant. The combined elevation correction, added to the observed value, for each station is then

$$\Delta g = (0.094 - 0.025)h = 0.069 \text{ h mgals/ft.}$$

Terrain of sufficient relief to cause concern about the effects of local topography was lacking and no topographic corrections were applied to the data.

A latitude correction was applied to the observed values to effectively place the observation stations at the same latitude as a base station. Using

$$dg/d\theta = 1.307 \sin 2\theta$$

as the rate of change of gravitational attraction, g, with latitude, θ, we have for the Gainesville base station

$$\Delta g = 1.12 \text{ mgals/mi.}$$

Station distances north or south of the Gainesville base station were recorded to the nearest 1/8 mi and appropriate corrections calculated. The resulting latitude correction was subtracted from the observed value for stations north and added to the observed value for stations south of the base station.

The computation of Bouguer anomalies by the reduction and comparison of observed station values to the base stations is summarized by

$$\text{Boug. Anom. of field station} = g_{obs} \pm \text{drift corr.} + \text{elev. corr.} \pm \text{lat. corr.} - g_{theor}$$

where g_{theor} is the expected gravity value at one of the base stations. Figure 1 shows the locations of the two base stations and 255 observation stations as well as the Bouguer anomaly contours for Alachua County.

The final Bouguer anomaly value for each station includes several possible errors. Observed values were evaluated by subsequent observations on separate days at the same location and the results were consistently reproducible to within 0.10 milligals. The maximum total drift recorded in a station loop was 0.50 milligals/4 hrs. The maximum error incurred by considering the drift rate to be linear is estimated to be 0.15 milligals.

Since relative locations were measured to the nearest 1/8 mi for latitude corrections, the maximum error was placed at 1/16 mi with a corresponding correction error of less than 0.10 milligals. Elevations of most stations were known to within a fraction of a ft from official markers. However, many of the markers were 30-40 yr old. Based on an elevation error of 0.069 milligals/ft and our general assumption of a uniform rock density value, a maximum elevation error of 0.10 milligals is estimated. Thus, a total maximum error from all sources is less than 0.5 milligals and an error of approximately 0.2 milligals is considered more probable.

DISCUSSION—Because all observations were made near roads, the distribution of station points shown in fig. 1 reflects the highway and improved road pattern of Alachua County while exact station positions are coincident with accessible elevation markers. The Bouguer anomaly contour lines have an interval of one milligal and range from –17 to +5 milligals.

The major feature of the anomaly pattern is a steep gradient in the northwestern part of the county with a maximum change of about –2 milligals/mi. In general, the anomaly contours for this feature trend northeasterly and the steepest gradients northwesterly. The eastern and southern portions of the county are dominated by a contour pattern with relatively broad intervals and indistinct gradients. The seemingly north-south trending contours which progress to +5 milligals in eastern Alachua County actually represent the southwestern end of a major northeasterly trending positive anomaly centered in Clay County (Oglesby et al., 1973) to the northeast.

The sharp negative contour gradient in northwestern Alachua County and the broad pattern of positive anomaly contours in the eastern part of the county represent a very good agreement and contribution of detail to the comprehensive statewide map of Oglesby et al. (1973). Only in the extreme southwestern corner of the county does this detailed survey reveal a discrepancy (about 2 milligals) with the statewide map.

Puri and Vernon (1964) have outlined the general stratigraphic units of Florida while Applin (1951), Bass (1969), Milton (1972), and Barnett (1975), among others, have presented discussions of the Florida basement rocks. Relatively large scale anomalies such as those present in, but extending beyond, northwestern and eastern Alachua County may be attributed to either irregularities in the contrasting density interface between the igneous/metamorphic basement and overlying sedimentary layers or to density variations within the basement. Conversely, the smaller scale anomaly patterns, such as the –4 milligal closed contour about 5 mi north of Gainesville, may be a result of lateral inhomogenieties creating local density variations within the shallower sedimentary strata.

Possible basement configurations based on interpretations of the major Bouguer anomaly patterns would require data over a larger geographic area than that represented by Alachua County. However, in a simplistic sense, the negative Bouguer anomalies of western and particularly northwestern Alachua County would imply a greater thickness of low-density sedimentary rocks and, therefore, a deeper basement in those areas than in the eastern portion of the county. Indeed, Barnett (1975) has proposed a northwest trending graben in the basement that underlies the northwestern corner of Alachua County. The east to west progression of positive to negative anomalies may reflect the presence of the peninsular arch in the basement with its axis under eastern Alachua County (Puri and Vernon, 1964) and a sharply dipping flank beneath the western part of the county.

CONCLUSIONS—The Bouguer anomaly map of Alachua County presented herein is derived from observations with a Worden gravity meter at 255 stations and two newly created base stations at Gainesville and near Archer. Observed values were corrected for drift and reduced with a latitude correction and an elevation correction using a surface rock density of 2.0 gms/cm^3. No topographic correction was considered necessary. A maximum error of 0.5 milligals is assigned to the station values, but a probable error of 0.2 milligals is considered more likely.

With a contour interval of one milligal, the map augments the present statewide Bouguer anomaly map of Oglesby et al. (1973) with increased detail and fine structure. The contour pattern reveals a sharp gradient from a low anomaly of −17 milligals in the northwestern corner of the county to a zero anomaly in central Alachua County and, to the east, a gradual increase through broadly-spaced contours to a high anomaly of +5 milligals. The large anomalies are attributed to density variations inherent to basement features and the small scale (1-4 milligals) local anomalies are considered representative of lateral inhomogenieties in the near surface sedimentary rock sequence.

Acknowledgments—We thank W. R. Oglesby and the Florida Bureau of Geology, Department of Natural Resources, for their kind permission to use the gravity meter. D. P. Spangler read the manuscript and offered many helpful suggestions for its improvement.

LITERATURE CITED

Applin, P. L. 1951. Preliminary report on buried pre-Mesozoic rocks in Florida and adjacent states. U. S. Geol. Surv. Circ. 91.

Barnett, R. S. 1975. Basement structure of Florida and its tectonic implications. Trans. Gulf Coast Assoc. Geol. Soc. 25:122-142.

Bass, M. N. 1969. Petrography and ages of crystalline basement rocks of Florida—some extrapolations. *In* Tectonic relations of northern Central America and the western Caribbean—The Bonacca Expedition. Am. Assoc. Petrol. Geol. Mem. 11:283-310.

Chaki, S., and W. R. Oglesby. 1972. Bouguer anomaly map of northwest Florida. Florida Bur. Geol. Map Ser. 52.

Dobrin, M. B. 1976. Introduction to Geophysical Prospecting. 3rd edn. McGraw-Hill. New York.

Gunter, H. 1948. Elevations in Florida. Florida Bur. Geol. Bull. 32.

Johns, R. K. C. 1976. Gravimetric studies, Sarasota/Charlotte/DeSoto Counties (abst.). Florida Sci. 39(Suppl.):25.

Lyons, P. L. 1950. A gravity map of the United States. Tulsa Geol. Soc. Digest 18:33-43.

Milton, C. 1972. Igneous and metamorphic basement rocks of Florida. Florida Bur. Geol. Bull. 55.

Oglesby, W. R., and M. M. Ball. 1971. Bouguer anomaly map of south Florida. Florida Bur. Geol. Map. Ser. 41.

———, ———, and S. Chaki. 1973. Bouguer anomaly map of the Florida peninsula and adjoining continental shelves. Florida Bur. Geol. Map Ser. 57.

Puri, H. S., and R. O. Vernon. 1964. Summary of the geology of Florida and a guidebook to the classic exposures. Florida Geol. Surv. Spec. Publ. No. 5.

Smith, D. L., and G. J. Taylor. 1975. Bouguer anomaly values for Alachua County, Florida (abst.). Florida Sci. 38(Suppl.):14.

Taylor, G. J. 1975. A detailed gravity survey of Alachua County, Florida, with structural and magnetic interpretation. M. S. thesis. Univ. Florida. Gainesville.

Wolansky, R. M. 1973. A gravity survey and the interpretation of gravity data of the Ocala National Forest area, Florida. M. S. thesis. Univ. South Florida. Tampa.

———, and D. P. Spangler. 1975. A gravity interpretation of the Ocala National Forest area, Florida (abst.). Geol. Soc. Amer. Abst. with Prog. 7:550-551.

Florida Sci. 40(2):149-154. 1977.

Biological Sciences

NIGHT-FLOWERING WATERLILIES IN FLORIDA

DANIEL B. WARD

Department of Botany, University of Florida, Gainesville, Florida 32611

ABSTRACT: *Subgenus* Hydrocallis *of the Nymphaeaceae has not previously been reported to occur in the United States. Its species are night-flowering waterlilies native to South America. Two of these species are now known to have occurred in apparently natural situations in peninsular Florida.* Nymphaea blanda *G. F. W. Meyer is cited from two stations in Citrus and Levy counties, and* Nymphaea jamesoniana *Planchon is cited for DeSoto County. A key separates these and other* Nymphaea *in Florida.**

THE GENUS *Nymphaea* (Nymphaeaceae), the waterlilies, is a familiar component of Florida lakes and waterways. For many years three species have been recognized from the state, the white-flowered *N. odorata* Ait., a common and conspicuous aquatic of widespread distribution, the yellow-flowered *N. mexicana* Zucc., found scattered throughout the Peninsula, and the pale-blue-flowered *N. elegans* Hook., largely restricted to southern Florida. The literature of the genus as it applies to the southeastern United States has been competently summarized by Wood (1959).

For a number of decades, however, several responsible observers of Florida plants have contributed, in correspondence and by word-of-mouth, to a "lore" that there were other species of waterlily in the state, and that these additional species were night-flowering. This nocturnal trait is characteristic of *Nymphaea* subgenus *Hydrocallis,* a South American group of perhaps ten species (Conard, 1905). In the only printed mention of these species in Florida, St. John (1942) casually referred to an unnamed "night-blooming water lily" near the Citrus County station of his newly described fern, *Thelypteris macrorhizoma.* But the known collections were very few, later efforts to re-locate the plants in their rumored stations were unsuccessful, the "night-flowering" attribute was unfamiliar and perhaps a bit suspect to North American botanists, and little attention or credence has been given to the possibility of these other species occurring in Florida.

Over a period of years, beginning in 1961, the writer has pursued the thin leads to night-flowering waterlilies in Florida. An informal "Florida Flora Newsletter," distributed primarily to Florida residents with interests in the flora of their state, has been useful in soliciting and exchanging information and in encouraging assistance in the field. Materials of subgenus *Hydrocallis* have been studied in several herbaria, and the scanty collections from Florida have been examined and named. Although the retiring characteristics of these plants and their undoubted rarity in Florida leave them still a largely enigmatic component

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

of the state's flora, the information gained thus far indicates the presence in Florida, probably in a native state, of two species of subgenus *Hydrocallis*: *Nymphaea blanda* G. F. W. Meyer, and *Nymphaea jamesoniana* Planchon.

Conard (1905) recognized ten species within subgenus *Hydrocallis,* all with ranges in South America although four are also known in southern Central America or on islands of the Greater Antilles. *Nymphaea blanda* occurs from Chiapas, Mexico, to Panama and Colombia, and eastward to Gayana; it is also in Cuba and has been reported, perhaps erroneously, from Jamaica. *Nymphaea jamesoniana* appears to be of disjunct distribution, with one center in Ecuador and a second in Cuba, Hispaniola, and Puerto Rico.

Nymphaea blanda—Two capable amateur botanists, both now deceased, were responsible for the initial discovery of *Nymphaea blanda* in Florida.

In 1931 Dr. Edward P. St. John, a religious educator and author, retired and moved to Floral City, Citrus County, where he expanded his interest in botany to become ultimately one of the better known investigators and writers on Florida ferns. With his brother, Dr. Robert P. St. John, he collaborated with J. K. Small in writing portions of the latter's *Ferns of the Southeastern States*.

Mrs. Mary W. Diddell, a fern enthusiast and horticulturist of Jacksonville, Duval County, traveled and collected widely in Florida and published accounts of many of her discoveries during the 1940's and '50's, largely in the *American Fern Journal.* She and St. John were both friends and rivals, and her correspondence (in FLAS) contains many stories of competition in their search for novelties among the Florida ferns.

Of particular interest to St. John was "The Cove," an area in eastern Citrus County he described (1942) as "a wild region of low hammocks, cypress swamps, marshes and ponds some 15,000 acres in extent." In the summer of 1940 he guided Mrs. Diddell and other friends to Sheep Island Lake, a secluded spot near the southern end of Lake Tsala Apopka. Although their primary interest was in searching for ferns, Mrs. Diddell noted in the shallow water of a ford, "a small Nymphaeoid plant." She transplanted it to a backyard pool at her Jacksonville home and observed it for several days, each day noting the appearance of a bud at the surface which was gone by the following morning. The third day "it dawned on me what I should have at first suspected, that the *Nymphaea* was nocturnal." She confirmed this behavior by observation late the following night.

Mrs. Diddell did not prepare specimens of her night-flowering water-lily, and the plants failed to survive a "cold spell" the following winter. But later in the summer of 1940 she was again in Floral City and asked St. John about the plant. "He knew absolutely nothing, had never seen nor heard of it, though that did not deter him from writing about it in an article on the Sheep Island fern." Her pique was perhaps a bit unjustified, for St. John did, in the fall of 1940, prepare collections of the night-flowering waterlily; these have survived and form part of the basis for the present report.

The writer and his colleagues, over a period of more than 15 yr, have tried repeatedly to re-locate the Sheep Island Lake *Nymphaea.* When conventional diurnal searches were unavailing, a vigil by canoe was attempted for one night in the hope that the behavior of the plant would call attention to its presence among the abundant day-flowering *Nymphaea odorata,* but without reward. The probable area once known as Sheep Island Lake is now heavily choked with aquatic vegetation, including water-hyacinth (*Eichhornia crassipes*), and it is possible that *Nymphaea blanda* no longer occurs at that station.

A second collection of *Nymphaea blanda* was recently found among herbarium materials obtained in the fall of 1959 by George R. Cooley, Richard J. Eaton, and James D. Ray, Jr., from near Lebanon Station, Levy County. The collection consisted of plants with unopened buds and had originally been named *Nymphaea odorata.* This station, too, seems no longer to have plants of this species.

A third station probably once existed somewhere in northern Hillsborough County. Mrs. Diddell (in correspondence, FLAS) described an episode from her youth. "We were living near Tampa, and my two brothers frequently went hunting, returning home via Cross Pond, a wide but shallow waterfilled sinkhole, where they would stop for a swim and from which they would bring me an unopened *Nymphaea* flower. I would set the bud in a soup plate full of water and place it on a corner of the piano in the living room. It was my habit to put in a couple of hours practicing after dinner each night, and by the time I was ready to sit down to the piano the *Nymphaea* flower would be fully expanded, much wider than the plate. . . . It would irk my soul that by dawn the lovely thing would be closed forever. . . . The memory of that nocturnal *Nymphaea* has remained vividly in my mind ever since. Many years later I drove back down there . . . but was told that Cross Pond had long since been filled in and no one knew anything about the nocturnal *Nymphaea.*"

Although the Nymphaeaceae, in general, have received much horticultural attention, the subgenus *Hydrocallis* has been little studied and the floral behavior of its species little investigated. Conard (1905) cultivated and carefully reported on *Nymphaea amazonum* Mart. & Zucc., but no other member of the subgenus appears to have documentation of its floral behavior. Mrs. Diddell's informal observations of her Sheep Island Lake collection thereby bear recording.

"On the advent of the third bud, I cut it just before dark . . . and put it in a bowl of water. . . . The night was bright, starry, cloudless, with no moon. . . . By 11:30 p.m. it was about half open. . . . At 4:00 a.m. . . . the flower had opened wide. . . . I could see it well, but I wanted a close careful study of it, so I picked up the bowl and started into the living room. As the light struck it, the flower snapped shut, instantaneously. . . . I do not know if this plant has a name or not, but it should be *N. heliophobia.*"

"I did not cut any of the few flowers which developed later, but studied their habits in the pool. On the morning before it opened, the bud could be detected below the surface of the water. About sundown it was entirely above the water, and about 9 p.m. showed evidence of opening. It was probably fully expanded at midnight or soon after. After daylight, the peduncle began to recurve and by mid-morning had pulled the spent flower down to the bottom of the pool, where it matured its capsule. . . . Capsule dehiscence occurred at night. Early in the morning the surface of the pool would be covered with floating seeds, each with a dark mucilaginous integument, but when the morning sun hit the pool . . . all the seeds sank to the bottom. . . . None of the seeds germinated."

SPECIMENS EXAMINED: *E. P. St. John*, 1 Oct 1940. Shallow water of ford leading to Sheep Island, The Cove, Floral City, Citrus County, Florida. FLAS 38615, FLAS 125678. *G. R. Cooley* 7151, 22 Sept 1959. Slough near Lebanon Station, Levy County, Florida. FLAS, GH, USF.

Nymphaea jamesoniana—The dean of nymphaeologists was, without question, the late Dr. Henry S. Conard, whose opulently illustrated monograph of *Nymphaea* (1905) has remained the standard of knowledge for the genus. Dr. Conard retired to Lake Hamilton, Polk County, in 1954, at the age of 80, and became an avid student of the flora of central peninsular Florida. The insubstantial leads from Mrs. Diddell and from other sources intrigued him, for he could see the probability of their correctness, based on his own observations more than a half century before. He was unable to find *Nymphaea blanda* in the field, but in the fall of 1967, guided by Mr. Tom Sexton, he made an even more unexpected find. In a pond near Arcadia, DeSoto County, he found a second species of subgenus *Hydrocallis*—*Nymphaea jamesoniana* Planch.

Dr. Conard immediately set out to determine whether the *Nymphaea* was native. Although not close to habitation, the pond from which the plants came was in the angle of two state highways and might have been subject to past disturbance and introduction. But the District Drainage Engineer (M. Y. Lett, in correspondence with Dr. Conard, now in FLAS) described the area as natural and within the flood plain of the Peace River. He did not believe it had been changed appreciably because of the adjacent roads. Although Dr. Conard collected the plant again in the following year, he did not succeed in finding it outside the original station. Whether it is, in fact, more widespread in the Peace River drainage is an investigation that was interrupted when Dr. Conard, still of sound and inquisitive mind, died in October 1971, at the age of 97.

SPECIMENS EXAMINED: *H. S. Conard*, 4 Nov 1967. Old shallow *Pontederia* pond, in angle of Fla. 70 and Fla. 72, 2.5 miles northwest of Arcadia, DeSoto County, Florida. FLAS, FSU, GH, US, USF. *H. S. Conard*, 24 Oct 1968. Shallow pond between Fla. 70 and Fla. 72, 2.5 miles northwest of Arcadia, DeSoto County, Florida. FLAS, FSU.

IDENTIFICATION—The two Florida species of subgenus *Hydrocallis*, as well as the other Florida species of *Nymphaea*, may be differentiated by the following key:

1. Petals blue (at times very pale, almost white, but always with a bluish tinge which deepens on drying); sepals with short (1-4 mm) purple lines or spots on back; carpels not fully fused, the partition between ovary cells double-walled.
   2. Leaves usually wine-red beneath; upper surface of blade without mound of tissue or viviparous plantlet; papillae (protruding tips of transverse sclereids) more closely spaced over veins; petals very faint blue to medium blue; sepals (at anthesis) 4-4.5 (– 5.5) cm long, lengthening somewhat in fruit.
      Nymphaea elegans Hook. (= *Castalia elegans* (Hook.) Greene)

2. Leaves usually green beneath; upper surface of blade with mound of fibrous tissue (rarely with viviparous plantlet) at point above attachment of petiole; papillae densely and uniformly spaced over surface; petals medium to bright blue; sepals (at anthesis) 5-6 cm long. [Horticultural hybrid, derived in part from *N. micrantha* Guill. & Perr. of West Africa.]

Nymphaea daubeniana O. Thomas

1. Petals white or yellow; sepals with fine closely-spaced lines many mm long on back, or plain; carpels fully fused, the partition between the ovary cells single-walled.
   3. Flowers night-blooming; petals white; sepals with fine closely-spaced longitudinal crimson lines; upper surface of leaf covered both with papillae (tips of transverse sclereids) and short lines (horizontal sclereids); styles clavate.
      4. Leaf blade suborbicular, green above and below, thin and easily torn. [Florida collections are var. *fenzliana* (Lehm.) Casp., with glabrous peduncles and petioles.]

         Nymphaea blanda G. F. W. Meyer
      4. Leaf blade ovate-cordate to elliptic, green above and purple below (the color restricted to numerous, short, forking, dark purple lines), firm in texture.

         Nymphaea jamesoniana Planch.
   3. Flowers day-blooming; petals white or yellow; sepals without longitudinal crimson lines; upper surface of leaf covered only with papillae; styles linear.
      5. Petals white or with slight yellowish tinge at base; leaves orbicular, the petiole nearly central; overwintering by stout elongate rhizome, without clusters of banana-like roots; seeds 2-3 mm in diam.

         Nymphaea odorata Ait. (incl. *Castalia lekophylla* Small)
      5. Petals bright yellow; leaves ovate (or orbicular if submerged), with the petiole inserted closer to the basal lobes than to the apex; overwintering by a short stem to which are attached several descending curved fleshy roots, resembling miniature (1.5-3.5 cm long) bananas; seeds 4-5 mm in diam.

         Nymphaea mexicana Zucc. (= *Castalia flava* (Leitner) Greene)

ACKNOWLEDGMENTS—The years that have elapsed since the beginning of my interest in night-flowering waterlilies have permitted the involvement of many people. I appreciate the diverse assistance given me by John Beckner, Dr. Monroe Birdsey, Dr. R. K. Godfrey, A. S. Jensen, Dr. Albert Laessle, James and Rita Lassiter, Dr. James D. Ray, Jr., Dr. Robert R. Smith, Dr. E. G. Voss, Albert A. Will, Dr. Carroll Wood, and Dr. Richard P. Wunderlin. But the most necessary help of all was given by friends now gone, Dr. Henry S. Conard and Mrs. Mary W. Diddell, and by a friend in spirit whom I never met, Dr. Edward P. St. John.

This paper is Florida Agricultural Experiment Station Journal Series No. 159.

LITERATURE CITED

CONARD, H. S. 1905. The Waterlilies, a Monograph of the Genus *Nymphaea* Carnegie Inst. Wash. Publ. 4:279 pp.

ST. JOHN, E. P. 1942. A new *Thelypteris* from Florida. Amer. Fern J. 32:145-147.

WOOD, C. E. 1959. The genera of the Nymphaeaceae and Ceratophyllaceae in the southeastern United States. J. Arnold Arb. 40:94-112.

Florida Scientist 40(2):155-159. 1977.

Earth Science

CALLIANASSID BURROWS IN THE AVON PARK FORMATION OF FLORIDA

HAYMAN SAROOP

Grand Turk, Turks and Caicos Islands

ABSTRACT: *Burrows identified as those of the decapod crustacean,* Callianassa, *occur in cores of the Avon Park Formation taken at the site of the Crystal River Nuclear Power Plant, Citrus County. The formation is a prograding carbonate shoreline sequence characterized by periodic fluctuations in sea level. Most callianassid burrows occur in a zone adjacent to, and transitional from, facies deposited in intertidal-shallow subtidal marine grass flats.**

RECONSTRUCTIONS of the environments of deposition of ancient sedimentary sequences are often handicapped by the paucity of remains of soft-bodied organisms and burrowing crustaceans. Studies of these faunal constituents must hence largely rely on indirect evidence of their former existence, whether it be deduced from community relationships or more visibly expressed in trace fossils. Biogenic structures are useful aids in deciphering the habits of missing faunal assemblages, and the traces of many genera of sessile and semisessile endobenthos have been identified by comparisons with modern analogues (Howard, 1971; Perkins, 1971). The burrowing strategies of decapod crustaceans in the Holocene sedimentary record have been well documented (MacGinitie, 1934; Pohl, 1946; Hoyt and Weimer, 1963; Shinn, 1968; Thompson and Prichard, 1969; Frey and Mayou, 1971), and their dwelling structures, or *Domichnia,* have been recognized from a wide range of environments. Decapod burrows are relics of a comparatively stable faunal element of the Avon Park Formation of Citrus County, and their mode of preservation offers clues to the habitats of the organisms and the subenvironment of sedimentation.

LOCATION AND LITHOLOGY—Five cored sections taken at the site of the Crystal River Nuclear Power Plant (Fig. 1) were studied. The cores penetrate the Pamlico, the Inglis and the Avon Park Formations revealing the lithologic sequence shown in Fig. 2.

The Avon Park Formation is a prograding carbonate shoreline sequence characterized by short-term fluctuations in sea level (Randazzo and Saroop, 1976). This is evidenced by periodic changes in the style of deposition concomitant with minor transgressive—regressive cycles of sedimentation (Fig. 2). The sequence is unconformably overlain by the Inglis Formation with facies being deposited in the supratidal, intertidal and shallow subtidal areas.

The Avon Park Formation is represented by the following succession of subfacies (classification after Dunham, 1962): Dasycladacean-foraminiferal packstone; Rooted wackestone; Dolomitized packstone; Rooted wackestone; Sapro-

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

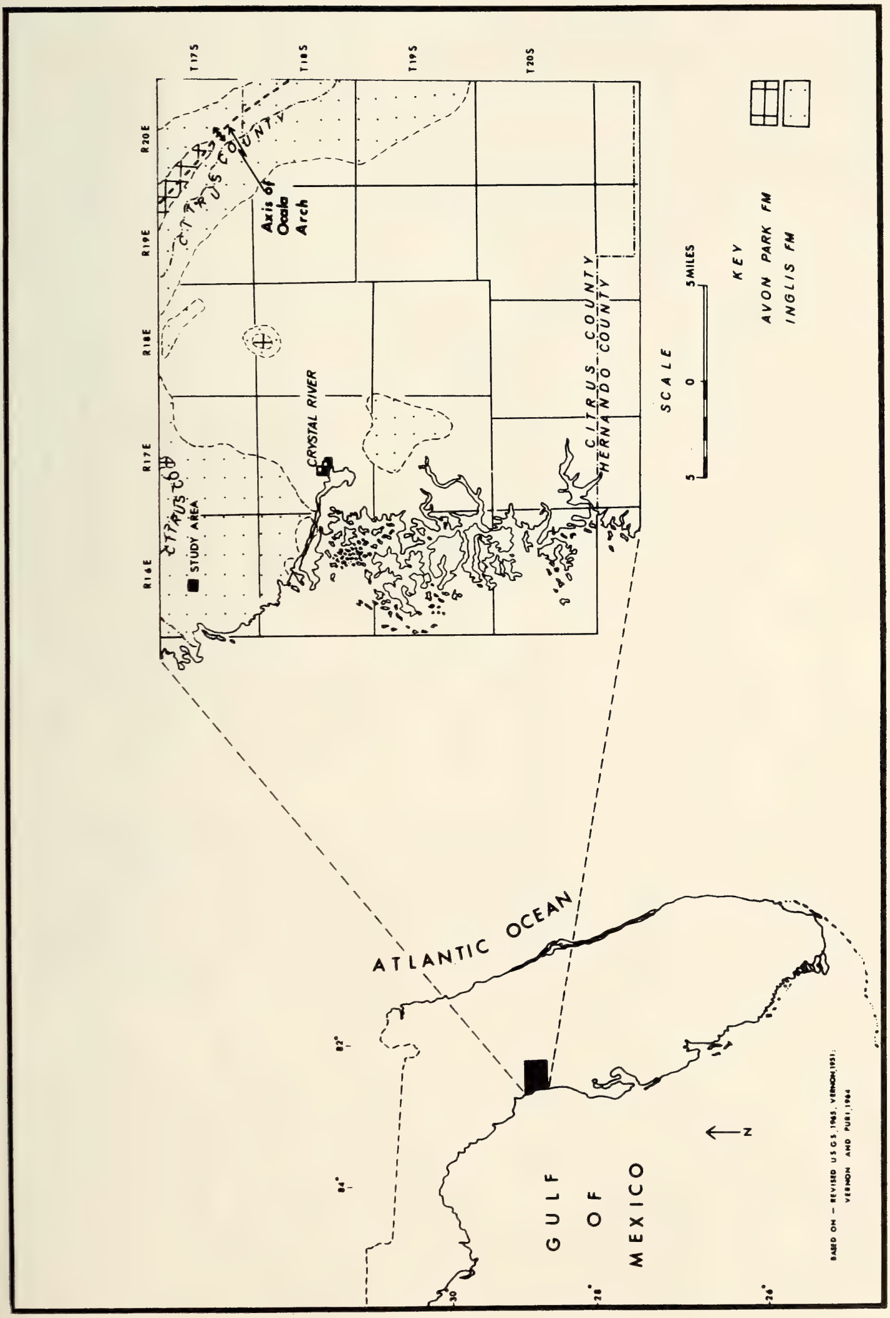


Fig. 1. Index map showing surface exposures of Inglis and Avon Park Formations in Citrus County.

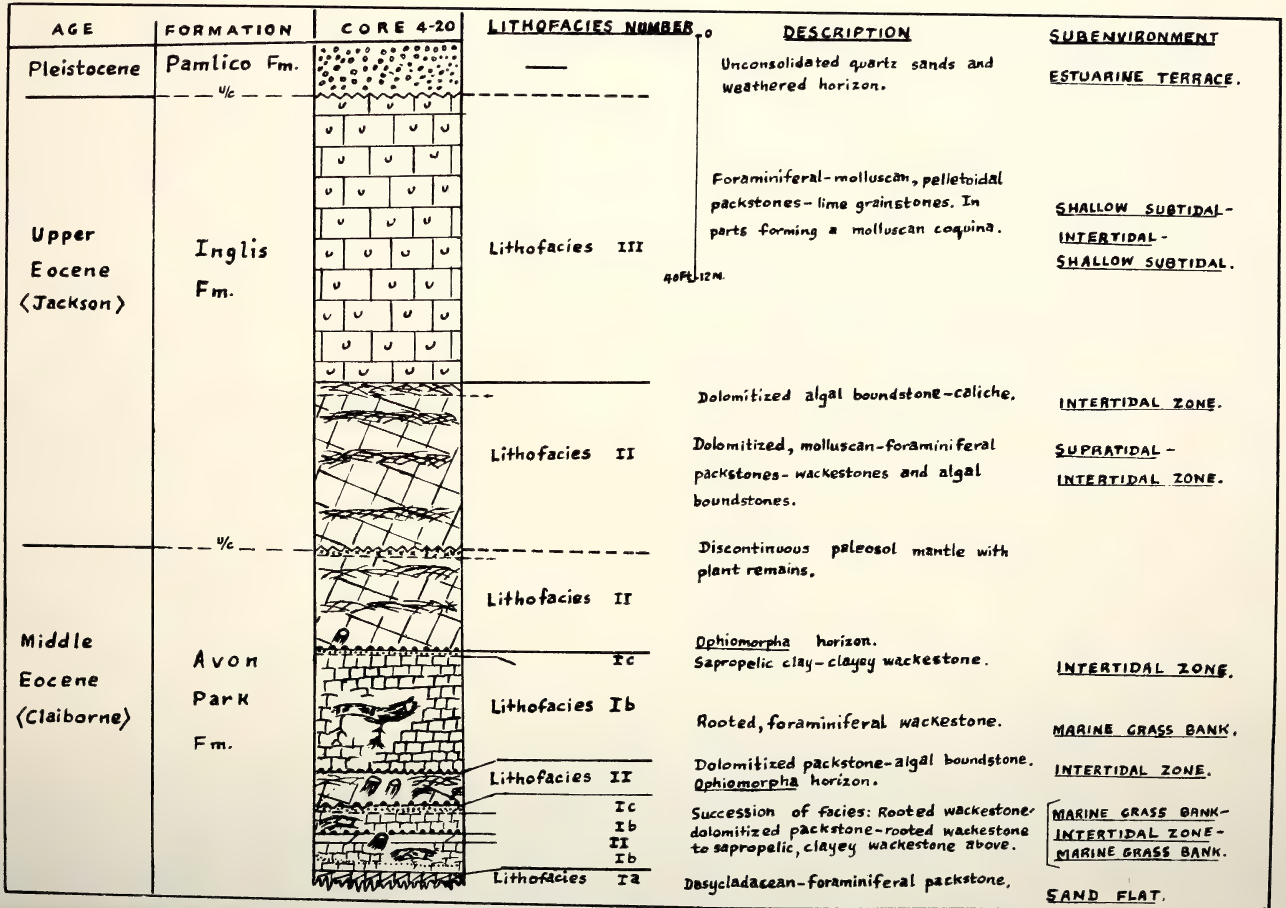


Fig. 2. Generalized succession of lithofacies from core taken at Crystal River locality.

pelic, clayey wackestone; Dolomitized packstone-algal boundstone; Rooted wackestone; Sapropelic clayey wackestone; Dolomitized packstone-algal boundstone; Dolomitized vuggy and laminated wackestones; Dolomitized algal boundstone-wackestone-packstone and a Dolomitized wackestone-paleosol. Several micro-unconformities, representing intervals of both erosion and non-deposition of sediments, are recognized in the section.

Depositional Environment and Habitat—All but one of the large, open, biogenic structures in the Avon Park Formation occur in dolomitized packstones and algal boundstones. The exception is found in a crumbly, vuggy wackestone deduced to have been deposited in a tidal pool. The burrow wall is lined with a "stacked array" of unsquashed, fine gravel-sized, pelletoidal aggregates (cf. Hester and Pryor, 1972, p. 685, Fig. 11). The retention of the original pelletoidal form is an indication that such sediments were kept wet and cohesive rather than being continuously exposed to wave action.

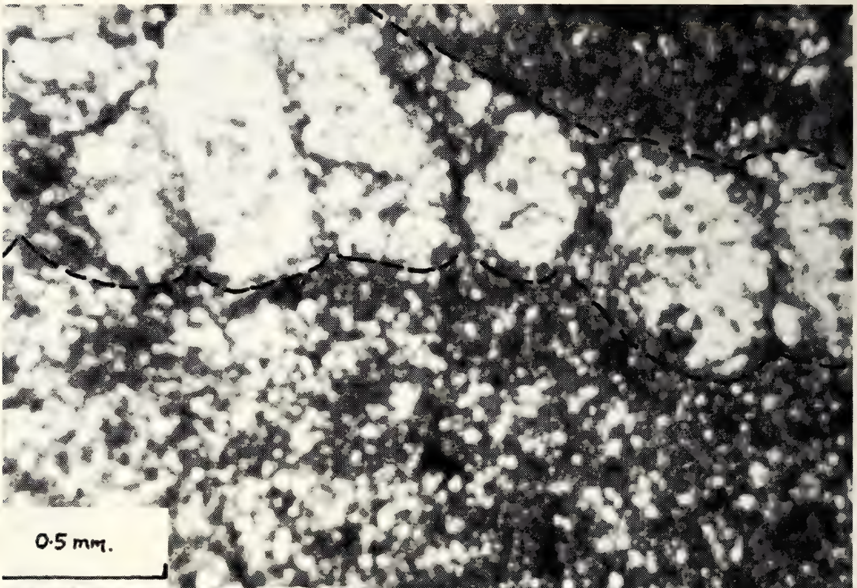
The other cavities occur in facies which were deposited in tidal areas adjacent to, and transitional from, shallow subtidal marine grass flats (Fig. 2). Thin section examination shows that the burrows are often fringed by algal boundstones having a net-like fabric, and their walls abut against molds of foraminifera and other bioclasts. Algal-laminated structures are one of several indicators of intertidal-supratidal deposition (Shinn et al., 1969).

The intertidal zone itself is favorable for the construction of large dwelling structures as there is a virtual absence of the tangle of subsurface roots, rootlets and rhizomes propagated by marine grasses. Low-energy mud flats are also continuously supplied with bacteria-laden detritus washed in by tides so that they afford suitable feeding grounds for many species of microphagous malacostracans. Analyses of fecal pellets and examination of undigested particles in the stomach of species of *Callianassa* indicate that bacteria, diatoms and algal cells are important elements of their everyday diet (MacGinitie, 1934; Pohl, 1946; Frankenberg et al., 1967; Pryor, 1975).

Description of Ophiomorpha—Although several fragments of thoracic appendages of decapod crustaceans occur at the base of the Inglis Formation, only part of an antenna with its podomeres was identified from the Avon Park horizon (Fig. 3). However, recognition of the excavators is facilitated by survival of the structures as open vugs, which resulted in many traces of their anatomy being preserved.

The full lengths of burrows could not be determined from the core samples, but many were found to be in excess of 20 cm. Their mid-shafts range from 11 to 15 mm in diam, reflecting significant decreases during the early stages of lithification. This may be contrasted with Holocene shafts made by specimens of *Callianassa major* at Bulkhead Shoal, Beaufort, North Carolina, which clustered at between 17 and 22 mm (Pohl, 1946). Of 18 burrows examined, 15 were between 17 and 22 mm diam; the remaining three, apparently constructed by juveniles, measured only 7-8 mm (Pohl, 1946).

Despite decreases in burrow diam, the former occupants can be readily identified. For example, the sides show numerous rows of linear micro-furrows resulting from the scrapings of the feathery, sensory hairs of the creatures (Fig. 4). Many tiny pits, between 0.5 and 0.6 mm, penetrate as much as a mm or more into the walls; these could only have been pierced by the pointed chelae, that is,



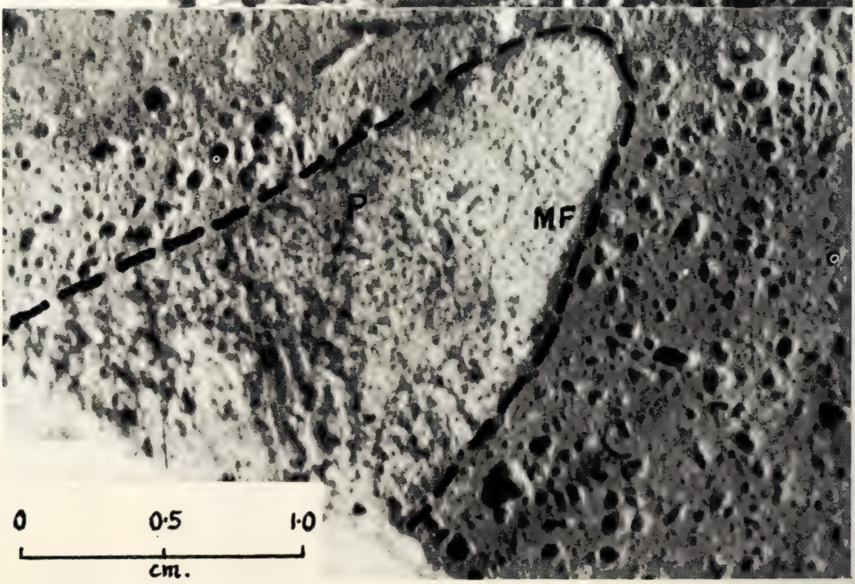


Fig. 3. (upper) Section through antenna of a decapod crustacean, possibly *Callianassa* sp., Dolomitized wackestone, Avon Park Formation.

Fig. 4. (lower) Oblique view of *Ophiomorpha*, a form of burrow made by a species of the decapod crustacean, *Callianassa*. The walls of the burrow are described by numerous tiny pits (P), and linear micro-furrows (MF) made by sensory hairs of the organism. Dolomitized algal boundstone, Avon Park Formation.

the fifth endopodites, of the walking limbs of decapods. The frequency of the scratches is an indication that the burrows did, in fact, function as *Domichnia* or dwelling structures.

Most of the portions of the structures are inclined to the bedding (or laminations), some are U-shaped. There appear to have been a few horizontal galleries since several cavities of suitable size were reported in the core record at this horizon.

The size and geometry of the burrows and the presence of numerous scratch marks are analogous to those made by modern decapods. The imprints of abdominal grooves (Fig. 5) and the nature of the depositional environment (Fig. 2) affirm that the structures housed a species of callianassid shrimp and should, more properly, be referred to as the ichnogenus, *Ophiomorpha* (Hantzschel, 1952; Weimer and Hoyt, 1964; Hester and Pryor, 1972).

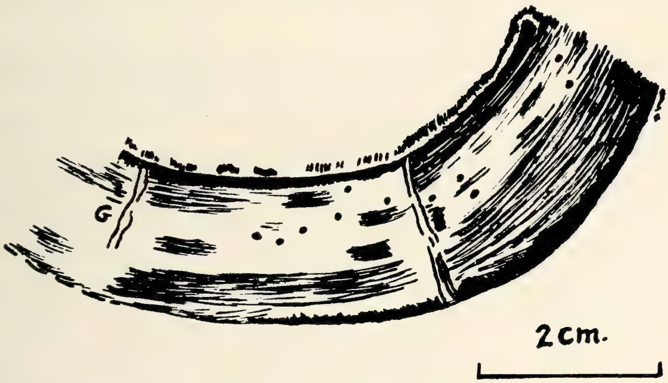


Fig. 5. Sketch of longitudinal section of the U-turn of *Ophiomorpha* to show imprints of segmental grooves (G). Dolomitized algal boundstone. Avon Park Formation.

Discussion—Burrows excavated by species of the callianassid shrimp have been observed in a wide range of estuarine and marine environments, including low energy tidal flats, coastal lagoons and low energy neritic zones (Pohl, 1946; Weimer and Hoyt, 1964; Shinn, 1968; Frey and Mayou, 1971; Pryor, 1975). However, most dwelling cavities are filled in by later sediments or destroyed by sedimentary processes. Their survival as open vugs in the Avon Park Formation is attributable to the low energy of the environment and the general progradational nature of the shoreline. Modern analogues have been found in tidal channels in South Florida where open burrow complexes occur under as much as 8 ft of overburden (Shinn, 1968). The various species of *Callianassa* tend to be gregarious and are almost constantly involved in adding new tunnels or in extending their dwellings so that the potential of burrow systems for being preserved in the fossil record is greatly enhanced.

Conclusions—The large open burrows in the sections studied are interpreted as former dwellings of a species of shrimp. The most common decapod crustacean in Middle and Upper Eocene strata of the northern sector of Citrus County is *Callianassa inglisestris*, which has been collected from the base of the

Inglis Formation (Roberts, 1953). While it has not been identified from the Avon Park horizon, its general stratigraphic occurrence suggests that the species, or a closely related form, inhabited the *Ophiomorpha* structures.

The preservation of the structures as open vugs is related to the low energy of the environment of deposition and the general progradational nature of the shoreline. The burrows could not have remained thus in shallow subtidal areas where sedimentary processes are active.

ACKNOWLEDGMENTS—I express my thanks to David Nicol and A. F. Randazzo for their critical review of the original manuscript.

LITERATURE CITED

DUNHAM, R. J. 1962. Classification of carbonate rocks according to depositional texture. Pp. 108-121. *In* W. E. HAM, ed. Classification of carbonate rocks. Amer. Assoc. Petrol. Geol. Mem. 1. Tulsa.

FRANKENBERG, D., S. L. COLES AND R. E. JOHANNES. 1967. The potential trophic significance of *Callianassa major* fecal pellets. Limnol. Oceanogr. 12:113-120.

FREY, R. W., AND T. V. MAYOU. 1971. Decapod burrows in Holocene barrier island beaches and washover fans, Georgia. Senckenberg. Marit. 3:53-77.

HANTZSCHEL, W. 1952. Die Lebensspur *Ophiomorpha* Lundgren im Miozan bei Hamburg ihre weltweite Verbreitung und Synonymie. Mitt. Geol. Staatinst. Hamburg 21:142-153.

HESTER, N. C., AND W. A. PRYOR. 1972. Blade-shaped crustacean burrows of Eocene age: A composite form of *Ophiomorpha*. Geol. Soc. Amer. Bull. 83:677-688.

HOWARD, J. D. 1971. Trace fossils as paleoecological tools. Pp. 184-212. *In* J. D. HOWARD ET AL., eds. Recent Advances in Paleoecology and Ichnology. Amer. Geol. Inst. Short Course Lecture Notes. Washington, D.C.

HOYT, J. H., AND R. J. WEIMER. 1963. *Callianassa major* burrows, geologic indicators of littoral and shallow neritic environments. Georgia Acad. Sci. Bull. 21:10-11. (abstract).

MACGINITIE, G. E. 1934. The natural history of *Callianassa californiensis* Dana. Amer. Midland Nat. 15:166-177.

PERKINS, B. F. (ED.) 1971. Trace fossils, a field guide to selected localities in Pennsylvanian, Permian, Cretaceous and Tertiary rocks of Texas, and related papers. Misc. Public. 71-1, School of Geoscience Louisiana State Univ. Baton Rouge.

POHL, M. E. 1946. Ecological observations on *Callianassa major* Say at Beaufort, North Carolina. Ecology 27:71-80.

PRYOR, W. E. 1975. Biogenic sedimentation and alteration of argillaceous sediments in shallow marine environments. Geol. Soc. Amer. Bull. 86:1244-1254.

RANDAZZO, A. F., AND H. C. SAROOP. 1976. Sedimentology and paleoecology of Middle and Upper Eocene carbonate shoreline sequences, Crystal River, Florida, U.S.A. Sediment. Geol. 15:259-291.

ROBERTS, H. B. 1953. A new species of decapod crustacean from the Inglis member Appendix. Pp. 64-67. *In* H. G. RICHARDS AND K. V. M. PALMER (eds). Eocene Mollusks from Citrus and Levy Counties. Florida Geol. Surv. Bull. 35. Tallahassee.

SHINN, E. A. 1968. Burrowing in Recent lime sediments of Florida and the Bahamas. J. Paleontology 42:879-894.

————, R. M. LLOYD AND R. N. GINSBURG. 1969. Anatomy of a modern carbonate tidal flat, Andros Island, Bahamas. J. Sedim. Petrology 39:1202-1208.

THOMPSON, L. C., AND A. W. PRICHARD. 1969. Osmoregulatory capacities of *Callianassa* and *Upogebia* (Crustacea: Thalassinidea): Biol. Bull. 136:114-129.

WEIMER, R. J., AND J. H. HOYT. 1964. Burrows of *Callianassa major* Say, geologic indicators of littoral and shallow neritic environments: J. Paleontology 38:761-767.

Florida Sci. 40(2):160-166. 1977.

Biological Sciences

PREDATION ON INTRODUCED GRASS CARP (*CTENOPHARYNGODON IDELLA*) IN A FLORIDA LAKE

Robert D. Gasaway

Florida Game and Fresh Water Fish Commission, Lake Wales, Florida 33853

Abstract: *Grass carp (*Ctenopharyngodon idella*) stocked for aquatic weed control in Lake Baldwin were preyed upon by largemouth bass (*Micropterus salmoides*). Shifts from other prey with a selectivity toward grass carp were found. Implications of changes in the predator prey relationship are discussed. Largemouth bass predation is a factor to be considered when stocking grass carp.*[*]

In April, 1975, a project was undertaken on Lake Baldwin, a 193 acre lake in Orange County, Florida. The lake was under an aquatic plant management program conducted by the U. S. Navy with direction from the Florida Game and Fresh Water Fish Commission. *Hydrilla verticillata,* an exotic macrophyte, *Panicum* spp. and various forms of blue-green algae dominated the plants of the ecosystem. In the past, stands of *Najas guadalupensis* were present in the lake along with heavy algal blooms. The lake drainage basin is almost entirely urbanized and excessive amounts of nutrients add to the complexity of the system. A chemical application program using "Hydout TM" (endothal technical), a product of the Pennwalt Corporation has been used in the lake for several years to manage *Hydrilla* (Table 1).

In 1974, the U. S. Navy requested that Lake Baldwin be stocked with grass carp. At that time the species was being researched by the Florida Game and Fresh Water Fish Commission and the Department of Natural Resources to evaluate the feasibility of its use in Florida for aquatic weed control. Literally hundreds of published papers were available on the ability of the species to control aquatic plants, but little information was available on the associated ecological changes.

The first pond experiments in Florida using grass carp were performed by Dr. D. L. Sutton in four 0.25 acre (0.1 ha), man made ponds near Orlando, Florida. Results of Sutton's (1974) weed control experiments with grass carp indicated high stocking rates were necessary to control hydrilla. Stocking densities of 30 to 80 lb/acre (34 to 91 kg/ha) did not control hydrilla in the Orange County ponds. Only when carp populations were increased to 160 to 280 lb/acre (182 to 320 kg/ha) were desirable results obtained. Sutton concluded that herbicides or mechanical methods used in conjunction with grass carp would be more effective than using the fish alone.

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

TABLE 1. Chemical treatments on Lake Baldwin, Orlando, Florida, using "hydout TM" endothall technical.[1]

Year	Pounds of Chemical
1972	88,200 lbs.
1973	46,000 lbs.
1974	57,050 lbs.
1975	30,362 lbs.

[1]Author does not necessarily endorse the product.

MATERIALS AND METHODS—A project plan using chemical treatment and grass carp stocking to control noxious vegetation was undertaken in Lake Baldwin. Chemical treatment would be conducted as in previous years. The first phase of the project was to evaluate the effectiveness of stocking grass carp to establish a population for weed control.

Grass carp were obtained from the Florida Game and Fresh Water Fish Commission's Richloam hatchery near Webster. They were seined from ponds on the hatchery and stocked 15 to 16 April, 1975 in two groups totaling 4,999 fish. Fish sizes measured from 120 to 212 mm total length; however, most were small and slightly emaciated. The fish were stocked in a small, hydrilla choked cove (approximately 2 acres) on the east side of Lake Baldwin. The first group (2,500) was stocked April 15, 1975 in the cove without predator removal. The second group (2,499) was stocked on April 16, 1975 in the cove with large predators removed by electrofishing. The cove was blocked by seine netting during initial stocking and opened after the second stocking.

Two techniques, electrofishing and seining, were used to collect fishes in the cove and along the lake's south and west shores. Larger fish were captured by using a front-mounted, boom-type electrofishing unit with copper electrodes and gasoline generator. Seining yielded the smaller fish and was accomplished by the use of 4.6 m (3.2 mm mesh) and 9.1 m (6.4 mm mesh) seine nets. Electrofishing was conducted in the cove 6 hr after stocking the initial 2,500 fish. Attempts were made to collect all predatory fish longer than approximately 100 mm (the size of the smallest stocked grass carp). A second predation evaluation on these stocked carp was conducted after removal of the seine barrier. Two 152 m shoreline areas were chosen to study predation in the main body of the lake. Ten small seine hauls, five large seine hauls, and approximately 15 min of electrofishing were done on each shoreline. Each sample was taken to determine densities of grass carp and other potential forage fishes, and stomach contents of largemouth bass. One shoreline was sampled in mid-morning and the other in late evening (mostly after dark).

Feeding selectivity of largemouth bass for fishes in the lake was determined by using a quantitative index (Ivlev, 1961), calculated by the equation:

$$E = \frac{r_1 - P_1}{r_1 + P_1}$$

where r_1 is the occurrence of an item in the fish diet expressed as a percentage of total number of P_1 is the relative quantity of the same item in the lake expressed as a percentage. The limiting values of E are -1.0 (indicating complete selection against an item) and +1.0 (indicating exclusive selection for an item). An E value of 0.0 indicates no selection.

RESULTS—Twenty-two largemouth bass from 286 to 559 mm were collected and examined for stomach contents. Sixteen contained grass carp and 6 were empty (Table 2). The smallest bass taken which contained grass carp for stomach contents was considered to be the smallest size capable of feeding on the stocks. No other piscivorous fishes were captured in the cove.

TABLE 2. Stomach contents of largemouth bass captured in Lake Baldwin after the initial cove stocking on April 15, 1975.

Largemouth bass		Stomach contents		
Length (mm)	Weight (g)	Food items	Number	Mean Length (mm)
559	2476.1	Grass carp	2	137
486	1680	" "	1	100
430	1367	" "	4	119
408	953.7	Empty		
430	1213.6	Grass carp	3	111
428	1167.8	" "	2	128
378	746.9	Empty		
372	651.3	Empty		
369	662.5	Grass carp	1	120
397	919.0	Empty		
359	592.9	Empty		
336	502.0	Grass carp	1	130
321	442.0	Empty		
311	390.9	Grass carp	1	120
336	494.0	" "	2	117
337	448.0	" "	1	130
286	328.3	" "	2	115
291	328.0	" "	1	125
525	2466.0	Grass carp and Unidentified fish	2	117
546	2636.5	Grass carp	2	155
518	2259.4	" "	3	139
361	572.0	Empty		

After the second stocking, largemouth bass are sampled. Only two bass were captured and neither contained food items. The barrier at the mouth of the cove had proved ineffective and grass carp were distributed in all areas of the lake which were sampled. The barrier was removed at that time and cove sampling was discontinued.

Table 3 gives a summary of the species captured, their relative abundance, and size range of fishes sampled on the south shore. The large number of bass present is due primarily to recent spawning since 134 fish were less than 50 mm. When examining stomach contents of all largemouth bass captured, those probably incapable of feeding on fish contained only sunfish—either redear or bluegill (Table 4). Only four of the seven bass were presumed capable of taking grass carp. Ivlev's selectivity index of +.26 demonstrates some selectivity for *Lepomis* spp. overall and +1.00 for those specimens 286 mm or over.

TABLE 3. Species composition, relative abundance and sizes of fishes captured in Lake Baldwin, south shoreline, April 23, 1975 at night.

Species	Number	Size Range (mm)	% Composition
Largemouth bass (*Micropterus salmoides*)	141	26-512	54.4
Golden shiner (*Notemigonus crysoleucas*)	3	26-294	1.2
Seminole killifish (*Fundulus seminolis*)	2	8-29	.8
Bluegill (*Lepomis macrochirus*)	99	74-168	38.2
Grass carp (*Ctenopharyngodon idella*)	3	133-212	1.2
Bluespotted sunfish (*Enneacanthus gloriosus*)	2	35-40	.8
Brown bullhead (*Ictalurus nebulosus*)	1	347	.4
Redear sunfish (*Lepomis microlophus*)	1	186	.4
Warmouth (*Lepomis gulosus*)	1	74	.4
Threadfin shad (*Dorsoma petenense*)	2	100-107	.8
Brook silverside (*Labidesthes sicculus*)	1	83	.4
American eel (*Anguilla rostrata*)	3	481-616	1.2
TOTAL	259		

The following morning the west shore was sampled using similar procedures. Summary of the species captured, their relative abundance and size range is presented in Table 5. When examining largemouth bass captured which were capable of feeding on grass carp (Table 6), only grass carp were present in the stomachs. Ivlev's selectivity index of +.68 demonstrates selectivity for grass carp overall and +1.00 for those fish which were 286 mm or over.

TABLE 4. Stomach contents of largemouth bass captured in Lake Baldwin, south shoreline, April 23, 1975 at night.

Length (mm)	Weight (g)	Stomach contents
512[1]	1877	Sunfish remains
435[1]	1072	Empty
347[1]	517	Sunfish remains (130 mm. length)
299[1]	301	Empty
179	62	Empty
161	45	Empty
146	35	Grass shrimp

[1]Probably capable of taking grass carp.

A lakewide sampling effort using electrofishing was initiated on 16 May, 1975, during daylight hours, to sample largemouth bass food habits and grass carp present in the lake. Grass carp were not present in the stomach contents of bass. The catch per unit effort of electrofishing had decreased from eight grass carp per hr to two grass carp per hr. Average size of grass carp captured by this method increased from 158 mm to 183 mm.

TABLE 5. Species composition, relative abundance and sizes of fishes captured in Lake Baldwin, west shore, April 24, 1975, during daylight hours.

Species	Number	Size Range (mm)	% Composition
Largemouth bass	44	21-576	46.8
Golden shiner	1	241	1.1
Bluefin killifish	6	19-39	6.4
Bluegill	18	59-177	19.1
Grass carp	3	135-141	3.2
Bluespotted sunfish	4	14-134	4.0
Brown bullhead	10	24-349	10.6
Warmouth	2	62-97	2.1
Brook silverside	6	78-90	6.4
TOTAL	94		

DISCUSSION—These data indicate bass predation to be a significant factor on stocked grass carp in a lake system with an existing largemouth bass population. Stocking mortality, due to handling, was only 8 fish, while 28 were known to succumb to predation from limited sampling in a short period of time.

Largemouth bass are considered by most fishery biologists to be "sight feeders". This could partially explain their apparent heavy predation on grass carp. Lewis, et al. (1961) investigated the food choices of the largemouth bass based on availability and vulnerability of food items. They found that golden shiners were eaten more readily than any other food item and continued, ". . . the constant movement on the part of the shiners appeared to attract the bass and may account for the shiner appearing as the preferred food." Also, bass seemed to prefer items which were thrown into the water causing a disturbance. Kramer and Smith, (1962), using direct observation concluded that bass fingerling fed mostly on moving prey. Similar observations were made by Chew (1974) and

TABLE 6. Stomach contents of largemouth bass captured electrofishing in Lake Baldwin, west shore at 1:00 p.m., April 24, 1975.

Length (mm)	Weight (g)	Stomach contents: Food items	Number	Length (mm)
576	3012.4	Empty		
455	1392.4	Grass carp	1	120
358	585.7	Grass carp	1	(pharyngeal teeth)
376	695.4	Empty		
360	360.1	Empty		
286	280.0	Grass carp	1	120
255	180.8	Bass fry	2	27
223	118.9	Brown bullhead	2	25
225	111.0	Unidentified remains		
198	88.1	Small fry	2	20
164	49.5	Bass fry	4	25
141	30.0	Bass fry	4	22

McLane (1955) in Florida. A general conclusion was drawn by Marler and Hamilton (1967) that prey movement evoked feeding in a great variety of predators. Based on personal observations, grass carp tend to move incessantly and occasionally disturb the water's surface. This is a possible explanation for their appearance as preferred food. Also, largemouth bass stomachs taken during the day contained grass carp while none were found in stomachs collected at night.

A second explanation would be the fact that the grass carp are non-native stocked fish. Generally, stocked populations are weaker and less well adapted to the environment than established native populations. This explanation is supported in part by Avault, Smitherman, and Shell (1966) when attempting to establish a population of common carp (*Cyprinus carpio*). They found introduced fingerling carp to be highly susceptible to predation by largemouth bass. In three ponds the mortalities were 95% within 1 month, 77% within 12 months, and 87% within 29 months. Stocking with larger carp, 20 to 40 cm in length, resulted in better survival in two bluegill brood ponds. After 84 da, one pond was drained and 18 of 20 carp were recovered. The second pond was drained 99 days after stocking and all 20 carp were recovered.

Many of the grass carp which were stocked appeared to be emaciated. Herting and Witt (1967) showed that impairment of physical condition significantly increased the vulnerability of some fishes to predation. This could also contribute to the vulnerability of introduced grass carp.

The overall effects of such predation shifts would depend on many factors. Swingle (1950) illustrated the importance of predator-prey relationships using largemouth bass and *Lepomis* spp. Other studies (Forney, 1974; Carlander, 1957) have illustrated the importance of indirect interactions on multi-species populations based on prey densities. Changes occurred in both natural populations and angler success with changes in predation.

Bennett (1954) initially recognized that the effects of predation on natural populations were a necessity in maintaining good reproduction and stocks. He continued (1962) illustrating that changes in predator pressure could cause insufficient culling of the fish population, overpopulation of forage, excessive food competition and stunting. Two points were well made concerning introduction of potential forage fishes: (1) food chains of fishes are very complex and the introduced species may not serve the purpose intended (2) forage fishes that are capable of expanding their populations in the face of existing populations of predatory species already present may constitute a danger of over-population as the gizzard shad, *Dorosoma cepedianum*, has done in some waters.

It is now an established fact that the grass carp will reproduce in warm water streams and reservoirs associated with rivers in North America (Sport Fishing Institute, 1975; Stanley, 1976). The interference of the predator-prey balance by stocked fingerling grass carp or by natural reproduction is important to consider in future stocking programs in the United States.

In summary, largemouth bass displayed selectivity for stocked grass carp over other available forage; therefore, predation is determined to be an important factor when attempting to establish grass carp in a lake for weed control.

Stocking grass carp of forage size will probably affect feeding conditions of largemouth bass.

Hypothetically, relief of predator pressure on other forage over a lengthy period of time or during critical times of the year by stocking forage size grass carp or grass carp reproduction could cause insufficient culling of the fish population, over-population of forage, excessive food competition among other forage species and stunting of forage fishes.

Acknowledgments—This study was funded by the U. S. Navy A-E Contract N62467-75-C-0687. Thanks are due to Commander H. M. Andress, Lt. Commander L. Bonning and Mr. R. J. Moffatt for their courtesy and help during the study. Thanks are especially due to Mr. Douglas DuRant for his assistance in the field work. Mr. J. W. Woods, Mr. F. G. Banks, Mr. F. T. Ware, Dr. D. L. Sutton, and Mr. R. S. Montegut reviewed the manuscript and provided helpful suggestions.

LITERATURE CITED

Avault, J. W., R. O. Smitherman and E. W. Shell. 1966. Evaluation of eight species of fish for aquatic weed control. Proc. World Symp. on Warm Water Pond Fish Culture. Rome, Italy.

Bennett, G. W. 1954. The effect of late-summer drawndowns on the fish population of Ridge Lake, Coles County, Illinois. Bull. Illinois. Nat. Hist. Surv. 26:216-276.

__________. 1962. Management of Artificial Lakes and Ponds. Reinhold Publ. Corp. New York.

Carlander, K. D. 1957. Disturbance of the predator-prey balance as a management technique. Trans. Amer. Fish. Soc. 87:34-38.

Chew, R. L. 1974. Early life history of the Florida largemouth bass. Florida Game and Fresh Water Fish Comm. Fishery Bull. 7:1-76.

Forney, J. L. 1974. Interaction between yellow perch abundance, walleye predation and survival of alternate prey in Oneida Lake, New York. Trans. Amer. Fish Soc. 103:15-24.

Herting, G. E., and A. Witt, Jr. 1967. The role of physical fitness of forage fishes in relation to their vulnerability to predation by Bowfin (*Amia calva*). Trans. Amer. Fish Soc. 96:427-430.

Ivlev, V. S. 1961. Experimental ecology of the feeding of fishes. Yale University Press. New Haven, 302 p.

Kramer, R. H., and L. L. Smith. 1962. Formation of year classes of largemouth bass. Trans. Amer. Fish Soc. 91:29-41.

Lewis, W. M., G. E. Gunning, E. Lyles and W. L. Bridges. 1961. Food choice of largemouth bass as a function of availability and vulnerability of food items. Trans. Amer. Fish Soc. 90:277-280.

Marler, P., and W. J. Hamilton, III. 1967. Mechanisms of animal behavior. John Wiley and Sons, Inc. New York.

McLane, W. M. 1955. Fishes of the St. Johns River System. Ph.D. Dissert. Univ. Florida. Gainesville.

Sport Fishing Institute. 1975. North American Reproduction of Grass Carp. SFI Bull. 269:1-5.

Stanley, J. G. 1976. Reproductive requirements and likelihood for naturalization of escaped grass carp in the United States. Symposium on Transplants and Introduction of Fishes in North America. Ann. Meeting Amer. Fish. Soc.

Sutton, D. L. 1974. Control of aquatic plant growth in earthen ponds by the White Amur. Ann. Res. Rept. Fla. Dept. Nat. Res. 75 p.

Swingle, H. S. 1950. Relationships and dynamics of balanced and unbalanced fish populations. Alabama Agr. Exp. Sta. Bull. 274:1-74.

Florida Sci. 40(2):167-173. 1977.

Engineering Science

REMOTE SENSING OF TURBIDITY IN BISCAYNE BAY, FLORIDA

D. C. Rona[1]

Department of Mechanical Engineering, University of Miami, Coral Gables, Florida 33124

Abstract: *Multispectral Scanner (MSS) images of Biscayne Bay, Florida from the LANDSAT satellite were examined to evaluate their potential as a means of monitoring turbidity in the Bay. MSS images were found to be useful in detecting and monitoring both man made and natural suspended sediment. Man made sediment plumes emanated from a dredging operation in the principal ship channel connecting Biscayne Bay to the sea (Government Cut). Natural suspended sediment was tentatively identified emanating from a bank of carbonate sediments along the seaward margin of Biscayne Bay (the Safety Valve region). Distribution of both man made and natural suspended sediment is closely related to tidal cycle. The technique employed provides repetitive, synoptic data over large areas and greatly reduces the volume of in situ measurements required to accurately describe turbidity in a near shore environment.*°

Suspended particulate matter occurs naturally in all world oceans. It is most obvious and of most concern in the near-shore environment where it affects the penetration of daylight into the sea (a prime controller in the marine ecosystem). Turbidity has become the accepted term used to describe the lack of optical clarity in water. Definitions of turbidity vary (McCluney, 1975). Turbidity is here considered to be caused by suspended particulate matter and hence is a qualitative measure of the relative particulate matter concentration. Previous methods to measure the nature and movement of turbidity have been point sample techniques which severely limit data synopticity.

Biscayne Bay is a large, shallow, protected lagoon, 56 km long, up to 16 km wide, and 3.6 m deep. Land use around the Bay varies from commercial and industrial to agricultural and recreational. The Bay itself is important to man as a nursery for local fisheries, a buffer against the brunt of storm waters, and a source of recreation.

Turbidity in Biscayne Bay must be monitored and understood as it directly relates to the health of this environment. Turbidity is beneficial as a substrate for near-surface microorganisms (ZoBell, 1946), and detrimental as a reducer of light penetration to benthic flora. The effects of turbidity on fish and shellfish are highly controversial; however, it is agreed that prolonged exposure to excessive turbidity is damaging to fauna.

Materials and Technique—In the monitoring of turbidity, remote sensing from a satellite is the most efficient means of collecting synoptic data over large areas. The NASA LANDSAT satellite is equipped with a Multispectral Scanner system (MSS) which simultaneously images four spectral bands. These bands are Band 4 (wavelengths 0.5 to 0.6μm) Band 5 (wavelengths 0.6 to 0.7μm) Band 6

[1]Present Address: Water Management Division, Metropolitan Dade County, Environmental Resources Management, 909 S.E. 1st Avenue, Miami, Florida 33131.

°The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

(wavelengths 0.7 to 0.8μm) and Band 7 (wavelengths 0.8 to 1.1μm). Utilizing the spectral information, subtle color patterns may be detected. These color variations indicate, in part, the presence and concentration of turbidity.

The maximum utilization of MSS satellite data involves complex algorithms (Maul and Gordon, 1975) with variables that are difficult to define. Simpler methods of infiltration and selection, requiring previously developed algorithms for image alignment and handling procedures, provide an immediate output that may be utilized for qualitative analysis.

This investigation utilized computer types of LANDSAT images on the General Electric Image 100 System. For efficient utilization of the System in attaining the maximum scale print-out maps, only the northern portion of Biscayne Bay images was used. The maximum resolution capability of the system was attained (each printed symbol represented an area of 80 sq m).

MSS data was recorded on computer tape in four bands each containing relative radiance information in a scale of 0 to 63 for 6 and 7, and 0 to 127 for the remaining three bands. These numbers (which shall be called digital values) are an indication of the relative intensities within the wavelengths accepted by a given band. Zero (0) represents the lack of any measurable radiance (black); sixty three (63) represents the highest measurable radiance. (The scale is adjusted prior to launch to the anticipated range of radiance values.) Land and clouds reflect more light than water so a radiance range cut off filtration is used to select those digital values which correspond to water. The Image 100 system is capable of producing 8 theme images with each theme assigned one or more digital values. These images are shown in color on a video display, or symbolically in black and white on a line printer. To achieve maximum spacial resolution in the present study, a map was printed using symbols to represent the digital values under examination. These maps were then colored to aid visual interpretation and contoured for presentation (i.e. figures 1b and 1c).

Images were selected at various stages of the tide with moderate cloud cover. Each image was displayed and the prominent marine features divided into 8 theme maps. A breakdown of the conditions and observations for each day's data are presented in Table 1. The relative radiance value as given by the digital values are consistent within each image. That is, a given digital value corresponds to the same conditions throughout the image (assuming the absence of spotted atmospheric haze). However the digital values in this investigation cannot be compared directly from image to image due to daily atmospheric differences.

Observations—On two days, April 3 and June 14, 1974, a plume of high radiance values was observed exiting Government Cut (e.g. fig. 1b). On April 3, the tide had been ebbing from the Bay for 5 hr. On June 14, the tide had been ebbing from the Bay for 6 hr and had just begun to reverse into the Bay. On both days a dredge was operating in Government Cut to deepen the channel. On January 4, 1974 a similar situation without dredging operations produced no plume. The plumes are unrelated to bottom topography and can be traced about 3 mi north of Government Cut along the Miami Beach coastline. The satellite observations

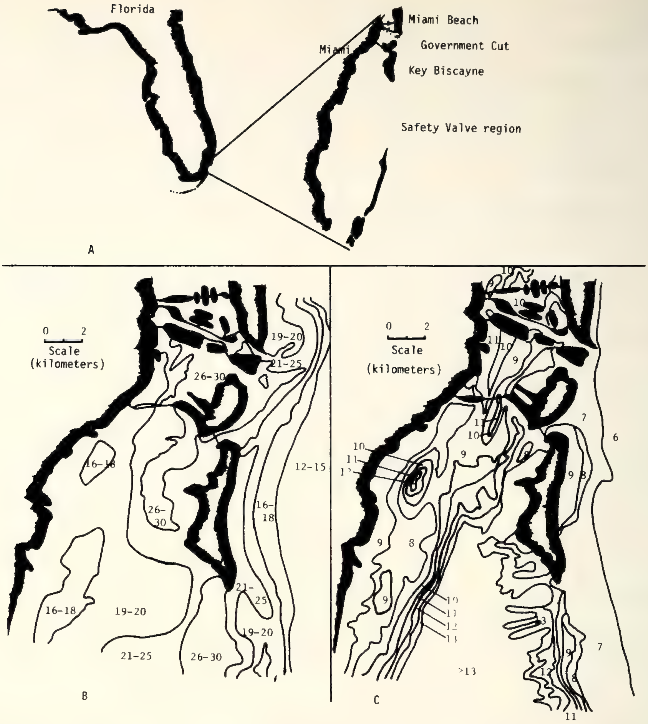


Fig. 1. A. Location of Biscayne Bay with respect to Florida; B. Radiance map of northern Biscayne Bay on April 3, 1974 in band 5. Numbers indicate values within the contour lines; C. Radiance map of northern Biscayne Bay on February 26, 1974 in band 5. Numbers indicate digital values within contour lines.

correspond to acoustic observations in May of 1974 by Proni and others (1975), that delineated a plume of suspended material extending 5 mi north from the dredging operation in Government Cut. The acoustically observed plumes outside Biscayne Bay and the plumes observed by LANDSAT occurred only on days of ebbing tides coincident with dredging operations. Therefore, it is inferred that the plumes of high radiance values observed on April 3, and June 14, 1974 are sediments suspended by the dredging operation. Since such suspended sediments are a cause of turbidity, it is concluded that the LANDSAT radiance maps can be utilized to analyse and observe turbidity in Biscayne Bay. The distribution of higher radiance values within Biscayne Bay between Miami Beach and Key Biscayne on flood tides, indicated that the suspended material from the dredging was drawn into Biscayne Bay on flowing tides, and only partially circulated within the Bay before being expelled by the ebbing tidal currents. Thus LANDSAT radiance maps may be used to indicate circulation patterns.

On two days, February 26 and October 19, 1974, the tide had been flowing into Biscayne Bay for nearly 6 hr. On both days digital values were observed to form smooth and regular bands of equal radiance parallel to the shoreline (hereafter referred to as stratification). The area of higher radiance values was in the center of the Bay (e.g. figure 1c). In contrast, on ebbing tides an irregular strati-

TABLE 1. Synopsis of conditions and observations for MSS data.

Date	Tidal Current	Tidal range (in meters)	avg wind that day dir.[1] /speed[2]	wind avg for 7 days prior dir.[1]/speed[2]	stratification of radiance	plume present	dredge in operation
Jan. 4, 1974	slack almost low	.67	12/16.25	12.5/14.48	irregular	no	no
Feb. 26, 1974	flood almost high	.73	33/27.83	16.8/16.89	smooth	no	yes
Apr. 3, 1974	ebb at low	.88	14/18.98	17.5/16.73	irregular	yes	yes
June 14, 1974	just flooding	.64	8/12.71	12.1/10.62	irregular	yes	yes
Oct. 19, 1974	flooding almost high	.91	35/13.03	13.4/16.25	smooth	no	yes

[1]Directions are those from which the wind blows in terms of degrees from true North: i.e. 09 for East, 27 for West.

[2]Wind speed in km per hr.

fication was observed. The central high radiance area does not correspond to either shallower bottom topography or benthic sediment regimes. The high radiance area appears to originate primarily from the portion of Biscayne Bay designated the Safety Valve region (see fig. 1a).

Images corresponding to a number of wave and wind conditions were examined to insure this was not an effect caused by specular or diffuse return from the surface.

The predominant sediment size in the Safety Valve region is 250μm or greater (Wanless, 1976). According to the sixth power law (Graf, 1971) which relates critical current velocity required to initiate motion to the diameter of the particles, a velocity of 2 cm per sec or greater would be required to put cohesionless sediment of the size present into suspension. This velocity is less than that predicted for Government Cut, which attains a maximum of 60 cm per sec, assuming the existence of current velocities at the Safety Valve region of a similar order of magnitude to those at Government Cut, and allowing for error introduced by the cohesionless sediment approximation, it is evident that the Safety Valve region is a potential source of suspended sediment in the Bay. The presence of current velocities competent to transport existing sediment supports the inference that the observed high radiance values in the central portion of Biscayne Bay correspond to higher turbidity levels, as in the case of the dredge derived plume. However, unlike the dredge derived plume, the turbidity in the central portion of Biscayne Bay requires further corroboration by field studies.

Conclusions—MSS data were used to observe turbidity derived from dredging in Government Cut, and from a carbonate bank in Biscayne Bay under various tidal conditions. These observations demonstrate the feasibility of using MSS data to monitor both man made and natural turbidity in the near shore environment.

Acknowledgments—I thank Janette Gervin of the Earth Resources Branch, National Aeronautics and Space Administration, Kennedy Space Center, for her assistance in making the radiance maps. Acknowledgment is given the guidance of my advisors Dr. T. Nejat Veziroglu, Dr. Sam Lee, and Dr. Joseph Hirschberg, of the University of Miami, where this work was done in partial fulfillment of a M.S. degree in Mechanical Engineering. I also wish to thank Dr. George Maul for his helpful review and comments on the manuscript.

LITERATURE CITED

Graf, W. H. 1971. Hydraulics of Sediment Transport. McGraw-Hill. New York.

Maul, G. A., and H. R. Gordon. 1975. On the use of the Earth Resources Technology Satellite in optical oceanography. Remote Sensing of Environment 4:95-128.

McCluney, W. F. 1975. Radiometry of water turbidity measurements. Water Pollution Contr. Fed. 47:252-266.

Proni, J. R., D. C. Rona, C. A. Laughter and R. L. Sellers. 1975. Acoustic observations of suspended particulate matter in the ocean. Nature 254:413-415.

Wanless, H. R. 1976. Geologic setting and recent sediments of Biscayne Bay region, Florida. Biscayne Bay Symposium I. Miami, Florida, April 2, 1976:1-32.

ZoBell, C. E. 1946. Marine Microbiology: A monograph of Hydro-Bacteriology. Chronica Botanica. Waltham, Mass.

Florida Sci. 40(2):174-178. 1977.

Science Education

AN INTERDISCIPLINARY FIELD COURSE IN MARINE SCIENCE[1]

Don C. Steinker (1) and Jack C. Floyd (2)

Department of Geology, Bowling Green State University, Bowling Green, Ohio 43403 (1); Big Pine Key, Florida 33043 (2)

Abstract: *Compartmentalization within science at the university level has led to narrower specialization in education and to a breakdown of basic unity in science. Commonly, the method of science is inadequately treated in both science courses and textbooks. Science education should stress individual experience, development of self-reliance, sharpening of the critical observational powers, and an interdisciplinary approach to problem solving. In our field course in nearshore marine environments in the Florida Keys for biology and geology students we try to stress these elements. Students are introduced to basic principles and concepts and to fundamental data as a basis for field work in the south Florida area. After a field-oriented introduction to the region, they concentrate upon developing and carrying out a research project. Normally, students from biology and geology work together on projects.*

As pointed out by Theodosius Dobzhansky (1964), "We live in the Age of Science. Considerably more than one half of the total number of scientists who ever lived are alive today." We are witnessing the greatest amount of scientific activity in history, even if much of it is just plain dull. A number of things about this modern science explosion are bothersome and are a cause for concern among educationists; a couple, perhaps, are pertinent here. One is that increased scientific activity has been accompanied and plagued by a trend toward narrower specialization. Perhaps this is acceptable if restricted to research, but it seems to have permeated our whole educational system. Geology, for example, becomes divided from within. Geology began as the study of the history of the earth and its inhabitants, and as such, it involved a synthesis of the other fields of science. Geologists were well-grounded in the fundamentals and principles of the various scientific fields, as well as those peculiar to their own discipline. They were natural historians, in the best sense of the term. Today, the trend is towards compartmentalization within geology departments into geochemistry, geophysics, and geobiology, with resultant breakdown in the exchange of ideas and the creation of unnecessary jargon. This is not unusual, nor is it unique to geology; science has become fragmented, and there are too few synthesizers left today. Students are exposed to fragments of science without ever getting a clear view of the whole.

It is also worrisome that either students demand a certain amount of specialized training, or we too often insist upon giving it to them. There is nothing intrinsically wrong with such training, provided that the fundamentals and principles are mastered first, but the time required may seriously interfere with education. Science students may become better trained, but decreasingly well edu-

[1]Presented at the 1976 meeting of the Florida Academy of Sciences; revised July, 1976.

cated. And, as a result of such training and increased specialization, too often their disciplinary boundaries become much too narrow.

It has now been more than a decade since M. King Hubbert (1963) asked the question: "Are We Retrogressing in Science?" He found the answer to be an emphatic *yes*. Nothing seems to have happened to change it. It is a telling comment upon the state of science when a graduate student is asked on his oral examination to define and discuss science and is unable to do so (this is not simply an isolated case). Many beginning textbooks do not include an adequate discussion of the topic, and certainly few advanced texts do.

In T. H. White's *The Once and Future King* (1939), a re-telling of the Arthurian legend in modern language, young Arthur asks Merlyn: "Do you mind if I ask you a question?" Merlyn replies: "It is what I am for." Merlyn provided education and experience, and taught Arthur to think for himself. Merlyn pointed out that "education is experience, and the essence of experience is self-reliance." Maybe we need more deluded old magicians like Merlyn, those teachers whose intellectual grasp of knowledge transcended artificial boundaries. We are not convinced that the present geochemists, geophysicists, and other assorted geowizards can replace them. Where have the necromancers gone? We think that they are nearly extinct.

"Every man in his youth—and who is to say when youth is ended?—meets for the last time a magician, the man who made him what he is finally to be" (Eiseley, 1970). That personal magician sets the final seal upon the individual's character. The magician makes science comprehensible rather than turning it into a religion. He is the holder of the spell of the natural world from which man sprang. He holds the power of revelation. We hold no delusions of necromancy, but we have attempted to pass on to students some revelations from our magician.

The themes of this essay are education, experience, self-reliance, and a decompartmentalization of scientific knowledge in teaching. We have been concerned about the previously mentioned problems in scientific education, whether they be real or imaginary. Central to our thesis is the conviction that the best place to learn about natural science is in the field. Several years ago we instituted an interdisciplinary field course in marine science and put some of our ideas to work. The course was designed primarily for students of biology and geology. One reason for this is that our interests are mainly in these areas of science; but another reason is that both geology and biology are firmly based upon the other branches of science and are strongly interdisciplinary in nature. Both are founded upon field observations, and we feel that field courses and field work are fundamental and indispensable elements in the education of biology and geology students. The course we established emphasizes nearshore marine environments, because this seemed like an ideal situation for bringing together students of biology and geology to study problems of mutual interest.

The first formal field course in geology in this country was instituted by Professor Andrew Lawson at the University of California, Berkeley, in 1891 (Vaughan, 1970). In this course, Lawson acted as more than a mere guide; he was also an active instructor and participant. Both instructor and student were inspired by a curiosity about the earth, and the goal was understanding. There was an emphasis upon the learning process and the development of the critical faculties of the student.

We don't know when the first marine biology field course appeared in the United States, although Louis Agassiz opened the first seaside laboratory in 1873 at Buzzard's Bay, and W. C. Allee started taking students from the University of Chicago to Woods Hole in 1915 (Ward, 1974). Ed Ricketts came under Allee's influence at Chicago, but moved to California in 1922 without completing a degree. There he met John Steinbeck and later was portrayed as "Doc" in Steinbeck's book *Cannery Row*. Ed made his living by collecting biological specimens along the California coast and selling them to universities and other institutions. At the same time, he became an astute student of the rocky intertidal zone. For 25 years he studied these habitats and kept meticulous notes on his observations. Ed Ricketts was a keen student of natural history. Ed loved true things, and he taught people how to think and how to see. His mind had no horizons (Steinbeck, 1951). Later Jack Calvin and Joel Hedgpeth (1962) were to write of him: "If Ed Ricketts has achieved a trace of immortality, we believe that it is because of his ability to plant in the minds of others not facts, since many can do that, but the essential truths beyond the facts: the shadowy half-truths, the profoundly disturbing questions that thinking men must face and try to answer."

Perhaps it is presumptuous, but we have used Andy Lawson and Ed Ricketts, to a certain extent, as models in developing the philosophy of our course. These men recognized the basic and essential unity of science. They instilled a sense of wonder in others. They caused men to think. Each, in his own way, was a professional, in the strictest sense of the word. They were magicians.

The south Florida Keys were chosen as the site of our course because of the warm, clear waters that facilitate direct observation of organisms and sediments and because of the easy accessibility of diverse environments and the abundance of a great variety of life forms. In addition, the intimate interrelationships between the organisms and the sediments in the south Florida carbonate depositional province encourage interdisciplinary studies involving not only geology and biology but also chemistry. The University of Miami field station at Pigeon Key has served as a base of operations. At Pigeon Key, dormitory, cooking, laboratory, and teaching facilities are available. In addition, the small island is surrounded by waters inhabited by several distinct shallow-water communities that serve as an introduction to the marine life of the region. In addition, the Department of Geology of Bowling Green State University maintains a houseboat as a field station at the Newfound Harbor Marine Institute on Big Pine Key. During our course, the houseboat serves as an office and as a sometimes welcome retreat for the instructional staff.

The main environments studied are Florida Bay; the beaches, rocky shores, and mangrove coasts of the Keys; the back reef; and the outer reef. In the course we try to integrate various biological, geological, and chemical aspects of these various environments. The main objectives are to give the student a better appreciation of the shallow-water marine environment through first-hand experience, to instill a sense of the fundamental unity of science through problem solving, and to increase the student's self-reliance.

In the first class meeting the purpose and philosophy of the course are discussed. This is followed by a few formal lectures in which pertinent general principles are reviewed. Later lectures deal with topics specifically related to the south Florida area. These include topics such as coral reef ecology, carbonate sedimentology, and organism-sediment interrelationships. Starting with the first afternoon, students are put into the field on a daily basis. Field excursions during the first week of the course serve to acquaint the student with the various environments, habitats, and organisms of this region. These are discussed in a guidebook written for the course, and each of the trips is previewed for the class. Although the emphasis is on modern marine environments, the students are also exposed to the Pleistocene rocks of this area, and the modern environments are seen to be directly related to the geologic history of the region. Observations of the modern coral reefs lead to paleoecologic analysis of the Key Largo limestone. And the present is seen to be a continuation of the past.

Beginning with the field work of the first day, students are required to keep a field notebook, which helps to focus their observations and sharpen their analytical powers. Discussions in the field call attention to particular features and problems at each locality. The instructors, at first, constantly ask questions. Before long, the students begin to ask questions of the instructors and, eventually, of themselves, and they learn to seek answers to their questions.

By the beginning of the second week, students are required to submit in written form a proposal for a research project and to discuss the proposal with the instructors. Pertinent literature and limited equipment for research are available, but not everything that might be desired. So they are immediately introduced to reality in this regard. They must learn to make do with what is available and their own innovations and ingenuity and to get on with the job at hand. Generally, participants work together on projects in small groups. Each group commonly includes people from different disciplines. This results in an interdisciplinary approach and in new insights to problems.

It is worth mentioning a few of the types of projects that have been undertaken. The shallow-water communities around Pigeon Key were mapped several years ago by Zischke (1973) and his students. Since then there have been some changes in distribution. Groups have re-mapped some of the communities and have tried to explain the changes. A number of studies have concentrated on the nearshore *Thalassia* beds. One group mapped grass beds growing under different hydrographic conditions and determined population densities of the constituent grasses and macroscopic algae. They also ran sieve analyses of the sediments and related the distributions of grasses, algae, and sediments to hydrographic conditions, such as current velocity. Others studied growth forms of calcareous algae and noted variations related to physical factors of the environment. Another group probed the bedrock topography under the *Thalassia* beds and related the development of the beds to the geologic history of the local area.

Three people studied mangrove colonization in Coupon Bight and the effects of mangroves on sedimentation, while others investigated water chemistry and its possible effect on biotic distribution within the Bight. A couple of students have observed the effects of holothurians on sediment diminution in the laboratory. Some have worked on the relative effects of physico-chemical processes and biological agents in the erosion of intertidal limestone. Also, in the intertidal zone, students have studied movement patterns in various invertebrates, such as neretid gastropods and chitons.

Although the emphasis is heavily upon field work, many of these studies have been supplemented with experimental work in the laboratory. Some behavioral studies with octopi and hermit crabs have been conducted in the laboratory, as well as experimental ecologic studies on various protozoans, invertebrates, and fishes.

Students engaged in different projects routinely exchange information and ideas, and the rather close living conditions on Pigeon Key tend to stimulate discussions among both students and instructors. When the students return to the university, many of them recognize the need to take additional courses in areas of science outside their major. Many biology majors, for example, take additional courses in geology. And some continue the research project that they initiated at Pigeon Key.

This course in shallow-water marine environments has been offered three times. Participants have been mostly advanced undergraduate or graduate majors in biology and geology; however, one of our best students was a sophomore girl, and we have had several participants who held the Ph.D. Official class meetings are normally from 9 to 5, six days a week, usually with lectures in the mornings and field work in the afternoons; however, at least a few students can be found working in the laboratory every day until midnight. For the instructors, it is always a 14 hr day every day. What makes it worthwhile for us is the influence upon individual students, who earnestly want to learn and who retain an enthusiasm beyond the bounds of the course.

LITERATURE CITED

Calvin, J., and J. Hedgpeth. 1962. Preface: About this book and Ed Ricketts. *In* E. F. Ricketts and J. Calvin. Between Pacific Tides. Stanford Univ. Press. Stanford, California.

Dobzhansky, T. 1964. Heredity and the Nature of Man. New American Library. New York.

Eiseley, L. 1970. The Invisible Pyramid. Charles Scribner's Sons. New York.

Hubbert, M. K. 1963. Are we retrogressing in science? Geol. Soc. Amer. Bull. 74:365-378.

Steinbeck, J. 1945. Cannery Row. Bantam Books. New York.

———. 1951. The Log from the Sea of Cortez. Bantam Books. New York.

Vaughan, F. E. 1970. Andrew Lawson: Scientist, Teacher, Philosopher. Arthur C. Clark. Glendale, California.

Ward, R. 1974. Into the Ocean World. Alfred A. Knopf. New York.

White, T. H. 1939. The Once and Future King. Dell. New York.

Zischke, J. A. 1973. An ecological guide to the shallow-water marine communities of Pigeon Key, Florida. Published by the author.

Florida Sci. 40(2):179-183. 1977.

Earth Science

EVAPOTRANSPIRATION PATTERNS IN FLORIDA[1]

ROBERT E. DOHRENWEND[2]

School of Forest Resources and Conservation, University of Florida, Gainesville, Florida 32611

ABSTRACT: *Knowledge of rates of evapotranspiration and their variation within Florida is necessary for development of a rational water resources management program for the state. A method is presented for use of temperature and precipitation data to determine spatial distribution of average annual rates of evapotranspiration across Florida. Although the method gives only a first order approximation of true distribution, it has practical utility for water resources management.**

FLORIDA'S POPULATION is growing rapidly, and is generating increasing water demands for industrial, municipal, and agricultural uses. Agriculture and forestry, two of the major industries of Florida, are important water users in the state. Most of this water is transpired, and it is not available for further use. Irrigation requires abundant water, and currently Florida has more acres under irrigation than all other states east of the Mississippi (Smerdon, 1973). The number of Floridian acres under irrigation is expected to increase by one third in the next 20 years (Eddleman, 1975). Florida already has difficulty meeting demands for adequate surface water under normal conditions. Periodic severe droughts which recur in different parts of the state on an average of once every seven years, when combined with normally dry winters in peninsular Florida, exacerbate this problem. It is obvious that water resources may shortly become a factor sharply limiting the industrial output and the quality of life within the state.

A viable program for developing the state's water resource is necessary if Florida's resources are to be rationally used to ensure an acceptable quality of life for the citizens of the state. A minimum requirement for the development of a successful water resources management program is a knowledge of the flows and storages in the pathways and storages of the hydrologic cycle. An important pathway is evapotranspirational losses from different vegetation and free water surfaces.

Few studies of evapotranspiration (ET) from vegetation surfaces in Florida exist, and those either are applicable to small areas or limited time periods. Lugo et al. (1975) have published some values for mangrove forests, using gas chamber techniques in the field. Cutright (1974) presented a very limited data series from a cypress dome, using changes in water table to estimate ET. Carter et al. (1973), using a variety of techniques to estimate ET, state that ET is the major pathway for water export from the Big Cypress region. Hashemi and Gerber (1967) found that Penman's formula could be used to estimate ET for periods of 9 days or

[1]Florida Agricultural Experiment Station Journal Series Number 6165.

[2]Now at Ford Forestry Center, Michigan Technological University, L'Anse, Michigan, 49946.

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

longer for citrus. Koo (1968) showed a relationship between monthly temperatures and average daily transpiration losses in citrus. Stewart and Mills (1967) and Stewart et al (1969) used non-weighing lysimeters to investigate changes in ET with depth to water table and percentage sod cover for St. Augustine grass and Bermuda grass. Stephens and Stewart (1963) compared nine methods for the computation of potential evapotranspiration (PET) with measured pan evaporation and grass covered tank-type evapotranspirometers. Bartholic and Buchanan (1976) found that pan evaporation grossly overestimates actual ET on an annual basis.

Because none of these results lend themselves to the extrapolation of ET on an annual basis, nor to the determination of the spatial distribution of annual average ET values over the state, and as some necessary groundwork had already been done as a part of the Climatic Impact Assessment Program (CIAP), (Dohrenwend and Harris, 1976), it was decided to use selected climatic data to determine first order ET distribution.

METHODS—The method used was that developed by Holdridge (1967) based upon his "life zone" bioclimatic classification system (Fig. 1). Although it is not well known in the United States, the life zone system has been extensively used in the tropics with great predictive success for the delimitation of vegetation systems from climatic data. The central variable for both vegetation classification and the estimation of ET is "biotemperature," defined by Holdridge (1967) as the sum of the hourly temperatures between 0° and 30°C divided by the number of hr in the yr with temperatures below 0°C and above 30°C added in as 0°C. Biotemperatures have been computed for 5 yr of record for 21 stations within Florida at the computer facility of the National Climatic Center of the National Oceanic and Atmospheric Administration (NOAA) in Asheville, North Carolina. These values had been used to construct a biotemperature map for the state of Florida as a part of the CIAP work.

Holdridge found that excellent estimations of PET could be obtained by simply multiplying the mean annual biotemperature by 58.9. Twenty-one stations in Florida were so studied and the results were extrapolated to generate a map of PET distribution for the state (Fig. 2). Holdridge defines PET as "the theoretical quantity (expressed as a depth) of water which would be given up to the atmosphere within a zonal climate and upon a zonal soil by the natural vegetation of the area, if sufficient but not excessive water were available throughout the growing season." Since Florida departs substantially from the stated conditions, we might expect that the values of PET thus obtained would be rather distant from values of actual ET.

To obtain estimates of actual ET, Holdridge constructed a nomogram (Fig. 3) based in part on his life zone chart (Fig. 1) and in part on extensive empirical observation. Details on the construction of the nomogram may be found in Holdridge (1967). When tested against values for actual ET obtained for Coweeta Watershed 21, predicted values of mean annual ET were within 2% of the measured values (Holdridge, 1967). The nomogram is very easily used:

1. Calculate the value of PET in millimeters.

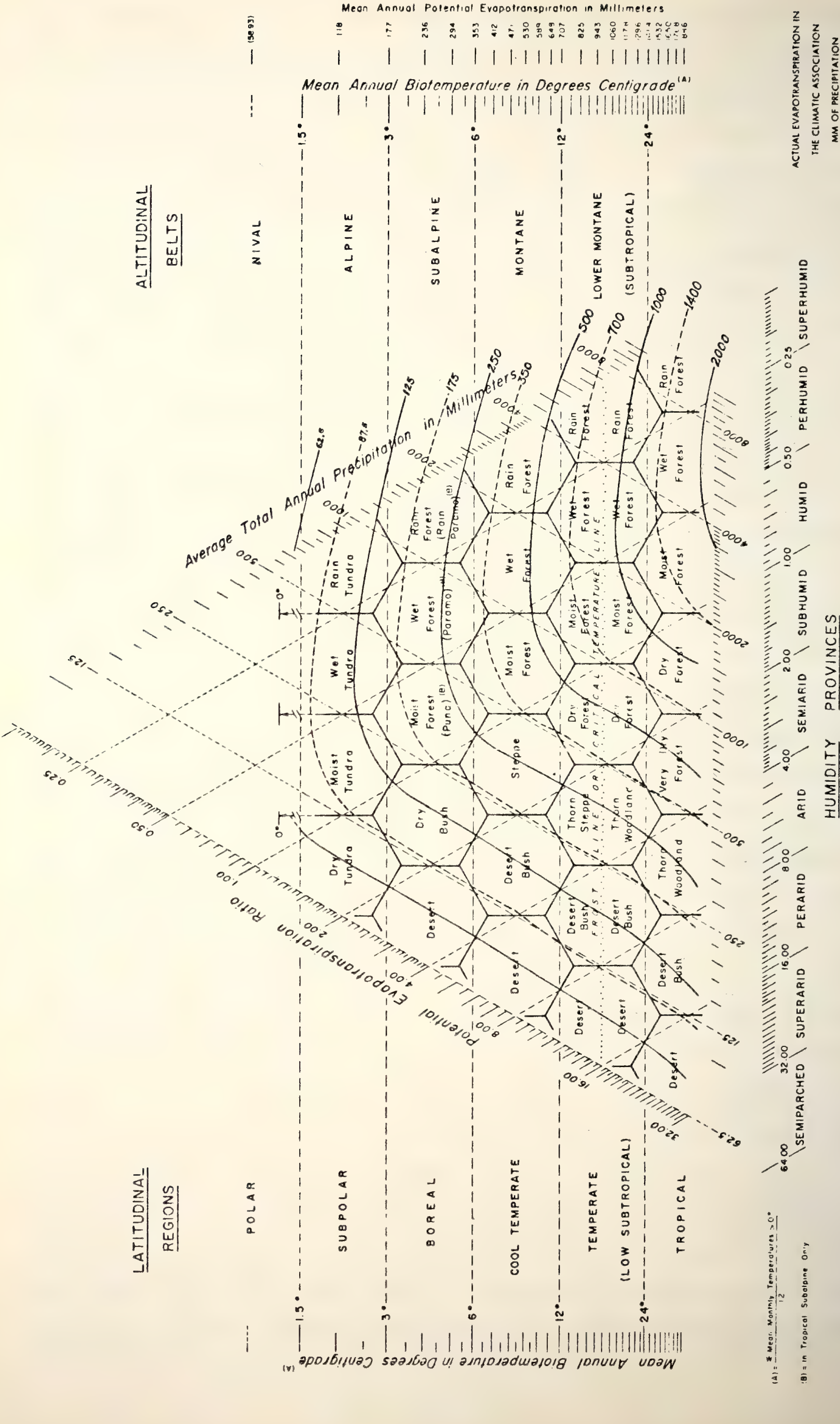


Fig. 1. The Holdridge Life Zone Diagram.

2. Calculate the potential evapotranspiration ratio.
   PET ratio = PET/Precipitation
3. Locate the vertical line corresponding to that ratio logarithmically.
4. Read off the percentage value where this vertical ratio line intersects the curve.
5. Multiply this percentage by the value of PET to obtain the estimate of actual ET in millimeters.

Results from our 21 stations were extrapolated to generate a map of actual ET distribution for the state (Fig. 4).

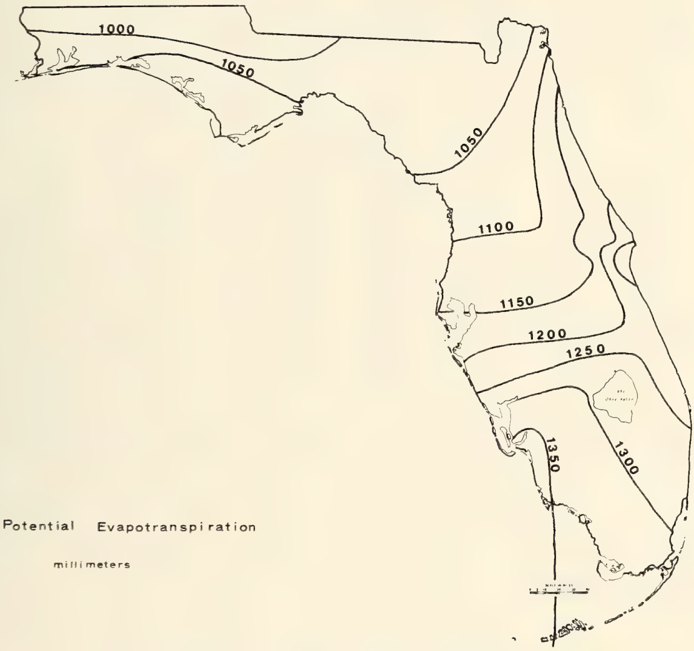


Fig. 2. Potential evapotranspiration patterns in Florida.

RESULTS—Major results are shown in Table 1 and in Figures 2 and 4. The first map (Figure 2) shows that potential evapotranspiration varies in a regular way with the temperature distribution within the state. This is to be expected because of the method of computation and because temperature is a good index of the amount of energy available for ET at a particular location. PET is a function of that available energy. Interestingly enough, when compared to pan evaporation based on 20 yr of record for Gainesville, the Holdridge value of PET was substantially lower. Comparing estimated PET values with those obtained from NOAA Climatological Annual Data Summaries for Florida, the discrepancy between PET and pan evaporation decreased from north to south.

The map of actual ET differs significantly from both the map of PET and from reported values of pan evaporation. Water availability is the important factor here. It is evident that the keys are drier than the remainder of the state. The ET isolines on both maps (Fig. 2 and 4) refer to ET loss from land surfaces only. Actual ET is closest to the potential in the panhandle, while the greatest difference is found in the keys.

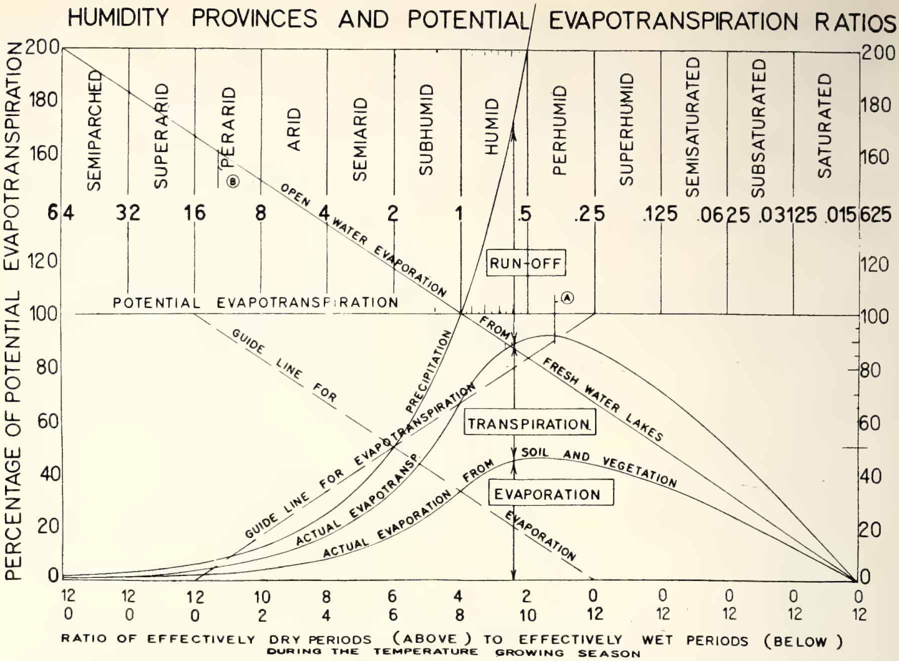


Fig. 3. The Holdridge nomogram for determining actual evapotranspiration showing water movements in climatic associations.

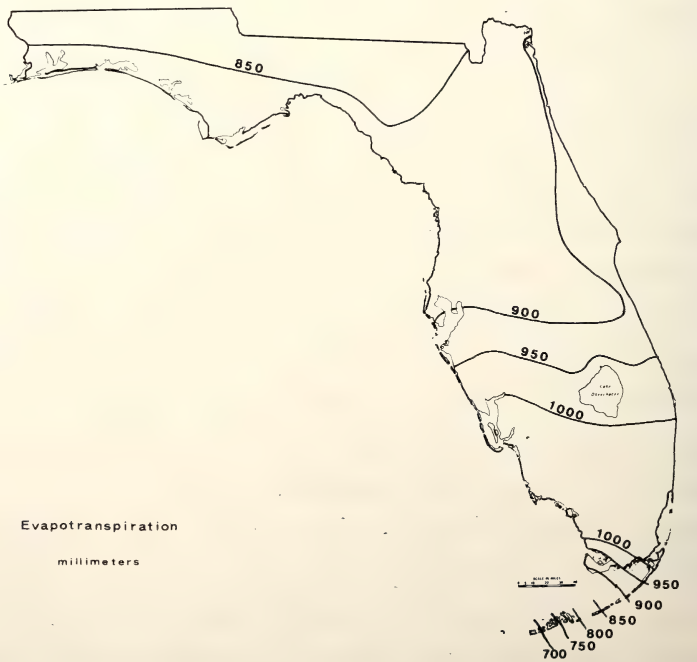


Fig. 4. Estimated actual evapotranspiration patterns in Florida.

TABLE 1. Florida ET distribution (Holdridge method). T = average annual temperature. T_{bio} = average annual biotemperature. PET = potential evapotranspiration. AET – actual evapotranspiration.

	$\overline{T}$ (°C)	$\overline{T}_{bio}$ (°C)	PET (mm)	Precip (mm)	PET/ Precip Ratio	AET/ PET %	AET (mm)	P-ET (mm)
Cape Canaveral	21.5	20.6	1214	1405	0.86	78	946	459
Cocoa Beach	22.2	21.8	1285	1405	0.91	74	951	454
Crestview	19.3	16.9	996	1421	0.70	83	827	594
Cross City	19.9	17.4	1025	1425	0.72	83	851	574
Ft. Myers	22.6	19.9	1355	1355	0.87	77	1043	312
Homestead	23.6	22.1	1302	1643	0.79	80	1042	601
Jacksonville	20.0	17.9	1055	1355	0.78	81	855	500
Key West	25.0	23.0	1355	1016	1.33	50	678	338
Marianna	19.4	16.6	978	1431	0.68	83	811	620
Mayport	20.0	19.3	1137	1473	0.77	81	921	552
Miami	23.9	22.0	1296	1518	0.85	78	1011	507
Milton	18.9	16.9	996	1501	0.66	83	827	674
Orlando	21.6	19.0	1120	1305	0.86	77	862	443
Panama City	20.0	18.6	1096	1473	0.74	82	899	574
Pensacola	19.5	17.8	1049	1597	0.66	83	871	726
Sanford	21.5	19.1	1126	1355	0.83	79	890	465
Tallahassee	18.9	17.1	1008	1444	0.70	83	837	607
Tampa	21.7	19.5	1149	1310	0.88	77	885	425
Valparaiso	19.2	17.7	1043	1588	0.66	83	866	722
Vero Beach	22.6	20.6	1214	1340	0.91	74	898	442
West Palm Beach	23.5	21.2	1249	1567	0.80	80	999	568

DISCUSSION—Discrepancies between pan evaporation and computed Holdridge PET values may be explained by different responses of evaporation pans and biotemperature to winter conditions. Evaporation pans are sensitive to advective losses and radiative heat loading, while biotemperature is much less responsive to these effects. This is almost certainly the reason that pan evaporation values approach Holdridge PET values when moving south. Actual ET values go to a maximum in the southern part of the state where both temperature and water availability reach their maximum. This was to be expected. The distributions of both potential and actual evapotranspiration as displayed represent a first order estimate of the distribution of these variables over the state.

Actual ET will vary not only with temperature and water availability, but also with land use patterns and with the distributions of vegetation communities. As yet, we have no really good technique in universal use within the state for the estimation of variation in ET at this scale. We have not defined absolute values of ET over the state, but rather display a pattern showing the approximate variation of values of ET within the state, values which can be used for preliminary water resources planning. The values presented on the maps are thus coarse values which may be used to give estimates of actual avg water use under normal conditions, over a wide area, and which provide a take off point for the assessment of water deficits and surpluses under extreme conditions.

As an example of the type of problem to which these distributions may be applied, subtracting actual ET from precipitation, values of water surplus for the entire state are obtained (Fig. 5). No region within the state may be expected to have a water deficit under avg conditions. However, there is an area identified

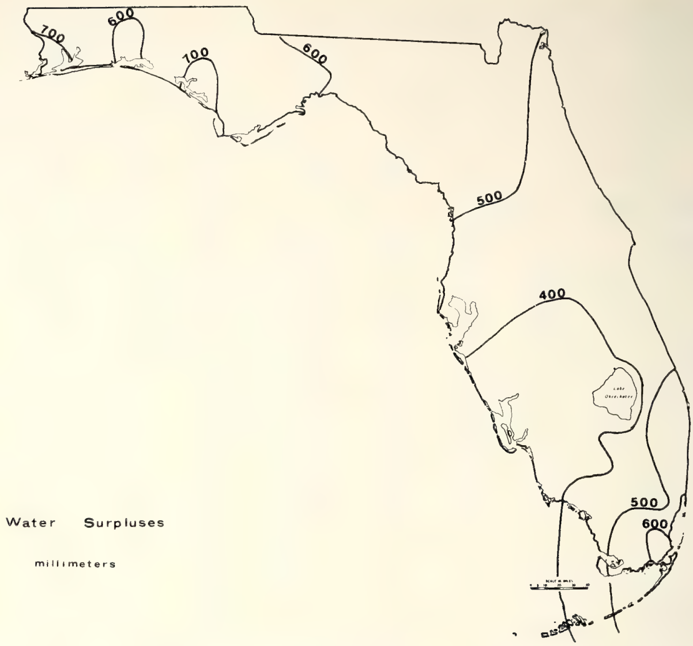


Fig. 5. Water surplus (precipitation—actual evapotranspiration) patterns in Florida.

to the west of Lake Okeechobee which has a smaller surplus than the other regions within Florida. It might be suspected that under conditions of reduced rainfall this region would develop deficits more rapidly than other regions. It would be more vulnerable to drought.

Visher and Hughes (1969) used rainfall data for the period 1931-1960 and avg annual lake evaporation as reported in Kohler, Nordenson, and Baker (1959), to generate a map showing the distribution of the difference between rainfall and PET in Florida. The values of lake evaporation show an increase from 1168 mm in the north to 1371 mm in the southern part of the state. The comparison between lake evaporation and PET calculated on the Holdridge basis shows close agreement in the southern part of the state, but values of lake evaporation exceed the calculated PET values by 100 to 150 mm (11-17%) in the northern part of the state. This difference reflects the difference between evaporation from a largely deciduous climax vegetation surface and from a free water surface.

The lake evaporation map has not been well tested, but the amount of agreement obtained by a comparison of the two methods is encouraging. The mapped difference between potential evaporation and rainfall, as presented by Visher and Hughes, is weighted towards a display of the state rainfall distribution since this pattern is known in much greater detail than the estimated potential evaporation.

The Holdridge technique for the estimation of PET and actual ET offers a means for the development of maps displaying the distributions of these climatic variables in detail. Such maps may be used along with the much better known rainfall patterns to give a closer estimate of patterns of water surpluses and deficits within the state than are currently available.

Discharges from the major Floridian streams are as follows:

Escambia	4,000	million gallons per day (Mgd)
Choctawhatchee	4,500	Mgd
Apalachicola	16,000	Mgd
Ochlockonee	2,000	Mgd
Withlacoochee	1,300	Mgd
Peace	1,400	Mgd
Caloosahatchee	700	Mgd
Kissimmee	1,500	Mgd
St. John's	3,700	Mgd
Suwannee	11,000	Mgd

(*Data from Florida Department of Natural Resources*)

If these discharges and rainfall are known, and if ET may be estimated, rates of aquifer recharge may then be estimated for much of the state under avg conditions. Predicting recharge rates for specific aquifers will depend on available knowledge of the location and extent of the particular recharge area(s) for that aquifer. This application assumes no net change in soil and surface storage over a normal yr. The method may be further adapted to drought conditions if temperature and precipitation records are available for the drought period of interest. An initial estimate of the magnitude of combined surface storage loss and aquifer drawdown may be obtained.

Departures of measured ET from the predicted annual ET may themselves be mapped as a function of land use and vegetation cover within the limits defined by the climatic observations of precipitation and temperature. In this way, the maps may be used to extrapolate measurements of ET differences resulting from different land use strategies or from the natural distribution of vegetation communities.

The value of the results obtained during this study are limited by the few data points used, and by the empirical nature of the methods used to estimate ET. In spite of these limitations, the results in their present form may be of use to water resource managers, since predicted values of actual ET (865 mm) agree closely with observed values of actual ET in Alachua County (912 mm) for 1973, (Bartholic and Buchanen, 1976), a year which recorded pan evaporation within 16 mm of the 21 yr average. The Holdridge ET estimations seem to be predictive; it would be worthwhile to expand the method further, using more data to generate ET distributions in greater detail. It would also be useful to test the Holdridge ET predictions against other field measurements of ET over a year at selected points within the state.

LITERATURE CITED

Bartholic, J. F., and D. W. Buchanan. 1976. Disposition of Water from Fruit Crops and Approaches to Increase Water Use Efficiency. Water Resources Res. Center Pub. 33. Univ. Florida. Gainesville.

Carter, M. R., L. A. Burns, T. R. Cavinder, K. R. Dugger, P. L. Fore, D. B. Hicks, H. L. Revells, and T. W. Schmidt. 1973. Ecosystems Analysis of the Big Cypress Swamp and Estuaries. U.S. Environ. Prot. Agency Atlanta EPA 904/9-74-002:VI-1—VI-20.

Cutright, B. L. 1974. Hydrogeology of a Cypress Swamp. North Central Alachua County, Florida. Ms. Thesis. Univ. Florida. Gainesville.

Dohrenwend, R. E., and L. D. Harris. 1975. A climatic change impact analysis on peninsular Florida biota. I Predicted shifts in vegetation distribution. Climatic Impact Assessment Prog. Dep. Transportation Washington, D.C. Monogr. 5:V-107—V-122.

Eddleman, B. R. 1975. Issues in land and water use. Pp. 1-19. *In* Selected Speeches from Agricultural Growth in an Urban Age Conference. IFAS. Univ. Florida. Gainesville.

Hashemi, F., and J. F. Gerber. 1967. Estimating evapotranspiration from a citrus orchard with weather data. Proc. Amer. Soc. Hort. Sci. 91:173-179.

Holdridge, L. R. 1967. Life Zone Ecology. Tropical Science Center. San Jose, Costa Rica.

IFAS. 1973. Water in Our Future. DARE (Developing Agricultural Resources Effectively) Report—1973. IFAS Univ. Florida Publ. 11:1-56.

Kohler, M. A., F. J. Nordenson, and D. R. Baker. 1959. Evaporation Maps for the United States. U.S. Weather Bureau Tech. Pap. 37.

Koo, R. C. J. 1968. Evapotranspiration and soil moisture determination as guides to citrus irrigation. Proc. First Intl. Citrus Symp. 3:1725-1730.

Lugo, A. E., G. Evink, M. M. Brinson, A. Broce, and S. C. Snedaker. 1975. Diurnal rates of photosynthesis, respiration, and transpiration in mangrove forest of South Florida. Pp. 335-350. *In* Golley, F. B. and E. Medina (eds.). Tropical Ecological Systems. Ecological Series Vol. 11. Springer Verlag. New York.

Smerdon, E. T. 1973. Water and agriculture. *In* Water in Our Future-DARE (Developing Agricultural Resources Effectively) Report—1973. IFAS Univ. Florida Publ. 11:23-27.

Stephens, J. C., and E. H. Stewart. 1963. A comparison of procedures for computing evaporation and evapotranspiration. Trans. Internat. Union Geodesy Geophysics 62:123-133.

Stewart, E. H., J. E. Browning, and E. O. Burt. 1969. Evapotranspiration as affected by plant density and water-table depth. Trans. Amer. Soc. Agric. Engin. 12:646-647.

__________, and W. C. Mills. 1967. Effect of depth to water table and plant density on evapotranspiration rate in South Florida. Trans. Amer. Soc. Agric. Engin. 10:740-747.

Visher, F. N., and G. H. Hughes. 1969. The difference between rainfall and potential evaporation in Florida (map). U.S. Dept. Interior. Geol. Surv. Map. Ser. 32. Bureau of Geology. Florida Dept. Nat. Resources. Tallahassee.

Florida Sci. 40(2):184-192. 1977.

Biological Sciences

LARGE-SCALE MASS CULTURE OF THE MARINE BLUE-GREEN ALGA, *GOMPHOSPHAERIA APONINA*

D. L. Eng-Wilmot and D. F. Martin

Department of Chemistry, University of South Florida, Tampa, Florida 33620

Abstract: *A bio-active isolate from unialgal cultures of the marine blue-green alga,* Gomphosphaeria aponina, *is cytolytic towards* Gymnodinium breve. *An apparatus for continuous culture has been designed to provide sufficient material for biophysiochemical characterization of the substance. Enhanced rates of growth and maximum cell population have improved yields and reduced culture time in this system which recycles artificial sea water medium.**

Large-scale mass culture of the marine blue-green alga, *Gomphosphaeria aponina* has become desirable as a result of observations by Kutt and Martin (1975), McCoy and Martin (1976), and Martin and Martin (1976a) that a bio-active material, termed aponin, extracted from concentrates of cultured cells is cytolytic towards Florida's red tide organism, *Gymnodinium breve.* Clearly, a biophysiochemical characterization of aponin is of interest, inasmuch as it is a bio-dynamic compound with potential for bio-control of the red tide, a fish-killing phenomenon that periodically develops in coastal ecosystems along the western coast of peninsular Florida (Martin and Martin, 1976b). Traditional large scale (20 1) batch or static culture techniques applied to the alga have been successful, but were unsatisfactory in terms of final yields of the extracted material (a few mg), and the time for maximum culture populations to be reached (3 to 4 wk). Thus, we sought an alternative to batch cultures in order to provide large, cultured populations in a minimum of time.

Our alternative for culturing *Gomphosphaeria aponina* applied continuous culture to a large-scale system, under nutritional and physiochemical growth optima. The essential feature of continuous culture is steady-state cell growth, where the cell division rate is regulated by, and becomes equal to, the rate at which new medium (critical nutrients are present in limiting amounts, all others in excess) is added to the culture vessel. An excellent discussion is given by Kubitschek (1970). The technique of continuous culture is not new, having been applied to a number of organisms during the past decade or so, but the application to *G. aponina* is new. The present paper presents a useful approach to convenience and economy in continuous culture, and the results indicate qualitatively the usefulness of recycling the culture medium.

The Apparatus—An operational schematic of the large-scale continuous mass culture unit employed in the mass culture of *G. aponina* is given in Fig. 1.

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

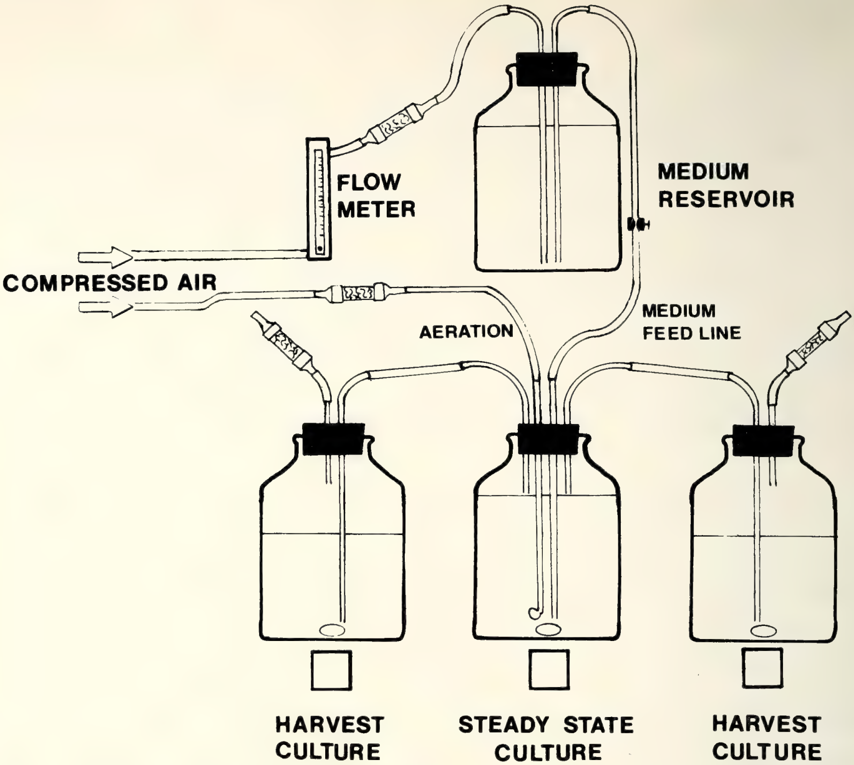


Fig. 1. Operational schematic diagram of the large-scale continuous culture apparatus for the mass culture of *Gomphosphaeria aponina*.

Sterile 20-liter Pyrex carboys were used as culture vessels. The carboys were fitted with rubber stoppers modified for input and output lines. The steady-state culture had two input lines, one for aeration (filtered compressed air) and another for the medium. Medium output lines transferred growing cells to the harvest vessels by a syphon (positive pressure), thus maintaining a constant working volume (16 l) in the steady-state culture. Cultures were stirred with magnetic stirrers, and illuminated continuously at approximately 5400 lux of incident light provided by 40 watt cool-white fluorescent lamps placed in front of and behind the vessels.

Certain convenient procedures were followed routinely. Artificial sea water media was prepared from Utility Marine Mix (Utility Chemical Co.). The salinity was determined and adjusted if necessary, and then the medium was filtered (0.2 μm Millipore membrane). After enrichment, as detailed by Byrdon and co-workers (1971), the medium was autoclaved. The steady-state vessel was inoculated with log-phase cells, and medium flow was adjusted with a flow meter. Appreciable grow-back in the reservoir was prevented by manipulating the clamp on the medium feed line and maintaining a positive pressure in the reservoir. When a desired culture population was attained in the steady-state culture, the syphon was initiated to the harvest vessels, which filled at the same rate.

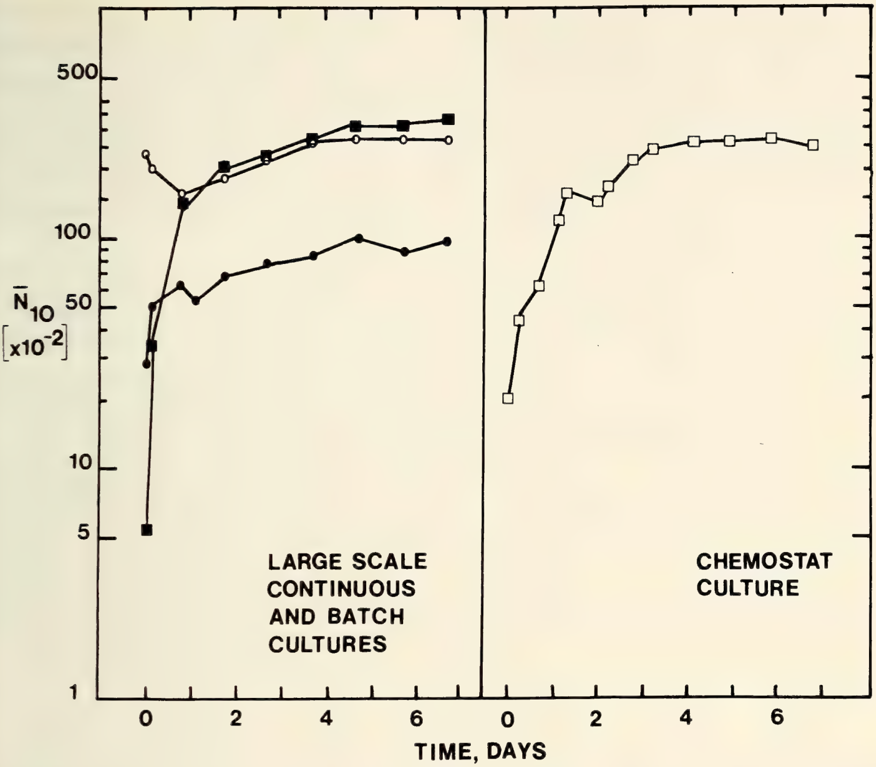


Fig. 2. Growth profiles of *Gomphosphaeria aponina* brought into culture in both the large-scale continuous culture unit where ○ is the steady-state culture, ■ is the harvest culture, and ● is the batch culture; and in a commercial chemostat, BioFlo, Model C-30, □.

Samples were removed periodically, and cell populations were enumerated electronically, using a Coulter Counter Model B, equipped with a 100 μm aperture and a Coulter C-100 Channelyzer, using settings previously reported (Eng-Wilmot et al., 1976). Cell numbers are reported, as elsewhere, in units of cells per 10 sec flow through the aperture. Cell viability was checked with a Nikon inverted binocular microscope.

Results and Discussion—The conditions for optimum growth of *G. aponina,* both nutritional and physical, are summarized by Eng-Wilmot and Martin (1976) and Gonzales and Martin (1976). Ferric iron, as the EDTA complex, and carbon dioxide provided the most dramatic enhancements in the growth of the organism. Optimum growth was also a function of physical conditions: salinity (28$^\circ/_{oo}$), illumination (5400 lux), pH (8.2) and temperature (24-29°C).

Large-scale continuous and batch culture methods were compared under optimized culture conditions. Results are summarized in Fig. 2. Included was a typical growth profile of *G. aponina* brought into culture in a commercial chemostat, the BioFlo, model C-30 (New Brunswick Scientific). In the BioFlo, cells grew with a specific growth constant, K_e, of 1.49 days^{-1} until a steady-state condition was reached (3 da), at which time a growth constant of 0.31 days^{-1}

was maintained, and cell populations remained at approximately 37,000 cells. Results in the large scale continuous culture unit were similar: the steady-state culture was maintained at a flow rate (200 ml/hr) corresponding to a growth constant of 0.33 $days^{-1}$, at approximately 27,000 cells. Under these growth conditions high cell populations were established in the harvest culture, reaching 32,284 ± 210 cells at 8 days, and 37,205 ± 201 cells after 21 da. Slower growth was observed in the batch culture, where a population of 9,862 ± 89 cells as noted after 8 da, and 27,816 ± 378 cells on the 21st da.

Clearly, the large-scale continuous culture system is superior to batch methods. However, large volumes of the sea water medium were required to maintain the system (medium reservoir requires replenishment every 3 to 4 da). Consequently, medium recycling was considered. Following cell harvest (continuous centrifugation, Sorvall Superspeed Centrifuge, Model SS-3, 10,000 rpm), the sea water was re-filtered, re-enriched, and autoclaved for use again.

To determine the effects of the recycled medium on the growth characteristics of *G. aponina,* batch cultures were employed, under identical conditions using fresh and recycled media. The results are summarized in Table 1. Although a 22% increase in the mean growth constant of *G. aponina* was observed in recycled medium, a more remarkable enhancement (59%) was noted in culture populations. Simple iron re-enrichment of the medium does not account for the enhancement of growth, inasmuch as the concentrations of the critical nutrient, initial iron, were the same (Table 1).

These observations are the first to be reported for *G. aponina.* The enhancement of cell growth kinetics and culture yield in recycled medium has been of interest for a number of years, yet explanations for such observations have not been well defined. Presumably, such increases are the result of "conditioning" of the medium by organisms (Fogg, 1965). Such an effect might result from the elaboration of a heat stable growth-promoting factor, or from removal by uptake or chelation of a particular trace metal (such as copper), or substance, to a level that is not growth repressing. A more quantitative explanation for the growth enhancement of *G. aponina* in recycled culture medium is being considered.

TABLE 1. Summary of the mean growth parameters of *Gomphosphaeria aponina* cultured in fresh and recycled (once) sea water medium.[1]

Medium[2]	Initial Iron Concentration[3] $\mu g l^{-1}$	Growth Constant[4] K_e, $days^{-1}$	Mean Generation Time, Tg, days	Culture Population[5]
Fresh	27.4	0.51 ± 0.02	1.35 ± 0.06	22,017 ± 302
Recycled	28.4	0.62 ± 0.05	1.12 ± 0.09	34,934 ± 572

[1]Studies in quadruplicate, at 25 ± 1°C, continuous illumination at 4300 lux.
[2]Medium: Artificial sea water, salinity 28 °/oo.
[3]Iron concentration determined using TPTZ method for Technicon Auto Analyzer II.
[4]First order growth constant, $K_e = (1/T_2\text{-}T_1) \ln (N_2/N_1)$ from a least-squares treatment. $Tg = \ln 2/K_e$.
[5]Cell numbers in units of cells per 10 sec flow through a 100μm aperture, as enumerated with the Coulter Channelyzer at 14 days.

ACKNOWLEDGMENTS—This work is a result of research sponsored by NOAA Office of Sea Grant, Department of Commerce, under grant numbers 04-5-158-44 (1975) and 04-6-158-44055 (1976). The U.S. Government is authorized to produce and distribute reprints for governmental purposes not withstanding copyright notation that may appear herein. Special thanks is given to L. F. McCoy for his helpful suggestions and advice.

LITERATURE CITED

BRYDON, G. A., D. F. MARTIN, AND W. K. OLANDER. 1971. Laboratory culturing of the Florida red tide organism, *Gymnodinium breve.* Environ. Letters 1:235-244.

ENG-WILMOT, D. L., W. S. HITCHCOCK, AND D. F. MARTIN. 1977. The effect of temperature on the proliferation of *Gymnodinium breve* and *Gomphosphaeria aponina.* Mar. Biol. 41:71-77.

________, AND D. F. MARTIN. 1976. Characterization of the blue-green alga, *Gomphosphaeria aponina* for mass culture. Florida Sci. 39 (Suppl. 1):19.

FOGG, G. E. 1965. Algal Cultures and Phytoplankton Ecology. Univ. Wisconsin Press. Madison.

GONZALES, M. H., AND D. F. MARTIN. 1976. Effects of salinity on the synthesis of DNA, acidic polysaccharide, and growth in the blue-green alga, *Gomphosphaeria aponina.* Florida Sci. 39 (Suppl. 1):18.

KUBITSCHEK, H. E. 1970. Introduction to Research with Continuous Culture. Prentice-Hall. Englewood-Cliffs, N.J.

KUTT, E. C., AND D. F. MARTIN. 1975. Report on a biochemical red tide repressive agent. Environ. Letters 9:195-208.

MARTIN, D. F., AND B. B. MARTIN. 1976a. Aponin, a cytolytic factor toward the red tide organism, *Gymnodinium breve.* Biological assay and preliminary characterization. J. Environ. Sci. Health A11:613-622.

________, AND ________. 1976b. Red tide, red terror. Effects of red tide and related toxins. J. Chem. Ed. 53:614-617.

McCOY, L. F., AND D. F. MARTIN. 1976. The influence of *Gomphosphaeria aponina* and its bioactive components on the growth and ichthytoxicity of *Gymnodinium breve.* Florida Sci. 39 (Suppl. 1):18.

Florida Sci. 40(2):193-197. 1977.

SURFACE CAPTURE OF *GYMNACHIRUS MELAS* (PISCES: SOLEIDAE) FROM OFFSHORE WATERS OF THE EASTERN GULF OF MEXICO—

William F. Grey, Florida Department of Natural Resources, Marine Research Laboratory, 100 Eighth Avenue S.E., St. Petersburg, Florida 33701

ABSTRACT: *On 13 January 1976 a mature specimen of the naked sole was captured while night-light sampling in water 39.6 m deep. Only one previous report of a surface capture is known.*

A single mature specimen (138 mm total length: 106 mm standard length) of the naked sole, *Gymnachirus melas,* was captured while night-light sampling aboard the R/V HERNAN CORTEZ on 13 January 1976 (ca. 2100 hr). This specimen was taken at the surface with a dipnet as it came into the floodlight field of view. Capture location was 27°22.8′N, 83°22.4′W, 64 km SW of St. Petersburg, Florida; the water depth was 39.6 m. Water temperatures (18.8° C surface, 17.9° C bottom) and salinities (35.96 ppt surface, 35.78 ppt bottom) were recorded on 14 January (ca. 0800 hr).

Geographic range of *G. melas* is from Massachusetts south to Dry Tortugas, Bahamas, eastern Gulf of Mexico (Dawson, 1964), and southwest Caribbean (Palacio, 1974). *Gymnachirus melas* has a known bathymetric range of 1.8 to 182.9 m and has been collected most frequently between 29.3 and 45.7 m (Dawson, 1964). Most captures have been by bottom dredge, indicating that this species remains closely associated with the substrate (Topp and Hoff, 1972). Although vertical migration related to feeding is plausible, stomach analyses indicate a preferred bottom feeding habit (Topp and Hoff, 1972), and the feeding apparatus of soles is adapted for taking strictly benthic prey (Yazdani, 1969).

Woodhead (1966) has expressed the opinion that vertical migration at night does not take most flatfish species far above the sea bed. He indicated that relatively few reports have been made of flatfishes swimming near the surface in deeper waters and that most data concerning vertical movements originated from midwater trawling. Evidence of periodic vertical migration does exist for some soles (e.g., *Solea vulgaris*) and also for some species of Pleuronectes (Woodhead, 1966). Beebe and Tee-Van (1928) captured juvenile specimens of *Achirus lineatus* (17.5-25 mm) near surface at night.

Only one previous report of a surface capture of *G. melas* is known (Fahay, 1975). That capture was made on 3 February 1968 at night (ca. 0600 hr) over 15 m of water, 16 km east of Cape Kennedy, Florida; the specimen measured 123 mm (total length?).

In view of the apparently isolated occurrences of surface swimming in flatfishes, this documentation of a surface capture of *G. melas* may be pertinent to present or future studies relevant to the vertical migration of demersal fishes.

ACKNOWLEDGMENTS—I acknowledge the assistance of the captain and crew aboard the R/V HERNAN CORTEZ during the cruise. I also wish to thank C. Futch, K. Steidinger, and D. Hensley for their assistance in the preparation of the manuscript. Critical review was provided by R. Schlieder and D. Hensley.

Contribution Number 292, Florida Department of Natural Resources Marine Research Laboratory.

LITERATURE CITED

BEEBE, W., AND J. TEE-VAN. 1928. The fishes of Port-Au-Prince Bay, Haiti, with a summary of the known species of marine fish of the island of Haiti and Santo Domingo. Zoologica 10:1-279.

DAWSON, C. E. 1964. A revision of the western Atlantic flatfish genus *Gymnachirus* (the naked soles). Copeia 1964:646-665.

FAHAY, M. P. 1975. An annotated list of larval and juvenile fishes captured with surface-towed meter net in the South Atlantic Bight during four RV DOLPHIN cruises between May 1967 and February 1968. NOAA Tech. Rept. NMFS SSRF-685. Supt. of Documents. Washington, D.C.

PALACIO, F. J. 1974. Peces colectados en el Caribe Columbiana por la universidad de Miami. Museo del Mar. Bol. 6:1-137.

TOPP, R. W., AND F. H. HOFF, JR. 1972. Memoirs of the HOURGLASS cruises: flatfishes (Pleuronectiformes). Florida Dept. Nat. Res. Mar. Lab. 4(2):1-133.

WOODHEAD, P. M. J. 1966. The behavior of fish in relation to light in the sea. Oceanogr. Mar. Biol. Ann. Rev. 4:337-403.

YAZDANI, G. M. 1969. Adaptation in the jaws of flatfish (Pleuronectiformes). J. Zool. (Lond.) 150:181-222.

Florida Sci. 40(2):197-198. 1977.

Earth Sciences

CALCULATED AND OBSERVED X-RAY POWDER DIFFRACTION PATTERNS FOR PARAVAUXITE

FRANK N. BLANCHARD

Department of Geology, University of Florida, Gainesville, Florida 32611

ABSTRACT: *Many lines of low and moderate intensity are newly listed and line($I_{rel}=90$) does not belong to paravauxite.*

THE X-ray powder diffraction pattern for paravauxite, $FeAl_2(PO_4)_2(OH)_2 \cdot 8H_2O$, in the Powder Diffraction File (card #14-247) is incomplete, includes errors in indexing, and includes one line (listed among the three most intense) which does not belong to the mineral. I am able to provide better data for this mineral, including both calculated and observed powder patterns. The observed data are from a sample of paravauxite from Llallagua, Bolivia, and the calculated pattern is based on the crystal structure of paravauxite as refined by Baur (1969) to $R=.054$.

METHODS—Several small single crystals of paravauxite from Llallagua, Bolivia, were ground to less than 325 mesh and the powder was prepared (1) directly as a smear on a glass slide and (2) mixed 1:1 with synthetic corundum (Al_2O_3, Linde A) prior to preparing as a smear. The preparation with synthetic corundum was used to determine the observed intensity ratio I/I_c (c = corundum). Immediately before the analysis the diffractometer (General Electric XRD-5) was realigned and the specimen support was shimmed so that at 0° 2θ the primary beam was split in half by the sample and slide. Scans were made with Ni-filtered Cu-radiation at 0.2° 2θ per minute from 2° to 90° 2θ using a 1° divergence slit and .02°, .05°, and 0.1° detector slits, and with monochromatic Cu $K\alpha$ -radiation at 0.2° 2θ per min with a 1° divergence slit and a 0.1° detector slit. With aid of the computer program of Appleman and Evans (1967) the lattice parameters were refined and d-spacings were calculated from the refined lattice dimensions. Indexed reflections obtained from the calculated powder diffraction pattern (described below) were used in the input to the Appleman and Evans program.

In addition to the observed powder diffraction pattern, a computer-simulated diffractometer chart and calculated d-spacings and relative intensities were obtained for paravauxite. This was accomplished using the FORTRAN IV program for calculating X-ray powder diffraction patterns—version 5 (Clark et al., 1973) and crystal structure data for paravauxite (Baur, 1969). These results are useful for identification standards, for evaluating the quality of existing powder diffraction data, in determining absolute intensities for quantitative analysis, in evaluating the degree of preferred orientation in powder mounts, and in evaluating the reliability of the structure determination.

TABLE 1. Calculated and observed X-ray powder diffraction data for paravauxite. I_1 is relative intensity corrected for flat-plate absorption while I_2 is corrected for Debye-Scherrer absorption.

Calculated				Observed		
d A	I_l	I_2	*hkl*	*d A*	*I*	*hkl*
9.8187	65.7	64.2	010	9.89	154	010
6.3694	100.0	100.0	001	6.40	100	001
5.9240	16.7	16.8	$0\bar{1}1$	5.95	12	$0\bar{1}1$
4.9093	24.0	24.6	020	4.93	47	020
4.7887	50.9	52.4	$\bar{1}\bar{1}1$	4.79	45	$\bar{1}\bar{1}1$
4.7601	23.0	23.7	100	4.78	33	100
4.7277	19.6	20.2	110	4.75	24	110
4.1368	9.9	10.5	$\bar{1}\bar{2}1$	4.14	8	$\bar{1}\bar{2}1$
3.9445	6.1	6.5	$\bar{1}10$	3.95	10	$\bar{1}10$
3.8898	20.4	21.8	120	3.90	26	120
3.6228	15.0	16.2	$\bar{1}11$	3.63	9	$\bar{1}10$
3.5535	3.1	3.3	021	3.56	3	021
3.3703	5.7	6.3	101	3.376	5	101
3.3010	1.3	1.4	$\bar{1}\bar{1}2$	3.306	3	$\bar{1}\bar{1}2$
3.2729	5.7	6.4	030	3.280	12	030
3.2415	14.0	15.6	111	3.247	12	111
3.2289	2.0	2.2	$0\bar{1}2$	3.223	10	$0\bar{1}2$
3.1875	16.2	18.2	$0\bar{3}1$	3.193	46	002,$0\bar{3}1$
3.1847	55.2	61.7	002			
3.1611	17.0	19.1	$\bar{1}\bar{2}2$	3.167	15	$\bar{1}\bar{2}2$
3.0838	32.6	36.8	$\bar{1}20$	3.089	32	$\bar{1}20$
3.0402	4.9	5.5	130	3.046	6	130
2.9620	2.5	2.8	$0\bar{2}2$	2.968	4	$0\bar{2}2$
2.8508	8.9	10.2	121	2.851	31	$\bar{1}21$,121
2.8444	32.7	37.8	$\bar{1}21$			
2.7830	1.5	1.7	$\bar{1}\bar{3}2$			
2.7116	6.5	7.6	$1\bar{2}1$	2.717	10	$1\bar{2}1$
2.6960	6.7	7.9	031	2.705	7	031
2.5792	34.3	41.1	$\bar{1}\bar{4}1$	2.584	32	$\bar{1}\bar{4}1$
2.5645	2.2	2.6	$\bar{2}\bar{2}1$			
2.4794	8.9	10.8	$\bar{2}01$	2.483	6	$\bar{2}01$
2.4655	6.4	7.8	$0\bar{4}1$	2.470	8	$0\bar{4}1$
2.4547	0.9	1.1	040	2.456	3	040
2.4443	0.5	0.7	210	2.448	2	210
2.4180	1.7	2.1	140	2.423	1	140
2.3943	6.6	8.1	$\bar{2}\bar{2}2$	2.398	4	$\bar{2}\bar{2}2$
2.3843	0.8	1.0	$\bar{2}\bar{1}2$	2.384	7	$\bar{2}12$
2.3801	8.4	10.4	200	2.380	6	200
2.3712	3.0	3.7	$\bar{2}\bar{3}1$			
2.3642	2.3	2.8	$\bar{1}\bar{4}2$	2.368	6	220,$\bar{2}\bar{3}1$+
2.3639	6.5	8.7	220			
2.3490	13.6	16.9	102	2.353	9	102
2.2881	0.7	0.8	$\bar{1}\bar{2}3$			
2.2875	1.7	2.2	$1\bar{3}1$	2.289	3	$\bar{1}31$,$1\bar{3}1$+
2.2860	1.3	1.6	$\bar{1}22$			
2.2836	2.3	2.8	$\bar{1}31$			
2.2721	12.5	15.9	$\bar{2}\bar{3}2$	2.275	7	$\bar{2}32$
2.2652	4.8	6.1	112			
2.2467	2.6	3.3	$\bar{2}02$	2.246	2	$\bar{2}02$
2.1915	2.0	2.5	$\bar{1}03$			
2.1641	0.8	1.1	$\bar{1}\bar{3}3$			
2.1509	3.2	4.1	$1\bar{2}2$	2.155	2	$\bar{1}\bar{3}1$ $1\bar{2}2$,041
2.1481	0.6	0.7	041			
2.1232	6.0	7.9	003	2.127	3	003
2.1121	8.9	11.6	$0\bar{2}3$	2.115	9	$0\bar{2}3$,$\bar{2}\bar{4}1$
2.1110	6.2	8.1	$\bar{2}\bar{4}1$			
2.0883	5.0	6.6	122	2.086	4	032,122
2.0801	5.9	7.7	032			
2.0684	2.5	3.3	$\bar{2}\bar{4}2$	2.071	3	$\bar{2}\bar{4}2$
2.0539	5.2	6.9	211	2.058	3	211
2.0368	1.6	2.1	141	2.047	3	141,201
2.0157	4.4	5.8	$\bar{2}\bar{2}3$	2.019	2	$\bar{2}\bar{2}3$
2.0083	2.3	3.0	$\bar{1}13$	2.007	9	$\bar{1}13$
2.0034	13.2	17.8	$\bar{1}40$	2.004	7	$\bar{1}40$
1.9947	0.8	1.1	$0\bar{5}1$			
1.9838	1.1	1.5	$\bar{2}\bar{1}3$	1.988	2	$\bar{2}\bar{1}3$,150
1.9818	0.7	0.9	150			
1.9753	2.1	2.9	$\bar{2}21$	1.977	6	$\bar{2}21$,$0\bar{3}3$
1.9734	2.3	3.1	$\bar{1}\bar{4}3$	1.974	5	$\bar{2}20$,$\bar{1}\bar{4}3$
1.9722	4.8	6.5	$\bar{2}20$			
1.9654	7.2	9.7	$\bar{2}\bar{3}3$	1.970	6	$\bar{2}\bar{3}3$
1.9497	2.7	3.7	$2\bar{1}1$	1.947	3	240,$2\bar{1}1$+
1.9449	4.2	5.8	240			
1.9436	0.9	1.2	$1\bar{3}2$			
1.9388	0.7	0.9	$\bar{1}32$	1.938	3	$1\bar{4}1$,$\bar{1}32$
1.9355	2.5	3.4	$1\bar{4}1$			
1.8876	0.9	1.2	$\bar{1}41$			
1.8803	1.4	1.9	$\bar{2}03$			
1.8750	0.5	0.8	132			
1.8485	0.6	0.8	$0\bar{5}2$			
1.8442	1.5	2.1	231			
1.8427	0.8	1.2	$\bar{2}\bar{5}2$			
1.8182	3.0	4.3	023			
1.8114	5.0	7.1	$\bar{2}22$			
1.8043	1.1	1.5	$2\bar{2}1$			
1.8007	4.1	5.9	$\bar{1}23$			
1.7656	2.6	3.8	$\bar{1}\bar{5}3$	1.765		
1.7575	5.7	8.3	103			
1.7536	0.6	0.9	$\bar{1}\bar{6}1$			
1.7375	6.0	8.8	$\bar{1}\bar{2}4$	1.739		

RESULTS AND DISCUSSIONS—Table 1 includes the calculated *d*-spacings and relative intensities for paravauxite. The first column of intensity is integrated intensity corrected for flat-plate absorption while the second column is integrated intensity corrected for Debye-Sherrer absorption. Reflections with intensity less than 1.0 have been omitted. Figure 1 includes the computer-simulated diffractometer chart based on Cu Kα –radiation, a Cauchy line profile, and a half-width at 40° 2θ of 0.1°.

Hubbard et al. (1976) recommend reporting a standard scale factor (γ) with calculated powder diffraction patterns. This practice permits conversion from relative intensity to absolute/relative intensity. They also point out that the scale factor, γ, may be used with appropriate data for corundum to calculate "the reference intensity ratio" I/I_c. I/I_c is the integrated intensity ratio of the strongest line of a sample to the strongest line of corundum. For paravauxite $\gamma = 0.256 \times 10^{-3}$ and $I/I_c = 0.49$. The reference intensity ratio was computed using the computed value of γ for paravauxite and values of γ, linear absorption coefficient, and density for corundum given by Hubbard et al. (1976).

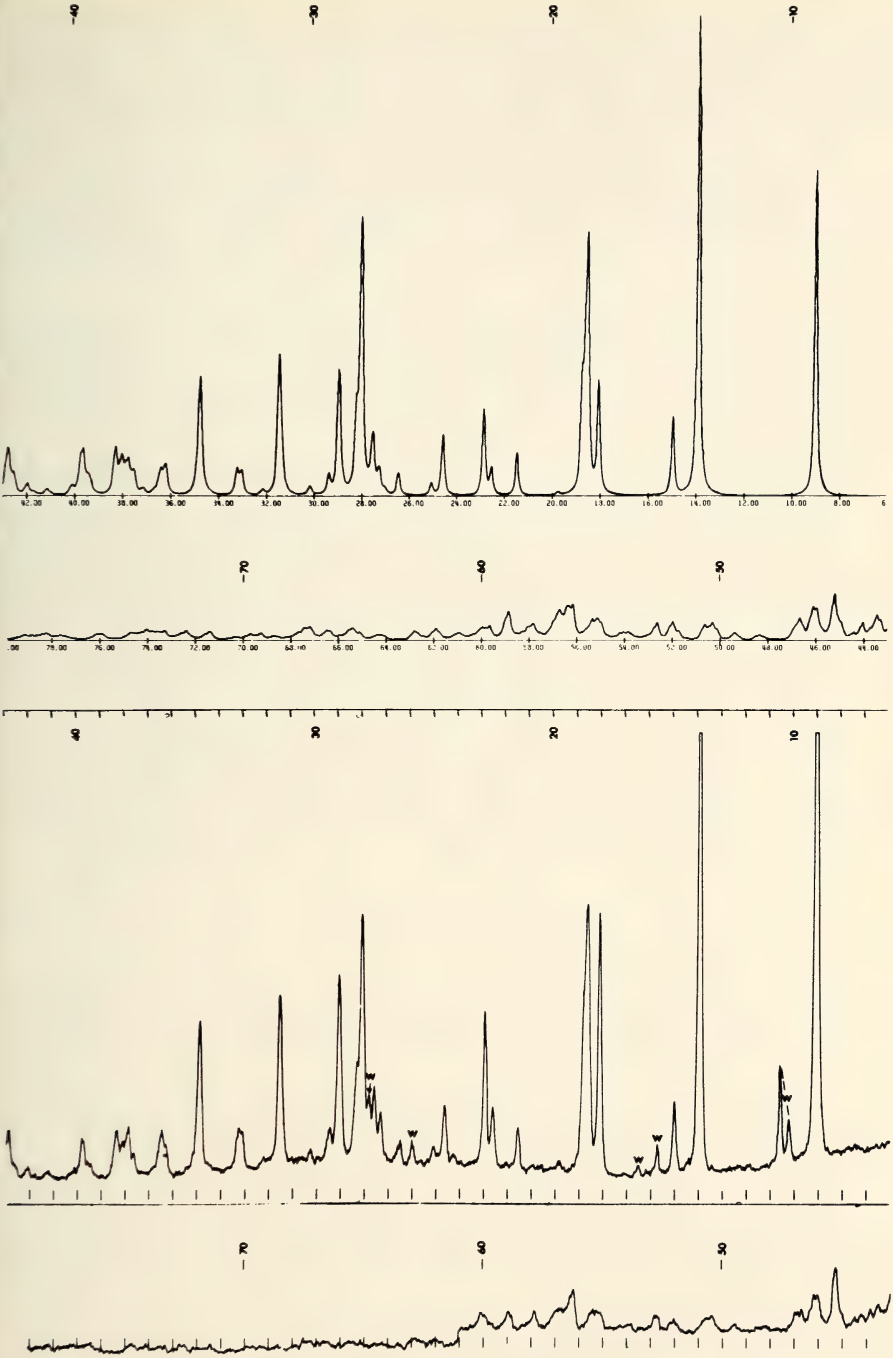


Fig. 1. Computer-simulated diffractometer chart (top) and observed diffractometer chart (bottom) for paravauxite. Lines marked "W" result from contamination by wavellite.

Table 1 includes the observed d-spacings and relative intensities (peak height). Refined lattice parameters obtained from these d-spacings are $a=5.239$, $b=10.56$, $c=6.972$, $\alpha=106.80°$, $\beta=110.78°$, and $\gamma=72.13°$. Figure 1 shows a representative diffractometer chart with the computer-simulated chart. Peaks at $d=8.73$, 8.44, 5.68, 5.38, 3.44, and 3.22 ($2\theta=10.13°$, 10.48°, 15.60°, 16.48°, 25.90°, and 27.70°) are due to contamination by wavellite. Intensity measurements of the 001 line (theoretically the most intense) of paravauxite and the 113 line of corundum yield values for I/I_c of .49 (peak height) and .86 (integrated area).

Comparisons between the observed and the calculated patterns for paravauxite show reasonably good correlation. The most noticeable discrepancy is the reversal in relative intensities of the 010 and 001 reflections. This results from preferred orientation in the sample due to the $\{010\}$ cleavage which overemphasizes all orders of 010.

The calculated pattern was very helpful in indexing the reflections as unequivocal indexing would have been very difficult without it.

Comparison of the observed data presented in this report with that of Hurlbut (1962), which is currently used as the only standard for paravauxite in the Powder Diffraction File (card #14-247), indicates that in Hurlbut's data there are many lines of low and moderate intensity which are not listed, some lines which are listed are indexed incorrectly, and at least one strong line ($I_{rel}=90$) which is listed does not belong to paravauxite.

Acknowledgments—Calculation of the powder diffraction patterns was done with the facilities of the Northeast Regional Data Center of the State University System of Florida. R. A. Wicker adapted the program written by Clark, Smith, and Johnson to the NRDC computer and wrote the plot routine.

LITERATURE CITED

Appleman, D. E., and H. R. Evans, Jr. 1967. Experience with computer self-indexing and unit cell refinement of powder data (abstr.). Geol. Soc. Amer. Spec. Pap. 115.

Baur, W. H. 1969. The crystal structure of paravauxite, Fe^{2+} $Al_2(PO_4)_2$ $(OH)_2(OH_2)_6 \cdot 2H_2O$. Nues Jahrbuch fuer Min Monatshefte 69:430.

Clark, C. M., D. K. Smith, and G. G. Johnson. 1973. A FORTRAN IV program for calculating X-ray powder diffraction patterns—version 5. Pennsylvania State Univ. University Park.

Hubbard, C. R., E. H. Evans, and D. K. Smith. 1976. The reference intensity ratio, I/I_c, for computer simulated powder patterns. J. Appl. Crystalogr. 9:169-174.

Hurlbut, C. S., and R. Hower. 1962. Sigloite, a new mineral from Llallagua, Bolivia. Amer. Mineral. 47:1-8.

Joint Committee on Powder Diffraction Standards. Selected Powder Diffraction Data for Minerals. 1974. Swarthmore, Pennsylvania.

Florida Sci. 40(2):199-202. 1977.

AN INEXPENSIVE AND EASILY FABRICATED SAMPLER FOR COLLECTING SEDIMENT CORES TO MEASURE EH POTENTIALS—*Gerald A. Moshiri* (1), *David P. Brown* (2) *and William G. Crumpton* (1), Faculty of Biology, University of West Florida, Pensacola, Florida 32504 (1); Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061 (2)

ABSTRACT: *Collection of single or multiple cores for the purpose of measuring mud and/or water Eh potentials in estuarine sediments similar to those encountered in northwest Florida estuaries is simplified by new modifications to corer design to reduce fabrication costs and facilitate collection and analysis of samples.**

EMPLOYMENT of the redox phenomenon as a mechanism for delineating aspects of sediment chemistry in lakes and estuaries has been under investigation for a number of years (Whitfield, 1969; Mortimer, 1971). In spite of theoretical questions raised concerning applicability of the redox potential approach to the ecology of benthic sediments (see discussion and review by Whitfield, 1969), much evidence has been presented which relates the Eh status of the sediment and the sediment-water interface to a number of ecologically significant phenomena (Whitfield, 1969: Mortimer, 1971; Hargrave, 1972). The collection of reliable redox potential values, however, has always been rather difficult, owing primarily to the unavailability of a satisfactory and conveniently operated shallow-water coring device. Numerous corers have been devised and presented in the literature (Brinkhurst et al., 1969; Milbrink, 1971; Schindler and Honick, 1971), but few combine simplicity of fabrication, reliability of operation, and economy in construction with adaptability to both hard and soft sediment conditions that we encounter in Northwest Florida estuaries. Furthermore, most devices already available, even those with adjustable weights, are not adaptable as multiple corers and cannot be operated from small boats. Thus, it is difficult to obtain replicate samples and cores from a vertical position. Finally, it would be highly desirable if such a corer would also incorporate a means to store core samples in order to later measure temporal variations or changes in such microcosms.

Our coring mechanism was devised to meet the above criteria. It is designed to remove undisturbed sediment cores and to permit Eh measurements of any part of the sediment and sediment-water interface without exposure of the system to air.

DESIGN—The construction of the coring device is detailed in Fig. 1. It employs a standard plexiglass tube 3.8 cm diam and 95.0 cm long. Starting at 20 cm below the top, 42 holes 0.64 cm diam are drilled as shown in Fig. 1. These openings are covered with wide bands of tight-fitting tubing or silicon septa (Schindler and Honick, 1971) through which electrodes or hypodermic syringes may be inserted for the measurement of Eh potentials or for the extraction of water samples.

The coring devices are attached to lengths of end-threaded galvanized pipe, with extensions added as necessary (Fig. 1). Furthermore, it is possible and quite

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

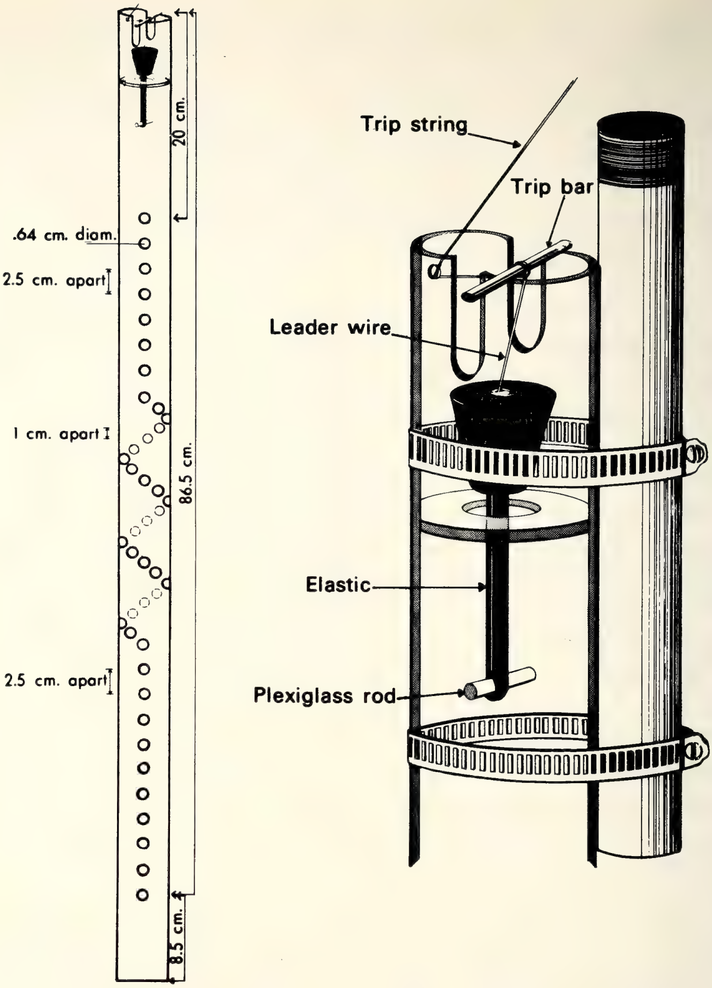


Fig. 1. General design of the coring tube and tripping device (left); and proximal end of the coring tube showing details of the tripping mechanism and mode of attachment to the threaded galvanized pipe handle (right).

convenient to attach as many as four corers to the same handle for multiple extraction. The device is inserted into the substrate by hand. The simple tripping mechanism to hold the core in the tube employs a number 6 rubber stopper attached by rubber tubing to a plexiglass rod glued to the inside of the coring tube (Fig. 1). The core tube is kept open during insertion by pulling the trip bar out of the slot at the top of the plexiglass tube and placing it on the top edge of the cylinder (Fig. 1). The trip string is pulled to bring the trip bar into the slot provided at the top of the coring device. This causes the release of tension on the rubber stopper which drops to seal the opening.

Our extensive use of this core sampler throughout a 2 yr period has demonstrated its effectiveness in either hard or flocculent and loose substrates, both of which are commonly encountered in Northwest Florida estuaries.

ACKNOWLEDGMENTS—This research was supported by grant number B-024-FLA provided by the U. S. Department of the Interior, Office of Water Research and Technology as authorized under the Water Resource Research Act of 1964. The authors gratefully acknowledge the logistic support provided by the Faculty of Biology of The University of West Florida. They are also indebted to Mr. Nicholas G. Aumen and Mr. Paul R. Barrington for their assistance in the construction and testing of the original, and numerous modifications, of the core sampler.

LITERATURE CITED

BRINKHURST, R. O., K. E. CHUA, AND E. BATOOSINGH. 1969. Modifications in sampling procedures as applied to studies on the bacteria and tubificid oligochaetes inhabiting aquatic sediments. J. Fish. Res. Bd. Canada 26:2581-2593.

HARGRAVE, B. T. 1972. Oxidation-reduction potentials, oxygen concentration, and oxygen uptake of profundal sediments in a eutrophic lake. Oikos 23:167-177.

MILBRINK, G. 1971. A simplified tube bottom sampler. Oikos 22:260-263.

MORTIMER, C. H. 1971. Chemical exchanges between sediments and water in the Great Lakes—speculations on probable regulatory mechanisms. Limnol. Oceanog. 16:387-404.

SCHINDLER, J. E., AND K. R. HONICK. 1971. Oxidation-reduction determination at the mud-water interface. Limnol. Oceanog. 16:837-840.

WHITFIELD, M. 1969. Eh as an operational parameter in estuarine studies. Limnol. Oceanog. 14:547-558.

Florida Sci. 40(2):203-205. 1977.

GROWTH OF HYDRILLA IN VARIOUS CONTAINERS; COMPARATIVE RATES AND ADVANTAGES—*Dean F. Martin and George A. Reid, Jr.*, Department of Chemistry, University of South Florida, Tampa, Florida 33620

ABSTRACT: *The perennial submersed aquatic plant,* Hydrilla verticillata *Royle has been grown in the laboratory in flasks (250, 500 ml), carboys (20 l), and large tank (350 l). Rates of oxygen production have been measured for each, and the advantages and disadvantages of each size container for measuring viability-growth studies are considered. Flasks could be used for screening studies, but were unsuitable for kinetic studies (rate of production of oxygen) which were done with 20 l and 350 l containers. Comparable kinetic data can be obtained with both containers, but the 350 l system is less likely to cause plant stress owing to oxygen supersaturation. The possibility for reducing plant growth by addition of Chelex-100 was explored.**

FACTORS responsible for dense growth of such aquatic plants as hydrilla (*Hydrilla verticillata* Royle) and egeria (*Egeria densa* Planch) are of considerable interest. Infestations of these plants (Holm et al., 1969) cause loss of navigability of natural waters, decreased water flow (with attendant flood problems in some instances), reduced recreational use, and the costs of chemical and/or mechanical control (Holm et al., 1969). Chemical, mechanical, and biological control methods are available (FDNR, 1974).

It also seems worthwhile to consider another approach (Martin et al., 1971),

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

i.e. deprivation. Presumably it should be possible to manage the growth of these nuisance plants by depriving them of critical nutrients. Earlier, it was suggested (Martin et al., 1971; Reid et al., 1974) that this might involve control of a trace element such as iron (Reid et al., 1975) or manganese (Martin and Reid, 1976).

Deprivation might be achieved by altering the form of a nutrient, e.g. iron, by altering the oxidation state through oxygenation of lake water or by precipitating the material as the pH is altered (cf. Laing, 1974). The possibility for checking these approaches in the laboratory is more reasonable and controllable than in natural ponds or lakes. We have compared the advantages and limitations of using different size containers for bioassays with hydrilla and tested the use of a chelating resin as a deprivation mechanism.

METHODS AND MATERIALS—Hydrilla plants were gathered from the Hillsborough River, washed thoroughly with tap water and cultured in well water or suitable medium for at least 1 wk before use. The basic medium consisted of either deep well water without further enrichment or a Hoagland's solution (cf. Steward and Elliston, 1973).

Plants were studied in two systems. One consisted of 20 l carboys filled with well water and 40 g of plant, closed to the atmosphere and attached to matching 20-l polyethylene reservoirs. As a sample of water was withdrawn periodically from the carboy by releasing a clamp on a second tube, an equal volume of water was withdrawn from the reservoir. Carboys were illuminated with 1800 lumens for 13 hr per da (40 W fluorescent coolwhite lamps). Secondly, a 350 l Plexiglas tank (89 cm × 73 cm × 61 cm deep) was used with 360 g of plant, well water medium, and the top was covered by 10 mil polyethylene held down tightly by Plexiglas screwed to the tank top. Plants were illuminated from above by 4 40 W cool-white fluorescent lamps (30 cm from the surface) and along the side by single lamps. The systems were stirred with magnetic stirring bars. Room temperature was $22 \pm 2°C$. Dissolved oxygen (D.O.) samples were obtained by a Winkler (single bottle) titration (Martin, 1972) for samples taken daily for the first 3 da then alternate days during a 21 da period.

Pseudo-first order rate constants (Martin and Reid, 1974) were calculated from the data using relationship:

$$k_{O_2} = (1/\Delta t) \ln [(D.O.)_f - (D.O.)_i] \,/\, [(D.O.)_f - (D.O.)_t] \quad (1)$$

Here (D.O.) refers to dissolved oxygen concentration, and the subscripts f, i, and t refer to the maximum, initial and time t values, respectively. Generally, standard systems followed the indicated rate expression, and fair precision (± 3-5%) could be obtained.

Initial rates of dissolved oxygen production were calculated by least-squares analysis of appropriate dissolved oxygen versus time, t, data (Hall et al., 1976)

$$y = a + bt; \quad (2a)$$
$$y = [(D.O.)_t - (D.O.)_i]/t \quad (2b)$$

The initial rate, a, was obtained with fair precision (Table 1).

TABLE 1. Comparison of rate of oxygen production characteristics for study systems with *Hydrilla.*

		Specific Rate Constant day^{-1}	Initial Rate, ppm/day
Comparison of sampling position in 350 liter tank	Top	0.205 ±0.15	0.82 ±0.04
	Bottom	0.201 ±0.006	0.85 ±0.03
Effect of treatment with Chelex 100 in 350 liter tank	Top	0.060 ±0.010	0.188 ±0.02
	Bottom	0.072 ±0.022	0.27 ±0.03
Standard study system		0.187 ±0.02	

RESULTS AND DISCUSSION—Measurement of dissolved oxygen provides a good measure of plant viability and, presumably, of plant growth. It is possible to obtain kinetic data with the 20 and 360 l systems. Two characteristics are used to express plant viability and, thus, suitability of a given medium or natural water for hydrilla growth: growth characteristic (% D.O. increase), and rate of oxygen production (expressed as pseudo-first-order rate constants, k_{O_2}, Eqn. 1, or as initial rates of oxygen production, Eqn. 2). Increase in dissolved oxygen can be related to the increase in biomass (as increase in dry wt). For example, for the manganese-enriched system (using 20 l systems and enrichments with Mn-$(EDTA)^{=}$, the correlation between D.O. increase and dry wt increase (Martin and Reid, 1976) was significant ($r = 0.9195$; $P = 0.025$–0.01).

Specific rate constants for oxygen production in the 20 l and in the large tank seem comparable. Samples were run using deep well water, and compared for an initial phase of the study. Relative means and standard errors [Relative standard errors of the mean $= (SEM_1^2 + SEM_2^2)^{1/2}$] for large aquarium (top and bottom) and for standard systems (three carboys) were 1.02 + 0.06 and 0.93 ± 0.06, respectively. Thus for present purposes, the two systems seem justly comparable, though probably more detailed experiments with defined media would be needed to definitively establish the point.

The effect of sampling position on the apparent specific rate constants was evaluated. Samples of dissolved oxygen were taken using clamped syphons that had outlets 17 cm and 51 cm from the top in the 56 cm deep water sample. Specific rate constants were calculated for the first 10 da and the top and bottom were compared. Relative rate constants (values for the bottom relative to the top sampling location) were calculated for two experiments and for two time spans (2-10 da and overall), and values obtained were 1.02 ± 0.06, 1.14 ± 0.14, and 1.02 ± 0.10, 1.0 ± 0.25. It appears that the system was sufficiently well stirred, and observed changes in dissolved oxygen were representative of the entire water column.

Some experiments were initiated concerning the possibility of hydrilla management through trace-metal control. In the present instance, the 350 l system was treated with Chelex 100 resin suspended in tubes and thus accessible, albeit slowly through diffusion. This resin is known to remove trace metals (Davey et al., 1970). The specific growth constants and initial rates of O_2 production were about 33% of the values obtained in the absence of Chelex resin (da 2-8) (Table 1). Control and test systems reached oxygen saturation of 11 ppm about the same time (17 and 13 da, respectively), but the control maintained saturation to the end of the experiment. Oxygen levels for the test system gradually decreased and the final value at 47 da was 9% less than the initial value and substantially below saturation values. The plants clearly were in a stressed condition as indicated by the onset of chlorosis.

The observations summarized here indicate the utility and some of the advantages and limitations of different size containers in studying the characteristics of submersed aquatic plants, though further studies are required to elucidate the role of ion-removal agents, e.g. Chelex-100.

ACKNOWLEDGMENT—The financial support of the Florida Department of Natural Resources, Bureau of Aquatic Weed Research and Control is gratefully acknowledged.

LITERATURE CITED

DAVEY, E. W., J. H. GENTILE, S. J. ERICKSON, AND P. BETZER. 1970. Removal of trace metals from marine culture media. Limnol. Oceanog. 15:486-488.

HALL, K. J., T. I. QUICKENDEN, AND D. W. WATTS. 1976. Rate constants from initial concentration data. J. Chem. Educ. 53:493-494.

HOLM, L. G., L. G. WELDON, AND R. D. BLACKBURN. 1969. Aquatic weeds. Science 166:699-709.

FLORIDA DEPARTMENT OF NATURAL RESOURCES, BUREAU OF AQUATIC PLANT RESEARCH AND CONTROL. 1974. Aquatic Weed Identification and Control Manual. Tallahassee.

LAING, R. L. 1974. A non-toxic lake management program. Hyacinth. Contr. J. 12:41-43.

MARTIN, D. F. 1972. Marine Chemistry 1: Analytical Methods (2nd ed.). Dekker. New York.

———, M. T. DOIG, III, AND D. K. MILLARD. 1971. Potential control of Florida Elodea by ion-control agents. Hyacinth. Contr. J. 9:36-39.

———, AND G. A. REID, JR. 1974. Comparison of growth constants of two aquatic plants. Environ. Letters 6:47-54.

———, AND ———. 1976. Uptake of manganese in *Hydrilla verticillata* Royle. J. Agric. Food Chem. 24:1161-1165.

REID, G. A., JR., D. F. MARTIN, AND M. T. DOIG, III. 1974. Rate constants as a diagnostic tool for comparing *Hydrilla* and *Egeria*. Hyacinth Contr. J. 12:5-8.

———, ———, AND Y. S. KIM. 1975. Stimulation of hydrilla growth by Fe(EDTA) . J. Inorg. Nucl. Chem. 37:357-358.

STEWARD, K. K., AND R. A. ELLISTON. 1973. Growth of hydrilla in solution culture at various nutrient levels. Florida Sci. 36:228-233.

Florida Sci. 40(2):205-208. 1977.

INSTRUCTIONS TO AUTHORS

Rapid, efficient, and economical transmission of knowledge by means of the printed word requires full cooperation between author and editor. Revise copy before submission to insure logical order, conciseness, and clarity.

Manuscripts should be typed double-space throughout, on one side of numbered sheets 8½ by 11 inch, smooth, bond paper.

A Carbon Copy will facilitate review by referees.

Margins should be 1½ inches all around.

Footnotes should be avoided. Give Acknowledgments in the text.

Address should be given following the author's name.

Abstracts should be typed double-spaced immediately following the address.

Literature Cited follows the text. Double-space every line and follow the form in the current volume.

Tables are charged to authors at $25.00 per page or fraction. Titles must be short, but explanatory matter may be given. Type each table on a separate sheet, double-space, unruled, to fit normal width of page, and place after Literature Cited.

Legends for illustrations should be grouped on a sheet, double-spaced, in the form used in the current volume, and placed after Tables. Titles must be short but may be followed by explanatory matter.

Illustrations are charged to authors ($20.00 per page or fraction). Drawings should be in India ink, on good board or drafting paper, and lettered by lettering guide or equivalent. Plan linework and lettering for reduction, so that final width is 4 5/8 inches, and final length does not exceed 7 inches. Do not submit illustrations needing reduction by more than one-half. Photographs should be of good contrast, on glossy paper. Do not write heavily on the backs of photographs.

Proof must be returned promptly. Leave a forwarding address in case of extended absence.

Reprints may be ordered when the author returns corrected proof.

FLORIDA ACADEMY OF SCIENCES

Institutional Members for 1976

Archbold Expeditions
Barry College
Eckerd College
Edison Community College
Florida Atlantic University
Florida Institute of Technology
Florida Southern College
Florida State University
Florida Technological University
Gulf Breeze Laboratory
Jacksonville University
John Young Museum and Planetarium
Manatee Junior College
Miami-Dade Community College
Stetson University
University of Florida
University of Miami
University of South Florida
University of Tampa
University of West Florida

Membership applications, subscriptions, renewals, changes of address, and orders for back numbers should be addressed to the Executive Secretary, Florida Academy of Sciences, 810 East Rollins Street, Orlando, Florida 32803.

ISSN: 0098-4590

Florida Scientist

Volume 40 Summer, 1977 No. 3

CONTENTS

(*Continued on back*)

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

FLORIDA SCIENTIST

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

The FLORIDA SCIENTIST is published quarterly by the Florida Academy of Sciences, Inc., a non-profit scientific and educational association. Membership is open to individuals or institutions interested in supporting science in its broadest sense. Applications may be obtained from the Executive Secretary. Both individual and institutional members receive a subscription to the FLORIDA SCIENTIST. Direct subscription is available at $13.00 per calendar year.

Original articles containing new knowledge, or new interpretation of knowledge, are welcomed in any field of Science as represented by the sections of the Academy, viz., Biological Sciences, Conservation, Earth and Planetary Sciences, Medical Sciences, Physical Sciences, Science Teaching, and Social Sciences. Also, contributions will be considered which present new applications of scientific knowledge to practical problems within fields of interest to the Academy. Articles must not duplicate in any substantial way material that is published elsewhere. Contributions are accepted only from members of the Academy and so papers submitted by non-members will be accepted only after the authors join the Academy. Instructions for preparation of manuscripts are inside the back cover.

Published by the Florida Academy of Sciences, Inc.
810 East Rollins Street
Orlando, Florida 32803

Printed by the Storter Printing Company
Gainesville, Florida

Florida Scientist

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Harvey A. Miller, *Editor* Walter K. Taylor, *Associate Editor*

Volume 40 Summer, 1977 No. 3

Symposium Debate

CAN FLORIDA AFFORD THE PHOSPHATE INDUSTRY?

William H. Taft

Office of Sponsored Research, University of South Florida, Tampa, Florida 33620

In my opinion, Florida cannot afford the phosphate industry, as it presently operates, because of:

1. The high demand for electricity by the industry and associated environmental degradation caused by the generation of that electricity.
2. The excessive amount of fresh-water consumed by the industry.
3. The complete destruction of land, vegetation and creeks through the strip-mining process.
4. The threat of contamination by radioactive materials.
5. The effect of slime pond spills on streams.
6. The serious threat to streams and the ground water caused by acid wastes (gypsum ponds).

To say the Florida Phosphate Industry has acted on behalf of the best interests of the citizens of this State would be to seriously misrepresent the facts. I doubt there is anyone in this State who is not aware that the industry has a very strong lobbying influence, not only in Tallahassee but in Washington as well.

My best illustrations of their lobbying influence consist of the following:

1. Doyle E. Carlton, Jr., speaking about the Florida Phosphate Industry, was quoted in the Herald-Advocate August 26, 1976, "while I was in the (Florida) senate, I introduced and had passed some anti-pollution bills with little teeth in them, as we knew, because of the power of the industry."

2. The fact the national strip mining bill excluded phosphate and speaks only of coal, is a testimony to the phosphate industry's lobbying influence on the national level.

Unfortunately, most people don't appreciate the magnitude of damage caused by the Florida Phosphate Industry's strip-mining process. According to the U. S. Soil Conservation Service (1972), Florida ranked second in the nation among states with land that had been disturbed by surface mining. The top ten are as follows:

State	Land Requiring Reclamation in Thousand Acres
1. *Pennsylvania*	240.9
2. *Florida*	196.0
3. *Ohio*	191.6
4. *Texas*	136.8
5. *Alabama*	127.9
6. *West Virginia*	100.0
7. *Missouri*	93.0
8. *Michigan*	72.4
9. *California*	69.7
10. *Kansas*	67.4

One does not have to travel far within the mining areas of Polk, Hillsborough and Hardee counties to see the moonscape so typical of the phosphate industry's strip-mining process. Typically, however, one can best see the damage from the air because the industry, as of late, has recognized the public relation value of reclamation along the roads.

In 1975, Legislation became effective requiring the phosphate companies to "institute and complete a reclamation and restoration program upon each site of severance, which shall include the following standards:

1. Control of the physical and chemical quality of the water draining from the area of operation.
2. Soil stabilization, including contouring and vegetation.
3. Elimination of health and safety hazards.
4. Conservation and preservation of remaining natural resources.
5. Time schedule for completion of the program and the various phases thereof."

In other words, a company may elect to restore an old mined-out area and recover a portion of the taxes paid to the State without restoring everything mined since 1975.

The arrangements for the severance tax bear review. The State imposes a 5% severance tax on the value of the phosphate ore at the point of severance. This is the point in the process when the phosphate has been taken from the ground and separated from the matrix and is "identifiable as to kind and quality". In the language of the industry, this is the wet rock bin. The point here is, when phosphate is selling for $45-60 per ton, the industry is not paying 5% of the sale price. They are taxed on the product's value at the bin—$12.57 per ton, or .60/ton tax is imposed.

The tax arrangement is as follows: of the .60/ton, 40% goes to the Incidental Trust Fund for use by the State, up to 20% of the tax can be credited against *ad valorem* taxes and the remaining 40% goes to the Land Reclamation Trust Fund. This Fund is used to reimburse the phosphate companies for restoring and reclaiming the land. The tax picture, in light of this breakdown no longer looms so bright for the State because the Industry can get back 60% of their required tax. I would argue that the industry should be forced to restore (not reclaim) the land and should not get any tax rebate. That type of statement would cause the weeping and gnashing of teeth in the phosphate industry—so let's look at how the industry must be doing financially. The following is a comparison of export prices per ton of Moroccan and Florida Phosphate Rock from 1962 through January of 1976:

Year	Morocco, 74%	Florida, 74-75% BPL	Production in Million Tons/yr
1962	11.25	9.25	16
1967	11.75	10.18	31
1972	11.75	11.18	35
1973	14.17	10.20	32
1974 January	42.00	27.50	32
1974 July	63.00	42.00	--
1975 January	68.00	55.00	35
1976 January	50.00	47.00	--

Clearly, the costs of production could not have risen from 1973 to 1976 as rapidly as the sale price of phosphate. World demand drove up the price and more of Florida became moonscape.

The industry points with pride to the fact that they "started or completed reclamation projects on almost 15,000 acres" in 1975. According to official figures from the State Bureau of Geology, only 2,515 acres of land were reclaimed during 1975 for which the industry received $10,000,000 from the State or approximately $3,976/acre from the taxes they paid into the Land Reclamation Trust Fund. According to the Mines and Mine Reclamation Section of the Department of Geology the "industry average cost from 1972 through 1975 for all types of reclamation is $1,311.96 per acre". Thus, one must assume the industry is making a profit from land reclamation.

The tax on Florida phosphate should be changed to more adequately reflect the value of the product and thereby provide an excellent source of income to the State during the life of this resource. This increased revenue could be used to monitor the industry.

The following are some additional reasons why Florida can't afford the phosphate industry as it is presently operated:

1. Slime Pond Breaks—The last major break occurred in 1971 when a slime pond dam broke and millions of gallons of phosphate waste found its way to the Peace River killing millions of fishes and temporarily destroying their habitat. I'm confident the industry believes it cannot afford another dam failure because of the outcry of Florida citizens, but another break is inevitable, simply because there are in excess of 642 miles of earthen dams and there is no government review of these structures. In other words, industry is policing itself.

2. Gypsum Ponds—Slime ponds, although esthetically displeasing, cannot hold a candle to the contents of gypsum ponds. These structures hold the chemi-

cal wastes of processing the phosphate. These ponds contain up to 60 ft of acid wastes with a high concentration of fluorides and other obnoxious chemicals. If one can recognize that most, if not all, ponds are mined areas resting close to or on the limestone, you can appreciate the likelihood of these acid wastes entering into the aquifer. This particular problem has received little attention but should receive more now and in the future.

There are also a number of secondary effects of the industry that must not be ignored, such as:

1. Electricity Consumption—Most residents of the Tampa Bay area are aware of the rising costs of their electric bills and the pollution problems caused by Tampa Electric Company, but I daresay few recognize how much electricity goes to the phosphate industry and what the industry pays for the power. Tampa Electric Company's annual report to the stockholders for 1976 shows the phosphate industry in 1976 consumed 31% of the electricity sold, but only accounted for 21.9% of TECO's revenue. As the industry continues to expand, they will demand more electricity and therefore, the pollution problem in the Tampa Bay area will increase.

2. Tampa Harbor Deepening—For years, the phosphate industry had complained about the shallowness of the Tampa Bay ship channel which prevented their outgoing vessels from being filled to capacity. The Corps of Engineers has the authorization and appropriation from Congress to widen and deepen the Tampa ship channel to the 43 ft that will accommodate the design of the super size, ocean-going, bulk cargo vessels most common to the phosphate carriers. It is interesting to note that when asked by the Tampa Port Authority if the phosphate industry would help pay for the environmental costs associated with widening and deepening of the harbor, the industry responded by offering help only if the other users contribute. The industry pledged 2.5 million dollars over the next 5 yr, if the other users would contribute a like amount. That's $500,000/yr or 2.5¢/ton based upon 20 million tons. To put this request in perspective you should recognize the phosphate industry paid 20.3 million State severance taxes in 1975. There is not much question why the port required deepening—to get more phosphate out of Florida, faster.

3. Ground Water—Before an area is mined, the companies must drop the water table as much as 35 to 50 ft in order to remove the ore. In addition, a large quantity of water is used in the mining and processing phases of the operation. As an example, on March 10, 1977 a notice of application for a consumption use permit in Polk County appeared in the Tampa Tribune. This request was for use of 13,048,300 gallons a day, and not more than 27,040,000 maximum per day in connection with the Bonnie Land Mine. When the consumption use permits of the industry are totaled they amount to at least 250,000,000 gallons per day. That's 35 times the daily residential use by the City of Tampa.

4. Natural Resources—From a cypress swamp, a grassy prairie, or dense native mixed vegetation to a moonscape does not leave much in the way of natural resources. Picture, if you will, a typical Florida creek winding its way through a forested area and the generations of young and old alike who wandered

along the creek and became one with nature. After the phosphate industry removes the trees, strips the land, removes the ore, ditches the creek and then uses it to transport waste—one must ask—what price profit?

5. Radioactivity—Recently there have been reports of radioactivity associated with homes constructed on reclaimed lands, but there are other problem areas as well, such as water in the recirculating gypsum systems which contain 6-100 picocuries per liter of radioactive radium-226. This concentration exceeds by at least 2-3 times the former AEC standards for discharge to an unrestricted environment. Gypsum piles contain thousands of curies of radium-226 in a readily leachable form. This material will continue to pose a threat to the ground water until it is stabilized.

Florida Scientist 40(3):209-213. 1977.

Symposium Debate

PHOSPHATE IN FLORIDA TODAY—AN OVERVIEW

Homer Hooks, President, Florida Phosphate Council
P.O. Box 5530, Lakeland, Florida 33803

The image of the open pit miner in the eyes of environmentalists has often been less than favorable. The Florida phosphate industry, an important part of Florida's economy since the late 19th century, has been accused of every known environmental sin, and some unknown ones as well. Some of the less genteel names we are regularly called include: "Land Rapists", "Water Guzzlers", and "Opportunists". The publisher of an influential Gulf Coast daily newspaper called phosphate "one of the dirtiest and highest polluting industries in the country".

In addition to being called polluters of the highest order, it is frequently editorially suggested that the phosphate industry has a "sweetheart arrangement" with government agencies and elected officials—that the industry is "under-regulated", or even "un-regulated". There are frequent calls for the state and federal government to get tougher on the phosphate industry—to bring the "polluters" to heel.

The thing that troubles me and others in the industry most about these charges is that they are simply not true. The Florida phosphate industry is *not* a major polluter of the state's air, land, and water, and the industry *is* subject to very strict regulations on the county, regional, state and federal levels, regulations which the industry is completely complying with, and will continue to comply with. I'll go over some of these regulations with you in just a moment.

Unfortunately, the phosphate industry has not always been as responsible an environmental citizen as it is now. There are environmental sins in our past, and we in the industry are the first to admit this. But times have changed, and it is patently wrong to continue to charge us now for the horrors of the past.

Over the past decade there has been an increasing awareness in the industry of environmental responsibilities. This awareness paralleled a growing concern on the part of the general public over pollution problems, and has brought about, in part, a multitude of new environmental regulations.

Before I get into a discussion of these very strict regulations the industry is complying with, I hope I can persuade you to agree that the phosphate industry is absolutely necessary. We simply cannot do without the chemical fertilizers made from the phosphate rock we mine. Some well-meaning but ill-informed persons have taken the extreme position that phosphate mining in Florida should be banned altogether. I trust that an audience of scientists, as we have here, has a greater understanding of the need for phosphorus to support life. Isaac Asimov put it this way: "We may be able to substitute nuclear power for coal, plastics for wood, yeast for meat, and friendship for isolation—but for phosphorus there is neither substitute nor replacement."

Phosphorus, as everyone in this room knows, is a fundamental nutrient—an essential part of nerve and brain tissue, and a decisive factor in muscle action and cell growth. It is indispensable to the life, growth, and health of all animals, plants, and human beings.

Plants get phosphorus from the soil. But most soils contain relatively small amounts of phosphorus—so to feed plants and animals and to produce food, man must extract phosphate from the earth where it is deposited, convert it to useful ingredients, and make it available to plants and animals for ultimate production of food. And this is the business of the Florida phosphate industry.

Our job is to feed people. And as we know from the book of Genesis and from just looking around us, people beget people. And how they do beget! In 1830, the world had a population of a mere one billion people. Just 100 years later the population had doubled to two billion people. By 1960, there were three billion, and right now, it is estimated that four billion people live on the earth. World population is expected to reach five billion in 1985, and seven billion by the year 2000. If we are to have even the remotest hope of feeding these teeming billions, the world will have to have the most efficient agriculture possible, and this means fertilizer and plenty of it. Put in this perspective, it is easy to see that the fertilizer industry is not a luxury, but an absolute necessity, if we are not to sentence billions to starvation.

Now that we've seen that the phosphate industry is vital, let's take a look at the importance of Florida phosphate in the U. S. and the world. Last year, Florida phosphate miners produced about 40 million tons of phosphate rock, more than 80% of the total U. S. production and one-third of the world output. Florida is clearly the world's most productive source of phosphate rock, and with the deposits we have in Florida, if we are allowed to mine them, we will continue to be the world's most productive source of phosphate rock for many decades.

Along the way to providing the world with an essential mineral for life, the Florida phosphate industry provides the state with other things it could ill-afford to do without—investment in the state has been estimated at $3 billion, with another $1 billion invested when planned mines in Hardee, DeSoto, and Manatee counties are operating. Phosphate is one of Florida's "Big Four", ranking right with tourism, citrus, and construction, and one of the state's major economic beneficiaries.

More than 11,000 people in Florida work directly for phosphate companies. More than 7,000 others work for companies which do all or substantially all of their business with phosphate companies. In addition to these direct and indirect employees of the industry, the U. S. Bureau of Mines estimates wages and salaries paid to employees of the phosphate industry, and employees of all levels of suppliers, leads to consumer expenditures which generate production of goods and services in many other industries, leading to more than 43,000 additional jobs in the state. The Bureau of Mines estimates that direct and induced employment created by the phosphate industry provides more than 60,000 jobs in Florida.

While we're on the subject of phosphate employment, I might add that phosphate industry workers are among the most highly paid industrial workers in central Florida. The Florida state employment service estimated last September that phosphate production workers, and this does not include higher paid engineers and managers, were averaging $243 per week. This compares to $207 per week for all manufacturing and $162 per week for agriculture and services.

Now, if I may, I'd like to take a few minutes to give you a brief survey of some of the regulations that the "under-regulated" phosphate industry is complying with.

FEDERAL CLEAN AIR AND WATER ACTS—One basic premise of the Federal Clean Air Act of 1970, was that, whereas the federal government should set nationwide ambient air standards, it would be the responsibility of the states to implement control measures to maintain those standards. Florida's implementation plan, submitted and approved by the Environmental Protection Agency, called for attainment of not the primary, but the secondary, or more stringent, ambient air quality standards by 1975.

The primary standards as you may know, are those standards requisite to protect the public health. The secondary standards are designed to "protect the public welfare from any known or anticipated adverse effects associated with the presence of air pollutants in the ambient air" and are about one-third more strict than the primary standards. With few exceptions, (most of these in highly urbanized or industrialized sections of the state) the air quality goal has been met. Using EPA guidelines, the state is currently designating air quality maintenance areas where existing regulations appear to be inadequate to prevent new emissions from exceeding the ambient air quality standards.

Areas of the state with air quality superior to the ambient standards are being approached by EPA with the concept of non-significant deterioration. Final rules defining area classification procedures and incremental allowances in increased ambient air pollution concentrations were promulgated November 27, 1974, with the effective date of the regulation January 6, 1975. All sources in 19 major categories with emissions of sulfur dioxide or total suspended particulate matter, which commenced construction or modification after June 1, 1975, are affected.

In addition, EPA has promulgated new source performance standards on latest available technology for virtually all of the major processes in the phosphate chemical industry. Under Section III (D) of the Clean Air Act, new source standards have been proposed applicable to existing sources for certain pollutants for which air quality criteria have not been issued. Fluorides are included in this category.

The Federal Water Pollution Control Act of 1972, led to more legislative action in 1975 and 1976 than any other major environmental law. The overall goals of the act are achievement of high water quality by July 1, 1983, drastic reduction of pollutants discharged (in some cases to zero) by 1985, and the elimination of toxic-pollutant discharge.

Effluent guidelines and standards have been promulgated for phosphate mining and chemical plants on three separate levels: (1) The best practical control technology currently available, which existing plants must meet by July 1, 1977; (2) The best available demonstrated control technology, which new plants must meet upon start-up; and (3) The best available control technology economically achievable, which all plants must meet by July 1, 1983. The guidelines have been challenged by the industry, primarily because of difficulty in interpretation of parts of the rules. The practice of EPA promulgating interim-final guidelines does not allow sufficient time for consideration of differences before the comment period closes. Adjudication is often necessary to hold the door open for discussion until after the rule appears in final form.

National Pollutant Discharge Elimination System—All effluent discharges into navigable water must be permitted under the National Pollutant Discharge Elimination System. Until 1975, NPDES permits for new plants had to be filed at least 180 days prior to commencement of effluent discharge. In 1975, EPA requested that NPDES applicants hold a pre-application conference with the agency at least 24 months before beginning discharge.

Environmental Impact Statement—Under the National Environmental Policy Act of 1969, EPA is required to prepare an Environmental Impact Statement before taking any action which would affect the environment, such as allowing a new plant to discharge into the environment. Under the EIS system, firms seeking permits or land leases must supply the government agency with pertinent information in the form of an Environmental Impact Report. The agency then completes and circulates a draft EIS for comment and modification before preparing a final EIS. The extra time provided by the 24 month pre-application conference allows for better planning and time may be saved by finding and resolving problems at earlier stages.

Dredge and Fill—Section 404 of the Federal Water Pollution Control Act was designed to protect sensitive water and adjacent wetland areas from environmental degradation resulting from the discharge of dredged or fill material. It authorizes the Corps of Engineers to issue permits for the discharge of dredged or fill material into navigable waters. A federal court has interpreted navigable waters to mean all waters of the United States, and has ordered the Corps to expand its jurisdiction to all such waters. The Corps process may be lengthy, and an EIS and/or public hearings may be required.

FUTURE CONCERNS—Three other major regulatory actions with possible impact on the phosphate industry are waiting in the wings. The Safe Drinking Water Act, which becomes effective this June; the Resource Conservation and Recovery Act signed into law last October; and the Consent Decree signed into law last June, which required EPA to review and revise the 1983 limitations to include effluent guidelines for 65 toxic pollutants in 21 industries. All three of these could be viewed as vehicles for federal control of pits, ponds, and lagoons with jurisdiction over and permitting of gypsum stacks, clay settling ponds, and sand tailings area.

STATE REQUIREMENTS—The Florida Department of Environmental Regulation (DER) issues five basic permits which are currently required for existing operations in the phosphate industry. The permits are for (1) point sources of air emissions, (2) industrial wastewater, (3) dredge and fill activities, (4) sewer waste water, and (5) dam construction.

Air and wastewater operating permits generally require mandatory monitoring and reporting and are issued for two and five years, respectively. In the case of water, water quality criteria and the class of the receiving streams are considered. The DER sub-district with jurisdiction over the phosphate industry has also requested, without specific statutory authority, that each company submit an annual mining plan illustrating pipelines and other activities which could conceivably contaminate a receiving stream in the case of an accident. Most companies have complied with this request.

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT—The Southwest Florida Water Management District has jurisdiction over the central Florida phosphate producing area. This agency requires a permit from the governing board for well construction, water withdrawal, or discharge into, construction across or within, or to otherwise make use of bodies of water under the district's jurisdiction.

In 1974, SWFWMD adopted rules for permitting "consumptive uses of water". These rules are based on a "water crop" concept which presently allows withdrawal of 1,000 gallons of water per day per acre of land owned, leased, or otherwise controlled. The industry is required to monitor and report the volumes of all fresh water withdrawn from the aquifer or surface streams. Permits are issued using good water conservation practices as criteria. SWFWMD and industry have jointly promoted such projects as gravity recharge wells which now put more than 30,000,000 gallons of water per day back into the aquifer.

DEPARTMENT OF NATURAL RESOURCES AND DEPARTMENT OF REVENUE—The state is directly involved with supervision of land reclamation through the Department of Natural Resources. Guidelines must be met before credit is given companies toward the cost of reclamation for a rebate of a portion of the severance tax. The present tax rate is 5% on the value of the phosphate at the point of severance.

DEVELOPMENT OF REGIONAL IMPACT—The phosphate industry participates in the Division of State Plannings' Development of Regional Impact (DRI) program. For mining operations, a Development of Regional Impact is required if "the removal or disturbance of solid minerals or overburden over an area, whether or not it is contiguous, is greater than 100 acres, or if proposed consumption of water would exceed 3 million gallons per day". A broad spectrum of information is required for a DRI permit, including description of the proposed mining activity in detail and its effect on the environment and the economy of the region. An enormous amount of baseline data is required on ambient air and water, groundwater quality and expected pumping impact on the aquifer, animal and vegetation surveys, soil surveys, transportation and economic surveys, archaeological and historical surveys, and other detailed investigations. I don't need to tell you preparation of a statement of this type required enormous time, expertise in specialized fields, and is costly.

COUNTY REQUIREMENTS—Six counties in the state have enacted mining ordinances. They all require a zoning variance for mining based on a detailed master plan and a permitting procedure which allows ongoing monitoring and annual detailed operational reports. The annual reports require information on mining methodology, reclamation progress and compliance with numerous environmental considerations including: dam construction and settling ponds, easements to adjacent owners, soil vibrations and noise, flood plain restrictions, monitoring requirements for water and air, ground water rainfall, sewage effluent, radiation, etc.

The list I've just given you is not complete. But it should give you some feeling for the scope and detail of regulations which affect the industry. We're not "under-regulated", but we're not complaining about being regulated. We recognize the need for regulation of any industry or enterprise which might have an effect on Florida's environment. Both the need to produce phosphate for food and the need to protect our environment are vital. We who work in the industry are Floridians too and we want to leave a clean and beautiful Florida for our children, and for all the future generations of Floridians to come.

Florida Sci. 40(3):213-218. 1977.

Environmental Sciences

AIR QUALITY IN A CONFERENCE ROOM

T. C. WANG AND J. P. KRIVAN, JR.
Harbor Branch Foundation, Inc., Fort Pierce, Florida 33450

ABSTRACT: *Man is one of the main sources in contaminating the air quality in a conference room. Air quality was measured while the room was occupied. Miran Infra-red analyzer, MSA Lira analyzer and Ecolyzer carbon monoxide analyzer were used to analyze the air samples. Carbon dioxide, carbon monoxide, alcohol, methane and acetone were found. A mathematical model was derived to predict the instantaneous pollutant production rate from human beings, and to select an optimal ventilation rate to avoid excess pollutant accumulation in the room.*[*]

MAN HIMSELF presents one source of atmospheric contamination inside a confined room. Chemical pollutants from body effluents such as expired air, sweat, flatus, feces or urines have been a matter of concern in the space program as well as in the atmosphere of nuclear submarines (Adams, 1966; Conkle, 1970; Roth, 1968; Slonium, 1966). While the effects of effluents play an important role in a sealed cabin atmosphere, they are also important as components in atmospheric pollution whenever people remain in a confined room for any length of time. This study attempts to identify and quantitate those effluents most prevalent from a sample of people in an air-regulated room.

The test facility is a conference room in the Johnson Science Laboratory of Harbor Branch Foundation, Inc. The conference room is used for seminars, meetings, and the showing of movies. This room contains about 20 seats and has a total volume of 63.4 m^3. Exhaust air ducts are located on the top end of the room. Air constantly feeds into the room from floor vents and circulates into the room before going to the exhaust vent. The sampling site was chosen in front of an exhaust vent. Air was withdrawn into a tube and connected to monitoring devices. Neither the speaker nor the audience knew when samples were being taken.

MATERIALS AND METHODS—The data gathering system is as follows: 5/16 in. flexible tygon tube was run from the conference room, near the exhaust vent, to a MSA Lira Model 200 infra-red CO_2 analyzer coupled with a chart recorder. The gas sample was drawn at 2 cc/min through the sample cell.

When a steady influx of CO_2 indicated that a steady concentration was present in the conference room, the air samples were drawn into a Wilks Miran I infra-red analyzer and then into one 3.75 l stainless steel pressurized sampling tank.

The Miran infra-red gas analyzer was used to make a scan from 2.5μ to 14.5μ at 20.25 m pathlength and a 1 $\times$ 10 absorbance at 5-10 cc/min of sample flow.

Total hydrocarbons (as methane), carbon monoxide, carbon dioxide, acetone and alcohol were analyzed. Total hydrocarbons and carbon monoxide quantitative results were confirmed by an Ecolyzer Carbon Monoxide Analyzer and MSA, total hydrocarbon analyzer, respectively.

---

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

MATHEMATICAL MODEL—

A. *Pollutant Accumulation*: The concentration of pollutants inside a ventilated seminar room can be calculated using a material balance scheme.

Pollutants are continuously produced by the human beings at rate P, but they are also being continuously carried away by the flow V_E.

The first order differential equation could be set up as follows:

$$\frac{d(CQ)}{dt} = C_A V_A + P - C_E V_E \qquad (1)$$

C_A = pollutant concentration in fresh air
$C = C_E$ = pollutant concentration in exhaust air at any instantaneous time
Q = volume of seminar room
V_A = volume flow rate of input air to the room
V_E = volume flow rate of exhausted air to environment
P = production rate of the pollutant by human beings in seminar room
t = elapsed time

The final or equilibrium concentration; C_f, becomes,

$$C_f = C(t) = (C_f - C_A)\, e^{-kt} \qquad (2)$$

P, the generation rate of pollutants, can also be calculated from the final or equilibrium concentration and the initial concentration in the seminar room is in equation (3).

$$P = V_E\,(C_f - C_A) \qquad (3)$$

By combining equations (2) and (3), we can obtain

$$C = C_f - (P/V_E)\, e^{-kt} \qquad (4)$$

so that the time profile of pollutant concentration can be obtained for any time period providing the generation rate, ventilation rate and initial pollutant concentration inside the room are known. (Where k is the time constant = V_A/Q).

Rearranging equation (2), the equation can be rewritten as

$$\frac{C - Co}{C_f - Co} = (1 - e^{-kt}) \qquad (5)$$

This equation can be used to predict the time required to reach any fraction of final equilibrium concentration in a room.

B. *Pollutant Decay Calculations*: The concentration of pollutants in a ventilated room is varied with the activities of human beings in the room. As soon as the people leave the room, the concentration of pollutant inside the room will start to decay. The decay calculation of any pollutant using a material balance can be determined as:

$$\frac{d(CQ)}{dt} = C_A V_A - C_E V_E = C_A V_A - C V_E \qquad (6)$$

$$\text{and } C = C_A = (C_i - C_A)\, e^{-kt} \qquad (7)$$

Where:

C = pollutant concentration at time t

C_i = initial decaying concentration inside the room

C_A = pollutant concentration in input air

$K = \frac{V_E}{Q}$

t = elapsed time

Pollutant decay is seen to be an exponential process, the actual decay rate being determined by the K constant and by the concentration of pollutant present.

TABLE 1. Carbon dioxide production rate of human beings at meetings.

Run No.	No. of People	Initial Concentration in the room (ppm)	Final Concentration in the room (ppm)	Production Rate (g/day/person)
1	17	410	800	244
2	9	379	550	260
3	7	370	600	249
4	8	400	620	292
5	33	418	1320	291
6	18	403	1015	361
7	10	411	757	386
8	16	408	802	261
9	3	370	480	390
10	8	362	630	302
11	7	360	560	285

RESULTS AND DISCUSSION—Carbon dioxide, carbon monoxide, alcohol, methane and acetone were found in the conference room. These pollutants were contributed from human beings while occupying the room. The results of each of the detected pollutants are shown in Tables 1-5.

TABLE 2. CO production rate of human beings at meetings. Initial CO concentration in the room was approximately 1.83 ppm.

Run No.	No. of People	Final Concentration in the room (ppm)	Production Rate (g/day/person)
1	18	3.5	.62
2	10	3.1	.86
3	10	2.3	.32
4	16	3.0	.42
5	15	3.2	.45
6	12	2.8	.54
7	14	4.0	1.04
8	14	2.9	0.41

TABLE 3. Alcohol production rate of human beings at meetings.

Run No.	No. of People	Initial Concentration in the room (ppm)	Final Concentration in the room (ppm)	Production Rate (g/day/person)
1	18	.0142	.48	.0522
2	10	.0040	.21	.0147
3	10	.0014	.19	.0088
4	16	.0105	.37	.0386
5	15	.0107	.36	.0392
6	12	.0090	.295	.0331
7	14	.0103	.35	.0399
8	18	.0101	.34	.0378
9	11	.0065	.25	.0240

The initial CO_2 concentration in the room was about 400 ppm, which was similar to the CO_2 concentration as monitored outside the building. The uncontaminated air level is usually given at 320 ppm (Miller and Wand, 1966). The avg CO_2 concentration in ambient air could be higher due to automobile pollutants, because there is a parking lot just outside the room and one floor level lower. The final equilibrium CO_2 concentrations found in the room were from 500 ppm to 1320 ppm depending upon the number of people present and the activities of the people in the room. The typical CO_2 build-up curves are shown in Fig. 1. When people left, the CO_2 concentration decayed as shown in Fig. 2. The CO_2 buildup and decaying curves were used to measure the K value as derived in Equation (4). The K value was found to avg 0.055. Theoretically, the K($=VE/Q$) value was 0.06. The ventilation rate of exhaust vent was about 3.74 m3/min and the room volume is 63.4 m^3.

TABLE 4. Methane production rate of human beings at meetings. Initial methane concentration in the room was not detectable.

Run No.	No. of People	Final Concentration in the room (ppm)	Production Rate (g/day/person)
1	33	1.22	.074
2	18	1.03	.093
3	10	0.71	.044
4	16	1.00	.095
5	15	0.79	.049
6	12	0.74	.049
7	14	0.76	.044
8	18	0.82	.060
9	5	0.51	.041

TABLE 5. Acetone production rate of human beings at meetings. Initial acetone concentration in the room was not detectable.

Run No.	No. of People	Final Concentration in the room (ppm)	Production Rate (g/day/person)
1	33	.15	.0580
2	18	.063	.0269
3	10	.045	.0575
4	10	.049	.0512
5	16	.058	.0463
6	15	.06	.0512
7	14	.07	.0640
8	5	.04	.0519

The experimental K values for each meeting show only an 8% deviation from the theoretical value. The derived equations (2) and (3) can therefore be used to calculate the production rate of CO_2 per person per day as shown in Tables 1-5. The production rate of CO_2 varied as the results of different metabolic activities of human beings. Different activities inside the room could cause different CO_2

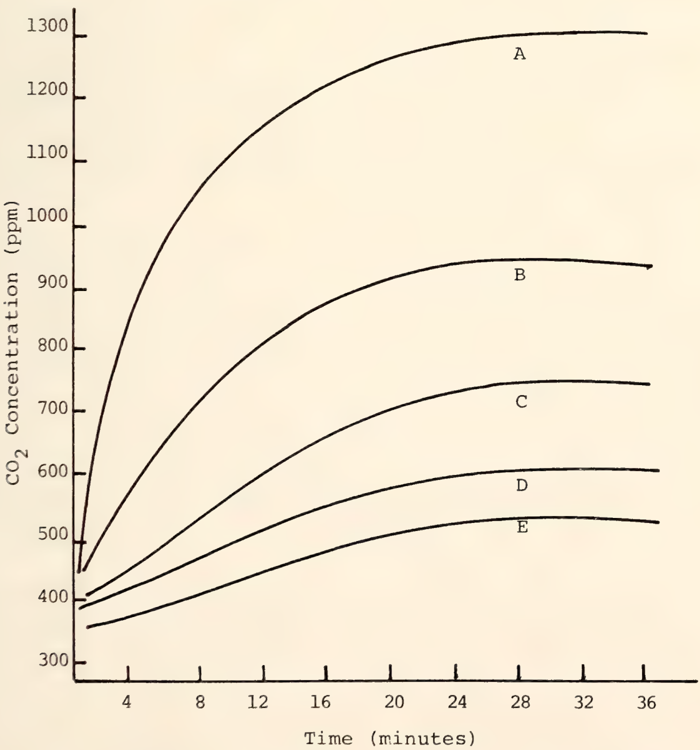


FIGURE 1. CO_2 build-up curves in the conference room. A=33 persons; B=16 persons; C=13 persons; D=10 persons; E=3 persons.

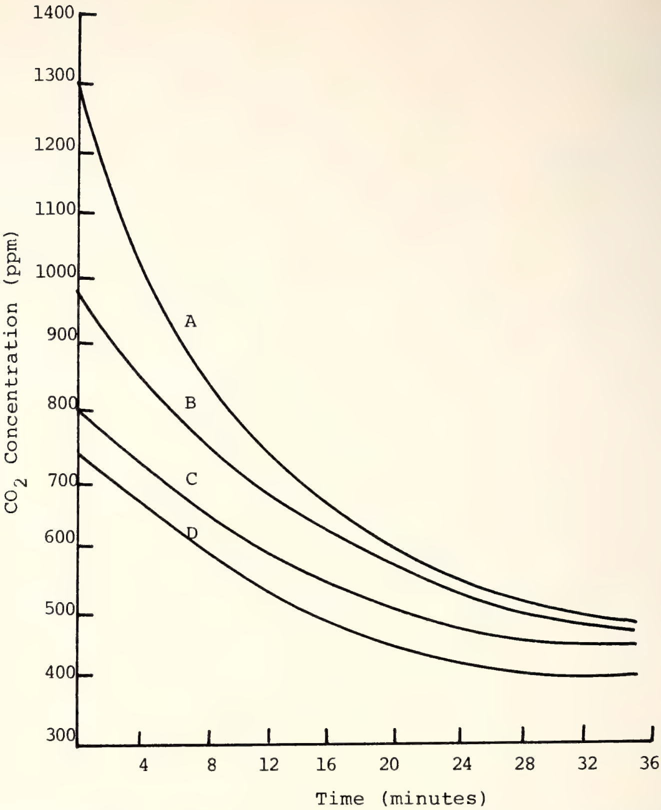


FIGURE 2. CO_2 decaying curves in the conference room. A = 33 persons; B = 16 persons; C = 13 persons; D = 10 persons.

production rates. The observed CO_2 production rate inside the room was between 244 and 390 g/day/person. This production rate verifies that the activities of people inside the room were equivalent to doing very light work (Christensen, 1950; Fletcher, 1964). Indeed, people in the room were mostly sitting and were very relaxed while attending the meetings. CO_2 production rate for sitting and resting and sleeping in the space cabin were reported to be 530 g/day/person and 320 g/day/person (Vinograd, 1964). Observed CO_2 production rate in this study was considered to be relatively low. Air leakage throughout the doors and floor and a nonuniform CO_2 concentration in the room could account for the lower values.

Carbon monoxide was another pollutant found in the study. The ambient air around the building avg 1.83 ppm. The steady CO concentration in the room was from 2.8 to 4.0 ppm. Consequently, the production rate of CO was calculated as demonstrated in Table 2. CO is a product of the metabolism of human beings. It is generally produced from the normal degradation of hemoglobin. The CO production rate found was 0.59 g/day/person. Tables 3, 4 and 5 indicate the concentration of methane, alcohol and acetone in the air and their produc-

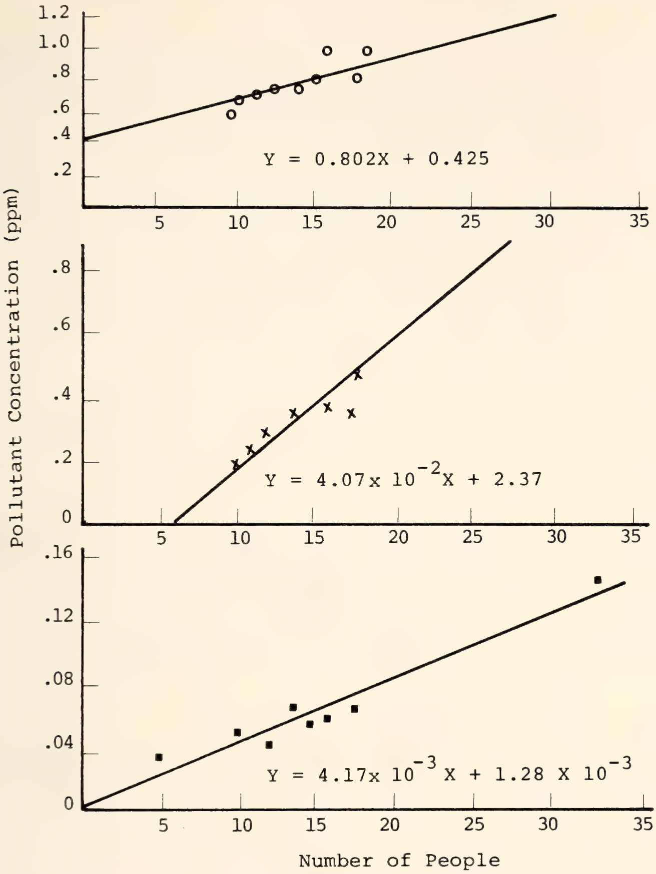


FIGURE 3. Air quality contamination from different numbers of people in the conference room. Circles = methane; x = alcohol; squares = acetone.

tion rate in the room. Alcohol is a normal constituent of blood and breath resulting from acetaldehyde by oxidation. Acetone is also a normal blood component resulting from the non-enzymatic breakdown of oxaloacetic acid.

Plots of final steady pollutant concentration against the number of people present in the conference room are shown in Fig. 3. A linear regression was used to treat these data. The equation derived from the statistical treatment is also shown in Fig. 3.

SUMMARY—1. Air pollutants in the conference room were found as carbon dioxide, carbon monoxide, methane, alcohol, and acetone. Their concentrations in the air and production rate from people at the meetings were presented in Tables 1-5.

2. The derived equations provided the methodology to predict the pollutant concentration in the air, to calculate the pollutant's production rate, and to select an optimal ventilation rate to avoid excess pollutants accumulating in the room.

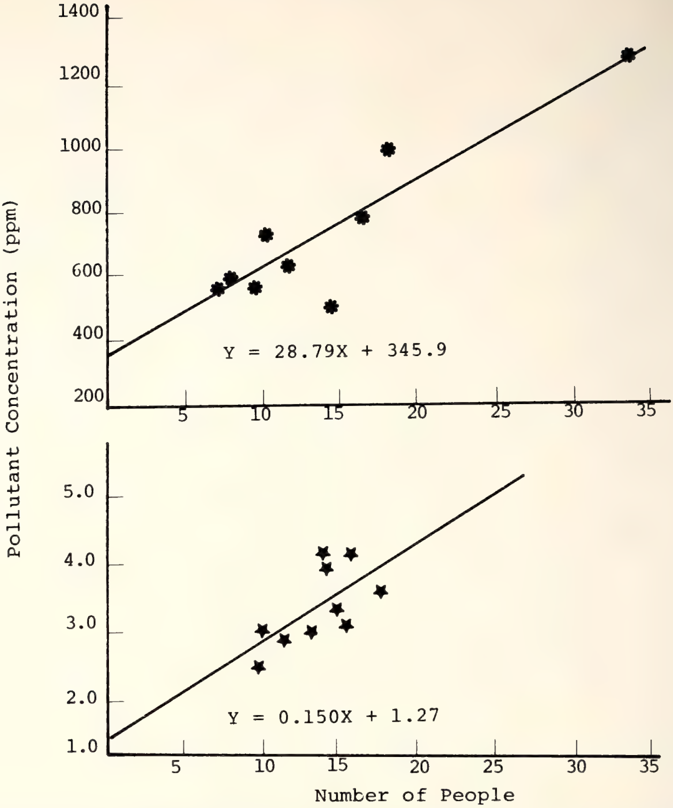


FIGURE 4. Air quality contamination from different numbers of people in the conference room. ° = carbon dioxide; star = carbon monoxide.

LITERATURE CITED

ADAMS, J. D., J. P. CONKLE, ET AL. 1966. Study of man in oxygen-helium. II. Major and minor atmospheric components. Aerospace Medicine 37(6):555-558.

CHRISTENSEN, E. H., AND P. HOGBERG. 1950. Physiology of skiing. Arbeitsphysiol. 14:292-303.

CONKLE, J. P., J. D. ADAMS, ET AL. 1970. Detailed study of contaminant production in a space cabin simulator at 258 mm Hg. Aerospace Medicine 41(9):1031-1038.

FLETCHER, J. G. 1964. Energy costs. Pp. 167-190. In Webb, P. (ed.) Bioastronautics Data Book. NASA-sp-3006. Washington, D.C.

HUBER, D. D., AND T. P. JACKSON, 1966. An introduction to trace contaminant control problems. Chem. Engineer. Symp. Ser. 62:55-62.

MILLER, R. L., AND C. H. WAND. 1966. Algal bioregenerative systems. Pp. 186-222. *In* Kammermeyer, K. (ed.) Atmosphere in Space Cabins and Closed Environments. Appleton-Century-Crofts.

ROTH, E. M. (ed.) 1968. Contaminants Standards, Compedium of Human Response to the Aerospace Environment. Vol. 3. NASA CR-1205 (III) 13:1-113. Washington, D.C.

SLONIUM, A. R. 1966. Waste management and personal hygiene under controlled environmental conditions. Aerospace Medicine 37:1105-1114.

Florida Sci. 40(3):219-226. 1977.

Medical Sciences

PAIN IN JAWBONES AND TEETH IN CIGUATERA INTOXICATIONS

Wm. B. Deichmann (1), W. E. MacDonald[2] (1), D. A. Cubit[3] (1), C. E. Wunsch (2), J. E. Bartels (3), and F. R. Merritt (4)

(1) Research and Teaching Center of Toxicology, University of Miami School of Medicine, Coral Gables, Florida; (2) Department of Pathology, University of Miami School of Medicine, Coral Gables, Florida; (3) Section of Radiology, Auburn University School of Veterinary Medicine, Auburn, Alabama; and (4) Cutler Ridge Veterinary Clinic, Miami, Florida.

Abstract: *During 1975, 14 incidents of moderate to severe ciguatera intoxication involving 76 adults of Greater Miami came to our attention. Eight individuals who had ingested black and yellow fin grouper caught in Bahamian and Florida coastal waters complained particularly of severe pain in the jaw bones (primarily lower jaw), teeth, and throat, which lasted, in three of the subjects, for approximately 5 mo. Portions of the fish which caused these intoxications were fed to beagle dogs which developed marked fibrous dysplasia of the lower jaw bone with reabsorption of the peridontal membrane and lamina dura. Another dog demonstrated reabsorption of bone at the apex of each individual mature tooth root. Blood chemical studies revealed reduction in blood calcium, phosphorus, and alkaline phosphatase. These studies appear to lend support to the theory that there may be a relationship between the pain in the jaw bones and teeth of the human subjects and the reabsorption and arrest of bone growth noted in the dogs.*°

During 1975, 70 incidents of ciguatera intoxication were reported to Dr. Joel Nitzkin of the Dade County Health Department—an increase of almost 100% over the 1974 report for Greater Miami. Fourteen incidents of ciguatera intoxication, involving 71 adults, were referred to the senior author by Dr. Donald P. de Sylva of the University of Miami's School of Marine and Atmospheric Science, and by physicians of the Greater Miami area, the Bahamas, and Caracas, Venezuela. In most instances, personal contact was established between those poisoned and the senior author; in a few instances, the discussions were by telephone with the victim or his physician. The attending physicians were concerned because of prolonged illness. Portions of raw fish that caused these intoxications were obtained for studies with beagles.

As a rule, ciguatera is a nonfatal intoxication with symptoms generally evident within 3-5 hr after ingestion of "toxic" reef and semiplagic fish from tropical and subtropical waters. The onset of ciguatera is acute and may lead to signs and symptoms of partial incapacitation for a brief or prolonged period of time—weeks, months, or even for as long as a year or more.

---

[1]This investigation supported by funds from the World Health Organization, and Toxicological Research Account (University of Miami).

[2]Now with Tracor Jitco, Inc., Rockville, MD.

[3]Now with Enviro Control, Rockville, MD.

°The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

Although ciguatera is well known in the Bahamas and Florida, little precise documentation is available from these areas, with the exception of the identification of the fish most frequently implicated and the symptoms of intoxication (de Sylva, 1956, 1963; de Sylva and Hine, 1972; Fogel, 1964). The great barracuda (*Sphyraena barracuda* Waldbaum), caught off the coast of East Florida and the Bahamas, has apparently caused most of the intoxications. Unquestionably, some intoxications were attributed to this fish when actually other species were the culprits, such as groupers (*Sphraenidae*), jacks and pompanos (*Carangidae*), and others. Insofar as could be established, the fish that caused the intoxications in our studies included barracuda, dolphin, amberjack, and several species of grouper and snapper (Table 1).

Since barracuda caught off the East Coast of Florida have, on occasion, caused ciguatera, we investigated 281 barracuda caught in these waters (weight: 1.1 to 18.3 kg; fork length: 58 to 153 cm). Cats were fed (on an empty stomach) composite samples of 50 g of raw tissues (equal portions of liver, fat [when available], pyloric cecum, stomach, intestine, and half the gall bladder contents). Since signs of intoxication were not noted following ingestion of these tissues, nor from liberal portions of cooked fish, it was concluded that the tissues of none of these barracuda contained ciguatera type "poisons", at least not in quantities sufficient to induce signs of intoxication in the cat—a mammal sensitive to chemicals that produce central and peripheral nervous system effects (Deichmann et al., 1972).

Signs and Symptoms of Intoxication—The predominant signs or symptoms noted in our subjects were very similar to those reported in detail by Halstead (1959), Russell (1975), Hashimoto et al., (1967), Hashimoto (1970) and others. These included: nausea, vomiting, diarrhea, abdominal cramps, tingling (crawling) or burning sensation of the lips, fingers and toes, and/or pain in muscles, joints, and bones, temperature inversion (cold objects felt hot and hot objects felt cold), severe itching, frequently all over the body, and sometimes headache, fever, or burning of the eyes with lacrimation.

The primary purpose of this report is to call attention to severe pain in the jaw (primarily the lower jaw), teeth and throat, experienced by: 1) three adults (2 M and 1 F) who ingested black grouper caught off Great Abaco, Bahamas; 2) one woman who ingested black grouper of unknown source; 3) three adults (2 M and 1 F) who ate a yellow fin grouper caught off Rum Cay, Bahamas; and 4) one woman who ingested part of a gray grouper caught off the Tortugas, Florida. More accurate identification of these fish was not possible, since evidence (head, skin, etc.) was destroyed before ingestion of the fish.

The three subjects in the first episode, in addition to weakness to the point of collapse and other signs and symptoms which necessitated hospitalization, complained of severe pain in teeth, jaws, and throat, primarily in the area of the wisdom teeth. Recovery began after 3 mo. The woman in the second instance suffered "jaw pain" in addition to "terrible leg pains with numbness from the knee down". All three individuals in the third instance complained of a "burning sensation in the mouth, throat, and tongue". One man added: "Every tooth in

TABLE 1. Signs and Symptoms of Ciguatera Intoxication.

No. of Adults Who Ingested Fish and Suffered Intoxication	Fish	Source of Fish	Onset of Signs or Symptoms[1]	Diarrhea	Abdominal Cramps	Nausea and Vomiting
2	?	Miami fish store		severe	moderate	marked
3	Barracuda 2.5 kg	Caught off Ft. Pierce Fla.	During night after evening meal	marked		marked
2	Grouper	Jamaica: restaurant	3-4 hrs	marked		moderate: no vomiting in one
3	King or Cero Mackerel	Caught off Gingerbread Grounds, Bahamas	3 hrs	severe	moderate to severe	
3	Black Grouper 30 kg	Caught off Gr. Abaco, Bahamas	few hrs	marked	marked	marked
8	Grouper 28 kg	Caught off Gingerbread Grounds, Bahamas	4-5 hrs	moderate	moderate	moderate
1	Black Grouper	Bahamas ?				
5 (of 7)	1 Hog Snapper, 2 Nassau Groupers (mixed fillets)	Caught off Victory Cay, Bahamas	5-6 hrs	moderate	moderate	moderate
1	Grouper	Caught off Gingerbread Grounds, Bahamas	5-7 hrs	marked	moderate	
25?	Black Grouper 15 kg	Miami Restaurant	3 hrs	moderate to severe	mild to severe	mild to severe
9 (of 11)	8 Dolphins	Caught off Fort Lauderdale, Fla.	2-3 hrs	severe	severe	severe
3	Yellow fin Grouper	Caught off Rum Cay, Bahamas	8 hrs	moderate		
1	Gray Grouper 21 kg	Caught off Tortugas, Fla.	6 hrs	marked	marked	marked
5	Smoked Amberjack?	Miami fish store	several hrs	mild to moderate		

[1]Unless otherwise stated, the individuals recovered from gastroenteric effects, supersensitivity to cool objects, itching, and tingling in approximately one week.

Table 1. (*continued*).

Tingling of Lips, Toes and Fingers	Heaviness and Pain in Muscles and Bones	Headache	Fever	Super-Sensitivity to Cool Objects Temperature Inversion	Itching	Pain in Teeth, Jaws and Throat
	severe		low grade. chills	extreme	severe: mainly hands & feet	
	marked					
		dull ache		severe: could not stand on cool tile floor	severe: hands, arms, extremities	
moderate to severe	severe			severe	severe	
					marked	Severe on and off for two months
				severe in some	severe in some	
						Marked
moderate	extreme in two			severe in two		
	marked			marked	moderate	
mild to severe				mild to severe	mild to severe	
severe	moderate, severe in those suffering mild arthritis			mild to moderate	mild to moderate	
	severe			marked	severe	severe involving all teeth
marked	marked			marked	marked	severe and lasting
	mild to moderate	mild to moderate		mild to moderate		

TABLE 1. (*continued*).

Other Observations and Complaints	Late Signs or Symptoms
"Burning eyes" in one.	For several weeks, sensitivity to cold, muscle weakness and aching.
Marked depression of all vital signs when entering Emergency Room; discharged on her 9th day. (Effects severe in one; less severe in two persons.)	Aching and stiffness in left side, including neck, back, and arm (one person).
	Two weeks: weakness and extreme fatigue; lost 3.5 and 5 kg body weight.
	Seven days: still itching, muscular weakness.
Within hours: exhaustion to the point of collapse; itching around eyes.	Three months: recovery began.
	Three months: dizziness, leg pains, lacrimation, tingling in tongue, hands & feet; itching over entire body still marked.
	5-6 weeks: extreme muscle weakness and reverse temperature sensations began to ease.
Itching all over body started after ingestion of cold beer or cocktail.	
Eyes burn; lacrimation	5 weeks: stomach cramps persisting in one.
In one, marked dizziness after 24 hrs; in another, marked chills after 4 days; drop in body temperature in all.	6 months: essentially recovered at this time.
Was hospitalized.	Recovery from the pain began in approximately 4 weeks.
Sweats and chills in all.	

my head ached". In the last case, the woman complained of "pain in the face and especially the lower jaw bone". And she added: "These were the worst pains I ever had". (Table 1)

Some of these people, as well as others, complained of an extreme supersensitivity to cool objects and air: "Cool air felt like ice", and to be in an air-conditioned room "was murder". Even the air current on the skin, throat, and in nose and upper respiratory tract "felt like an icy, painful wind".

A physician (patient) found it "extremely painful to stand barefoot on a cool tile floor", which seemed very hot to him. A woman complained that swimming in warm water felt like "extremely cold water", and she felt "as though frozen", and her "skin turned white". A man stated that: "A glass of iced tea made my lips tingle and even seemed carbonated, and the ice cream container 'burned' my fingers, as did the ice tray. During this time I accidentally touched the hot oven burner, which felt like a cool object, but left a bad blister." Another reported: "my hands felt as if frozen and the skin of my body felt as if sunburned."

Some individuals also complained of unbearable pain in muscles, bones and joints. These symptoms were noted from 2-10 da after ingestion of the fish. One couple experienced "a strange muscle weakness with onset 10 days after ingestion of fish, and lasting for four to six weeks". One 21-year-old "felt as though (his) bones were being 'twisted' ". Nine of 11 subjects developed neurological symptoms, particularly pain in all joints. Primarily affected were those suffering with mild arthritis. These had "pain in the back and spinal column and all joints". Another group—a couple and their boat captain—complained of "terrible pains between hips and knees, with accompanying weakness, which prevented everyone from walking normally".

Fig. 1. Lateral oblique view, skull, cervical spine. Severe fibrous dysplasia of the premaxilla, maxilla and mandibular shaft. The dental arcades appear to be "floating" in fibrous tissue with reabsorption of the peridontal membrane and lamina dura. Mandibular shaft is further characterized by cystic reabsorption of bone and a suggestion of fibrous tissue deposition with cortical expansion of the mandibular shaft anteriorly. Dog No: 4.

Itching "all over the body" was a severe and very annoying symptom in several men and women. This symptom, as well as the supersensitivity to cool or cold objects and the temperature inversion, frequently appeared a day or two following ingestion of the "toxic" fish, and lasted several da, and in 2 instances for 2 wk. The weakness or pain in legs, bones, and joints usually persisted for 1-6 wk; two individuals (in Caracas, Venezuela) had not recovered from these symptoms 10 mo later.

Effects in Dogs—Table 2 presents a summary of the feeding of cooked fish to 6 beagle dogs. X-ray studies of 3 dogs revealed the following: Dog No. 4 (a 7-yr-old beagle), which suffered a severe intoxication and was sacrificed *in extremis* 3.5 mo after ingestion of the first portion of fish, demonstrated a marked fibrous dysplasia of bone with reabsorption of the peridontal membrane and lamina dura (fig. 1). Dog No. 5 (a 5-mo-old beagle) suffered a severe intoxication and died 35 da after ingestion of the first portion of "toxic" fish. Because of the immaturity of the animal, assessment of osteodystrophic changes was not possible. Dog No. 6 (a 6-yr-old beagle), which suffered a mild intoxication, demonstrated reabsorption at the apex of each individual mature tooth root 2 mo after ingestion of the first portion of fish. The lamina is not present at this point, nor is the alveolar periosteal reflection.

Blood chemical and hematological studies were conducted on Dog No. 5 and Dog No. 6. The latter showed only mild signs of intoxication, with complete recovery in 33 da, even though this animal ingested a larger quantity of fish than Dog No. 5 (which died in 35 da). The determinations included: BUN, glucose, creatinine, uric acid, calcium, phosphorus, total protein, albumin, bilirubin direct and total, alkaline phosphatase, GPK, HBD, LDH, SGOT, SGPT, hematocrit, hemoglobin, red blood cells, and total and differential white blood cells. All values remained within normal limits in both dogs except calcium, phosphorus, and alkaline phosphatase which decreased in Dog No. 5, suggesting that in this animal bone growth may have been arrested as the result of the ingestion of ciguatoxic fish (Table 3).

Treatment of Intoxications—Because of our lack of knowledge of the specific toxin(s) involved, treatment at this time is directed toward: a) elimination of the "toxic" fish from the gastroenteric tract; and b) providing relief from the signs and symptoms. As Rayner et al. (1969) and Russell (1975) put it: "Until our physiopharmacological data are a little more convincing, it may be wise to reconsider the old clinical adage of treating the patient rather than the disease."

It would seem wise to induce vomiting (following the ingestion of several glasses of water, fat-free milk, or tea) at the first signs of nausea. When the intoxication enters the acute stage, vomiting is usually spontaneous. A saline cathartic ($MgSO_4$ or Na_2SO_4) may be considered for hastening the elimination of the intestinal contents.

During the early stages of an intoxication, Russell (1975) considers atropine (0.5 mg every 4 hrs, I.V., in a continuous drip as a multiple electrolyte solution) to be the drug of choice for controlling gastroenteric complaints (nausea, abdominal pain, vomiting) and cardiovascular disturbances (hypotension and abnormal

TABLE 2. Feeding of "Toxic" Fish to Beagle Dogs[1].

I.D. No. of Dog	Sex	Body Weight kg	Cooked Fish Fed Over Period of	Quantity Ingested gm/kg	Signs of Intoxication
1	F	15.0	2 days	20	Mild muscular weakness for several days, followed by recovery on 8th day.
2	M	9.9	2 days	40	2nd day: refused regular diet 3rd day: tremors, muscular weakness 4th day: unable to stand, listless, diarrhea, eyes swollen, lacrimation 9th day: died; had lost 2.2 kg body weight.
3	M	7.6	2 days	80	2nd day: diarrhea 3rd day: muscular weakness, fine tremors 4th day: difficulty in maintaining balance; front legs appeared to be rotated outward giving appearance of "bow-legs;" marked lethargy 8th day: walked with great difficulty 11th day: marked recovery; accepted food; stool firm.
4	F	7.0	First feeding period over 2 days; later feeding with cooked & raw fish for 1-2 months after recovery from the acute "bow-legs" effects.	63 15?	Acute effects (same as above, Dog No. 3) with recovery in 10-12 days. When feeding was resumed, dog began to salivate profusely, also "palsy-like" paralysis of lower lip with fine tremors over entire body, eyes swollen, severe lacrimation. Dog killed *in extremis* 3.5 mo after ingestion of first portion of fish. (See X-ray of skull.)
5	F	5.3	35 days	66	Periodic mild diarrhea, vomiting, mild muscular weakness and tremors. Died 35 days after ingestion of first portion of fish; lost 1.4 kg body weight. X-rays at start and after 21 days. Blood chemistry and hematology—control and after 21 and 32 days.
6	M	7.7	34 days	108	Periodic mild diarrhea and vomiting, but no specific signs of ciguatera, gained 1.4 kg Blood chemistry: control and 62 days after first dosing.

[1]Fish fed to dogs No. 1 to No. 4: Kept frozen for 1 to 3 mo.
Fish fed to dogs No. 5 and No. 6: Kept frozen for 3 to 8 mo.

TABLE 3. Effect of Feeding "Toxic" Fish to Beagle No. 5.

	Control	Days after feeding first portion of fish	
		21	32
Calcium (mg/%)	11.2	10.0	10.2
Phosphorus (mg/%)	6.0	6.2	5.3
Alkaline Phosphatase (units)	117.0	65.0	42.0

sinus rhythm). Atropine, however, has no significant effect on skeletomuscular and neurological disturbances, weakness, pruritus, and fatigue. Oxygen is indicated for respiratory distress.

Russell maintained his patients on: a) high electrolyte I.V. solutions; b) daily I.V. injections of calcium gluconate and Vitamin B Complex, supported by c) a high protein diet plus the oral administration of Vitamin C and disintegrating capsules containing phenobarbital, hyoscyamine sulfate, atropine sulfate, and scopolamine HBr. For insomnia, he recommended diazepam (Valium), and an analgesic cream to relieve pruritus. A patient of Hessel et al. (1960), who suffered severe episodes of bronchospasm, responded promptly to aminophylline and neostigmine I.V.

The use of pyridine-2-aldoxime methiodide (2-PAM) is not generally recommended. This drug was of some, or questionable, value when given during the early hours of a ciguatera intoxication, but may be quite dangerous when administered some 20 or more hr after the onset of illness (Okihiro et al., 1965; Russell, 1975; Dufva et al., 1976; Deichmann and Gerarde, 1969). Calcium disodium edetate (EDTA) was tried by Russell, but the effects were inconclusive. Steroids were ineffective. From the antidotes which have been used, with or without success, in ciguatera intoxications, it is evident that neither ciguatoxin nor ciguaterin are "true" anticholinesterase compounds—supporting the *in vivo* studies by Rayner et al. (1969).

DISCUSSION—It has been demonstrated that two different types of toxin cause ciguatera, namely: 1) ciguatoxin, a fat-soluble compound (or compounds) that has been studied extensively by investigators at the University of Hawaii (Banner et al., 1960, 1963; Scheuer et al., 1967); and 2) ciguaterin, a water-soluble compound (or compounds) first reported by Hashimoto et al. (1967).

Hashimoto (1970) reported the primary effect of ciguaterin in cats to be violent vomiting within 0.5-2 hr after ingesting portions of the viscera of certain fish caught in the waters of the Ryukyu and Amami Islands in the Pacific. After one or two hr of vomiting, the animals became lethargic, but usually recovered within 48 hr. Ingestion of the muscle or liver of fish containing ciguatoxin by cats produced "paralysis of limbs and hypersalivation" in approximately 20 hr.

Vomiting and diarrhea were "inconsistent" in these animals. Those severely affected died in a coma within a few days.

On the basis of these cat studies, it appears that the various fish that caused the intoxications in our human subjects contained both ciguaterin and ciguatoxin, since nausea and vomiting, as well as effects on muscles, joints, and bones (including jaw bones and teeth in some people) ranged from "marked" to "severe" in most of these individuals.

Salivation, a sign of ciguatoxin intoxication, was not reported by our subjects, but was noted in one dog (No. 4) fed the "toxic" fish. This animal salivated profusely for days. Our observations in the human subjects also support the Hashimoto findings—that the effects of ciguaterin are relatively brief (one to several da), while some ciguatoxin effects may last for several weeks or months. These observations emphasize that in order to effect a reduction in the period of suffering, it is essential to recognize the earliest signs and symptoms of an impending intoxication and to make every effort to eliminate the offending material from the entire gastroenteric tract.

It appears that once absorption of ciguatoxin has occurred, the intoxication will "run its course", modified only partially by symptomatic treatment. To reduce or avoid ciguatera intoxications, it is well to keep in mind certain facts and observations:

1. There is no specific method (short of feeding fish to an animal) for recognizing "toxic" fish, even though some natives in the Caribbean and elsewhere believe that certain signs (black spots, unusual fins or teeth, etc.) indicate that a fish is "toxic".
2. Fish caught in the vicinity of tropical or subtropical coral reefs are more likely to be toxic than fish caught in open waters.
3. Intoxications in South Florida (and elsewhere) occur much more frequently during hot summer months than during the remainder of the year.
4. Ciguatera intoxications are unrelated to fish "spoiled" by heat or bacteria.
5. The larger fish of a species are much more likely to be toxic than younger, smaller ones.
6. More likely than not, the fillet of "toxic" fish will have a normal appearance, odor, and taste.
7. Neither cooking nor freezing, drying or smoking, destroys the toxin(s).
8. Ingestion of gonads, liver, and other viscera of tropical and subtropical fish should be avoided, since ciguatoxin and/or ciguaterin, if present, will be found in these organs in much higher concentrations than in the flesh.
9. There is some evidence that washing (leaching) the flesh of "toxic" fish effectively removes some of the ciguaterins.

LITERATURE CITED

Banner, A. H., P. Helfrich, P. J. Scheuer and T. Yoshida. 1963. Research on ciguatera in the tropical Pacific. Proc. Gulf Carib. Fish. Inst. 1963:84-98.

———, P. J. Scheuer, S. Sasaki, P. Helfrich and C. B. Alender. 1960. Observations on Ciguatera-type Toxin in Fish. Ann. New York Acad. Sci. 90(3):770-787.

———, S. H. Shaw, C. B. Alender and P. Helfrich. 1963. South Pacific Comm. Tech. Paper no. 141.

Deichmann, W. B., D. A. Cubit, W. E. MacDonald and A. G. Beasley. 1972. Organochlorine pesticides in the tissues of the Great Barracuda (*Sphyraena barracuda*, Waldbaum). Arch. Toxicol. 29:287-309.

———, and H. W. Gerarde. 1969. Fish (Ichtyosarcotoxism). Pp. 263-268. *In* Toxicology of Drugs and Chemicals. Academic Press, Inc. New York.

Dufva, E., G. Loison and B. Holmstedt. 1976. *Duboisia myoporoides*: Native antidote against ciguatera poisoning. Toxicon 14:55-64.

Fogel, B. J. 1964. Neurotoxicity due to barracuda ingestion. J. Ped. 64(4):561-564.

Halstead, B. W. 1959. Dangerous Marine Animals. Cornell Maritime Press.

Hashimoto, Y. 1970. A summary of the study on toxic marine animals under the Japan-United States Cooperative Science Program. Pp. 904-910. *In* Halstead, B. W. (ed.) Poisonous and Venomous Marine Animals of the World. U.S. Govt. Printing Office. Washington, D.C.

———, S. Konosu and T. Yasumoto. 1967. Ciguatera. *In* Technical Report VIII, Lab. of Marine Biochem. Fac. of Agric., Univ. Tokyo.

Hessel, D. W., B. W. Halstead and N. H. Peckham. 1960. Marine biotoxins. I. Ciguatera poison: Some biological and chemical aspects. Ann. New York Acad. Sci. 90:789-797.

Okihiro, M. M., J. P. Keenan and A. C. Ivy, Jr. 1965. Ciguatera fish poisoning with cholinesterase inhibition. Hawaii Med. J. Inter-Isl. Nurs. Bull. 24(5):354-357.

Rayner, M. D., M. H. Baslow and T. I. Kosaki. 1969. Marine toxins from the Pacific—ciguatoxin. J. Fish. Res. Bd. Canada 26:2208-2210.

Russell, F. E. 1975. Ciguatera poisoning: A report of 35 cases. Toxicon 13:383-385.

Scheuer, P. J., W. Takahashi, J. Tsutsumi and T. Yoshida. 1967. Ciguatoxin: isolation and chemical nature. Science N.Y. 155:1267.

Sylva, D. de. 1956. Poisoning by barracuda and other fishes. Spec. Publ. Mar. Lab. Univ. Miami 13:1-19.

———. 1963. Systematics and life history of the great barracuda, *Sphyraena barracuda* (Waldbaum). Stud. Trop. Oceanography, Miami. 1:1-179.

———, and A. E. Hine. 1972. Ciguatera—marine fish poisoning—a possible consequence of thermal pollution in tropical seas. Pp. 594-597. *In* Marine Pollution and Sea Life, Ruivo, M. (ed.) Fishing Books (News), Ltd. London.

Florida Sci. 40(3):227-237. 1977.

OCCURRENCE OF FLORIDA RED-BELLIED TURTLE EGGS IN NORTH-CENTRAL FLORIDA ALLIGATOR NESTS[1]—*Thomas M. Goodwin and Wayne R. Marion*, Wildlife Ecology Laboratory, School of Forest Resources and Conservation, University of Florida, Gainesville, Florida 32611

Abstract: *Co-occurrence of turtle and alligator eggs in the same nest suggests a possible symbiotic relationship.*

While studying the nesting ecology of American alligators (*Alligator mississippiensis*) in north-central Florida, we found that the Florida red-bellied turtle, *Chrysemys nelsoni* Carr (*Pseudemys nelsoni* in many manuals), frequently uses alligator nests as nesting sites. Utilization of alligator nests by various turtles is a rather common phenomenon and other researchers have noted the presence of turtle eggs within alligator nest mounds (Hines and Dietz, Florida Game and

[1]Contribution No. 563 of the Journal Series, Florida Agricultural Experiment Station, Gainesville, Florida 32611.

Fresh Water Fish Commission, personal communication). This symbiotic relationship, although known to some investigators, has apparently not been previously published.

Alligator nests were visited by the authors after they were located from the air in June and July 1976. A total of 15 nests were observed and of these, 5 contained eggs of *C. nelsoni* Carr and a normal clutch of alligator eggs. The nests were studied in two habitat types: wet prairie and fresh marsh. All nests were composed of adjacent vegetation which was primarily button bush (*Cephalanthus occidentalis*), maidencane (*Panicum hemitomon*), primrose willow (*Ludwigia virginiana*), pickerelweed (*Pontederia cordata*), arrowhead (*Sagittaria sp.*) and sawgrass (*Cladium jamaicense*).

All alligator nests in this study were located within 40 miles (64 km) of Gainesville, Florida; 5 were in Putnam County (Levy's Prairie), 1 in Gilchrist County (Lake McCain), 5 in Levy County (Sawgrass Springs Prairie and Bowen Lake), and 4 in Alachua County (Moss Lee Lake and Colcloughy Hill Pond).

As previously mentioned, the turtle eggs were present in 5 alligator nests. The McCain Lake nest contained 2 clutches of 21 and 28 turtle eggs on 30 June 1976. The 2 nests in adjoining Bowen Lake contained clutches of 24 and 29 eggs in one nest and a single clutch of 31 in the other. No embryonic development was evident on this date and the nests were revisited on 18 August 1976 to make positive identification of the developing turtles as well as to obtain additional data on the alligator eggs. A fourth alligator nest on Sawgrass Springs Prairie contained 19 turtle eggs which were identified as *C. nelsoni* Carr. The last nest containing turtle eggs was discovered on Levy's Prairie on 13 August 1976 and contained a single clutch of 13 eggs which were well enough developed to allow positive field identification as *C. nelsoni* Carr.

Mean clutch size was 24 eggs and avg temp within the alligator nests was 30.04°C. Mean distance from open water for 5 nests was 5.3 m and all nests had worn access trails leading the nest mound.

The fact that these and possibly other turtles utilize alligator nests as their nesting sites suggests some form of symbiotic relationship between these reptiles. Because alligator nests are elevated above the surrounding marsh, they provide ideal nesting sites for turtles and it seems probable that use of alligator nest mounds by turtles is rather extensive. Two turtles were observed basking on top of the Lake McCain nest on 7 July 1976. This tends to support the theory that not all female alligators actively defend their nest mounds. In fact, during this nesting study, no female alligator was aggressive or attempted to prevent us from approaching her nest.

Most of the turtle egg clutches were located either level with or below the alligator egg cavity suggesting that the turtle eggs were laid prior to those of the alligator. In one nest, turtle eggs were laid at least 17 da prior to those of the alligator. Most of the turtle egg clutches were located very close to the alligator egg cavity and in one case the turtle eggs were almost touching the alligator eggs.

Florida Sci. 40(3):237-238. 1977.

Environmental Engineering

STORMWATER RUNOFF CHARACTERISTICS AND IMPACT ON URBAN WATERWAYS

THOMAS D. WAITE (1) AND LEONARD GREENFIELD (2)

Department of Civil Engineering (1) and Department of Biology (2), University of Miami, Coral Gables, Florida

ABSTRACT: *Runoff water quality from urban land use forms was determined in residential areas of Miami, Florida. Runoff from parking areas contained extremely high levels of bacteria and macronutrients. Pollutional input from rainwater was also monitored and correlated with a general air pollution index. An urban canal system was investigated chemically and ecologically to determine the water quality impact of the stormwater discharge. In most cases the water quality of the canal system was degraded due to stormwater inputs. High levels of all contaminants occurred during periods of high rainfall intensity. In addition an indicator algal index showed the canal section receiving the stormwater discharges to have higher numbers of pollution tolerant algal genera.*[*]

ONE of the prime factors affecting the quality of surface waters is the quality of the stormwater runoff at their confluence (Bryan, 1971; EPA, 1971; Weibel et al., 1964; Whipple et al., 1971). Usually, this is applied to storm drainage (from various land-use forms), which seeps through the soil bordering surface water masses or enters them more directly via storm drains.

Until recently, the quantitative aspect of surface water degradation due to this factor was not clear. There are now available several studies pertaining specifically to runoff, e.g.: Argino et al. (1972) monitored BOD and COD levels of runoff in a small urban watershed; Geldreich et al. (1968) measured bacterial numbers pertaining to indicator species; and Kluessener and Lee (1972), in measuring plant nutrient loads to surface waters from storm water, found that all the NH_3-N and more than half the NO_3-N (2% of the organic-N loading), originated from rainwater itself.

Perhaps the most thorough study of runoff water quality was performed by the EPA in Tulsa, Oklahoma (EPA, 1970). Fifteen test areas were identified with respect to land-use and population density. Water quality parameters measured were BOD, COD, TOC organic nitrogen, phosphate, chloride, pH total solids, coliform bacteria and fecal streptococci. Perhaps the most important finding of the study was the less than 5-fold difference at low concentrations in pollutants among various land-use forms. Average organic nitrogen values only varied between 1.48 mg/1 and 0.36 mg/1 and the PO_4-P levels only varied between 3.5 mg/1 and 0.81 mg/1 among all the different land-use forms. Individual bacterial counts fluctuated as well, but the avg values showed consistently very high levels.

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

Had other analyses, e.g. trace metals, hydrocarbons etc., been performed, a greater difference between residential and industrial areas might have been observed.

The value of such studies cannot be overstressed, but as yet it is difficult to extrapolate them to other areas of the country. Therefore, in Metropolitan Miami, a study was initiated of the characteristics of stormwater runoff and resultant impacts on a brackish water canal system. The purpose of the study was to define the quality of runoff in Miami, and to determine the level of degradation in canal systems due to stormwater input. Chemical and microbiological analyses of both stormwater runoff and canal water were performed for over a yr. In addition ecological evaluations of the canal were performed on plankton, invertebrates and fishes.

TEST AREAS—Three land-use forms were selected for investigation in the study. Figure 1 shows the Coral Gables area of Metropolitan Miami where the study was performed. All of the drainage areas discharge into the Coral Gables Waterway which was the focal point of the study.

Area #1 was a large drainage area encompassing 251 acres. The land-use pattern consists of single-family homes and about 5 acres of light industry. Approximately 62% of the total area is paved and subsequently drains into the Coral Gables Waterway. Areas #2 and #3 are both small, one-acre plots, which were chosen to represent specific land uses. Area #2 is a completely paved parking lot while area #3 is a residential section of the University of Miami campus with approximately 60% paved.

The weather in South Florida is subtropical in nature. The avg yearly temperature is 75°F, and the avg precipitation is 60 inches. Most of the rain falls in the months of June-July and September-October. It is not uncommon to have rainfall intensities of 3-5 in per hr during summer storms, which causes a tremendous flushing of the paved areas. From November through April, little precipitation occurs.

RESULTS—*Rainwater*: Rainwater quality was monitored in the test areas for 0.5 mo during the 1974 rainy season (summer). The substances tested and their concentrations are shown in Fig. 2. Also presented is the Dade County Pollution Index for the same period; this relates an avg concentration of various pollutants in the air. It is difficult at this point to discuss specific trends, but further study should reveal correlative values between the Pollution Index and rain composition. The rainfall values themselves show some fluctuation, especially with regard to NH_3-N.

Runoff: The results of a 1-yr analysis (July 1974 to June 1975) are shown in Table 1. Samples were collected for measurement shortly after each storm had begun. This was because the area is large and it was difficult to be in place exactly after each storm. It can be seen that total coliform values fluctuated between 24,000 MPN and 200 MPN with an avg value of 5,000 MPN. Nitrate values vary between 1.5 and 0.2 mg/1 NO_3-N, phosphate levels fluctuated between 0.35 and 0.03 mg/1 ortho PO_4, and ammonia levels varied from 1.33 to 0.028 mg/1 NH_3-N.

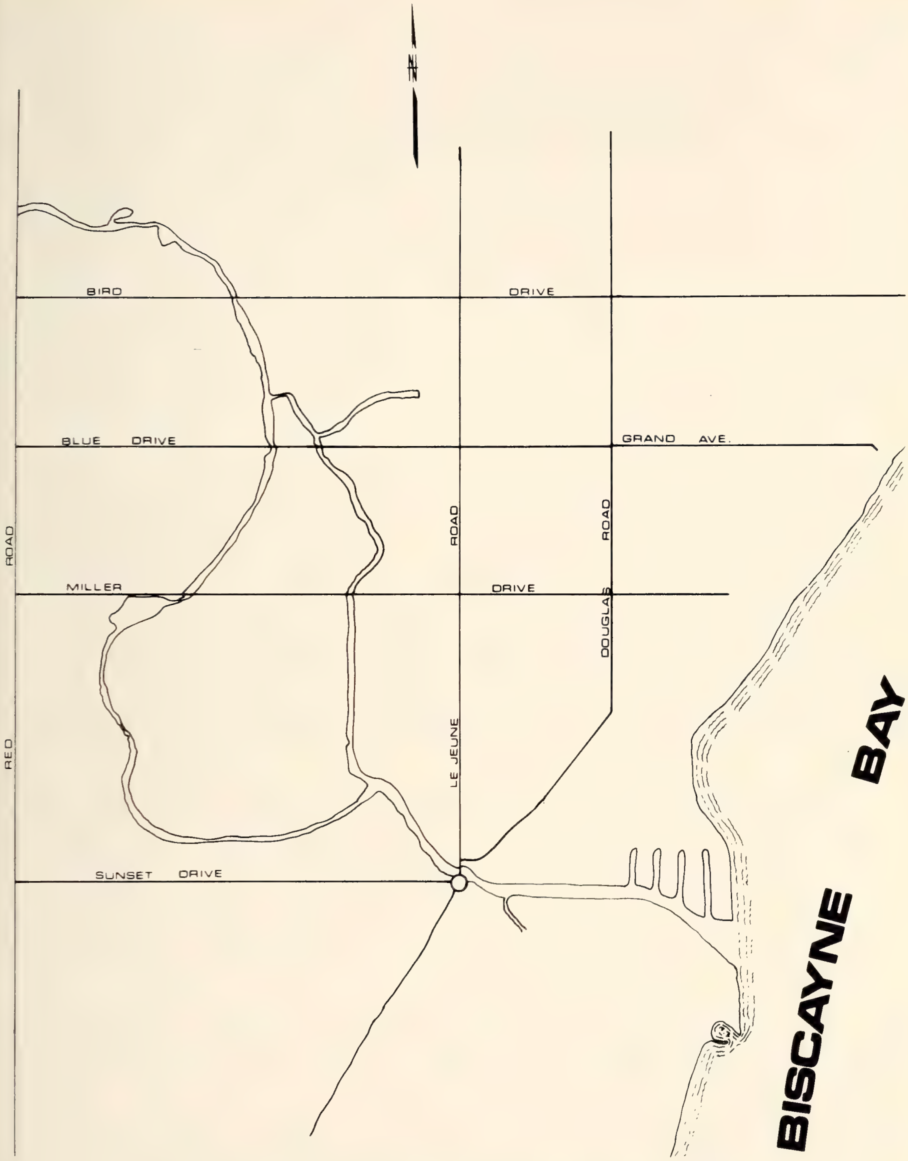


FIG. 1. Schematic of study area of Coral Gables Waterway, Coral Gables, Florida.

In comparing Fig. 1 with Table 1, all the nutrient concentrations seem to be lower on an avg than those found in the rainwater. It is not exactly clear why this occurs, but may be due to interactions of the nutrients with intrusion from ground water. Also rainwater quality values were not taken on the exact same days as stormwater quality was measured, hence the relative levels of nutrients may be closer than is shown in the figures.

Table 2 shows runoff characteristics from July 1974 to June 1975 from Area

TABLE 1. Chemical and bacteriological analyses of stormwater runoff from Area #1 from July 1974 to June 1975.

DATE	TOTAL COLIFORM MPN	FECAL COLIFORM MPN	FECAL STREP MPN	PO_4 ppm	NH_3-N ppm	NO_2-N ppm	NO_3-N ppm
7-31-74	2,200	1,400	360	.260	.994	.280	1.20
8-8-74	4,600	4,600	1,300	.340	1.330	.310	1.50
8-9-74	1,300	1,300	40	.270	.860	.240	1.10
8-22-74	200	200	180	.270	.930	.005	.30
9-26-74	7,900	2,400	212	.200	.116	.025	.45
10-3-74	1,700	1,100	224	.200	.137	.021	.60
10-10-74	9,200	5,400	440	.110	.028	.012	.51
10-17-74	790	490	83	.110	.028	.009	.49
10-24-74	1,100	330	88	.075	.046	.007	.45
10-31-74	1,300	270	35	.120	.043	.006	.40
11-7-74	1,300	490	59	.050	.051	.010	.39
11-14-74	1,300	790	180	.350	.022	.013	.60
11-21-74	16,000	16,000	624	.050	.040	.010	.75
11-27-74	24,000	24,000	6420	.230	.110	.010	.55
1-22-75	5,400	2,400	154	.050	.049	.010	.62
2-12-75	790	270	148	.030	.126	.005	.70
5-7-75	3,500	3,500	167	.100	.030	.010	.20
5-16-75	700	700	1,270	.100	.059	.010	.35
5-29-75	13,000	3,300	1,230	.040	.075	.010	.20

#2 (1-acre parking lot). This test area is completely paved and drains directly to the Coral Gables Waterway and, therefore, reflects a greater sensitivity to stormwater washing. Total coliform values fluctuate between MPN counts of 240,000 and 800. Phosphate levels vary between 2.8 and 0.05 mg/l ortho PO_4, while nitrogen levels fluctuate between 1.3 and 0.01 mg/l NH_3-N, and between 1.4 and 0.1 mg/l NO_3-N. These values are somewhat higher than observed for Area #1, indicating that parking lots contribute significantly to runoff contamination, and also that a small amount of intrusion (and hence dilution) was occurring in test Area #1.

Table 3 shows concentrations of pollutants in runoff from Area #3. Total coliform levels can be seen to vary between 24,000 and 1,400 MPN. Phosphate levels fluctuate between 2.6 and 0.03 mg/l ortho PO_4, while ammonia and nitrate vary between 0.48 and 0.06 mg/l NH_3-N and 1.65 to 0.3 mg/l NO_3-N respectively. Note the frequency with which fecal coliform counts match those of

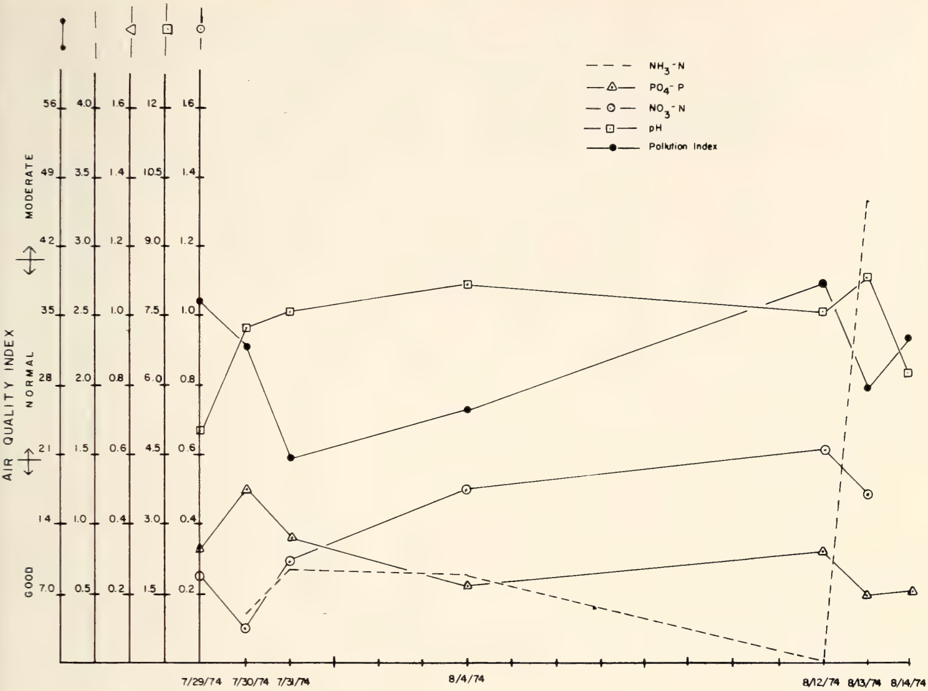


Fig. 2. Chemical analyses of Miami rainwater collected between July 1974 and August 1974.

total coliform. This is a common occurrence in the area and has been officially noted several times by the Dade County Pollution Authority.

It is difficult to use raw data such as those given in Tables 1-3 for quantitative application due to the rather large fluctuations. Therefore, Table 4 shows avg concentrations for the yr-long study. It can be seen that the drainage from the 1-acre test sites contained much higher levels of bacteria and somewhat higher nutrient levels. In particular, Area #2 (100% paved) exhibited the largest concentration of parameters investigated. Once again, intrusion and subsequent dilution of runoff water in Area #1 may have contributed to the lower levels of pollutants.

Surface Waters (Canals): Water quality sampling stations were in the Coral Gables Waterway canal system and monitored weekly to determine the impact of runoff water on the canal itself. Sixteen stations were used, but only one typical station is discussed here. All the stations exhibited the same behavior as the one discussed, but relative concentrations of certain contaminants varied, with lower values being obtained in the seaward portion of the waterway. Figure 3 shows the yearly fluctuation of typical water quality parameters of canal waters at a waterway station close to the discharge of drainage from Area #1. The values seem to fluctuate on a yearly basis with the highest concentrations of most parameters occurring July through November, which coincides with the rainy season in South Florida.

TABLE 2. Chemical and bacteriological analyses of runoff from Area #2 from July 1974 to June 1975.

DATE	TOTAL COLIFORM MPN	FECAL COLIFORM MPN	FECAL STREP MPN	PO_4 ppm	NH_3-N ppm	NO_2-N ppm	NO_3-N ppm
7-31-74	2,300	2,300	430	.36	.059	.010	1.20
8-8-74	1,400	1,400	10	.26	.120	.020	.90
8-9-74	1,400	1,400	10	.18	.060	.010	.40
8-12-74	2,700	2,700	180	.54	.480	.010	.80
8-19-74	24,000	24,000	1,120	.13	.090	.030	1.30
8-22-74	2,700	2,700	70	.30	.470	.050	.50
8-23-74	4,900	4,900	270	.35	.420	.030	.60
9-27-74	92,000	92,000	2,280	.20	.290	.020	.80
10-1-74	24,000	24,000	1,840	.58	.280	.031	.14
10-9-74	17,000	17,000	1,820	2.30	.140	.064	1.40
10-16-74	14,000	14,000	1,570	2.60	.080	.081	1.20
11-20-74	4,900	4,900	875	.60	.140	.020	1.65
11-27-74	20,000	20,000	2,500	.05	.070	.070	.60
12-4-74	1,400	1,400	28	.03	.120	.020	.30
5-16-75	79,000	33,000	2,730	.14	.266	.039	.70

It appears that total coliforms and orthophosphate appear to be the best parameters to observe for stormwater input. Nitrate levels on the other hand do not fluctuate quite as much throughout the yr, and remain about equal to concentrations in the rain water.

Ecological observations were also performed on the waterway during the monitoring program. Species identification and densities were tabulated for the invertebrates, fishes and birds. The complex interactions of salinity, as well as the mobility of most of the animals precludes definite conclusions as to stormwater effects. However, diversity analyses were performed on the phytoplankton because of their rather well defined relationships with water quality (Williams, 1964, 1972; Fogg, 1966). Palmer (1969) has outlined a simple procedure for using indicator genera of phytoplankton to relate water quality characteristics. Based on data collected throughout the United States he compiled ratings for algae genera most frequently found to tolerate polluted waters. The ratings vary from 1 to 5 depending on the number of studies where the particular alga has been identified in polluted environments. As an example, *Euglena*, a very pollutant tolerant alga, has a rating of 5, while *Melosira*, being more fragile, has a rating of 1. All indicator algae occurring in densities greater than 50 individuals per ml were assigned an index number, and these numbers were totaled. Palmer's Index ranges from a low of zero (low organic enrichment) to 15 or 20 (high probability of pollution).

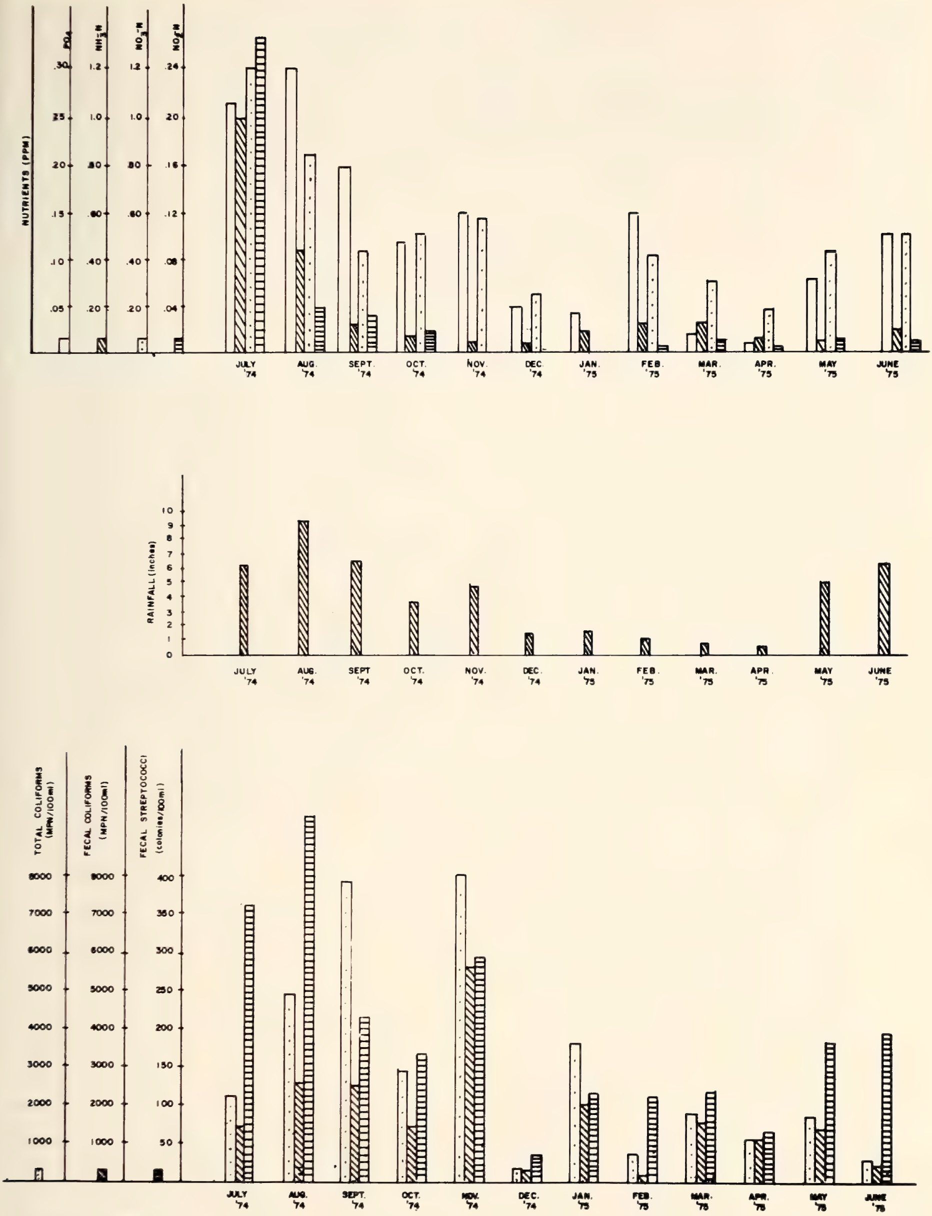


FIG. 3. Chemical and bacteriological analyses of canal water near discharge of storm drainage from Area #1.

Stations in the Coral Gables Waterway were selected for algal sampling, and indicator algae were quantified. Figure 4 shows values of the Palmer Index at stations beginning near the runoff discharge and progressing seaward. It can be seen that the predominant genera inland in the waterway were the more pollution tolerant forms. At the seaward end of the waterway, most pollution in-

TABLE 3. Chemical and bacteriological analyses of runoff from Area #3 from July 1974 to June 1975.

DATE	TOTAL COLIFORM MPN	FECAL COLIFORM MPN	FECAL STREP MPN	PO_4 ppm	NH_3-N ppm	NO_2^-N ppm	NO_3^-N ppm
7-31-74	17,000	17,000	10	1.060	.729	.008	.15
8-8-74	7,000	7,000	50	2.100	1.180	.017	.22
8-9-74	7,900	7,900	340	1.770	1.070	.020	.23
8-12-74	9,400	9,400	280	.580	.030	.003	.10
8-19-74	22,000	22,000	590	.175	.010	.006	.50
8-22-74	800	800	460	1.000	1.010	.009	.55
8-23-74	7,900	7,900	220	.500	.049	.009	.60
9-27-74	≥ 240,000	240,000	4,320	.200	.029	.015	.70
10-1-74	92,000	92,000	2,400	.210	.031	.022	.70
10-9-74	92,000	92,000	2,700	.370	.050	.028	.90
10-16-74	4,900	4,900	450	.850	.069	.025	1.10
10-31-74	7,000	7,000	895	2.800	1.290	.069	1.40
11-2-74	3,300	800	342	2.100	1.300	.025	.90
11-9-74	11,000	11,000	500	.270	.040	.018	.80
11-20-74	160,000	160,000	30,000	.910	1.020	.610	.95
11-27-74	3,400	3,400	2,330	.050	.020	.070	.40
12-4-74	9,200	9,200	191	.510	.040	.060	.80
1-17-75	≥ 240,000	240,000	672	.062	.150	.045	1.20
5-16-75	24,000	13,000	2600	.220	.238	.009	.50

tolerant forms were common. Once again this reflects the impact of a large stormwater discharge on a waterway system.

DISCUSSION—It is apparent from the above data that large amounts of nutrients and bacteria are being imposed on the Coral Gables Waterway during the rainy season. Loading rates can be approximated for Area #1 assuming 60 in of rain per yr falls on the paved areas and approximately 100% of that ends up in the stormwater runoff reaching the waterway. Approximately 56.6 acres of Area #1 are paved, therefore, approximately 9.2×10^7 gals/yr or 3.5×10^8 l/yr of the runoff reaches the waterway. The loading rate of various constituents to the waterway, using avg concentrations from Table 4 are shown in Table 5.

It can be seen that stormwater runoff imposes a rather large load of common pollutants on the waterway. Prediction of the resultant pollutant concentration is very difficult due to the complex hydraulic nature of the Coral Gables Water-

TABLE 4. Average concentrations of various water quality parameters in stormwater runoff in Areas 1, 2 and 3 from July 1974 to June 1975.

TEST SITE	SIZE (ACRES)	PAVED AREA (%)	TOTAL COLIF. (MPN)	FECAL COLIF. (MPN)	FECAL STREP. (org/100ml.)	ORTHO PHOSP. PPM	NITRATE (NO_3-N) PPM	NITRITE (NO_2-N) PPM	AMMONIA (NH_3-N) PPM
AREA#1	251	62	5,067	3,628	695	0.15	0.60	0.05	0.27
AREA#2	1	100	50,463	49,752	1,218	0.83	0.67	0.06	0.44
AREA#3	1	60	19,446	16,380	1,050	0.57	0.83	0.03	0.21

way. Relative increases in all of the monitored parameters during the summer and early fall rainy season (Fig. 3) do indicate that water quality of the waterway is degraded due to this loading.

It is interesting to compare loading rates to studies in other parts of the country. The EPA study in Tulsa, Oklahoma (EPA, 1970) evaluated yearly loading rates for several parameters not included in our study, but they found the avg yearly phosphate loading for all 15 test areas to be 2.5 lbs/acre/yr. This is very close to our loading rate even though the annual rainfall in Tulsa is only about half that of Miami. This indicates that at least for phosphate, much of the latter part of each storm washes little from paved surfaces.

Loading rates for the one-acre parking lot (Area #2), based on 60 in of annual rainfall, are seen in Table 5. Comparing the data with that of Table 4 it can

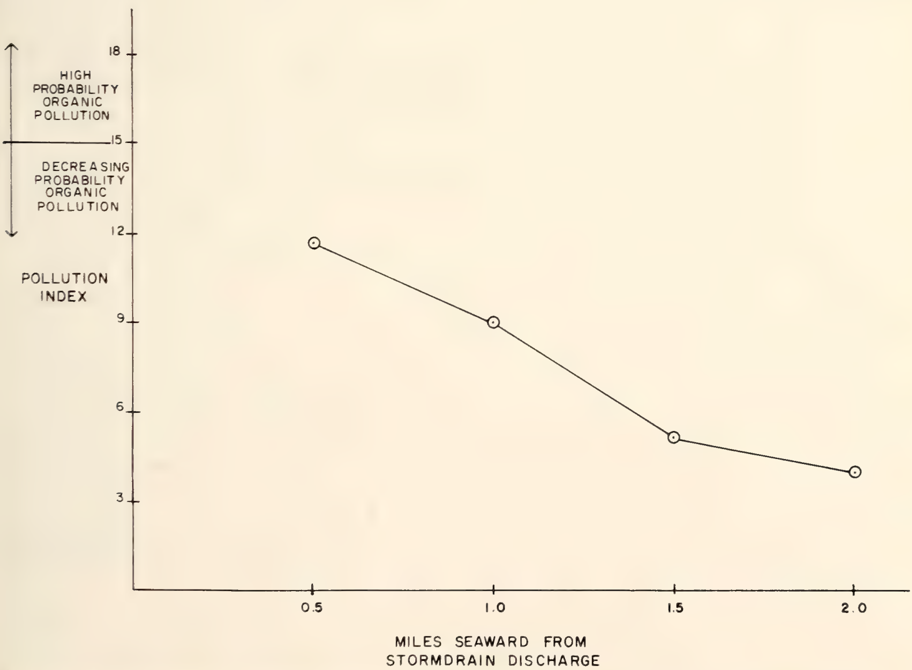


FIG. 4. Palmer index at selected stations along the Coral Gables Waterway to Biscayne Bay.

TABLE 5. Yearly loading rates of stormwater pollutants from study areas.

PARAMETER	LBS./YR.	LBS/YR/ACRE PAVEMENT
PHOSPHATE-ORTHO	116	2.01
NITRATE-N	462	8.20
NITRITE-N	38	0.67
AMMONIA-N	208	3.67

be seen that loading rates from parking lot areas are substantially higher than from a composite residential area. Nitrate nitrogen, however, is seen to be about equal which indicates most of the nitrate is in the rainwater, and very few biological or chemical processes are operating to change the relative concentration in the runoff.

Yearly monitoring of the Coral Gables Waterway showed a moderately polluted system. The resulting ecosystem also appeared stressed. Total coliform counts indicated rather heavy contamination throughout the year. Seasonality can be noted, however, and during the winter dry season total coliform levels drop below the limits for body contact (1000 per 100 ml). The rest of the year, however, total coliforms avg 3000-5000 MPN making the waterway only useful for boating.

All of the macronutrients, i.e., orthophosphate, nitrate and ammonia, in the canal system follow a seasonal pattern of low during the dry winter months and high during the wet summer season. Orthophosphate in particular exhibits very low concentrations during the dry season which is typical of the high alkalinity waters of South Florida. Nitrate levels fluctuate slightly, but in general remain around 0.5 mg/1 NO_3-N throughout the yr. As was noted previously, nitrate levels do not seem to be affected as significantly as phosphate by runoff water.

Palmer's algal pollution index indicated that more pollution tolerant forms of algae were found upstream in areas of the waterway most affected by runoff. The lower reaches of waterway which receive greater flushing from Biscayne Bay yielded a much lower index reflecting fewer pollution tolerant forms of phytoplankton. Diversity analyses were only run during the dry season when contaminant levels were low, and it is expected that more of the waterway would exhibit pollution tolerant forms during the times of high runoff. In any case the Palmer Index suggests that parts of the waterway system are stressed during most of the yr. Thus it can be seen that stormwater runoff degrades not only the water quality but the ecological system of the Coral Gables Waterway as well. Great care should be taken in future planning to preclude direct discharge of runoff water from entering surface water systems. Existing waterway systems will not recover until stormwater diversion or treatment is initiated.

CONCLUSIONS—1. Water quality studies on stormwater runoff from various land use forms in Metropolitan Miami were performed. A typical urban waterway that received the drainage was also investigated for water quality and ecological diversity.

2. Stormwater from residential areas runoff was shown to contain high concentrations of macronutrients and indicator bacteria.

3. Runoff waters from parking lots contained extremely high concentrations of all pollutants and are considered to be one of the greatest contributors to runoff pollution.

4. Water quality of the receiving surface water system was significantly degraded due to stormwater inputs. All water quality parameters showed an increase during the rainy season with lower concentrations during the dry seasons.

5. Palmer's pollution index (indicator algae) showed a high occurrence of pollution tolerant algae in the upstream section of the waterway which received the greatest impact from stormwater runoff. The lower section of the waterway which receives tidal flushing from Biscayne Bay exhibited mostly pollutional intolerant forms of algae.

6. Stormwater runoff is shown to be the main agent responsible for water quality degradation of the Coral Gables Waterway.

LITERATURE CITED

ANGINO, E. E., et al. 1972. Effects of urbanization on stormwater quality runoff. Water Res. Research 8:135.

BRYAN, E. H. 1971. Quality of stormwater drainage from urban land. Proc. 7th Ann. Conf. Amer. Water Res. Assn.

EPA. 1970. Stormwater pollution from urban land activity. EPA Water Poll. Contr. Res. Ser. 11034.

——————. 1971. Urban storm runoff and combined sewer overflow pollution. EPA Water Poll. Contr. Res. Ser. 11024 FKM.

FOGG, C. E. 1966. Algal Cultures and Phytoplankton. Univ. Wisconsin Press. Madison.

GELDREICH, E. E., ET AL. 1968. The bacteriological aspects of stormwater pollution. J. Water Poll. Contr. Fed. 40(11):

KLUESSENER, J. W., AND G. F. LEE. 1972. Nutrient loading from a separate storm sewer in Madison, Wisconsin. 44th Ann. Water Poll. Contr. Fed. Conf. San Francisco.

PALMER, C. M. 1969. A composite rating of algae tolerating organic pollution. J. Phycology 5:78.

WEIBEL, S. R., ET AL. 1964. Urban land runoff as a factor in stream pollution. J. Water Poll. Contr. Fed. 36:914.

WILLIAMS, L. G. 1964. Possible relationships between diatom species number and water quality estimates. Ecology 45:809.

——————. 1972. Planktonic diatom species biomass on the quality of American rivers and the Great Lakes. Ecology 53:1038.

WHIPPLE, W., ET AL. 1971. Unrecorded pollution from urban runoff. J. Water Poll. Contr. Fed. 46:873.

Florida Sci. 40(3):239-249. 1977.

Academy Medalist

CITATION FOR MICHAEL KASHA

CHEMISTRY is an extensive discipline, but it failed to contain its disciple, Dr. Michael Kasha, along much of its border. Dr. Kasha was born and reared in the petrochemical environment of Elizabeth, New Jersey, and earned baccalaureate and doctoral degrees in Chemistry from the University of Michigan and the University of California at Berkeley. However, after two years of postdoctoral association with his illustrious teacher, G. H. Lewis, he accepted an Atomic Energy Commission Postdoctoral Fellowship in Physics at the University of Chicago and soon thereafter became a leader in the establishment of the field of Molecular Biophysics.

His involvement in the biosciences has resulted in major contributions in such areas of biological molecular interaction as bioluminescience, photosynthesis, photocarcinogenesis, cell biology, radiobiology, DNA bases, molecular excitons, and neuroscience. He has had a part in the development of both the chemistry and the physics of plutonium, has studied fluorescence and phosphorescence in many substances, and has been the recipient of an unrestricted venture award from the Petroleum Research Fund.

Greatest of all has been Dr. Kasha's work in spectroscopy, some in atomic spectra, some in molecular rotational and vibrational spectra, but most in molecular electronic spectra, where he has scrutinized the structures and energy states of many sorts of molecular systems of interest in chemistry, biology, and physics.

Since 1960 Dr. Kasha has been the Director of the Institute of Molecular Biophysics at Florida State University where he had already chaired the Department of Chemistry. He participated in the development of the curriculum of the I.S.C.S. for junior high school science, is a member of the National Advisory Council on College Chemistry, and was named Distinguished Professor of the Year at Florida State University in 1962.

Dr. Kasha's scientific and educational achievements have not lacked national and international recognition. Ohio State University presented its Evans Award for Teaching and Research in Chemistry to Dr. Kasha. He has been visiting professor or guest lecturer in over a dozen major universities and laboratories and has been invited principal lecturer in a comparable number of international scientific conferences throughout the world.

Among his many honors may be mentioned a Guggenheim Fellowship served at the University of Manchester, a Charles F. Kettering Research Award, membership on the editorial boards of numerous national and international scientific journals, special recognition by the Florida Section of the American Chemical Society, election as Fellow of the Brazilian Academy of Sciences and of the American Academy of Arts and Sciences, and as a member of the National Academy of Sciences.

The Florida Academy of Sciences takes great pleasure in awarding its 1977 medal to Florida's outstanding chemist, chemical physicist, and molecular biophysicist, *Dr. Michael Kasha.*

DOLPHIN PREDATION ON MULLET—*P. V. Hamilton*[1] *and R. T. Nishimoto, Department of Biological Science, Florida State University, Tallahassee, Florida 32306*

ABSTRACT: *A stereotyped behavior pattern exhibited by dolphins preying upon mullet in the northern Gulf of Mexico is briefly described.*

FROM approximately June to October during both 1974 and 1975, we observed more than 100 instances of dolphins pursuing fish near the intertidal zone of Goose Creek Bay, Wakulla County, Florida, an estuarine habitat in the northern Gulf of Mèxico. These daytime observations were made while standing on shore or while sitting atop a 7 m tall tower on the shore, during all tidal phases. Observations were recorded for only those interactions occurring within approximately 150 m from the shoreline (water depth less than 3 m). Although neither specimens of the dolphin nor the fish were obtained for positive identification, they were visually identified as the Atlantic bottlenosed dolphin, *Tursiops truncatus*, and the mullet, *Mugil* sp.

Leatherwood (1975) summarized and described aspects of the food and feeding behavior of *Tursiops*, but the following behavior does not fit directly into any of the categories he described. Typically a single dolphin was observed swimming slowly in water 1 to 3 m deep. The commencement of an interaction was marked by the dolphin suddenly starting to swim rapidly on the surface in a circle, having an initial diam of 8 to 10 m, around a school of mullet. Noisy turbulence caused by this circular swimming often provided the first indication of a dolphin's presence in the area. Sometimes the dolphin decreased the diam of the circular path with successive revolutions (i.e., swam in tighter circles). In most cases, the dolphin executed a "tail slap", in which approximately the posterior one-half of its body was raised out of water, sometimes assuming a nearly vertical orientation, and then slammed down against the water surface. It could not be determined if the dolphin's head touched the bottom when these tail slaps occurred in shallow water. Each tail slap resulted in a large spray of water being splashed into the air. Mullet were often seen jumping from the center of the circle after a tail slap, and in all cases the fish involved appeared to be greater than about 20 cm in total length. Several tail slaps sometimes occurred in succession during a single interaction. The circling and tail slapping usually ended within 1 min of its start, and immediately thereafter the dolphin began swimming a convoluted path within the area of the circle, apparently feeding on mullet. Usually within about 1 min after submerging, the dolphin left the general area of the circle and continued swimming slowly through nearby areas in presumed search for more prey.

On two occasions, a dolphin was observed pursuing mullet into water so shallow that the upper one-third of its body was completely out of water, and the animal's locomotion was clearly being assisted by contact with the substrate. Dolphins have been reported to at least partially beach themselves for short periods when chasing fish in shallow areas on other occasions (Hoese, 1971;

[1]Present address: Faculty of Biology, University of West Florida, Pensacola, Florida 32504.

Busnel, 1973). Throughout these interactions, other dolphins were sometimes sighted nearby. However, two dolphins apparently cooperated on only one occasion, when they swam in the same circle. Most dolphins were observed feeding in the described manner in several successive locations along a stretch of shoreline.

Some local fishermen aware of this behavior claim the tail slap functions to temporarily stun the mullet, during which time they can easily be captured by the dolphin. However, considering the common predator strategy of attacking separated individuals in flocking, herding and schooling species, the tail slap may instead cause individual mullet to break off from the school. Tail slaps have also been reported in the non-feeding context of serving to communicate alarm through a dolphin herd (Caldwell and Caldwell, 1972).

Tavolga and Wodinsky (1963) suggested that most marine fishes are unable to detect the echo-ranging or communicatory sounds emitted by cetaceans. If this is true, fish would not be expected to exhibit acoustically-cued defensive responses upon the approach of dolphins similar to those some moths are known to exhibit upon the approach of bats. The regular occurrence of the behavior reported here, and the relative ease of obtaining large numbers of mullet, make the dolphin-mullet interaction ideal for experimentally testing this hypothesis under natural conditions.

We are grateful for the support and cooperation of the St. Marks National Wildlife Refuge, the Psychobiology Research Center of Florida State University (Grant PHS MH 11218) and Dr. W. F. Herrnkind (NSF Grant BMS 74-22276).

LITERATURE CITED

Busnel, R. G. 1973, Symbiotic relationship between man and dolphins. Trans. New York Acad. Sci. 35:112-131.

Caldwell, D. K., and M. C. Caldwell. 1972. The World of the Bottle-nosed Dolphin. Lippincott. New York.

Hoese, H. D. 1971. Dolphin feeding out of water in a salt marsh. J. Mammal. 52:222-223.

Leatherwood, S. 1975. Some observations of feeding behavior of bottle-nosed dolphins (*Tursiops truncatus*) in the Northern Gulf of Mexico and (*Tursiops* cf *T. gilli*) off Southern California, Baja California, and Nayarit, Mexico. Mar. Fish. Rev. 37(9):10-16.

Tavolga, W. N., and J. Wodinsky, 1963. Auditory capacities in fishes. Bull. Amer. Mus. Nat. Hist. 126:177-239.

Florida Sci. 40(3):251-252. 1977.

A NEW COUNTY RECORD FOR *BOTRYCHIUM BITERNATUM* IN FLORIDA—*James R. Burkhalter and Robert Kennedy Hood, Jr.*, Department of Biology, University of West Florida, Pensacola, Florida 32504

ABSTRACT: *Range of the southern grapefern in Florida is extended 100 miles westward to Escambia County.*

On July 22, 1975, while we were botanizing about two miles from the University of West Florida campus approximately 0.1 mi west of Westside Drive and 0.2 mi south of Jo-Jo Road (T1S, R30W, Sect. 13), we paused by a nearby unnamed creek, where we noticed a somewhat unusual juvenile fern frond emerging from the ground. The frond was too young to allow for positive identification; it resembled a vegetative leaf of the genus *Botrychium*, but it also looked like a very young frond of *Osmunda regalis*, a fern known to occur in the area. A few weeks later fertile pinnules had developed, and we were certain that our find was a *Botrychium*.

The senior author identified the fern as *Botrychium biternatum* (Sav.) Underwood, the southern grapefern or sparse-lobe grapefern. A specimen (Burkhalter 2845) was sent to the herbarium of the University of Florida in Gainesville for verification of identification. Dr. Daniel B. Ward, curator, stated that our find constitutes a new county record for Florida. Other specimens were deposited in the herbarium of the University of West Florida.

Small (1931), Wherry (1961, 1964), Radford, Ahles, and Bell (1968), Dean (1969), and Lakela and Long (1976) indicate that the southern grapefern is rather widely distributed throughout the southern states of Virginia, West Virginia, Kentucky, Tennessee, Georgia, Florida, and Alabama, and extends northward to Delaware, Maryland, Connecticut, Ohio, Indiana, Illinois, and Missouri, and westward to Texas. In Florida *Botrychium biternatum* is now known from the following counties: Alachua, Calhoun, Citrus, Clay, Columbia, Dixie, Duval, Escambia, Gadsden, Hendry, Hernando, Highlands, Leon, Liberty, Marion, Polk, Sumter, Union, Volusia, and Wakulla.

The *Botrychium* colony which we discovered is situated at the edge of a swamp forest dominated by *Acer rubrum*, *Magnolia virginiana*, *Cyrilla racemiflora*, and other hydric trees, and is exceedingly restricted, occupying only approximately 50 sq m. A search of the area revealed no other colonies. This is the only *Botrychium* known to grow in the Pensacola area. Other ferns which grew at the site were *Osmunda regalis*, *Osmunda cinnamomea*, and *Lorinseria areolata*.

LITERATURE CITED

DEAN, B. E. 1969. Ferns of Alabama, Revised Edition. Southern Univ. Press. Birmingham.
LAKELA, O., AND R. W. LONG. 1976. Ferns of Florida. Banyan Books. Miami.
RADFORD, A. E., H. E. AHLES, AND C. R. BELL. 1968. Manual of the Vascular Flora of the Carolinas. Univ. North Carolina Press. Chapel Hill.
SMALL, J. K. 1931. Ferns of Florida. Science Press. New York.
WHERRY, E. T. 1961. The Fern Guide. Doubleday & Co. New York.
———. 1964. The Southern Fern Guide. Doubleday & Co. New York.

Florida Sci. 40(3):253. 1977.

FIRST RECORD OF *OPHIOPHRAGMUS MOOREI* (ECHINODERMATA, OPHIUROIDEA) IN FLORIDA COASTAL WATERS—*Shelly Alexander and Keitz Haburay*, Biology Department, Pensacola Junior College, Pensacola, Florida 32504

ABSTRACT: *Known range is extended 75 km eastward.**

ON 12 October 1975, the senior author observed an extensive population of the amphiurid brittle star *Ophiophragmus moorei* in shallow coastal Gulf water off Santa Rosa Island, approximately 2.6 km west of Pensacola Beach, Florida. The brittle stars were not more than 7 m from shore buried in fine quartz sand. Each had several arms extended above the sand. The burrowing nature of *Ophiophragmus moorei* is typical of members of the family Amphiuridae, and the habit of protruding one or more arms from the sand probably represents feeding behavior (Moore, 1962). Specimens of *O. moorei* were collected from this "ophiurian shoal" at various times during October, 1975.

On 18 May 1976, members of the Invertebrate Zoology class (Pensacola Junior College) "dug up" several specimens of *O. moorei* from the sand bar off Johnson Beach (located 21 km west of Pensacola Beach). Identification to species was confirmed by Lowell P. Thomas, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida.

A specimen (Fig. 1) of the species has been accessioned into the echinoderm collections of the U.S. National Museum (USNM-uncat.). It agrees fully with the description of *Ophiophragmus moorei* by Thomas (1965). Data for the specimen are as follows: disc-tan, 9.3 mm diam; arms—130-138 mm long.

Thomas (1965) listed records of *Ophiophragmus moorei* from off Louisiana; Ship Island, Mississippi; and Mustang Island, Port Aransas, Texas. In the Pensacola area *O. moorei* appears to be the fine grain, quartz sand, open-beach counterpart of *O. filograneus* which has been collected from a soft mud bottom with sparse *Diplanthera* growth in the Pensacola estuary (cat. # AN1157, E.P.A., Gulf Breeze, Florida). *O. wurdemani,* a species closely related to *O. moorei,* has been collected on the Atlantic coast and at several points along the west coast of Florida, including the Ft. Myers vicinity (Thomas, 1961, 1962). Thomas collected *O. wurdemani* in very fine quartz sand on the sand bar off Ft. Myers Beach and *O. filograneus* from the soft mud of Estero Bay, Ft. Myers, Florida. Thomas (1962) reported *O. wurdemani* to be the stenohaline counterpart of *O. filograneus*; however, Stancyk (1970) reported both species living sympatrically in low salinity areas at Cedar Key, Florida. Stancyk (1970) recorded the range of *O. filograneus* as limited to Florida: extending from Alligator Harbor on the west coast to Cape Kennedy on the east coast. Menzel (1971) listed both species as occurring in the Apalachee Bay-St. George's Sound area; however, collection data are unavailable.

The collection of *O. wurdemani* at Cedar Key (Stancyk, 1970), and *O. moorei* from Pensacola, requires a revision of Thomas' (1965) estimate that *O. wurdemani* and *O. moorei* replace one another between west Florida and the Missis-

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

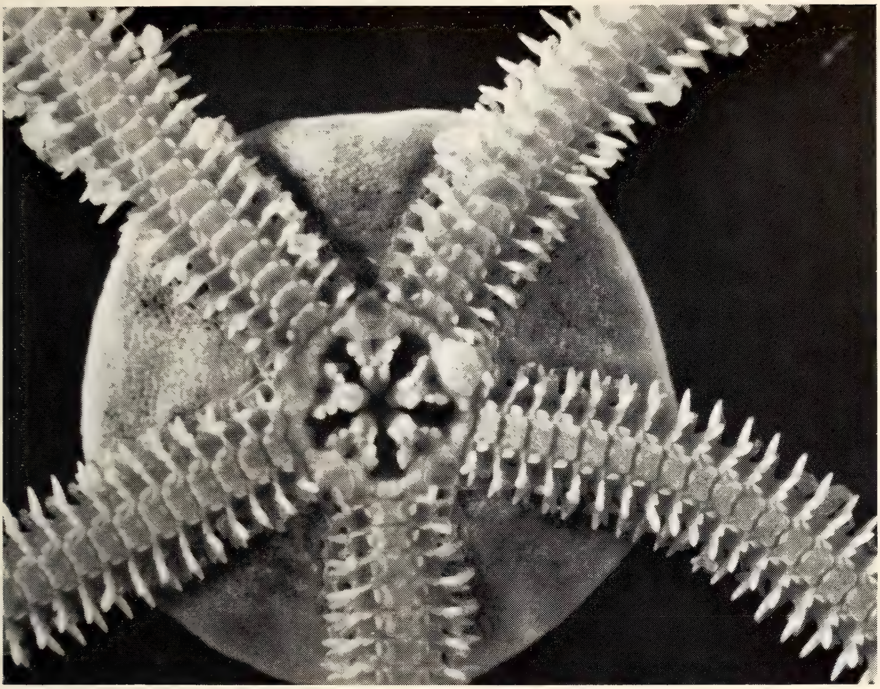


Fig. 1. Oral disc of *Ophiophragmus moorei* collected off Santa Rosa Island, Pensacola, Florida.

sippi River. If there is replacement, it must occur between Pensacola and Cedar Key or between Pensacola and the St. George's Sound area depending on whether or not the collection record for *O. wurdemani* reported by Menzel (1971) is valid.

The Pensacola specimens of *O. moorei* represent the only new locality record for the species since it was described and apparently constitute the first record of its presence in Florida coastal waters.

LITERATURE CITED

MENZEL, R. W. (ED.). 1971. Checklist of the flora and fauna of the Apalachee Bay and the St. George's Sound area. 3rd ed. Dept. of Oceanography, Florida State Univ. Tallahassee. 126 p.

MOORE, D. 1962. An ophiurian shoal on the Mississippi coast. Quart. J. Florida Acad. Sci. 25:70-72.

STANCYK, S. E. 1970. Studies on the biology and ecology of ophiuroids at Cedar Key, Florida. M.S. Thesis. Univ. Florida. Gainesville.

THOMAS, L. P. 1961. Distribution and salinity tolerance of the amphiurid brittlestar, *Ophiophragmus filograneus* Lyman 1875. Bull. Mar. Sci. 11:158-160.

———. 1962. The shallow-water amphiurid brittle-stars (Echinodermata, Ophiuroidea) of Florida. Bull. Mar. Sci. Gulf Carib. 12:623-694.

———. 1965. A new species of *Ophiophragmus* (Ophiuroidea: Echinodermata) from the Gulf of Mexico. Bull. Mar. Sci. 15:850-854.

Florida Sci. 40(3):254-255. 1977.

ABNORMALITIES OF SCUTELLATION IN A POPULATION OF *GOPHERUS POLYPHEMUS* (REPTILIA, TESTUDINIDAE)—*John F. Douglass,*
Archbold Biological Station of The American Museum of Natural History, Route 2, Box 180, Lake Placid, Florida 33852

ABSTRACT: *Nineteen (14.6%) of 130 gopher tortoises examined had divided, extra, or missing scutes on the carapace. A relatively high frequency of abnormalities in smaller animals suggests a higher mortality of abnormally-scutellated individuals in the population studied.*

ABNORMALITIES of shell scutellation and their possible significance in turtles have been considered by several workers (Gadow, 1899; Coker, 1905, 1910; Newman, 1906; Zangerl and Johnson, 1957; additional references in Zangerl, 1969). That scute abnormalities may be associated with deep-seated abnormalities leading to higher mortality in abnormal turtles was suggested by Coker (1905) and Grant (1937). Scute abnormalities have been described in all four species of tortoises of the genus *Gopherus,* but frequencies of abnormalities in wild populations of *G. polyphemus* have not been reported.

Variation in scutellation was studied in a population of *G. polyphemus* at Archbold Biological Station, 12 km south of Lake Placid, Highlands County, Florida. Normal carapace scutellation in this species consists of 1 cervical, 5 vertebrals, 1 marginal-12, 4 pairs of pleurals, and 11 pairs of marginal scutes (scute nomenclature follows that of Zangerl, 1969). Scute counts of 130 individuals were made between 1973 and 1976. Nineteen (14.6%) of these animals had divided, extra, or missing scutes on the carapace; of these, 6 were males, 4 were females, and 9 were of undetermined sex. The abnormalities and numbers of individuals possessing them (in parentheses) were: 6 vertebral scutes (9); 7 vertebrals (2); 5 pleurals on the left side (8); 5 pleurals on the right side (2); 6 pleurals on both sides (1); 10 marginals on both sides (1); 12 marginals on the right side (1); 12 marginals on both sides (1).

In 6 cases, extra vertebrals and pleurals occurred together in the same animal, but none of the 3 individuals with extra or missing marginals had other scute abnormalities. All of the cases of extra vertebrals appeared to have involved early division of the 2nd, 3rd, or 4th scutes in this series. In one of the 2 individuals with 7 vertebrals, the 2nd areola had divided early in development into 3 areolae of approximately equal size and each had continued growing; 5 left pleural scutes of approximately equal size were also present in this individual.

In order to determine whether any correlation existed between size and frequency of scute abnormalities, tortoises examined were divided into the following size classes based on plastron length: I ($n = 18$), under 100 mm; II ($n = 32$), 100-200 mm; III ($n = 80$), over 200 mm. The frequencies of carapace abnormalities in each of these classes were: I, 27.8%; II, 12.5%; III, 12.5%. These frequencies did not differ significantly (χ^2 test, $p > 0.05$) between size classes.

Auffenberg (1976) reported high frequencies of scute and bone abnormalities in museum specimens of all four species of the genus *Gopherus*; extra or fused marginals were the only abnormalities of carapace scutes reported in *G. polyphemus.* Grant (1936a, 1946) examined two populations of *G. agassizii* captives ($n = 366$ and $n = 119$) and reported conspicuous scute abnormalities in 8.2% and

20.2% of these animals, respectively. Various abnormalities of carapace scutellation have been described in this species (Grant, 1937, 1946; Woodbury and Hardy, 1948; Stuart, 1954; Miller, 1955; Jaeger, 1961; Baker, 1968; Auffenberg, 1976) and in *G. flavomarginatus* (Legler, 1959).

Plastral scutes of *G. polyphemus* in the series examined varied less than did scutes of the carapace. A single large individual of undetermined sex had an extra pair of small scutes between the femorals and anals, and one large male had a widely movable hinge (old and well-healed) between the humeral and pectoral scutes. The plastral scutes of *G. agassizii* have also been reported to vary in number far less than scutes of the carapace (Grant, 1936b, 1946; Woodbury and Hardy, 1948; Auffenberg, 1976). Hinge flexibility at the juncture of the abdominal and femoral scutes was reported in old female *G. agassizii* captives by Beltz (1954) and Patterson (1970).

The relatively high frequency of carapace abnormalities in smaller animals in the sample of *G. polyphemus* examined, although not statistically significant, suggests that there may be higher mortality of abnormally-scutellated individuals in this population.

ACKNOWLEDGMENTS—Support for this work was provided by Archbold Expeditions of The American Museum of Natural History. I thank J. N. Layne for opportunities to study tortoises at Archbold Biological Station and Richard Archbold for his help and hospitality.

LITERATURE CITED

AUFFENBERG, W. 1976. The genus *Gopherus* (Testudinidae): Pt. I. Osteology and relationships of extant species. Bull. Florida State Mus. 20:47-110.

BAKER, E. 1968. It can happen. Int. Turtle Tortoise Soc. J. 2(6):4-5.

BELTZ, R. E. 1954. Miscellaneous observations on captive Testudininae. Herpetologica 10:45-47.

COKER, R. E. 1905. Gadow's hypothesis of "orthogenetic variation" in Chelonia. Johns Hopkins Univ. Circ. 178:9-24.

———. 1910. Diversity in the scutes of Chelonia. J. Morphol. 21:1-75.

GADOW, H. 1899. Orthogenetic variation in the shells of Chelonia. Willey Zool. Results. Part 3:207-222. Cambridge Univ. Press.

GRANT, C. 1936a. The southwestern desert tortoise, *Gopherus agassizii*. Zoologica 21:225-229.

———. 1936b. An extraordinary tortoise shell. Copeia 1936:231-232.

———. 1937. Orthogenetic variation. Proc. Indiana Acad. Sci. 46:240-245.

———. 1946. Data and field notes on the desert tortoise. Trans. San Diego Soc. Nat. Hist. 10:399-402.

JAEGER, E. C. 1961. Desert Wildlife. Stanford Univ. Press.

LEGLER, J. M. 1959. A new tortoise, genus *Gopherus*, from north central Mexico. Univ. Kansas Publ. Mus. Nat. Hist. 11:335-343.

MILLER, L. 1955. Further observations on the desert tortoise, *Gopherus agassizi*, of California. Copeia 1955:113-118.

NEWMAN, H. H. 1906. The significance of scute and plate "abnormalities" in Chelonia. Biol. Bull. 10:68-114.

PATTERSON, R. 1970. A request for information on hinge flexibility and calcium metabolism in female tortoises. Int. Turtle Tortoise Soc. J. 4(5):39.

STUART, G. R. 1954. Observations on reproduction in the tortoise *Gopherus agassizi* in captivity. Copeia 1954:61-62.

WOODBURY, A. M., AND R. HARDY. 1948. Studies of the desert tortoise, *Gopherus agassizii*. Ecol. Monogr. 18:145-200.

ZANGERL, R. 1969. The turtle shell. Pp. 311-339 *In* Gans, C., ed. Biology of the Reptilia, Vol. 1. Academic Press, New York.

———, AND R. G. JOHNSON. 1957. The nature of shield abnormalities in the turtle shell. Fieldiana (Geology) 10:341-362.

Florida Sci. 40(3):256-258. 1977.

THE STANDING CROP OF FISHES IN A TROPICAL MARINE LAGOON—*Robert F. Holm*, Metropolitan Dade County, Department of Environmental Resources Management, 909 S.E. 1st Avenue, Miami, Florida 33131

ABSTRACT: *The ichthyofauna of a tropical marine lagoon in the upper Florida Keys was censused in early spring and mid-summer in 1973. Visual counts revealed a fish standing crop of 0.01 kg/m² (wet wt) in 1973. Carnivores represented the greatest percentage of the total standing crop of fish by wt. The visual censusing method employed may underestimate herbivore standing crop in tropical marine lagoons.**

TROPICAL—SUBTROPICAL marine fish community structure has been studied in Florida but lagoons have been overlooked. J. C. Briggs (1958) provided a list of Florida fishes and found the ichthyofauna of Florida to be far richer than any comparable area in North or Central America. Gilbert (1972) described this diverse fish fauna as being derived from the rich Indo-Pacific ichthyofauna. Voss et al. (1969) listed 469 fish species in the Biscayne National Monument, Dade County, Florida. Similar investigations in Florida (Reid, 1954; Springer and McErlean, 1962) have found the ichthyofauna to be most diverse and abundant during the summer and early fall. I studied the community structure of a nearshore tropical marine lagoon (Holm, 1975) and devoted a portion of the study to determining fish species diversity and standing crop within the lagoon.

Old Rhodes Key Lagoon is a shallow, nearshore, mangrove-lined (*Rhizophora mangle* L.) marine lagoon. It lies 5.6 km east of the Florida mainland on the west side of Old Rhodes Key, in the Biscayne National Monument, Dade County, Florida. The lagoon is oriented with its long axis in a north-south direction. Its maximum length is 2.24 km and maximum width is 0.80 km. The lagoon is naturally divided into a north intertidal section and a south subtidal section. The north intertidal section of the lagoon is characterized by deep sediments stabilized by *Thalassia testudinum.* The south subtidal section is characterized by shallow, unstable, sparsely vegetated sediments. Mean water depth in 1973 (mean high water) in the lagoon was 61cm. Average water temperature from April to July was 28° C. Average salinity was 37 °/oo. Tides in the lagoon are semidiurnal with an avg range of 0.5 m in the north section.

METHODS—Visual counts, trapping and fishing were employed to determine the abundance and distribution of fishes within the lagoon. Visual counts were the primary means of determining fish abundance. Monthly counts were conducted along six 100 m sampling transects. The transects were oriented east-west and spaced 373 m apart. The census method employed was modeled after

---

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

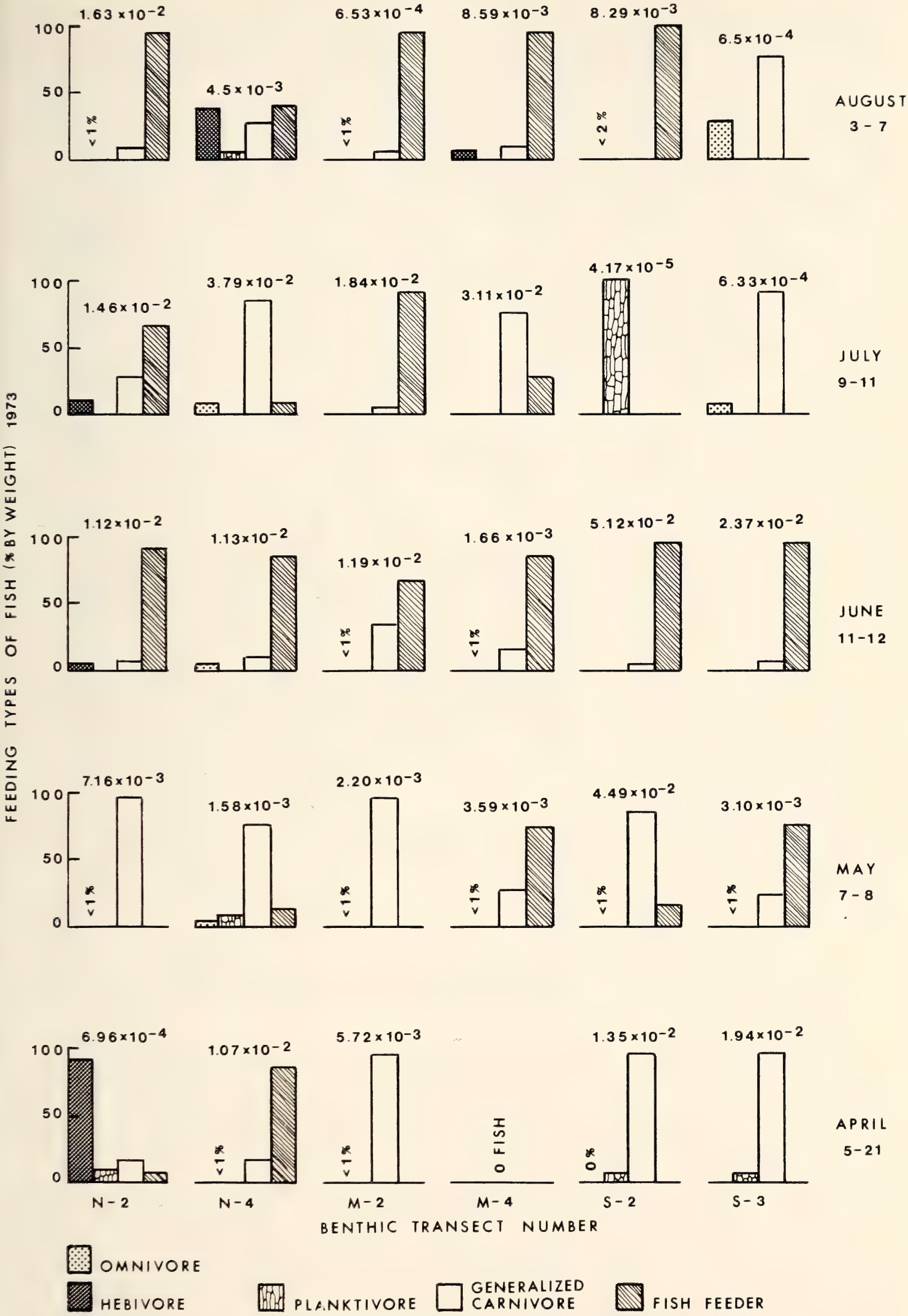


Fig. 1. Percentage distribution (percent total standing crop by weight) of the feeding-types of fish. April to August 1973. Value above each graph is the total standing crop of fish for each fish transect in kg/m^2.

TABLE 1. Fish species in Old Rhodes Key Lagoon: their feeding-type and "A" values. (Listed phylogenetically)

Species:	Feeding-Type[1]	"A" Value ($g./cm^3$)
Negaprion brevirostris (Poey): Lemon Shark	FF	.0069
Dasyatis americana Hildebrand and Schroeder: Southern Stingray	GC	.03 (width)
Elops saurus Linnaeus: Ladyfish	FF	.0091
Albula vulpes Linnaeus: Bonefish	GC	.0097
Clupeidae A: Herrings	P	.0053
Synodus sp.: Lizardfish	FF	.0048
Strongylura sp.: Needlefish	GC	.0020
Cyprinodon sp.: Killifish	O	.0199
Syngnathus sp.: Pipefish	P	29.5 mg/ind
Hippocampus sp.: Sea Horse	P	6.6 mg/ind
Atherinidae A: Silversides	P	.0199
Sphyraena barracuda (Walbaum): Great Barracuda	FF	.0065
Epinephelus striatus (Bloch): Nassau Grouper	GC	-
Echeneis sp.: Sharksucker	GC	-
Caranx ruber (Bloch): Bar Jack	FF	.0070
Caranx fuses Geoffroy-Saint-Hilaire: Blue Runner	FF	-
Lutjanus griseus (Linnaeus): Grey Snapper	GC	.0195
Lutjanus apodus (Walbaum): Schoolmaster	FF and GC	.0164
Lutjanus analis (Cuvier): Mutton Snapper	GC	.0195
Haemulon aurolineatum Cuvier: Tomtate	GC	.0198
Haemulon flavolineatum (Desmarest): French Grunt	GC	.0172
Archosargus rhomboidalis (Linnaeus): Sea Bream	O	.0227
Gerres cinereus (Walbaum): Yellowfin Mojarra	GC	.0231
Eucinostomus argenteus Baird and Girard: Spotfin Mojarra	GC	.0234
Scarus croicensis Bloch: Striped Parrotfish	H	-
Scarus sp.: Parrotfish	H	.0138
Paraclinus sp.: Blenny	GC	113 mg/ind
Lactophrys trigonus (Linnaeus): Buffalo Trunkfish	GC	.0579
Opsanus sp.: Toadfish	GC	900 mg/ind
Osteichthyes A (unidentified)	GC	5.4 mg/ind
Osteichthyes B (planktonic)	P	.0023

[1]FF = Fish Feeder (Fish Only), GC = Generalized Carnivore (Polychaetes, Crustaceans, Molluscs, Small Fish), P = Planktivore (Zooplankton), H = Herbivore (Benthic Macroflora), O = Omnivore. (After Randall, 1967)

that of Brock (1954). A diver swam along each of the 100 m sampling transects, and counted those fish seen within a 6 m wide band in front of him. At 20 m intervals the diver totalled the number and avg estimated length of each species counted in the 600 m^2 censusing area.

Lengths of fish species observed along each transect were averaged. A transformation of average length to weight was made using Brock's 1954 formula: $W = AL^3$, where "A" is a species constant, derived from known weights and lengths for each species; L is the estimated avg length of each fish species. The estimated weights thus obtained were multiplied by the numbers of such fish counted, to determine the total wt of each species, and these values when summed provided the standing crop of fishes within the transect area.

Fishes trapped and those caught with rod and reel were placed in 10% buffered sea-water formalin; weighed and measured for standard length. These measurements were used in determining length-weight transformation constants.

RESULTS AND DISCUSSION—Thirty-one species were observed during 1973 (Table 1). They represented a standing crop of 0.01 kg/m^2 (wet wt).

The greatest percentage of the total standing crop by wt consisted of carnivorous fish (Fig. 1). Herbivores (e.g. parrotfishes, *Scarus* sp.) were underestimated as they were easily disturbed and left the censusing area before being counted.

The biomass results obtained are similar to those found by other authors (Bardach, 1959) but due to herbivore disturbance, the species diversity is lower than expected for a tropical marine fish community (Reid, 1954). It is apparent that the censusing method employed needs modification. With modification, the method will prove useful in determining the causes of ichythyofaunal species diversity in tropical marine lagoons.

LITERATURE CITED

BARDACH, J. E. 1959. The summer standing crop of fish on a shallow Bermuda Reef. Limnol. Oceanogr., 4:77-85.

BRIGGS, J. C. 1958. A list of Florida fishes and their distribution. Bull. Florida St. Mus. 2(8):223-318.

BROCK, V. E. 1954. A preliminary report on a method of estimating reef fish populations. J. Wildl. Mgmt. 18:297-308.

GILBERT, C. R. 1972. Characteristics of the Western Atlantic reef-fish fauna. Quart. J. Florida Acad. Sci. 35:130-144.

HOLM, R. F. 1975. The Community Structure and Diversity of a Nearshore Tropical Marine Lagoon. Ph.D. Dissert. Northwestern University. Evanston, Illinois.

RANDALL, J. E. 1967. Food habits of reef fishes of the West Indies. Stud. Trop. Oceanogr. 5:665-847.

REID, G. K., JR. 1954. An ecological study of the Gulf of Mexico fishes in the vicinity of Cedar Key, Florida. Bull. Mar. Sci. Gulf Carib. 4:1-94.

SPRINGER, V. G., AND A. J. MCERLEAN. 1962. Seasonality of fishes on a South Florida shore. Bull. Mar. Sci. Gulf Carib. 12:39-60.

VOSS, G. L., F. M. BAYER, C. R. ROBINS, M. GIMON AND E. LAROE. 1969. The marine ecology of the Biscayne National Monument. Rept. to the U. S. Dept. of Interior Nat. Park Serv. Inst. Mar. Sci. Univ. Miami. Coral Gables. (107 pp., available from publisher)

Florida Sci. 40(3):258-261. 1977.

NEW DEPTH RANGE, LOCALITY, AND A LITERATURE CORRECTION FOR THE GEMPYLID FISH *PROMETHICHTHYS PROMETHEUS*[1]—

Richard Philibosian (1) *and Shirley Imsand* (2), Bureau of Fish and Wildlife, Box 1878, Frederiksted, St. Croix, U.S. Virgin Islands 00840 (1); and Scripps Institution of Oceanography, University of California, San Diego, La Jolla, California 92037 (2)

ABSTRACT: P. prometheus *is reported from shallow water in the Virgin Islands; depth range of the species is 5-550 m.*

PRIOR to the report of Grey (1960) *Promethichthys prometheus* was known in the western Atlantic Ocean from Bermuda and the Gulf of Mexico. Grey listed one specimen near Puerto Rico and four near the coast of northern South America, all caught at depths of 366-457 m. Rathjen (1960) recorded one off Massa-

[1]Contribution No. 38 of the West Indies Laboratory of Fairleigh Dickinson University.

chusetts at a depth of 320 m. In that report, reference was made to Springer and Bullis (1956), noting that they listed three *P. prometheus* from the Gulf of Mexico: one taken on a long line and two with dip nets while night lighting. However, Springer and Bullis listed only one specimen, and that from a depth of 357 m. Bullis and Thompson (1965) reported *P. prometheus* from four stations 411-457 m deep in the Gulf of Mexico.

Goode and Bean (1895) reported that fishermen obtain it from depths of 100-180 m near Bermuda and 180-550 m (possibly to 700 m) near Madeira. Depth ranges reported for the Pacific are Sagami Bay, Japan, and other coastal areas 180-500 m (Matsubara and Iwai, 1952; Ichihara, 1968), and Hawaii—90-360 m (Clarke, 1972). Thus the recorded depth range of *P. prometheus* was 90-550 m.

During darkness on 28 March 1974, one specimen of *P. prometheus*, 271 mm standard length, was caught with hook and line, 17° 44′ N, 64° 32′ W (5 km southeast of East Point, St. Croix, U.S. Virgin Islands). The hook was at a depth of 3-5 m, water depth was about 15 m. Some St. Croix fishermen report occasionally catching this fish within 5 m of the surface. This is the first of such reports that could be confirmed with a specimen. Apparently this species can occur over shallow banks and within a few meters of the surface.

Acknowledgments—The specimen is deposited in the Scripps Institution of Oceanography (SIO 74-158). The fish was caught by Douglas Nesbitt; Richard Rosenblatt confirmed identification and reviewed an earlier draft; Margo Hewitt and John Yntema assisted with this information.

LITERATURE CITED

Bullis, H. R., II, and J. R. Thompson. 1965. Collections by the exploratory fishing vessels Oregon, Silver Bay, Combat, and Pelican made during 1956 to 1960 in the southwestern North Atlantic. U.S. Fish Wildl. Serv. Spec. Sci. Rept. Fisheries 510:1-130.

Clarke, T. A. 1972. Collections and submarine observations of deep benthic fishes and decapod Crustacea in Hawaii. Pacific Sci. 26:310-317.

Goode, G. B., and T. H. Bean. 1895. Oceanic Ichthyology, Vol. 1. Spec. Bull. Smithsonian Inst. Washington, D.C.

Grey, M. 1960. Description of a western Atlantic specimen of *Scombrolabrax heterolepis* Roule and notes on fishes of the family Gempylidae. Copeia 1960:210-215.

Ichihara, A. 1968. On the parasitic helminths of marine fish in Sagami Bay-I. On horse mackerel, flasher butter fish, hashikinme, frigate mackerel, barracuda and alfonsis. Bull. Jap. Soc. Sci. Fish. 34:365-377.

Matsubara, K., and T. Iwai. 1952. Studies on some Japanese fishes of the family Gempylidae. Pacific Sci. 6:193-212.

Rathjen, W. F. 1960. A record of the gempylid fish *Promethicthys promethus* [*sic*!] from off the east coast of the United States. Copeia 1960:357-358.

Springer, S., and H. R. Bullis. 1956. Collections by the *Oregon* in the Gulf of Mexico. U.S. Fish and Wildl. Serv. Spec. Sci. Rept. Fisheries, 196:1-134.

Florida Sci. 40(3):261-262. 1977.

MORPHOMETRIC CHARACTERISTICS OF THE TEN THOUSAND ISLANDS RACCOON—*W. J. Bigler, A. S. Johnson and G. L. Hoff,* Health Program Office, Florida Department of Health and Rehabilitative Services, 1323 Winewood Blvd., Tallahassee, Florida 32301 and Institute of Natural Resources, University of Georgia, Athens, Georgia 30602

ABSTRACT: *Morphometric characteristics of raccoons from Marco Island, Collier County, Florida are presented. The raccoons were subspecies* Procyon lotor marinus *and data presented supplements and expands previously published information concerning this subspecies.**

SIX EXTANT subspecies of raccoon, *Procyon lotor,* have been described from Florida (Goldman, 1950): *P. l. varius, P. l. elucus, P. l. marinus, P. l. inesperatus, P. l. auspicatus* and *P. l. incautus.* The latter four, described by Nelson (1930), are almost entirely restricted to the Florida Keys and mangrove islands off the southern peninsular coast. The fragile habitat of these islands is particularly vulnerable to degradation by land developers and by pollution from a burgeoning human population. To date, one raccoon, *P. l. auspicatus,* has been officially recognized by the Florida Game and Fresh Water Fish Commission as a threatened species. Reports confirming the existence and distribution of these subspecies have been rather fragmentary (Goldman, 1950; Hall and Kelson, 1959) and mainly restate the data presented by Nelson. We present morphometric data on *P. l. marinus* which supplement and expand those presented in Goldman.

According to Goldman, *P. l. marinus* was established as a subspecies on the basis of 42 animals and 7 additional skulls. Thirty-eight specimens were from the type locality of Chokoloskee, Collier County. The raccoons we studied were collected on Marco Island, Collier County, approximately 45 km northwest of the type locality.

Nelson gave the mean weight for the type and topotype specimens as approximately 3400 gm for males and 2400 gm for females. Mean weight and standard error for 187 adult males from Marco Island was 3823 ± 116 gm and for 116 adult females 3010 ± 132 gm. Weights of males varied considerably throughout the year, being remarkably heavier in fall (4329 ± 114 gm) and lighter in winter (3299 ± 132 gm). Weights of females were relatively constant throughout the year except for a slight increase in fall (3329 ± 132 gm).

Selected body and skull measurements are given in Table 1. Fewer measurements were given for the type and topotype specimens. Comparable measurements were generally (but not significantly) shorter than those obtained from the Marco Island series. A t test showed that males were significantly ($P < 0.05$) larger than females for total length, body length, tail length, hind foot length, greatest length of skull, zygomatic breadth and width of upper canine.

Measurements of the Marco Island specimens were consistently greater than those reported by Goldman (1950) for the subspecies. However, the differences were small, and the measurements are well below those reported for *P. l. elucus.*

---

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

TABLE 1. Selected measurements (mm) of adult *Procyon lotor marinus* collected from Marco Island, Collier County, Florida 1970-1974.

MEASUREMENTS	MALES					FEMALES				
	N	Mean	(Range)	±	SE	N	Mean	(Range)	±	SE
Total length	156	720	(572-850)	±	3.71	114	681	(560-810)	±	3.60
Body length	156	511	(415-600)	±	3.44	114	479	(390-610)	±	3.50
Tail length	156	210	(160-255)	±	1.90	114	202	(170-245)	±	1.70
Hind foot length	156	103	(75-122)	±	0.50	114	97	(87-113)	±	0.47
Ear length	156	52	(35-62)	±	0.39	114	51	(39-60)	±	1.70
Skull greatest length	12	109.0	(97.4-119.0)	±	1.63	28	106.3	(97.7-116.3)	±	0.85
Condylobasal length	14	103.4	(92.4-112.6)	±	1.29	35	102.9	(93.0-112.3)	±	0.74
Zygomatic breadth	14	70.7	(63.4-75.9)	±	0.92	36	66.4	(59.0-73.2)	±	0.56
Least interorbital constriction	15	22.6	(18.6-25.7)	±	0.43	35	22.2	(20.-26.0)	±	0.21
Least width palatal shelf	14	15.7	(14.3-21.0)	±	0.45	36	15.4	(12.8-19.4)	±	0.18
Post orbital breadth	13	25.9	(21.0-35.9)	±	0.98	33	24.8	(20.8-27.0)	±	0.28
Mastoid breadth	15	56.5	(46.0-65.3)	±	1.13	35	54.4	(47.0-64.5)	±	0.55
Depth of cranium	10	45.3	(44.0-48.2)	±	0.44	28	44.5	(41.9-47.3)	±	0.29
Length of maxillary tooth row	14	40.8	(38.4-43.3)	±	0.38	36	40.3	(38.5-43.0)	±	0.21
Upper canine width	12	4.60	(3.8-5.2)	±	0.11	31	4.10	(3.0-5.5)	±	0.09
First molar width	13	9.10	(8.5-10.0)	±	0.14	33	8.70	(4.0-9.9)	±	0.17

LITERATURE CITED

GOLDMAN, E. A. 1950. Raccoons of North and Middle America. North Amer. Fauna 60. U. S. Fish and Wildl. Serv. Washington, D.C.

HALL, E. R. AND K. R. KELSON. 1959. The Mammals of North America. Vol. 2:884-891. Ronald Press Co. New York.

NELSON, E. W. 1930. Four new raccoons from the keys of southern Florida. Smithsn. Misc. Collect. 82(8):1-12.

Florida Sci. 40(3):263-265. 1977.

DRUG USE SURVEY AT FLORIDA TECHNOLOGICAL UNIVERSITY—

Robert Bird, Jack Armstrong and Charles Dziuban, College of Education, Florida Technological University, Orlando, Florida 32816

ABSTRACT—*Students enrolled in a drug abuse education course at FTU were questioned about drug use habits. Three drugs—alcohol, tobacco, and marijuana—were the only drugs on the survey list that were used by a relatively large percentage of those surveyed.**

DURING a drug abuse education course at Florida Technological University 180 students were selected for our survey. The sample was composed of 54% males and 46% females. No one in the group was under 18, 46% were between 18 and 21, 22% were between 22 and 25, and 17% were between 26 and 29 years old; 85% of the sample population was less than 30. The enrollment by college major was: Business Administration 18.6%; Education 22.4%; Engineering 9.1%; Humanities and Fine Arts 7.2%; Natural Science 13.8%; Social Science 19.5%; General Studies 5.0%; Undecided 4.5%. The sample population included: Business Administration 20%; Education 28%; Engineering 3%; Humanities and Fine Arts 6%; Natural Science 10%; Social Science 32%; General Studies 2%; Undecided 0%. The sample seems to adequately represent the student body at FTU by undergraduate major.

In spring quarter, 1975, all students enrolled in EDEL 482 Drug Abuse Education were asked to complete an anonymous questionnaire on drug use. This questionnaire listed eight different drugs and four categories of frequency of drug use, from zero times used over the past year to 50+ uses in the same time period. The results of this survey are summarized in Table 1.

Alcohol is the most widely used mood-altering drug used by FTU students. This survey shows that 79% of those in the sample reported using alcohol at least once in the preceding year. About 56% reported using it regularly, at least monthly (10-49 times) or weekly (50+). The next most popular drug used was tobacco. Although tobacco is not an intoxicant, it is a health hazard and should be reported along with other drugs used. The students in this sample reported

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

TABLE 1. Percent of students reporting drug used and frequency of use in past year.

DRUG	FREQUENCY OF USE				
	0	1-2	3-9	10-49	50+
Alcohol	21%	5%	18%	31%	25%
Tobacco	57	3	3	8	29
Marijuana	58	8	8	11	16
Amphetamines	89	3	3	3	2
Hallucinogens(LSD, etc.)	91	3	3	2	1
Barbiturates	92	3	2	2	1
Cocaine	93	5	2	0	0
Heroin	99	1	0	0	0

that 43% have used tobacco at least once in the past 12 months and 29% use it weekly. These results are consistent with what is known about tobacco users; i.e., most users use tobacco daily. After alcohol, marijuana is the most popular intoxicant with members of this group. Marijuana was used at least once in the past year by 42%, and 27% could be considered regular users (once a month to once or more a week).

It is interesting to note that these three drugs—alcohol, tobacco, and marijuana—are the only drugs mentioned on the survey list that are used by a relatively large percentage of the student body. Most college students at FTU haven't used any drugs other than alcohol, tobacco and marijuana in the past 12 months. This survey indicates that between 89% and 99% of the students have not used heroin (99%), cocaine (93%), barbiturates (92%), hallucinogens (91%), or amphetamines (89%).

The use of drugs by young adults is very complex; it involves variables of psychological, biological, and sociological nature. Drug use patterns vary according to time, place, kind of drug being used, and the user. Our survey provides information about who uses what drugs, and the extent of drug use. It does not provide insight into motivation, but if drug use is to be understood, determination of frequency of use is a first step toward such understanding.

LITERATURE CITED

CORNACCHIA, H. J., D. J. BENTAL, AND D. E. SMITH. 1973. Drugs in the Classroom. C. V. Mosby Company. St. Louis.

KILLINGER, R. R., B. J. HERSKER, AND D. M. GEORGOFF. 1970. The Use of Drugs by College and University Students in the State of Florida. Drug Research Foundation, Inc. Miami, Florida.

WALLACE, B. C. 1974. Education and the Drug Scene. Professional Educators Publications, Inc. Lincoln, Nebraska.

Florida Sci. 40(3):265-266. 1977.

Biological Sciences

REDISCOVERY OF SMALL'S ACACIA IN FLORIDA[1]

DANIEL B. WARD AND JAMES R. BURKHALTER

Department of Botany, University of Florida, Gainesville, Florida 32611;
Department of Biology, University of West Florida, Pensacola, Florida 32504

ABSTRACT: *Small's Acacia,* Acacia smallii *Isely, is a bushy tree known from northeastern Mexico eastward along the Gulf Coast to Louisiana. It was discovered at Pensacola, Escambia County, Florida, in 1901 and 1903, but has since not been confirmed to exist in Florida. Several populations along the edge of Pensacola Bay were recently discovered to be well established. A key is provided to Florida species of* Acacia.[*]

DURING the nineteenth century the city of Pensacola, Florida, boasted one of the most active ports on the entire Gulf Coast, annually shipping millions of board-ft of longleaf pine timber and attracting to its anchorage sailing vessels from all parts of the world. To take on the weighty timber these ships routinely disgorged great quantities of ballast—rocks, rubble, and waste materials of all kinds. Inevitably, the viable seeds of many foreign plants were transported fortuitously among these ballast wastes. The wealth of exotic species attracted early botanists to the dock areas and storage yards, and publications of that day (e.g., Chapman, 1897; Mohr, 1901) register an abundance of adventive plant "first records" from Pensacola.

Not all species found by early collectors have spread beyond the Pensacola area or, indeed, have persisted even there. Such a disappearance has been believed to have been the fate of Small's Acacia, a bushy tree well known in the drier areas of Texas and northeastern Mexico. On August 6, 1901, A. H. Curtis, a professional collector, made specimens of Small's Acacia at Pensacola. Additional specimens were obtained on April 30, 1903, by the botanist S. M. Tracy. Since that date, until the date of the collections reported here, this tree has not been seen by botanists within the state of Florida.

The obscurity of this small tree in Florida has been abetted by its similarity to a better known plant frequently cultivated and locally naturalized in the southern part of the state, and by changes in scientific name that have accompanied realization of the separate status of the two species. The South Florida species, also widely native throughout the American tropics, is the Sweet Acacia or Cassie, *Acacia farnesiana* (L.) Willd. The Pensacola plant, usually called Huisache in Texas, more fittingly is known to Florida botanists as Small's Acacia, in recognition of J. K. Small (1933) who first published the characters by which the two species may be separated. Its scientific name is *Acacia smallii* Isely (1969).

The absence of later Florida collections of *Acacia smallii* was not quickly perceived by subsequent writers. Small (1903, 1913) perhaps on the basis of the

[1]This paper is Florida Agricultural Experiment Station Journal Series No. 377.

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

Curtiss and Tracy collections, recorded the Texas plant as naturalized in Florida; he treated it as *Vachellia farnesiana* (L.) Wight & Arn. by which name he may have been referring also to the Sweet Acacia. Later (1933), clearly recognizing the Pensacola plant as distinct, he named it *Vachellia densiflora* Alexander *ex* Small and assigned it to "bayou-banks, fills, and waste-fields, along and near the Gulf Coast, W. Fla. to Tex." More recent students of the Florida trees (cf. West & Arnold, 1956; Kurz & Godfrey, 1962), lacking collections of their own, omitted the species. Isely (1973), in a thorough study of the mimosoid legumes of the United States, concluded: "I do not know whether two old records from the Florida Panhandle are from cultivation or are indicative of the original range of the species. Since there are no modern collections in Florida herbaria, I consider that *A. smallii* does not presently grow in Florida."

In recent years the junior author has attempted to document some of the early records for Pensacola introductions, by further collections in the areas known to Curtiss and Tracy and the pioneer botanists who preceded them. The Pensacola docks are no longer as these early collectors would have known them. The quantities of ballast have been leveled and distributed to fill much of the old harbor area, and warehouses, parks, and roadways are now scattered where once the sailing ships were at anchor. But waste areas have persisted, and with them many of the early introductions.

One of these is Small's Acacia. Trees of this species are to be found in a number of areas. In Baylen Street Park, at the southern edge of Pensacola and adjacent to the open waters of Pensacola Bay, the plants are most numerous. A series of small trees rim the waterfront or grow in clumps on the dry sandy fill. Most are around 2 m tall, with a few to 3 m. The branches are arching, reaching to the ground, or in the case of those nearest the bay, to the water 2 m below the base of the trees. The trunks are smooth and spineless. The trees flower abundantly in April and May and fruit heavily by late June. Their age has not been determined, but their vigorous state suggests it is not great.

In addition to the larger plants, the rough lawns of Baylen Street Park and adjacent areas contain a large number of very depressed closely-mown plants of the same species. Although it has not been observed, it seems probable that cessation of mowing would release these plants and generate a thicket of larger individuals.

Small trees and seedlings have been observed at intervals along the waterfront for a distance of 2 mi to the west of Baylen Street Park. Other stations, although with fewer individuals, are along Bayou Chico, just west of W Street, south of Pensacola, near Barancas Beach at the Naval Air Station, and across Pensacola Bay at the western end of Santa Rosa Island near Fort Pickens.

Although the inventory is incomplete, it is apparent that *Acacia smallii* is well established and thriving in the Pensacola area. Specimens documenting the current presence of the species in Florida have been deposited in appropriate herbaria (*J. R. Burkhalter 2261*, 2 May 1975, FLAS; *D. B. Ward* 8970, 24 June 1975, FLAS, FSU, ISC, NY).

The surprising abundance of these small trees along the shores of Pensacola

Bay, at times in areas of little recent disturbance, suggests that the plant may have been native, rather than a recent introduction. Isely (1973) mapped the coastal distribution of *Acacia smallii* from Mexico and Texas into eastern Louisiana. A collection not seen by him (*S. B. Jones 20360*, FLAS) extends its range to coastal Mississippi. There seems to be no reason why the plant could not have spread by natural means still further eastward, to western Florida. But the introduction of other species into the Pensacola area by the actions of man, particularly during the nineteenth century, and the absence of collections of earlier date, leave the question of the origin of this easternmost extension of Small's Acacia yet unanswered.

The following key will be useful in distinguishing *Acacia smallii* from *A. farnesiana* and the other species of *Acacia* native or naturalized in Florida.

KEY TO ACACIA IN FLORIDA

1. Herbaceous or suffrutescent; flowers white (rarely pinkish); leaves lacking glands on both petiole and rachis; pods flat.................. *A. angustissima* (Mill.) Kuntze var. *hirta* (Nutt.) Robins.
1. Woody, small trees or shrubs (often low in *A. pinetorum*); flowers yellow; leaves with a gland or glands on upper surface of petiole or both petiole and rachis; pods more or less terete (compressed in *A. choriophylla* and *A. macracantha*)........ 2
    2. Pods clearly compressed laterally; leaves with 14-20 pairs of pinnae; craterform gland present between terminal pair or pairs of pinnae.......... *A. macracantha* Willd.
    2. Pods terete or nearly so (compressed in *A. choriophylla*); leaves with 1-10 pairs of pinnae; glands absent between pairs of pinnae (although present on petiole).
        3. Plants unarmed; pod woody, laterally compressed; leaves with 1-3 pairs of pinnae. .... *A. choriophylla* Benth.
        3. Plants armed by sharp stipular spines, sometimes very much enlarged; pods terete or nearly so; leaves with 4-10 pairs of pinnae.
            4. Pods densely and shortly pubescent, 8-10 cm long, often constricted between the seeds. .... *A. tortuosa* (L.) Willd.
            4. Pods glabrous, 5-8 cm long, uniform in thickness except for tapering ends.
                5. Stipular spines very much enlarged, often wider at base than twig on which they are borne; pod with thin fragile wall....... *A. sphaerocephala* Schl. & Cham.
                5. Stipular spines not enlarged, narrower than the twig; pod firm-walled, nearly woody. 6
                    6. Leaflets 3-6 mm long, with 1-6 prominent lateral veins.......... *A. farnesiana* (L.) Willd.
                    6. Leaflets 1.5-3 mm long, without (or with very obscure) lateral veins.......... 7
                        7. Twigs zig-zag; peduncles frequently to 2 cm long; small shrub, often very low and matlike.......... *A. pinetorum* Hermann
                        7. Twigs straight or approximately so; peduncles usually under 1.5 cm long; small many-branched tree or large shrub. .... *A. smallii* Isely

LITERATURE CITED

Chapman, A. W. 1897. Flora of the Southern United States, ed. 3. Cambridge.
Isely, D. 1969. Legumes of the United States: I, Native Acacias. Sida 3:365-386.
_________. 1973. Leguminosae of the United States: I. Subfamily Minosoideae. Mem. New York Bot. Gard. 25:46-47.
Kurz, H. and R. K. Godfrey. 1962. Trees of Northern Florida. Gainesville.
Mohr, C. 1901. Plant Life of Alabama. Contr. U.S. Nat. Herb. 6:1-921.
Small, J. K. 1903. Flora of the Southeastern United States. New York.
_________. 1913. Flora of the Southeastern United States, ed. 2. New York.
_________. 1933. Manual of the Southeastern Flora. New York.
West, E. and L. E. Arnold. 1956. The Native Trees of Florida. Gainesville.

Florida Sci. 40(3):267-270. 1977.

Biological Sciences

DERO (AULOPHORUS) FLABELLIGER STEPHENSON (NAIDIDAE: OLIGOCHAETA) NEW TO CENTRAL FLORIDA

Robert N. Schmal[1]

Dames & Moore, Environmental Consultants, 1550 NW Highway, Park Ridge, Illinois 60068

Abstract: *The species is reported for the first time from a tributary of the St. Johns River in Central Florida; flabelliform acicular setae were confirmatory taxonomic characteristics for species recognition.*

Three specimens (two complete) of *Dero (Aulophorus) flabelliger* Stephenson were found during a benthic macroinvertebrate survey of Second Creek, east of Orlando, Florida. The species was first described from Lake Naivasha, Kenya, Africa; and later from Addis Ababa, Legation Garden, pond number 2; Australia and Nanking, China (Brinkhurst and Jamieson, 1971). One of our Florida specimens has been deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D. C. (USNM no. 53350). The other specimens are in the Dames & Moore macroinvertebrate reference collection at Park Ridge, Illinois.

Methods—The worms were collected from Second Creek (tributary to the St. Johns River), 10 m upstream from Florida State Highway 520 bridge, Orange County, Florida, on 20 October 1974. They were found in a sample collected with a standard Ekman grab, (231 cm^2), that was sieved in the field with a standard U.S. No. 30 sieve (0.595 mm opening) and preserved with 10% formalin buffered with magnesium carbonate. The oligochaetes were transferred to vials containing 70% ethanol, and later were mounted in CMC—10 medium.

---

[1]Present address: Wisconsin Cooperative Fishery Research Unit, College of Natural Resources, University of Wisconsin, Stevens Point, Wisconsin 54481.

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

TABLE 1. Comparative dimensions of *Dero (Aulophorus) flabelliger* Stephenson including Stephenson's (1931) type description and the Second Creek specimen (1974).

Taxonomic Characters	Stephenson's (1931) Type Specimen (Africa)	Second Creek (1974) Specimen (U.S.A.)
NUMBER OF SEGMENTS:	27-28	25 (setiferous)
SETAE:		
Number of ventrals in II-IV	5-7	4-5
Length of ventrals in II-IV	106-127μ	100μ
Thickness of ventrals in II-IV	3u	3u
Number of ventrals in VI posteriad	4	4
Length of ventrals in VI posteriad	49-53u	50u
Thickness of ventrals in VI posteriad	$\pm$ 2μ	$\pm$2μ
Length of flabelliform aciculars	50-60μ	60μ
Width of flabella of aciculars	18-19μ	15μ
Length of capilliforms	110-115μ	90-100μ
TERMINAL SEGMENT:		
Number of gills	3 pairs	3 pairs
Number of palps	2 presumptive	2 (+ 1 ?)

RESULTS AND DISCUSSION—The oligochaetes were collected in a predominantly sand substrate containing some accumulated organic detritus. Aquatic macrophytes were common at the site. A few apparently insignificant morphological differences exist between the Second Creek specimen and the original description (Table 1). Variability of external characters used in species recognition for tubificid oligochaetes, primarily the genus *Limnodrilus,* include the number of setae per bundle and setal shapes which can vary widely with age in the same species (Kennedy, 1969). The Naididae also vary widely in external morphological characters (Hiltunen, personal communication). The shape of the flabelliform (web-like) seta described in the Brinkhurst and Jamieson key (1971) was the confirmatory taxonomic characteristic used for species recognition (Fig. 1).

ACKNOWLEDGMENTS—This paper was supported by funds from Dames & Moore, Consultants in Environmental and Applied Earth Sciences; Dr. Kenneth Stimpfl, Technical Services Manager, provided administrative assistance; Charles Zimmerman and Christine Poulos, Aquatic Ecologists, Dames & Moore, Atlanta collected the material; Jarl K. Hiltunen U.S. Fish and Wildlife Service, Ann Arbor verified the species identification; and Dr. G. Zolton Jacobi, University of Wisconsin, Stevens Point reviewed the manuscript.

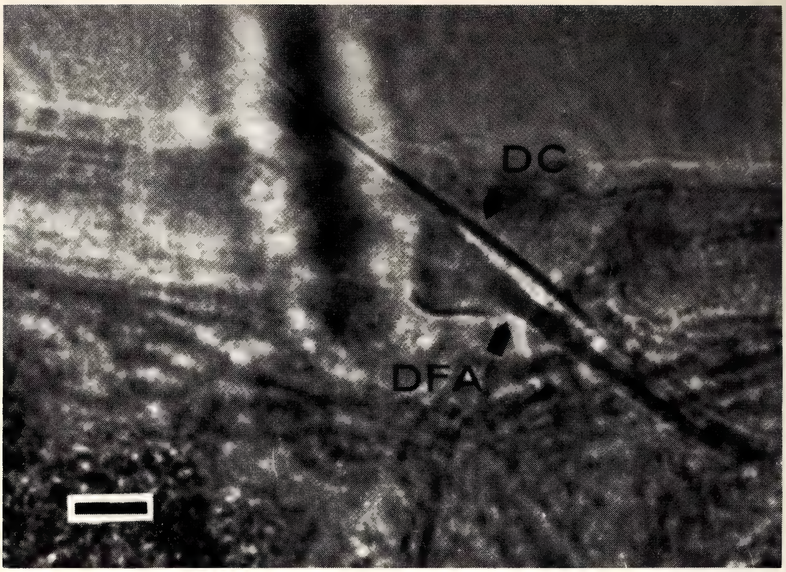


FIGURE 1. Lateral of the dorsal capilliform (DC) and dorsal flabelliform acicular (DFA) setae of *Dero (Aulophorous) flabelliger* Stephenson from Second Creek. Scale: 10 *microns*.

LITERATURE CITED

BRINKHURST, R. O. AND B. G. M. JAMIESON. 1971. Aquatic Oligochaeta of the World. Univ. of Toronto Press.

KENNEDY, C. R. 1969. The variability of some characters used for species recognition in the genus *Limnodrilus* Claparede (Oligochaeta: Tubificidae). J. Nat. Hist. 3:53-60.

Florida Sci. 40(3):270-272. 1977.

CONSTANT ALTITUDE RADAR REFLECTIVITY OBSERVATIONS OF HURRICANE BELLE, 1976. *David P. Jorgensen and Billy M. Lewis*, National Hurricane and Experimental Meteorology Laboratory, Miami, FL 33124.—Radar video recordings of the NWS Cape Hatteras WSR-57 radar were made during the passage of Hurricane Belle, which was about 92 km offshore at the closest point of approach. Recordings were made between 0840Z and 1900Z on August 8, 1976. During this time, Belle moved northward 480km and the central pressure increased 10 mb. Radar data was collected on a tilt-sequence cycle of 1° elevation for every rotation of the antenna, from 0° to ZO° elevation. This analog data was then digitized into 1.0 km by 2° azimuth bins by the NHEML Radar Digital Integrator for input to a large scale computer. This spherical coordinate data was then synthesized into constant altitude (x,y) radar reflectivity (rainfall rate) maps with a grid interval of 2km. Several of these maps for selected time periods and altitudes are presented to show the horizontal and vertical reflectivity structure of Hurricane Belle. (Previously unpublished abstract from 1977 Annual Meeting—*Ed.*)

Biological Sciences

MORPHOLOGICAL VARIATION IN BREEDING RED-WINGED BLACKBIRDS, *AGELAIUS PHOENICEUS*, IN FLORIDA

MARSHALL A. HOWE, ROXIE C. LAYBOURNE, FRANCES C. JAMES

National Fish and Wildlife Laboratory, National Museum of Natural History, Washington, D. C. 20560; Division of Law Enforcement, U. S. Fish and Wildlife Service, Washington, D. C. 20240; and Ecology Program, National Science Foundation, 1800 G St., N. W., Washington, D. C. 20550

ABSTRACT: *285 adult male and 298 adult female Red-winged Blackbirds,* Agelaius phoeniceus, *from localities throughout Florida were collected during the breeding season. Specimens were prepared and examined to determine the nature and extent of geographic variation in morphological characters. Mean wing length, tail length and weight decrease clinally from northwest to southeast, except that birds from the Keys are larger than birds from the Everglades. Other morphological characters vary similarly but to a lesser degree. Color of streaking in females in darkest in the northwest and lightest in the southeast. With the possible exception of the Everglades population, recognition of more than one subspecies of the Red-winged Blackbird in Florida is not warranted.*[*]

THE generally accepted taxonomic treatment of Florida Red-winged Blackbirds (*Agelaius phoeniceus*) at the intraspecific level has long been that of Howell and Van Rossem (1928). Their determinations of racial distinctions and boundaries are recognized by the A.O.U. Check-list of North American Birds (1957). Howell and Van Rossem identified four races that breed in Florida:

(1) *A. p. phoeniceus*, breeding throughout the eastern United States, south into the extreme north-central portion of Florida (Gainesville).

(2) *A. p. littoralis*, breeding from the other Gulf states into the northwestern portion of the Florida panhandle (Pensacola).

(3) *A. p. mearnsi*, breeding from Putnam County and Anastasia Island in the north to the Kissimmee Valley and the Caloosahatchee River in the south, to Apalachicola in the west.

(4) *A. p. floridanus*, breeding from Key West north to Lake Worth on the east coast and Collier County on the west coast.

This classification was predicated largely on the color of females, which were shown to be blacker in the northwest (*littoralis*) and lighter brown in the southeast and Keys (*floridanus*). Morphological measurements of males in their analysis showed few differences between *floridanus* and *mearnsi*, although the latter had somewhat longer tails and tarsi. *A. p. phoeniceus* specimens (including only 2 Florida males) had longer wings than *littoralis* (2 Florida males), which in turn slightly exceeded *floridanus* and *mearnsi*. Tails were longest in *phoeniceus* and

---

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

shortest in *littoralis*. Culmen length showed little variation but both culmen depth and tarsus were greatest in *phoeniceus*, decreasing southward to *floridanus*. Females varied similarly for wing, tail, and bill depth. Female culmen length, however, was largest in *littoralis* and *mearnsi* and smallest in *phoeniceus* (1 specimen only), while tarsus was longest in *littoralis* and shortest in *floridanus*. The small sample sizes of both sexes of *phoeniceus* and *littoralis* prohibit valid comparisons with the more southern forms. Howell and Van Rossem's study was based on a total of 65 males and 48 females. Also, some of their samples included sub-adult males, which they noted averaged 9% smaller than full adults.

In the mid-1960's, the need for control of blackbird populations seriously depredating sweet corn crops in Florida led the U. S. Fish and Wildlife Service to initiate an intensive study of morphological variation in these birds. One objective was to determine diagnostic characters of breeding populations so that 1) their proportion in depredating flocks relative to migrant birds could be determined and, accordingly, 2) control measures could be directed toward depredating flocks consisting largely of migrants, thus minimizing adverse impact on the local breeding population. This paper presents our findings on the nature of morphological variability among Red-winged Blackbirds breeding in Florida.

Methods—Between late April and late July of 1964, 1965, and 1966, breeding adult Red-winged Blackbirds were collected by Fish and Wildlife Service biologists at 99 localities throughout Florida. In many cases territorial males were collected along with females believed to be mated to them. 285 males and 298 females were secured, sexed, and examined for confirmation of sexual maturity. These birds were brought to the substation of the Patuxent Wildlife Research Center at Gainesville and then to the U. S. National Museum, where study skins were prepared for detailed examination.

To assess geographic variation, Florida was subdivided into seven zones. Designation of zone boundaries was partially arbitrary and partially determined by the boundaries of relatively distinct ecologic or geographic features (Fig. 1). The northern portion of Florida was separated into two zones (6 and 7) meeting in the portion of the panhandle where *littoralis* purportedly intergrades with *phoeniceus* (Howell and Van Rossem, 1928). The central zone of the peninsula (3) coincides roughly with the range described for *mearnsi*. Everglades birds (2) were considered separately from Florida Keys birds (1) because of potential island effects or divergence of birds adapted to the unique Everglades habitat. For similar reasons Merritt Island birds (4) and birds from salt marshes on the central Gulf coast (5) were treated separately from adjacent mainland populations. Mean measurements of birds from each zone were calculated.

Results—Measurements of five characters were made by R. Laybourne: wing chord, tail, exposed culmen, bill depth at the nostril, and tarsus. Additional data used in the analyses were weight at time of collection and color of breast streaking in females. The latter was scored on a scale of one (lightest) to five (darkest), each bird being assigned a score after comparison with a standard series of reference feathers representing each category. Summaries of the measurements for each character, subdivided by sex and geographic zone, are pre-

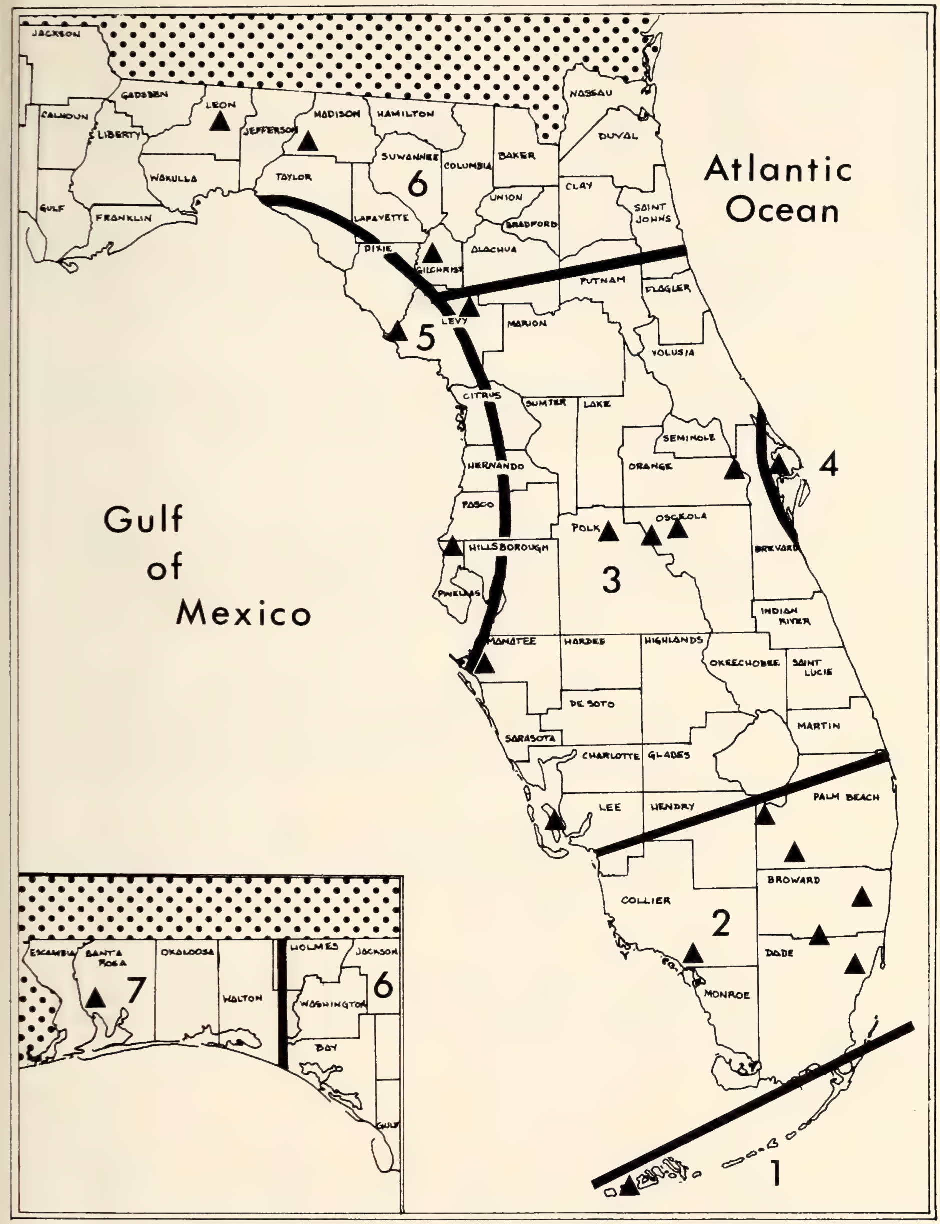


Fig. 1. County map of Florida showing the 7 zones from which breeding Red-winged Blackbirds were examined: (1) Keys, (2) Everglades, (3) Central, (4) Merritt Island, (5) West-Central Salt Marsh, (6) North, (7) Panhandle. Triangles indicate the areas of most intensive collecting.

sented in Table 1 which shows general trends of size variation through the state. Since the seven zones are not necessarily independent biological units, mean measurements from different zones are generally not compared statistically, except where differences between island and mainland forms appear to be substantial.

TABLE 1. Measurements in millimeters or grams of breeding Red-winged Blackbirds from Florida. Means and standard deviations are followed by ranges and samples sizes.

A. FEMALES

Zone	Wing Chord	Tail	Culmen	Tarsus	Bill Depth	Weight	Color of Breast-Streaking[1]
Keys	92.5±1.5 90.2-95.2 n=13	69.±2.1 66.6-73.5 n=13	19.4±0.7 18.2-20.4 n=10	23.5±0.8 22.0-24.5 n=13	7.3±0.2 6.8-7.5 n=10	36.9±2.1 33.5-40.0 n=13	1.5 1-3 n=9
Everglades	89.3±2.1 84.2-93.8 n=93	67.9±2.7 62.0-73.8 n=91	19.6±0.7 17.9-21.3 n=94	24.1±0.8 22.0-26.1 n=91	7.5±0.3 6.6-8.1 n=93	32.6±3.5 27.0-43.0 n=96	2.9 1-4 n=84
Central	92.2±2.2 87.9-97.5 n=73	70.4±2.5 64.5-76.0 n=72	19.6±0.7 18.0-21.8 n=73	24.8±1.1 21.9-28.5 n=73	7.6±0.3 6.9-8.2 n=69	38.4±3.6 29.8-44.6 n=73	4.1 3-5 n=73
Merritt Island	91.6±2.3 88.3-95.2 n=9	69.8±2.3 66.5-73.2 n=9	19.5±0.6 19.0-20.4 n=9	24.4±0.6 23.8-25.8 n=9	7.6±0.3 7.0-7.9 n=7	33.2±2.2 31.0-37.5 n=9	3.7 3-4 n=9
West-Central Salt Marsh	93.0±2.6 86.5-96.7 n=24	69.3±2.2 64.5-72.3 n=23	19.6±0.6 18.8-21.2 n=23	24.5±0.9 22.7-27.0 n=24	7.7±0.3 7.1-8.3 n=22	35.2±2.6 31.5-44.0 n=24	4.0 3-5 n=24
North	93.6±1.8 89.9-97.3 n=68	70.0±3.1 53.1-75.6 n=66	19.4±0.6 18.0-21.2 n=69	24.5±0.8 22.3-27.1 n=68	7.6±0.2 7.3-8.1 n=67	36.2±3.3 30.0-44.0 n=69	4.2 3-5 n=69
Panhandle	95.2±2.4 90.2-98.6 n=14	71.1±2.8 66.1-75.6 n=14	20.1±0.6 19.1-21.0 n=13	24.3±0.6 23.3-25.6 n=14	8.2±0.2 7.6-8.5 n=13	36.9±2.9 33.0-42.5 n=14	4.6 4-5 n=14

B. Males

Zone	Wing Chord	Tail	Culmen	Tarsus	Bill Depth	Weight
Keys	114.6±3.4	89.4±2.9	22.8±0.6	25.8±0.7	8.2±0.1	54.2±1.6
	107.0-118.5	85.0-94.5	22.0-23.8	25.2-27.2	8.2-8.4	51.5-56.5
	n=11	n=11	n=11	n=11	n=6	n=10
Everglades	108.6±3.0	83.5±3.5	23.5±0.8	25.9±1.1	8.7±0.4	48.1±3.2
	102.2-117.0	76.5-91.5	21.0-25.2	23.2-28.5	8.0-9.7	42.0-55.0
	n=82	n=82	n=80	n=84	n=78	n=84
Central	113.8±3.2	88.0±3.5	23.6±0.8	27.5±0.8	9.0±0.4	52.9±2.8
	106.5-122.5	78.9-98.6	22.0-25.2	25.5-29.7	8.1-9.6	48.0-61.0
	n=75	n=74	n=73	n=75	n=70	n=75
Merritt Island	114.7±2.0	89.7±3.3	23.4±1.2	27.6±0.9	8.6±0.2	51.9±2.9
	110.5-118.1	84.2-94.6	21.4-25.0	26.0-30.4	8.5-9.2	48.0-57.0
	n=20	n=20	n=16	n=20	n=12	n=20
West-Central Salt Marsh	113.9±2.9	87.4±3.7	23.0±0.7	27.5±0.8	9.1±0.4	53.9±3.0
	107.0-120.4	77.7-93.6	21.2-24.5	24.2-28.9	8.3-9.9	46.5-61.5
	n=41	n=41	n=38	n=38	n=38	n=41
North	114.0±3.5	87.6±4.1	23.4±0.8	27.1±0.6	9.0±0.3	55.9±3.6
	106.5-122.0	80.1-97.0	21.4-25.0	25.5-28.2	8.4-9.5	49.5-63.0
	n=42	n=42	n=41	n=41	n=39	n=42
Panhandle	117.3±2.2	89.0±3.1	23.9±0.8	27.5±1.2	9.6±0.2	58.0±3.1
	114.0-121.5	83.6-92.6	22.5-25.7	26.1-29.9	9.4-9.9	55.5-65.0
	n=9	n=9	n=9	n=9	n=8	n=9

[1]Based on a reference scale of 1 (lightest) to 5 (darkest).

Wing chord in both males and females is largest in birds from the panhandle and smallest in the Everglades. The overall pattern on the mainland is a gradual decrease from northwest to southeast. Birds from the Keys are larger than those from the Everglades, however. The differences between birds from the central zone and the Everglades, and between birds from the Everglades and the Keys, are greater than differences between other contiguous zones. Both males and females from the Keys have longer wings than Everglades birds ($t = 5.77$ and 5.22 for males and females respectively, $p < .001$). Wings of Merritt Island birds do not differ significantly from those of central zone birds.

The pattern of variation in tail length is similar to that of wing chord in both sexes. The largest mean tail lengths for males are from the panhandle populations and both island zones, Merritt Island and the Keys. A north-south cline is more evident in females than in males, largely due to greater differences between island and mainland forms in males. Both sexes of Keys birds have significantly longer tails than Everglades birds (males: $t = 5.41$, $p < .001$; females: $t = 2.53$, $p < .01$). Only males, however, from Merritt Island have significantly longer wings than adjacent mainland birds ($t = 1.96$, $p < .05$). For tail length, as with wing chord, birds from the Everglades are the smallest in the state.

With the possible exception of culmen length in males, variation in bill dimensions does not follow such a clearly definable pattern with respect to a north-south gradient. For both culmen length and bill depth the largest birds of both sexes are from the panhandle and the smallest birds from the Keys rather than the Everglades. Regional differences between means, however, are less than 1 mm for bill depth and culmen length in females. The greatest between-zone differences are for bill depth in males.

Tarsal length shows little consistent clinal variation in either sex except that Everglades and Keys males have shorter tarsi than the more northern populations.

Although body weight in birds may sometimes be unreliable as an indicator of size, because of variation in response to nutritional and reproductive states, weight data for males and females show the same geographic pattern as the mensural characters. The pattern is one of larger birds in the northwest and smaller birds in the southeast, except for the Keys birds, which are comparable in weight to birds from the panhandle and northern zones. Merritt Island females weigh slightly less than birds in the adjacent central zone ($t = 2.52$, $p < .01$).

No geographic variation in male plumage could be ascertained but ventral streak coloration in females varied from dark brown in the northwest to light brown in the Everglades and Keys, confirming the Howell and Van Rossem findings (1928). Most of the Everglades and Keys females have distinctly light streaks and can be readily recognized in a series of Florida specimens.

Discussion and Conclusion—In both sexes of breeding Florida Red-winged Blackbirds, wing length, tail length and weight show fairly consistent, gradual decreases from northwest to southeast. Birds from the Keys, however, average larger than those from the Everglades and are, therefore, usually inseparable from the birds of central and northern Florida on the basis of these three characters. Measures of culmen, bill depth, and tarsus exhibit similar but much less marked geographic variation within the state. Ventral streak color varies from dark brown in the northwest to light brown in the Everglades and Keys. The gradual nature of variation in all characters precludes the use of multivariate analysis of variance to evaluate statistical differences between zones.

An interesting feature of morphological variation in the state is the small size and relative distinctness of birds from the Everglades. This phenomenon has been obscured by the fact that earlier workers considered the Keys and Everglades birds together in their studies (Maynard, 1896; Howell and Van Rossem, 1928). Although the sample size from the Keys in this study is small, it is apparent that Keys birds average considerably larger than Everglades birds in wing length, tail length, and weight. The Everglades birds in turn average much smaller than birds of the central zone to the north. Whether Everglades birds represent a self-contained population, or whether they intergrade over a rather steep cline with neighboring populations, cannot be determined without more intensive collecting in the marginal areas of swampland and southern pine forest.

The pattern of decreasing size from north to south in Florida appears to be a continuation of the general pattern exhibited by Red-winged Blackbirds throughout the rest of the eastern United States (Howell and Van Rossem, 1928). Data provided by Howell and Van Rossem indicate, for example, mean wing chord lengths of 120.7 mm for males from New York and New England and 119.2 mm for males from South Carolina and Georgia. Mean wing chords of Florida males (this study) range from 117.3 mm in the Panhandle zone and 114.0 mm in the North zone to 108.6 mm in the Everglades and 114.6 mm in the Keys. Data for Red-winged Blackbirds from the Great Plains (Power, 1970) indicate a decreasing gradient for wing and tail length from western Canada to the southeastern plains, except that the largest birds are from the arid western plains of the United States. We are presently undertaking an expanded analysis of overall geographic size and shape variation of this species throughout North America.

Several other species of passerines and certain woodpeckers decrease in size from northwest to southeast in the eastern United States (James, 1970). The smallest Downy Woodpeckers occur in the zone that we are calling here the Everglades zone. James (1970) pointed out that the parallel patterns in the species considered may represent convergent trends toward phenotypes at each locality that optimize the difference between the evaporative power of the air and the respiratory surface of the bird. Intraspecific size variation in birds usually results in smaller birds in warm, humid climates and larger birds in drier climates (Hamilton, 1961). Since cold air is necessarily dry, birds are also larger in colder areas. These patterns seem to be general for breeding populations and resident species that vary geographically. The fact that the same pattern is evident in the fairly small geographic area of Florida, with the smallest birds occurring in the warmest and most humid section, is additional evidence of the generality of this phenomenon.

In conclusion, by means of grouping breeding Florida Red-winged Blackbirds into seven geographic zones, we have shown that the population is smallest in the Everglades and shows clinal increase in size northward. Neither these zones nor the four currently recognized subspecies in Florida are believed to have biological validity as there is no evidence of reproductive isolation among them. However, the possibility of some isolation between birds in the Everglades and adjoining areas may be worthy of further investigation.

ACKNOWLEDGMENTS—We thank John W. Aldrich and Robert B. Payne for reading and criticizing an earlier draft of this paper.

LITERATURE CITED

AMERICAN ORNITHOLOGISTS' UNION. 1957. Check-list of North American Birds. Baltimore.

HAMILTON, T. H. 1961. The adaptive significance of intraspecific trends of variation in wing length and body size among bird species. Evolution 15:180-195.

HOWELL, A. H., AND A. J. VAN ROSSEM. 1928. A study of the Red-winged Blackbirds of Southeastern United States. Auk 45:155-163.

JAMES, F. C. 1970. Geographic size variation in birds and its relationship to climate. Ecology 51: 365-390.

MAYNARD, C. J. 1896. Birds of Eastern North America. Newtonville, Mass.

POWER, D. M. 1970. Geographic variation of Red-winged Blackbirds in central North America. U. Kansas Publ. Mus. Nat. Hist. 19:1-83.

Florida Sci. 40(3):273-280. 1977.

INSTRUCTIONS TO AUTHORS

Rapid, efficient, and economical transmission of knowledge by means of the printed word requires full cooperation between author and editor. Revise copy before submission to insure logical order, conciseness, and clarity.

MANUSCRIPTS should be typed double-space throughout, on one side of numbered sheets 8½ by 11 inch, smooth, bond paper.

A CARBON COPY will facilitate review by referees.

MARGINS should be 1½ inches all around.

FOOTNOTES should be avoided. Give ACKNOWLEDGMENTS in the text.

ADDRESS should be given following the author's name.

ABSTRACTS should be typed double-spaced immediately following the address.

LITERATURE CITED follows the text. Double-space every line and follow the form in the current volume.

TABLES are charged to authors at $25.00 per page or fraction. Titles must be short, but explanatory matter may be given. Type each table on a separate sheet, double-space, unruled, to fit normal width of page, and place after Literature Cited.

LEGENDS for illustrations should be grouped on a sheet, double-spaced, in the form used in the current volume, and placed after Tables. Titles must be short but may be followed by explanatory matter.

ILLUSTRATIONS are charged to authors ($20.00 per page or fraction). Drawings should be in India ink, on good board or drafting paper, and lettered by lettering guide or equivalent. Plan linework and lettering for reduction, so that final width is 4 5/8 inches, and final length does not exceed 7 inches. Do not submit illustrations needing reduction by more than one-half. Photographs should be of good contrast, on glossy paper. Do not write heavily on the backs of photographs.

PROOF must be returned promptly. Leave a forwarding address in case of extended absence.

REPRINTS may be ordered when the author returns corrected proof.

FLORIDA ACADEMY OF SCIENCES

INSTITUTIONAL MEMBERS FOR 1976

Archbold Expeditions
Barry College
Eckerd College
Edison Community College
Florida Atlantic University
Florida Institute of Technology
Florida Southern College
Florida State University
Florida Technological University
Gulf Breeze Laboratory
Jacksonville University
John Young Museum
and Planetarium
Manatee Junior College
Miami-Dade Community College
Stetson University
University of Florida
University of Miami
University of South Florida
University of Tampa
University of West Florida

Membership applications, subscriptions, renewals, changes of address, and orders for back numbers should be addressed to the Executive Secretary, Florida Academy of Sciences, 810 East Rollins Street, Orlando, Florida 32803.

ISSN: 0098-4590

Florida Scientist

Volume 40 Fall, 1977 No. 4

CONTENTS

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

FLORIDA SCIENTIST

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Editor: Harvey A. Miller
Department of Biological Sciences
Florida Technological University
Orlando, Florida 32816

The FLORIDA SCIENTIST is published quarterly by the Florida Academy of Sciences, Inc., a non-profit scientific and educational association. Membership is open to individuals or institutions interested in supporting science in its broadest sense. Applications may be obtained from the Executive Secretary. Both individual and institutional members receive a subscription to the FLORIDA SCIENTIST. Direct subscription is available at $13.00 per calendar year.

Original articles containing new knowledge, or new interpretation of knowledge, are welcomed in any field of Science as represented by the sections of the Academy, viz., Biological Sciences, Conservation, Earth and Planetary Sciences, Medical Sciences, Physical Sciences, Science Teaching, and Social Sciences. Also, contributions will be considered which present new applications of scientific knowledge to practical problems within fields of interest to the Academy. Articles must not duplicate in any substantial way material that is published elsewhere. Contributions are accepted only from members of the Academy and so papers submitted by non-members will be accepted only after the authors join the Academy. Instructions for preparation of manuscripts are inside the back cover.

Published by the Florida Academy of Sciences, Inc.
810 East Rollins Street
Orlando, Florida 32803

Printed by the Storter Printing Company
Gainesville, Florida

Florida Scientist

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Harvey A. Miller, *Editor*
Walter K. Taylor and Henry O. Whittier, *Associate Editors*

Volume 40 Fall, 1977 No. 4

Ecosystem Studies [*with 8 maps (on 2 sheets) appended*]

VEGETATION OF THE ATLANTIC COASTAL RIDGE OF PALM BEACH COUNTY, FLORIDA[1]

Donald Robert Richardson[2]

Department of Biological Sciences, Florida Atlantic University, Boca Raton, Florida 33431

Abstract: *Predrainage vegetational patterns of the Atlantic Coastal Ridge of Palm Beach County were mapped using 1845-1870 survey maps, 1940 aerial photographs, 1913-1973 soil surveys and ground truth studies. A detailed analysis of vegetational changes regarding secondary succession was made by selecting specific areas throughout the overall study region. These areas were described by documenting community changes with regard to species composition and community location. A checklist of the vascular flora was made for each selected area. Using the entire coastal strip vegetation maps and specific study sites, generalizations were made regarding plant succession in the major plant communities; Beach, Coastal Strand, Tropical Hammock, Low Hammock, Scrub, Pine Flatwoods, Wet and Dry Prairies, Mangroves, Swamps and Freshwater Marshes. Pre- and post-drainage historical and hydrological information was correlated with geological history in order to show how the physical and biological factors affect vegetation.*[*]

Ecological change, regardless of its extent and whether natural or man-made, is poorly understood for peninsular Florida south of Lake Okeechobee. This stems from the fact that Florida was a wilderness, untamed and unexplored as late as the 1860's (Pierce, 1970). Many of the early observations were made in connection with the Indian wars. Few observers left detailed records before the 1920's and many of the early studies related to a particular local flora with little attention given to the changing environment. Only in the past 30 yr has serious study of the southern Florida flora been undertaken and notice made of its response to man-caused environmental change.

[1]This thesis was submitted to the faculty of the College of Science in partial fulfillment of the requirements for the degree of Master of Science, Florida Atlantic University, Boca Raton, Florida. 1976.
[2]Present Address: 4050 N.E. Terr. #36, Oakland Park, Florida 33334.

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "advertisement" solely to indicate this fact.

Growth and use of technology which makes it possible to rapidly modify the environment in any fashion has resulted in massive deterioration of the natural vegetation on the Atlantic Coastal Ridge in Martin, Palm Beach, Broward and Dade counties. The increasing human pressures in southern Florida made possible by application of technology has further disrupted natural balances by, for instance, depleting the underground freshwater supply. Inevitably, the costs associated with continued exploitation of diminishing resources must be paid by the consumer. Resident apathy has led to pollution of both air and water resources, congestion, water shortages and other problems too numerous to list.

Although perfect balance may never be achieved between natural and man-made forces, maintenance of modern living standards makes the capacity to predict and manage the ecosystem in a state of equilibrium an absolute requirement. Understanding of the ecosystem will allow us to locate and preserve environmentally important wild areas which will further and continuously aid in understanding the cyclic ecological dynamics that have been occurring in southern Florida for the past 5,000 yr. Only after defining the complexity of the natural system, will we be able to propose rules and guidelines necessary for us to adapt into that system. Thus, we sought to determine the extent and means by which natural vegetation has responded to environmental changes in Palm Beach County. Vegetation types usually defined as Beach, Coastal Strand, Tropical Hammock, Low Hammock, Mangroves, Pine Flatwoods, Scrub, Wet and Dry Prairies, Swamps and Freshwater Marshes were examined in detail. Then natural vegetation patterns of Palm Beach County were mapped from the coast to the Conservation Areas with emphasis on pre-drainage conditions. Selected study sites were chosen within each of the major plant communities of eastern Palm Beach County to document the nature and pattern of vegetational change that has taken place in the last 70 yr.

METHODS—Vegetational changes resulting from such natural environmental factors as weather, fires and drought as well as from man-made or artificial factors were examined. Many of the artificial factors such as drainage, lumbering, increased fires and urban sprawl had their beginning as early as 1900. An historical analysis of all natural and cultural environmental factors was made to associate these changes with alterations in natural plant community structure and location for Palm Beach County.

Vegetation maps showing pre-drainage patterns were produced by using remote sensing, ground truth studies and historical information. Due to the rapid urbanization of the higher coastal ridge system in Palm Beach, Broward and Dade counties, early imagery was necessary to establish a base reference. Aerial photographs (U.S. Department of Agriculture, 1940 and 1973; U.S. Department of Commerce, 1945) were used in this study. Because the earliest imagery available was 1940, two assumptions had to be made in order to map the vegetation: 1) the same conditions (soils, topography, drainage) affect vegetation today as have affected it in the past; and 2) because these conditions are the same, the changes visible in aerial photographs from 1940 to the present are comparable to those occurring in the preceding 40 yr.

Little indication of the identity of ground cover plants is feasible at any photographic scale and photographic indications were therefore supplemented by ground truth studies. This resulted in a checklist of the vascular flora from selected study sites throughout Palm Beach County. Plant nomenclature was based on Long and Lakela (1976). Weed species percentage was tabulated to show the disturbance due to changing environmental factors. This may be used as a quick index to determine the extent to which a site is stressed. The study area contained about 600 sq mi of coastal Palm Beach County, ranging from latitude 26°15′N to 27°00′N and longitude 80°00′W to 80°15′W. Ground truth studies covered approximately 400 sq miles.

Historical maps and surveys dating from 1700-1940 were used as indicated in the literature cited list. Soil surveys (Bureau of Soils, 1913; U.S.D.A., 1946, 1973) and topographic quadrangles (U.S.G.S., 1969, 1973) were also useful because soils and topography closely correlate to the vegetation in southern Florida. Very slight changes in soil moisture, slope or elevation can cause major shifts from one plant association to another.

Maps showing present hydrological conditions were prepared for Palm Beach County (Maps 8a & b). All measurements for the preparation of these maps were supplied by the U.S.G.S., Lake Worth Drainage District, Central and South Florida Flood Control District and selected municipal water systems throughout the county.

A brief description of the soils and how they relate to vegetational types was made for each major plant community in Palm Beach County (Table 1). All study sites were located and chosen so that future evaluations could be monitored.

History of Botanical Studies in South Florida—Many early explorers noted plant communities they encountered on their journeys through southern Florida, but few detailed descriptions remain. The first detailed account of the southeastern portion of Florida was given by Dickinson (1699). His first reference to vegetation was to "sand hills covered with shrubby palmetto" lacking any tree cover. He also made note of two other plant communities, Freshwater Marsh and Swamp. In more than one place throughout his book he describes Swamps with white mangroves.

The first attempts to order plant communities were published by DeBrahm (1773) and Romans (1775). In his final report to England, DeBrahm (1773) recognized four plant communities: Swamps, Prairies, Pineland and Hammock. Each major plant community was subdivided into dominant types. Included in the Swamp habitat, DeBrahms recognized four different low lands (1773:213-214).

> "Mangrove Swamp, which is only met with near the sea coast . . . Maple Swamp, its soil rich appears black, mixed with white sand . . . The third type is called Cypress Swamp; its soil is richer and blacker than that of the maple, has also a mixture of some white sand, but is not overgrown with canes. . . . The fourth kind is also of a black soil, but mixed with a great deal of white sand and goes by the name of Lobolly Bay Swamp, bordered on both sides by high Pineland . . ."

Savannahs or Meadows are described as being . . .

> "12 miles across on which grow bunch grass, cotton snake root and the blessed

> thistle. They are covered for the greatest part of the year with rain water on account of their rich soil having scarce any sand mixture or sand . . ."

DeBrahm mentioned that the Savannahs had scattered little groves of 12 to 20 trees, with some pine, cabbage palm and maple trees. This can be correlated with the typical Wet Prairie-Pine or cypress system that is still dominant today.

He recognized three types of Pineland: low pine-wire grass, middling pine-bunch grass and high pine-bunch grass (DeBrahm, 1773:212). From his description of each pine land, it is possible that the low pine is equivalent to scrub pine since he mentioned that the trees are not good for lumber and that the high pines are what is called today slash pine.

DeBrahm's Hammock category mentions a land that is similar to the middling pineland and produces live and red oak, hickory nut and wild mulberry trees. He calls this land Hammocks, as used by the Americans. According to some sources, the word "Hammock" originally was a nautical term, but its real source is not known. The word was first used in Florida by Tourson (1556) to describe a hump of ground with trees. Bartram (1765), DeBrahm (1773) and Romans (1775) use this term to describe a rounded area of live oaks and palmettos, generally surrounded by wet areas.

By the time Romans (1775) made his survey of the Florida peninsula, he recognized many more communities than DeBrahm. He described Pineland, Hammock land, Savannahs, Swamps, Marshes and Bays, or Cypress galls. Being a better botanist than DeBrahms, Romans (1775) described in detail the species composition of certain habitats.

> "First the Pineland, commonly called pine barrens, makes up the largest body by far . . . this land consists of a grey or white sand . . . produces a great variety of shrubs or plants . . . The Hammock land so called from its appearing in tufts among the lofty pines . . . The Savannahs are of two very different kinds, the one is to be found in the pinelands . . . the others are chiefly to be found in west Florida, they consist of a high ground often with a gentle rising . . . Swamps are of two kinds, river and inland swamps . . .while Marshes are of four kinds, two in the salt and two in the freshwater . . . The last is the Bay and Cypress galls; these intersect the pinelands and are seldom of any breadth . . ."

By the close of the Indian wars (1859), considerable data had been gathered on southern Florida (Williams, 1837; MacKay and Blake, 1839; MacKay, 1845). However, the publication by Lieutenant J.C. Ives (1856) was by far the best report of that time. He recognized Swamps, Prairies, Marshes, Pinelands, Hammocks, and Scrub. This was probably one of the first works to recognize Scrub as a major plant community.

> "The land in the immediate vicinity is grown up with thick scrub and is bare of timber . . ."

Ives also separated Hammocks into distinct types, "wet" and "dry" and used the term "sawgrass" to designate a different type of Marsh system.

Williams (1870) produced some very detailed survey maps recognizing many of the communities that Ives had. He recognized Scrub, Marshes, Pineland and Hammocks. However, it was not until after the turn of the century that Harshberger (1914) produced the first map which attempted to classify plant communities in an ordered system. Harshberger was a professional botanist from

Pennsylvania and added Salt Marsh and Sea Strand to the previous works. He also divided the Pinelands into sand-pine, slash pine and long leaf pine. Harshberger tried to relate these vegetation types to geology and physiography and he gave a possible explanation for the typical successional patterns of the plant communities he studied.

Thirteen yr later, Harper (1927) produced a much more detailed scheme of the vegetation. He recognized about 50% more communities than Harshberger but failed to correlate the vegetation with environmental parameters. His was a descriptive study of the habitats and the plants associated with each community.

With the improvement of photographic techniques relating to aerial photography, Davis (1943) made the first complete study utilizing remote sensing. His map divided the communities into very distinct phases and has been used as a base reference since that time. During the past 35 yr, only two works have supplemented the Davis map. Craighead (1971) discussed successional trends of the major plant communities in Dade, Collier and Monroe counties. Alexander (1974) studied community and change in the Everglades basin, but did no work on the Atlantic Coastal Ridge of southeastern Florida. Until the present study, only a few attempts (Austin, 1976 a,b; Steinberg, 1976) have been made to study the flora or fauna of the coastal areas. The following shows the spatial relationship between different plant communities, their successional trends and the influence of cultural and natural environmental factors which have modified their existence since the 1900's.

Geology—Peninsular Florida is the emergent part of the Floridian plateau, a projection of the continental land mass which separates the Gulf of Mexico from the Atlantic Ocean. Southern Florida occupies the southeastern portion of the Floridian plateau. The plateau has been in existence for millions of yr, during which it has been alternately dry land or shallow seas. During periods of submergence, layers of limestone were deposited and worked by the action of the sea. Each successive sea level left its mark behind as a series of parallel ancient shorelines which are still visible today.

During the Sangamon interglacial period, the shoreline of the Talbot terrace stood about 42 ft above present sea level. Preceding the Talbot epoch were the Wicomico and Penholoway epochs which apparently followed one another without intermission. The division between them is marked by successive drops in sea levels from 100 to 70 ft, and finally to 42 ft above present sea level (Cooke, 1939).

During this epoch, the shell beds and sandy limestones of the Anastasia formation were laid down north of Boca Raton. To the south, an extensive bar of Miami oolite was being built up along the eastern shore. On the higher terraces, the development of sand bars, beach ridges and dunes took place. These features today dictate land usage through their control of drainage, ground water, vegetation and soil types.

Following the Sangamon period, the Wisconsin glacial age occurred, with three distinct sub-stages: Iowan and late glacial substages and an intermediate interglacial substage.

During the Iowan substage, the sea fell to 60 ft below its present level. Rates of erosion at that time were increased, forming many solution holes in the existing limestone. From the lakes in the interior, cuts were made through the Atlantic Coastal Ridge, forming transverse glades (Hoffmeister, 1974). Dune building was common along the sandier shore areas, especially in St. Lucie, Martin and Palm Beach counties. Following the Iowan substage, the sea rose to 25 ft above present sea level and remained there long enough to produce the Pamlico terrace, which in this area is mainly sand locally hardened into sandstone. The eroded river valleys began to be filled with sand and silt transported from the north by longshore currents.

During the late Wisconsin glacial substage, the slow retreat of the sea to minus 25 ft was halted periodically to form a series of parallel shorelines. These fossil beach ridges and dunes can be seen in many parts of southern Florida, particularly in Martin and Palm Beach counties. As the glaciers retreated for the last time, the sea level slowly rose to its present level. Today, the sea level has been postulated to be rising at a rate of 3 in per 100 yr (Parker and Cooke, 1944; Alexander, 1973, 1975). Only a minor amount of Pamlico sands found its way into the Everglades Basin, because longshore currents that carried it south were not effective in the quieter waters.

Mineral and soil mantles that cover harder limestone rocks are mainly marine sands laid down during the Pamlico and Talbot epochs. With the recession of each glacier stage, the sand left behind became modified due to influences of climatic conditions and plant cover, bringing about the development of distinct soil profiles in some cases. An important feature of the areas covered by the Pamlico sea and other seas was that they did not cover all rock outcroppings. This resulted in the formation of recent soil materials. The development of some organic soils reflects the history of succession of different types of vegetation. Plant cover affects development of many of these soils, particularly soils high in organics.

Because of the nature of the superficial deposits of this region, certain soils are important in ground water recharge. Sands are highly permeable, while marls and organic soils retain large amounts of water over extended periods of time.

There are 54 soil types recognized for Palm Beach County by the soil conservation service (USDA, 1973). Most are geologically immature because of the relief and large amounts of rainfall. In most cases removal of the vegetation causes rapid leaching, leading to infertile and immaturely profiled soils. Palm Beach County soils can be broadly classified as mineral soils or organic soils with variations and mixtures of both. The eastern portion, which makes up the coastal ridges and beaches is composed of deep, sandy, well drained, somewhat acid soils. These soils were blown by the wind and worked into dry dunes along the coast and comprise the sites of most early settlements. With expanding population centers, construction has begun to move westward into the low prairie areas. Low prairie soils too are basically mineral but are characterized by many marshes and sloughs and have a higher organic content than the surrounding prairie land. Low areas require extensive drainage and frequently must be filled.

Finally, organic soils are found along the eastern fringe of the conservation areas where standing water has created a vast marsh system. These are peat soils, usually overlying limestone or shell layers. Recent reports show that these organic soils are oxidizing and decomposing due to drainage (Stephens, 1956). Ultimately, the end result of continued soil subsidence is soil which is unfit for agricultural use.

For many years biologists and soil scientists have recognized the relationship that exists between soil types and plant distribution (Table 1). The vegetation of an area invariably gives a close reflection of the soil characteristics. It is therefore important to assess the suitability of the land for development. The relationship between plant community, soils and drainage conditions may be used to decide the most appropriate use for a particular parcel of land.

TABLE 1. Relationships between plant communities and soil types.

HABITAT	SOIL NUMBER	& SOIL SERIES	DESCRIPTION
Pine Flatwoods and Dry Prairie	27 36 39 42 44 60 67 77 86 96	Boca Riviera Holopaw Hallandale Immokalee Myakka Oldsmar Pinellas Hallandale Wabasso	Ground water podzols that are gray to yellow with a dark brown organic stained layer or hardpan 24-46 inches below the surface. Plant nutrients are relatively low but they are well adapted to the production of a variety of crops when drained and fertilized.
Scrub	71B 73B 81B 92, 93	Palm Beach Poala Pomello St. Lucie	Gently sloping, excessively drained, strongly acid quartose sands. Sandy soil overlying white or brownish yellow sands extending to depths greater than 80 inches. So far as known these sands have a very low agricultural value except for pineapples. Due to the low content of mineral nutrients, the value of these sands even for forestry purposes may be limited.
Marsh	25 34 41 51 52 55 59 63 65 69 97	Dania Terra Ceia Arenic Lauderhill Sanibel Adamsville Okeechobee Torrey Okeelanta Pahokee Torrey	Bog soils of heavy organic peats, usually brown and somewhat fibrous, with less than 50% ash present. Highly valued for agricultural crops because of their nitrogen content. When severely drained, they decompose rapidly and become so dry that they burn readily.
Wet Prairies	3 5 6 9 22, 28, 37 30 36, 38, 40 39 47 58 60, 61 79 83	Anclote Basinger Basinger-Myakka Winder Floridana Pineda Riviera Holopaw Jupiter Okeechobee Myakka Placid Pompano	Half bog soils white to light gray sand to a depth of 3-4 inches, with a white or bright yellow subsoil, often with an organic scum layer on the surface. The soils are usually slightly acid and non-calcareous.
Swamp	6 9 79 65	Basinger-Myakka Winder Placid Okeelanta	Soils variable, poorly drained, light and dark colored, including muck and organic soils. Peat soils have brown to black organic material in which the parent plant parts are still visible. Muck soils have black organic material which is highly decomposed.
Low Hammock	44 81B 92	Immokalee Pomello St. Lucie	Soils variable, gray to dark gray surface soil with light gray to creamy colored marl subsoil.
Mangrove	94	Tidal Swamp	Soils of mangrove peats.
Beach and Strand	18	Coastal	Soils of mostly unclassified recent coastal sands.
Tropical Hammock	71B	Palm Beach	Well-drained hammock sands, grayish speckled brown surface with light brown sandy subsoil. Calcareous shells are present in both surface and subsoil. The Palm Beach sands occur in small localized areas along the lower east coast.

HYDROLOGY—*Surface Water*: Before the advent of man in southern Florida, the low relief and high rainfall caused much of the area west of the coastal dune in Palm Beach County to be under water for long periods. The Coastal Ridge acted as a barrier to the seaward flow of water which at that time continued through a series of marshes and lakes just west of the major dune. Natural drainage within southern Florida was generally southward within the Everglades and eastward from the Everglades across the middle wet lands through the Atlantic Coastal Ridge via transverse glades. Most of these breaks occurred south of the Boca Raton area. The Hillsboro River and Yamato Marsh are probably the only remnants of transverse glades in Palm Beach County. Today, drainage through these transverse glades is largely by way of extensive canal systems.

Early settlement in southeastern Florida was on the Atlantic Coastal Ridge because flooding during the rainy season was less probable there. Surface water levels and soil water levels may vary widely in this area from season to season. During pre-drainage times, much of the sandy flatwoods, as characterized by Davis (1943), was under standing water for months at a time. Shaler (1890) in his investigation of southeastern Florida, observed that the fresh water table only 3 mi inland from the shore measured 16 ft msl and that water flowed over the coastal ridge in rapids during periods of high water. This tremendous amount of fresh water acted as a barrier against salt water intrusion.

From the first canal dredged in 1882, connecting Lake Okeechobee to the Caloosahatchee River draining into the Gulf of Mexico, land reclamation by drainage has proceeded steadily despite early studies which showed that damage was occurring to the natural equilibrium of the system. As drainage canals were extended farther inland and improved, water levels were lowered sufficiently to permit construction along the transverse glades, natural drainageways and in areas immediately west of the coastal ridge. This allowed urban areas to move west along the drainageways on lands formerly used for agriculture, displacing farming lands to the eastern shore of the Everglades marsh system.

Ground Water: Water that occurs beneath the surface of the earth in the zone of saturation where it fills interstices, solution holes and other rock voids is called ground water. It is the water that supplies springs and wells and that seeps into lakes to maintain their stages between rains. The formations of rock strata from which this water is obtainable for use are called aquifers. Most of the water used in Palm Beach County comes from the Biscayne and Anastasia aquifers.

The Biscayne aquifer is composed of the Fort Thompson limestone formation which grades into the Anastasia formation in the area between Delray Beach and West Palm Beach. South of Delray Beach, the Biscayne aquifer is composed of sand, shell, sandy limestone and sandstone. Total thickness of the aquifer is about 300 ft near Boca Raton and gradually thins as one approaches the Everglades Basin. The uppermost part of the aquifer is composed of loose quartz sand and shell to a depth of 40-80 ft (Black, Crow and Eidsness, 1974). Rock materials below the surface sand vary from a soft calcareous sandstone to a rather dense limestone.

In that part of the coastal ridge north of West Palm Beach, the Fort Thompson or Biscayne aquifer disappears entirely. Materials of the Anastasia formation and the deeper parts of the Caloosahatchee marl compose the deeper parts of the Anastasia aquifer. These materials range from sand to shell marl in areas where cementation has occurred to local areas of sandy limestone.

The principal source of recharge to the aquifers of Palm Beach County is rainfall. This normally occurs as a result of percolation of rainfall into the sandy soils and thence into the aquifer. However, a substantial amount of recharge is due to infiltration from the network of canals crossing the county. These canals are connected with the conservation areas of the Central and South Florida Flood Control District and the Lake Worth Drainage District. Because of the relatively high water levels maintained in the controlled canals, water from inland areas is becoming increasingly important in recharging the aquifer near the coasts during periods of low water or drought. The possibility of saltwater intrusion is the principal limitation on the amount of freshwater which can be utilized from the aquifers in Palm Beach County (Richard Bosley, personal communication, 1976). The most significant sources of intrusion in Palm Beach County are the coastal saltwater bodies, represented by the Atlantic Ocean, the intracoastal waterway and the uncontrolled reaches of canals which empty into saltwater bodies.

Due to the higher land elevations along the Atlantic Coastal Ridge the saltwater encroachment is predominantly subterranean. The high permeability of the Biscayne aquifer allows freshwater to flow seaward in the wet season, forcing the saltwater farther offshore. During the dry season, the saltwater re-encroaches landwards, moving inland by as much as 3-6 mi and upward to the surface (Thomas, 1974).

Canal recharge during drought conditions has become more and more important over the last several yr, placing a higher dependence upon the conservation areas as a source of water replenishment (Leach et al., 1972). Rapidly increasing urban needs and the drainage and development of the land west of the coastal ridge suggests that, at some time in the future, water conservation in this county might not be adequate to fulfill the demands of the natural and municipal systems (McCoy and Hardee, 1970).

Pre– and post–drainage: The southern Florida ecosystem is unique from the standpoint that it received very little attention until the late 1800's. Prior to the coming of the Europeans, about the only artificial stress placed on the vegetation was the burning practices of the Indian tribes.

Early settlement in Palm Beach County began during the 1860's in the West Palm Beach area. The first thought at that time was to drain the low lying areas so that the land could be used for agricultural crops. Much of the sand hill country was already flourishing with pineapple fields in the late 1800's. These early crops partially supported such towns as Delray Beach, Lake Worth, Lantana, Hypoluxo and Boynton Beach. When Cuban competition ruined the market for pineapple production in southern Florida, many settlements grew this crop only for local use.

The principal effect of pre-1940 land reclamation was to increase the flow of water out of the Everglades Basin through canals. During 1905 under the Everglades Drainage District, construction of two dredges on the banks of the New River in Ft. Lauderdale began. The dredges were used to excavate four major channels from Lake Okeechobee to the Atlantic Ocean, and by 1913, the North New River Canal was opened. The Miami Canal was open except for the lower 6 mi section that was completed by May 1, 1913, the Hillsboro Canal was completed except for a 5 mi section and the West Palm Beach Canal was under construction. By 1921, the four canals were completed and fully operational (Leach et al., 1972). Because the source of normal flow in the canals is from Lake Okeechobee and the Everglades, changes in the hydrology caused by impoundment or diversion of natural drainage patterns are reflected in annual discharge rates to the ocean and historical evaluation of well fields.

Much of this early drainage was uncontrolled and during continued dry seasons some areas were overdrained, allowing sea water to enter canals, the aquifer and to migrate progressively inland. Adequate hydrologic data for the early 1900's are lacking, but estimates indicate that water levels were lowered generally 5 or 6 ft as a result of uncontrolled drainage (Leach et al., 1972; Thomas, 1974).

The combined effects of all the changes in the canal systems since 1953 show a total reduction of discharge to the ocean. Discharge records on the canal systems date back to 1939 and can be used to detect changes in the hydrologic conditions of water management. One of the most pronounced changes was noted with the completion of the levee systems on the east side of the conservation areas. Consequently, the overall reduction of freshwater flow to the ocean as a result of flood control is about 20% (Leach et al., 1972). Long term records of fluctuation in ground water levels and general trends from observation wells provide the most valuable information in determining water level changes. Scattered records of water levels indicate that ground water was at or near the land surfaces along much of the coastal ridge before drainage practices (Parker et al., 1955).

Most of the municipal well fields between Boca Raton and West Palm Beach have a built-in system of ground water replenishment supplied by the equalizing canals of the Lake Worth Drainage District. Data collected over a 36 yr period show that maintenance of water levels in most of the equalizing canals have remained fairly constant since 1940. This suggests that the 6 ft decrease in the water table mentioned by Thomas (1974) took place between the completion of the four major canals (1921) and the formation of the Lake Worth Drainage District (1940).

Water level contour maps (Maps 8a & b) are representations of the water surface for May (1976) and October (1976). Irregularities in the shape and slope of water tables are common and are produced chiefly by rainfall and pumping. The water table in Palm Beach County slopes eastward toward the coast, although in wet periods the water table may slope both east and west from the ridge. These maps generalize hydrologic conditions without taking into account canals and local municipal water supplies which might affect drainage patterns during pumping periods.

The rate at which municipal needs are increasing suggests that in the near future replenishment from the conservation areas alone might not be adequate to fulfill the water resources during prolonged droughts.

ENVIRONMENTAL FACTORS—Physical and biological factors exercise considerable control over the vegetation of an area. Therefore, better vegetational evaluations can be made with a knowledge of the environmental factors which affect vegetation. In southern Florida, water, storms, frost and fires have been important natural physical factors shaping the vegetation. However, most of southern Florida has been stressed by the influence of man's activities since the early 1900's. Increased fires, drainage and lumbering have short-circuited most of the normal successional trends exhibited by the native plant communities. The following is a brief summary of the changes that have occurred in these factors over the past 70 yr.

CLIMATE: The climate of southern Florida is subtropical with avg daily temperatures ranging from about 82°F in the summer to about 68°F in the winter. Annual rainfall in southeastern Florida occurs in distinct cycles, with the rainy season extending from June through October. This season contributes about 70% or 40-60 in of rain annually, based on a 36 yr avg of the index gauges in West Palm Beach (Fig. 1).

According to Richards (1966), this is sufficient moisture to allow the growth of native plant species. Yet, the southern peninsula has been stressed with severe drought conditions which, in many cases, hinder the growth of native plants. This has been particularly true since the imposition of drainage practices which have allowed the vegetation to be indirectly stressed by increased fires and saltwater intrusion. Droughts that are composites of several consecutive years have made major impact on the vegetation. The following years have proved to be the worst in terms of drought: 1937/1938, 1943/1944, 1950/1951, 1955/1956, 1960/1961, 1966/1967 and 1970/1971.

Not only do amounts of rainfall vary monthly, they also vary from yr to yr. The annual totals for the past 36 yr show a fluctuation of high and low periods. Thomas (1974) reported that there have been no significant changes in the rainfall patterns from 1918-1974. A 12 ft rainfall deficit for southern Florida between 1960-71 was reported (G. Parker, personal communication, 1976). His data do not hold true for Palm Beach County.

Analysis of rainfall indices and historical well-field records show that many of the low land areas in Palm Beach County were able to tolerate drought conditions prior to drainage. Pre-drainage conditions show that most of these wetland communities had water within a ft of the surface even during drought periods. Today, drainage has increased the number of drought months, extending the dry period longer into the former rainy season. Observations by Leach et al. (1972) show that the three conservation areas have nearly gone dry several times since being enclosed.

This increased stress due to drainage has caused a rapid oxidation and sub-

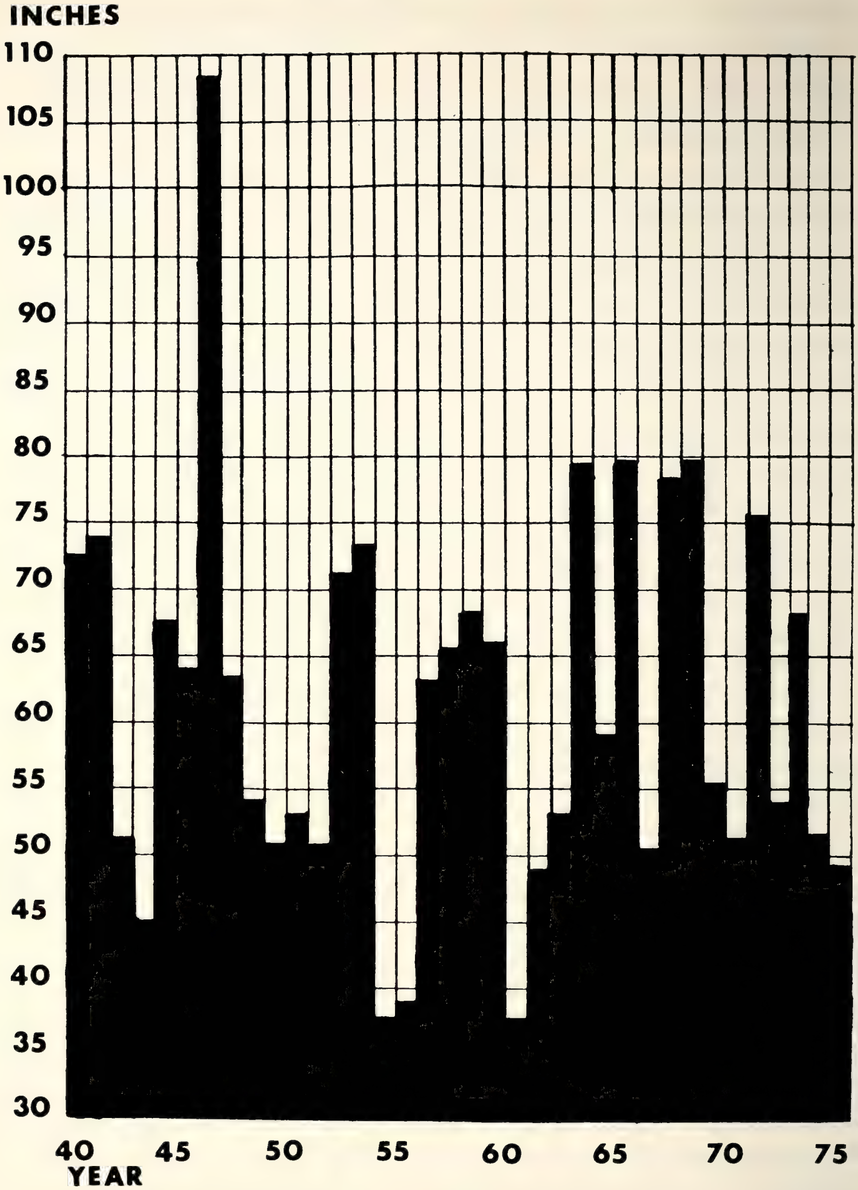


FIG. 1. Average total annual rainfall for Palm Beach County.

sidence of most organic soils. Observations during my 2 yr study show that as much as 2 ft of peaty material has been oxidized in some areas due to the reduced water levels and increased fires (e.g., Fla. 710, 1 mi west of Hwy 441). Many of the habitats responsible for buildup of extensive peat deposits are gradually being replaced by more xerophytic upland species. These data show that droughts severely affect the vegetation especially when coupled with drainage.

Low temperatures may have locally as much or more effect on plant life than the extremes of rainfall. This is because the native flora is composed of a mixture of both temperate and tropical species. Mitchell and Ensign (1928) showed that killing frosts extend much further south in the interior than along the coasts because of the ameliorating effects of the Atlantic Ocean and Gulf of Mexico. Studies have shown that open Pine woods, Marches and Prairies are much colder than Swamps or Hammocks (Davis, 1943).

Hammock canopies protect tropical species against cold. In many of the swamps in Palm Beach County, species of orchids and bromeliads grow in abundance beneath the dense canopies which moderate temperature and humidity. Subtropical and tropical species are usually found at slightly higher elevations because land is warmer than lowlands, and very small differences in elevation correlate with marked changes in species composition. Temperature also plays a major role in the migration of both temperate and tropical species. Warm temperatures restrict the southern migration of temperate zone species while low temperatures cause the opposite effect with tropicals. However, both temperate and tropical species are found together in varying amounts depending on their proximity to the coast and the latitude.

Fires: Fires have been of great importance in the development of many plant communities. Periodic fires coupled with local edaphic conditions have played a major role in the successional trends of many plant communities in southern Florida. The greatest impact on the environment has occurred in areas with organic soils.

During pre-drainage conditions, most fires were started in the summer months by lightning from thunderstorms. Standing water existed over much of the land for months at a time, eliminating the threat of fire to the root systems of most wetland species. These surface fires actually have been found to be beneficial in that they remove dead vegetative parts so that new growth can be initiated (Davis, 1943).

During the dry season from December through May, the surface water gradually disappears and the accumulation of organic materials becomes combustible. For the most part, winter fires consumed only the litter on the surface and killed only the stems. The roots were protected usually because the peat layer was still saturated with moisture.

Since the imposition of drainage programs in the early 1900's, the reduced soil moisture has allowed many fires to burn as much as 4-5 ft of muck off the surface. Some areas have been burned down to bare limestone, eliminating all plant cover that once stood in the area. Most fires, however, are surface fires destroying mainly parts of the plants above the soil and only the top few in of the organic layers. Man's activities have greatly increased the number and destructiveness of fires. There has been a 200% increase in fires over the last 10 yr (Albert DeClercq, personal communication, 1976). This change is attributed to an increase in population levels.

Hurricanes: The effect of hurricanes on the vegetation of southern Florida has been discussed by numerous authors (e.g., Craighead, 1971; Alexander, 1973). Most of the dramatic physical effects of hurricanes are usually on a very local scale. The rise in tidal levels and the elimination of certain plants within the coastal communities can have a long range effect. Hurricanes also change coastal topographic relief and land contour which affects surface water flow throughout the entire ecosystem.

Today, many of the effects of hurricanes are no longer visible, except in a few scattered coastal areas. Historical maps and surveys reveal that hurricanes were a major force in opening and closing the inlets in Palm Beach County. Boca Inlet or Boca Ratones was opened and closed at least 5 times since the late 1700's due to tropical storms (Austin and McJunkin, in press). Most of the inlets before the advent of man were very small breaks in the ridge, navigable only by very shallow draft vessels. Pierce (1970) mentions that schooners would anchor offshore from the inlets in Palm Beach County and raft their goods ashore because of the shallow waters at the mouths of the inlets. Henshall (1884) mentioned that the north Lake Worth inlet was periodically closed by storms and was finally opened and enlarged by 1875.

Lumbering: Most of the cypress and pineland communities in Palm Beach County have been subjected to severe lumbering since the 1800's. Many of the coastal scrub ridges were cleared for agriculture in the 1870's and no longer show direct signs of lumbering due to urbanization of these areas.

By 1895 the Florida Coast Railroad, under the direction of Henry Flagler, had begun surveys for an extension of the tracks to West Palm Beach. In April, 1896, the road was completed to Miami and Flagler's trains were causing a rapid depletion of the timber supply.

> "during the first few years of the F.E.C. Flagler spent much more in operating his train than he made. The engines burned wood and within one year his train consumed 15,305 cords of fuel, an average of fifty-six miles per cord. The wood which was chiefly fat pine was cut and stacked along the tracks . . . By 1900, the fat pine along the road was getting scarce . . . consequently, the wood burners were changed to coal burners" (Martin, 1949).

With the coming of the railroads the lumber industry changed. Sawmills could now be located away from river systems and in stands of timber that before had been unreachable. In Florida, lumbering could be carried on throughout the entire season and at much less expense than in the northern states. Most of the Florida virgin timber was cut by the 1930's (Blakey, 1975). Today, new stands of second growth timber, mainly slash pine (*Pinus elliottii*), are beginning to appear throughout Palm Beach County.

Harvesting of bald cypress, *Taxodium distichum*, has occurred throughout the study area. In many places throughout the northwestern portion, stump suckers are visible in the cypress strands. Most of the timber large enough for lumbering was cut over by the late 1920's. Only isolated stands of cypress exist in places which at one time were extensive forests. Virtually no seed germination is taking place in the coastal stands because of the lowered water level. Cypress demands a hydroperiod for a number of months before germination may take place. Today, most Wet Prairie/Pineland-Cypress habitats are used for cattle grazing, farming, urban development or other related business.

VEGETATION—Vegetation of Palm Beach County is often the most conspicuous feature of the landscape due to the slight terrestrial relief. Topography, drainage and vegetation are highly integrated parts of the ecosystem. Changes of inches in elevation can result in a completely different plant association. Plant communities naturally undergo changes from one type to another in orderly succession as the physical habitat is gradually changed by seral communities until the mature or climatic "climax" community develops. However, in southern Florida many communities are held in transitory state or subclimax due to local variation in soils, hydroperiod or elevation.

Alterations imposed by man have accelerated the normal sequence of events. This is true, for instance, where edaphic and water conditions that previously would have retarded succession have been eliminated. The impact of forces which have accelerated secondary succession (e.g., fires, hurricanes, drainage) is sometimes difficult to measure. Therefore, a complete survey of selected study sites throughout the county was undertaken to evaluate some of the major changes occurring in different plant communities.

Eleven plant associations were found in Palm Beach County. Many of these associations can be subdivided into seral or geographical variations. An attempt to consider seral stages was made where possible.

Vegetation Types: 1. BEACH—Sea Strand (Harshberger, 1914); Beaches and Dunes (Harper, 1927); Coastal Beach and Dune (Davis, 1943). This vegetation occurs along the coasts of tropical America and throughout other pantropical areas. The species are often dispersed by oceanic currents and are usually divided into distinct zones. In many areas throughout Palm Beach County, some zones are not apparent or are missing. This is because many beaches are undergoing rapid erosion and as much as 150 ft has been lost from some beaches since 1940. Vegetation associated with the Beach has adapted to changing conditions. Three distinct zones are usually present and are most often represented by the following:

Fore Dune: This zone lies closest to the ocean and is usually composed of pioneer plants capable of existing in areas subject to wind and sometimes storm wave action. Characteristic species include *Ipomoea pes–capre*, *Canavalia maritima*, *Iva imbricata* and *Sesuvium portulacastrum*.

Middle Dune: Usually this area is dominated by *Uniola paniculata* which acts as a dune stabilizer. Scattered throughout this zone will be *Helianthus debilis*, *Suriana maritima* and *Tournefortia gnaphaloides*. The two shrubs are found usually at the ecotone between the upper and middle dune.

Upper Dune: This zone is farthest from the ocean and contains thickets of spiny plants. Many beaches in the county do not have these spiny zone species. Most notable for this zone are *Yucca aloifolia*, *Cnidoscolus stimulosus* and *Opuntia compressa* var. *austrina*.

2. STRAND—In almost all previous studies of coastal vegetation, Strand has been lumped with discussions of the beach area. I feel that the species composition is different enough to warrant a distinct classification. This zone lies at the crest of the coastal dune, just behind the upper dune. Extensive areas of

Strand vegetation today are rapidly being replaced by residential developments. Characteristic species include *Coccoloba uvifera, Pithecellobium keyense, Eugenia* spp. and *Lantana involucrata.* In almost all parts of the Strand habitat the dominant species is *Serenoa repens* in admixture with the above species. This plant association is found throughout the entire coastal area of Palm Beach County (Maps 1-7).

3. TROPICAL HAMMOCK—Dry Hammock (Ives, 1856); High Hammock (Harshberger, 1914); Coastal Hammock (Harper, 1927; Davis, 1943); Tropical Hammock (Craighead, 1971). Most of these habitats seem to be confined to the coastal areas of both the east and west coasts of Florida. The most extensive hammocks occur in the Miami area on limestone outcrops. Fragments of these hammocks occur at Brickell and Matheson hammocks. Prior to development of the Atlantic Coastal Ridge, these hammocks existed as extensive tropical forests, extending northward into Brevard County. Their existence was mainly due to warmer temperatures caused by the oceanic currents moving warm water northward. A few of these hammocks are able to survive in inland areas due to higher elevations. Associated with tropical inland hammocks are temperate species, e.g., *Quercus* spp., which protect the hammocks against fires as well as produce a dense canopy which keeps the higher temperatures inside. These inland hammocks usually have a tropical species composition between 60-70%, while coastal areas may reach 90%.

Some of the characteristic species are: *Bursera simaruba, Metopium toxiferum, Mastichodendron foetidissimum, Simaruba glauca, Sabal palmetto, Zanthoxylum fagara, Erythrina herbacea* and a variety of herbs and vines. Extensive Tropical Hammocks occurred throughout the entire coastal areas of Palm Beach County (Maps 1-7). Many of the coastal hammocks in the northeastern portion of the county (Map 5) are found on extensive outcrops of Anastasia coquina limestone, whereas the southern areas are covered over with thick layers of recent marine sands.

4. LOW HAMMOCK—Wet Hammock (Ives, 1856); Low Hammock (Harshberger, 1914; Harper, 1927); Palm Hammock (Davis, 1943); Hardwood Hammock (Long, 1974). Historically, the term "Low Hammock" has been applied to any tree island or clump of trees that was not a Tropical Hammock or a Swamp and dominated by temperate species. Low Hammocks are found usually at lower elevations than Tropical Hammocks and also occur widely throughout the Wet Prairie-Pineland areas in shallow depressions. They are usually protected from fires by an outer perimeter of saw palmetto. Typical Low Hammock plants are *Quercus virginiana, Sabal palmetto, Psychotria sulzneri* and other species. Low Hammocks were frequently found associated with freshwater Swamps and ecotonal areas of Wet Prairie and Scrub. Pierce (1970) described a large band of Low Hammock bordering both sides of Lake Worth. Remnants of this Low Hammock system are still visible today (Map 1-4).

5. MANGROVES—Mangroves (Ives, 1856; Harshberger, 1914; Davis, 1943; Long, 1974). This community is typically found in protected or low wind and wave action areas along the shore. Most of the mangroves in Florida are zoned

with respect to dominant species. It seems that this relates to differences in propagule size, amounts of saltwater inundation and soil composition.

The outer zone, dominated by *Rhizophora mangle*, is nearly always flooded by low tides, and characteristically has a network of prop roots for support. It appears that red mangrove can tolerate the highest degree of wave action and has the largest propagules. Behind this zone, black (*Avicennia germinans*) and white (*Laguncularia racemosa*) mangroves are mixed. The black is usually found closest to the red mangrove and can always be spotted by the presence of vertical pneumatophores. Black and white mangrove are ecologically separated by differences in elevation but soil under both is exposed at low tide. The innermost zone is covered with sea water only during storm activity and is dominated by the mangrove relative *Conocarpus erecta*.

Mangrove communities have been dominant features of the Intracoastal Waterway and connecting canals since the early 1900's. Only a few areas (Maps 1-2) showed the presence of Mangroves before drainage.

6. SWAMPS—Includes all classifications based on a mixture of swamp species; Swamps (Ives, 1856); Cypress Swamps (Harshberger, 1914); Creek and Branch Swamps (Harper, 1927); Cypress Forests (Davis, 1943); Freshwater Swamps (Long, 1974). The term Swamp as I have used it includes a wide range of dominant species. In Palm Beach County I recognize under this category: Cypress Swamps (*Taxodium*), Mixed Swamps (*Acer/Taxodium*), Single Species Swamps (*Salix* or *Annona*) and Thicket Swamps (*Salix/Sambucus*).

Swamps are forests that are inundated by shallow surface water for most of the yr. Margins of most freshwater Swamps merge with Low Hammocks which sometimes makes the two habitats difficult to distinguish. Most extensive Swamp systems in Palm Beach County are found along old riverine valleys (Hillsboro River) or along the eastern margins of the Everglades (Maps 1-7). The common tree species include *Taxodium distichum*, *Acer rubrum*, *Ficus citrifolia*, and *Persea borbonia*; shrubby species include *Cephalanthus occidentalis*, *Myrica cerifera*, *Baccharis halimifolia*; and marsh herbs and vines also occur.

7. MARSH—Sawgrass (Ives, 1856); Freshwater Marsh (Harshberger, 1914); Sawgrass Marsh (Harper, 1927; Davis, 1943); Everglades (Long, 1974). Marsh, as I have defined it, includes a variety of habitats: Sawgrass Marsh (*Cladium*), Flag Marshes (*Pontederia/Sagittaria*), Cattail or Single Species Marshes (*Typha* or *Blechnum*) and Lakes or Sloughs (*Nuphar/Nymphaea*).

A marsh is a treeless habitat dominated by predominantly aquatic vegetation that is either seasonally wet or flooded with water most of the yr. Marsh systems usually have thick layers of peat and therefore must be distinguished from Wet Prairies. Prairies usually have a high diversity of grasses and occur on soils with only a thin layer of organics.

By far the largest Marsh community in southern Florida is the Everglades basin which extends from Lake Okeechobee southward to the Ten Thousand Islands. Marsh systems of similar composition are found in Palm Beach County to the east of the Everglades basin. These are the Loxahatchee Slough (Map 5) and the Lake Osborn-Clear Lake Marsh which parallels the coastal ridge (Maps

1-5). The most common species are: *Cladium jamaicensis, Sagittaria lancifolia, Pontederia lanceolata, Panicum hemitomon, Myrica cerifera, Ludwigia peruviana* and *Typha domingensis.* The admixture of these species varies among sites depending upon local water and soil conditions.

8. WET PRAIRIE—Prairie (Harshberger, 1914); Wet Prairie (Harper, 1927; Davis, 1943; Long, 1974). Most Prairies develop on sandy soils with thin layers of organic buildup. During the rainy season, these communities are covered with water up to 4 ft deep. With increased artificial drainage, most of the Wet Prairie communities today become completely exposed during the dry season. Typically, Wet Prairies merge with the Everglades and other Marsh formations. They often contain scattered islands of open pines and hammock vegetation and all intergradations exist. Some indicator species are: *Hypericum fasciculatum, Stillingia aquatica, Oxypolis filiformis, Myrica cerifera, Sagittaria lancifolia, Sabatia grandiflora* and *Xyris jupicai.* Historical surveys reveal that most of Palm Beach County was dominated by this system before drainage (Maps 1-7).

9. DRY PRAIRIE—Palm Savanna (Harper, 1927); Palmetto Prairie (Davis, 1943; Long, 1974; Long and Lakela, 1976). According to Harper (1927) Dry Prairies are made up of Flatwood species, except that *Pinus elliottii* does not exceed one tree per acre.

Former surveyors of the vegetation of southeastern Florida have called the region between the Everglades and the Atlantic Coastal Ridge a Pine Flatwoods (Harshberger, 1914; Harper, 1927; Davis, 1943). In spite of these studies, historical information (Hood, 1838; MacKay, 1838, 1845; Reyes, 1855; Williams, 1870) and 1940 aerial photography indicate an area dominated by Wet Prairies and Dry Prairies. Pine Flatwoods did occur in this region, but only as isolated islands of pines. Surrounding these small islands were extensive areas of Wet Prairies and in many areas Dry Prairies. Most of the Dry Prairies existed along the Atlantic Coastal Ridge bordering the Scrub habitat (Maps 2-3) and south near the Hillsboro River (Map 1). Characteristic species include: *Serenoa repens, Aristida* spp., *Lyonia ferruginea, Ilex glabra* and *Befaria racemosa.*

10. PINE FLATWOODS—Middling Pine (DeBrahm, 1773); Pines (Ives, 1856); Slash Pine (Harshberger, 1914); Flatwoods (Harper, 1927); Pine Flatwoods (Davis, 1943). Several variations of Flatwoods have been recognized by numerous authors in the past. Besides the regular Flatwoods, two subdivisions were found in Palm Beach County: Scrubby Flatwoods (*Pinus elliottii/Quercus* spp.) and Low Flatwoods (*Pinus/Aristida*). This habitat was not common in Palm Beach County near the turn of the century but is making extensive progress today by invading Wet Prairie habitats subject to drainage (Maps 4-5). Common species of regular Pine Flatwoods are: *Pinus elliottii, Serenoa repens, Lyonia lucida, Befaria racemosa, Coreopsis leavenworthii* and *Satureja rigida.*

11. SCRUB—Scrub (Ives, 1856); Sand Pine (Harshberger, 1914); Sand Pine Scrub (Harper, 1927; Davis, 1943); Sand Scrub (Craighead, 1971). Scrub vegetation is probably the oldest habitat in southern Florida. It occurs at elevations approaching 50 ft in northeastern Palm Beach County and shows evidence of early Pleistocene shorelines by occurring in parallel ridges. Scrub vegetation

can change in a number of ways, however regeneration of Scrub is occurring only under disturbed conditions.

The vegetation that occurs on these ridges is adapted to xeric conditions as infiltration of water through the fine sands is very rapid. Maintenance of this habitat is accomplished by a burning cycle of 20-40 yr. Indicator species in the Scrub are: *Pinus clausa, Quercus geminata, Q. chapmani, Q. myrtifolia, Palafoxia feayi, Ceratiola ericoides, Sisyrinchium solstitiale* and *Rhynchospora megalocarpa*. Scrub occurs in Palm Beach County west of the intracoastal waterway from Jupiter southward into Broward County (Maps 1-7).

ANALYSIS OF STUDY SITES

1. St. Andrews Dome—St. Andrews Dome (Fig. 2) is a unique geological feature which is physiographically located in a large Wet Prairie system (Map 1). Aerial photographs and ground truth studies revealed that this system of sand ridges and shallow depressions was once a Pleistocene shoreline. With a drop in sea level during the Pamlico epoch, ridges and swales were worked by the action of the sea and wind to form a series of parallel shorelines, many of which are still visible today throughout Palm Beach County. The normal drainage of this area is to the southwest into the old Hillsboro River system. During the rainy season, water accumulates in the shallow depressions or Wet Prairies, sometimes covering the surface for as much as a month at a time.

The dome is composed of three plant communities: Scrub, Wet Prairie and Dry Prairie. Most scrub ridges occur in the western half of the study area. Interspersed among the islands of Scrub are extensive Wet and Dry Prairies. Most Dry Prairies are located in the eastern portion of the study area and are rapidly maturing to secondary pine forests.

With the construction of the major canal systems (1900-1921) and the subsequent activities of the Lake Worth Drainage District in Palm Beach County, all three habitats are experiencing the effects of drainage. On a local scale, the Lake Worth Drainage District constructed equalizing canals every 0.5 mi between the Hillsboro River and West Palm Beach Canal. The dome is cut by two of these canals, one running along the northern boundary and the other almost splitting the study site into equal parts. This has greatly affected normal drainage patterns by channeling all excess water into the canals. A housing development and private school now occupy the southern portion of the dome. A recent study by Winston and Blanford (1975) named this area "Patch Reef Park". They recommended to the City of Boca Raton that the area be set aside for ground water recharge in order to meet the future water needs of the city.

Aside from the reduction of ground water supplies, fires have probably caused the most significant change in community structure. Records show that fires have burned through the eastern portion of the dome at least once every 2 yr. This short cycle precludes either Scrub or Wet Prairies which require longer burnfree periods. Most of the scrub ridges are in the western portion of the study area and have undergone a shift in community structure to what is now a Scrubby Flatwoods. With increased fires and accelerated erosion, the scrub

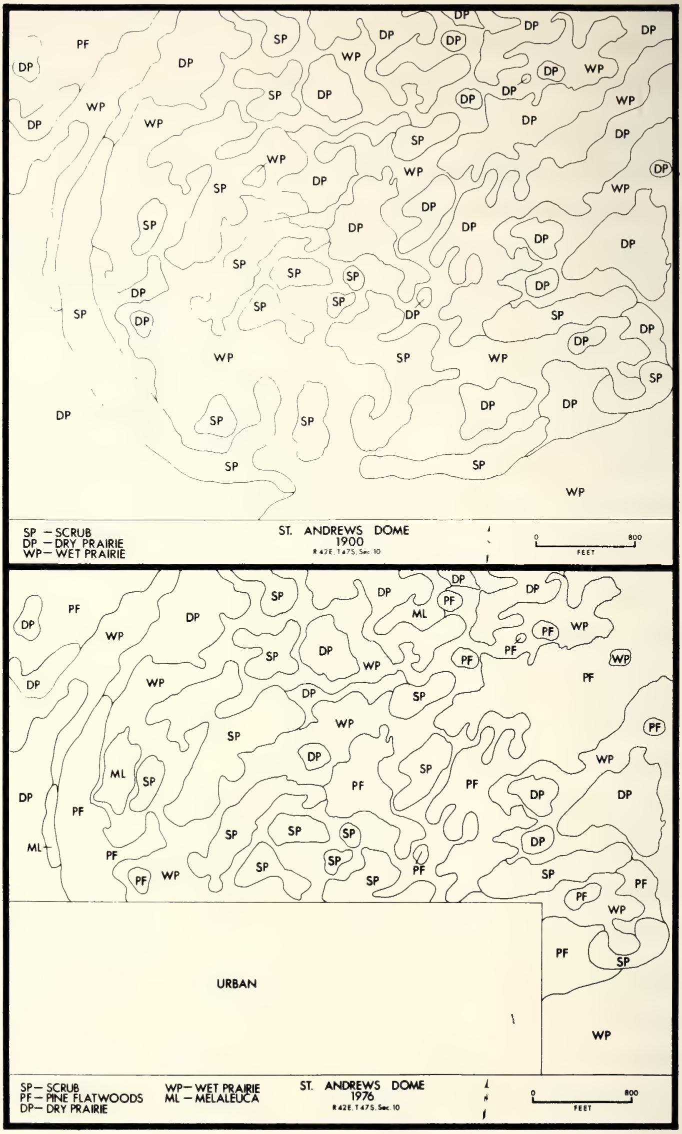


FIG. 2. St. Andrews Dome. Upper Map-1900 vegetation patterns. Lower Map-1976 vegetation patterns.

pines, *Pinus clausa*, have been eliminated and are being replaced by the slash pine, *Pinus elliottii.*

Examination of early imagery shows that most of the scrub pines had died off by 1940, probably due to the frequent numbers of fires associated with this area. Topographic surveys by Clif Nauman and myself showed that an avg scrub ridge is 17-23 ft msl. This slightly overlaps the elevations normally associated with Dry Prairies which were found to be 15-18 ft msl.

A line transect was established across the largest scrub ridge in order to characterize the ecotone. This ridge is located in the western portion of the study area and is situated between two drained Wet Prairies now being invaded by *Melaleuca.* My transect study showed that increased erosion due to removal of scrub pines has allowed a rapid invasion of the slash pine. The close proximity of Dry Prairie species, particularly *Lyonia lucida, L. ferruginea, Befaria racemosa* and *Myrica cerifera* has enabled these species to extend their distributions into the Scrub habitat. Under normal conditions, Dry Prairie species would not be able to tolerate the very xerophytic soil conditions, but with lowered elevations conditions favorable for their existence are closely approximated. This study also showed that the normal distribution of Scrub species has been altered and that the oaks *Quercus geminata* and *Q. myrtifolia* make up the bulk of the individuals. Only 15 vascular plant species were found along this transect which was typical for most of the scrub ridges throughout the entire study area.

During the 1900's, most of the Pine Flatwoods of today were isolated islands of Dry Prairie (Fig. 2). The invasion of Dry Prairies by secondary pine forests of slash pine is largely attributed to increased fires. Most of the slash pine in the eastern portion of the dome is less than 25 yr old. The species composition has remained fairly constant, but more frequent fires have allowed the invasion of *Emilia javanica, Eragrostis ciliaris, Eupatoruim capillifolium* and *Phytolacca americana.*

Wet Prairies are pioneer stages in the development of wetland communities. Normally, only wetland species are adapted to survive under waterlogged soil conditions, but with drainage, prairie bottoms contain water only for a limited period and hence short-circuit the normal sequence of events leading to Marsh formation.

Over the past 40-70 yr, Wet Prairies at the dome have changed into pure stands of *Melaleuca* or secondary pine forests of *Pinus elliottii* (Fig. 2) in response to drainage. The equalizing canal that runs along the northern boundary has effectively dewatered most of the Wet Prairie community. As a result, invasion by *Melaleuca* is occurring throughout the entire area at a much faster rate than the slash pine.

Meskinen (1962) has attributed *Melaleuca's* increase to its adaptability to acid soils, fires, flooded conditions, seed viability and many other factors. The overall effect of *Melaleuca* has been to eliminate the Wet Prairie species (*Sagittaria, Hypericum, Stillingia*) by forming almost impenetrable pure stands. Observations show that most pure stands of *Melaleuca* are devoid of all ground cover plants. This is especially the case in the Wet Prairies of the eastern portion of the dome. Invasion by slash pine is presently occurring at the ecotonal margins of Wet Prairies and Dry Prairies, where small fingerlike projections of pines are extending outward into the wetter areas.

Many of the Wet Prairies in the eastern section have changed greatly following fires which occurred in 1975. Species of *Hypericum, Stillingia* and to some extent *Lachnanthes* have been reduced in density. As the number of Wet Prairie species gradually decreases, exotics (*Melaleuca* and *Schinus*) and disturbance site plants gain some competitive advantage over the native species.

The western portions of the Wet Prairie community have changed severely from drainage due to the construction of a north-south canal along the western boundary. Most of this area has been invaded by *Andropogon virginicus.*

The following checklist of 150 plants collected by me in 1975-76 from St. Andrews Dome includes 30% considered disturbance-site plants. This high index is chiefly due to the construction of equalizing canals, increased fires and urban development which borders the entire study site.

Agalinis setacea (Gmel.) Raf. (Scrophulariaceae) Wet Prairie.
Aletris lutea Small (Amaryllidaceae) Dry Prairie, Pine Flatwood.
Ambrosia artemisiifolia L. (Asteraceae) Disturbed Sites.
Andropogon virginicus L. (Poaceae) Dry Prairie, Pine Flatwood.
Aristida condensata Chapm. (Poaceae) Dry Prairie.
A. spiciformis Ell. Wet Prairie.
Ascelpias pedicellata Walt. (Asclepidaceae) Dry Prairie, Pine Flatwood.
Asimina reticulata Shuttlew. *ex* Chapm. (Annonaceae) Scrub.
Baccharis halimifolia L. (Asteraceae) Disturbed Sites.
Bacopa monnieri (Walt.) Robinson (Scrophulariaceae) Marsh.
Bartonia verna (Michx.) Muhl. (Gentianaceae) Wet Prairie, Marsh.
Befaria racemosa Vent. (Ericaceae) Dry Prairie, Pine Flatwood.
Bidens pilosa L. (Asteraceae) Disturbed Sites.
Bigelowia nudata (Michx.) DC. (Asteraceae) Dry Prairie, Pine Flatwood.
Blechnum serrulatum Richard (Blechnaceae) Wet Prairie.
Buchnera floridana Gandogen (Scrophulariaceae) Disturbed Sites.
Carphephorus corymbosus (Nutt.) T. & G. (Asteraceae) Dry Prairie, Pine Flatwood.
C. paniculatus (J. F. Gmel.) Herb. Dry Prairie, Pine Flatwood.
Cassia fasciculata Michx. (Fabaceae) Disturbed Sites.
Cassytha filiformis L. (Lauraceae) Scrub.
Catharanthus roseus (L.) G. Don (Apocynaceae) Disturbed Sites.
Cenchrus incertus M.A. Curtis (Poaceae) Disturbed Sites.
Ceratiola ericoides Michx. (Empetraceae) Scrub.
Chamaesyce hyssopifolia (L.) Small (Euphorbiaceae) Disturbed Sites.
Cladium jamaicensis Crantz (Cyperaceae) Marsh.
Crotalaria angulata Mill. (Fabaceae) Disturbed Sites.
C. mucronata Desv. Disturbed Sites.
Cuphea carthagenesis (Jacq.) Macbride (Lythraceae) Disturbed Sites.
Cyperus planifolius Richard (Cyperaceae) Disturbed Sites.
C. virens Michx. Disturbed Sites.
Diodia virginiana L. (Rubiaceae) Marsh, Wet Prairie.
Drosera capillaris Poir. (Droseraceae) Marsh, Wet Prairie.
Emelia javanica (Burm.) C. B. Robinson (Asteraceae) Disturbed Sites.
Eragrostis elliottii Wats. (Poaceae) Wet Prairie, Marsh.
E. ciliaris (L.) R. Brown Disturbed Sites.
Erechtites hieracifolia (L.) Raf. (Asteraceae) Disturbed Sites.
Erianthus giganteus (Walt.) Muhl. (Poaceae) Marsh.
Eriocaulon decangulare L. (Eriocaulaceae) Wet Prairie, Marsh.
Eryngium aromaticum Baldw. (Apiaceae) Wet Prairie.
Eupatorium aromaticum L. (Asteraceae) Wet Prairie, Disturbed Sites.
E. capillifolium (Lam.) Small, Disturbed Sites.
E. coelestinum L. Wet Prairie.
Euphorbia polyphylla Engelm. (Euphorbiaceae) Scrub.
Galactia elliottii Nutt. (Fabaceae) Disturbed Sites.
Gnaphalium purpureum L. (Asteraceae) Wet Prairie.

Gomphrena decumbens Jacq. (Amaranthaceae) Disturbed Sites.
Gratiola subulata Baldw. (Scrophulariaceae) Dry Prairie, Pine Flatwood.
Hedyotis procumbens (J. F. Gmel.) Fosberg (Rubiaceae) Disturbed Sites.
Helenium vernale Walt. (Asteraceae) Disturbed Sites.
Helianthemum corymbosum Michx. (Cistaceae) Dry Prairie, Pine Flatwood.
Heterotheca graminifolia (Michx.) Shinners (Asteraceae) Pine Flatwood, Dry Prairie.
H. scabrella (T. & G.) R. W. Long, Scrub.
H. subaxillaris (Lam.) Britt. & Rusby, Dry Prairie, Pine Flatwood.
Hieracium gronovii L. (Asteraceae) Disturbed Sites.
Hypericum cistifolium Lam. (Hypericaceae) Wet Prairie.
H. fasciculatum Lam. Wet Prairie.
H. tetrapetalum Lam. Wet Prairie.
Hypoxis juncea L. (Amaryllidaceae) Pine Flatwood.
Ilex cassine L. (Aquifoliaceae) Swamp.
I. glabra (L.) Gray Pine Flatwood.
Juncus megacephalus M. A. Curtis (Juncaceae) Marsh.
J. scirpoides Lam. Marsh.
Lachnanthes caroliniana (Lam.) Dandy (Haemodoraceae) Marsh, Wet Prairie.
Lachnocaulon anceps (Walt.) Morong (Eriocaulaceae) Wet Prairie.
Lantana camara L. (Verbenaceae) Disturbed Sites.
Lechea cernua Small (Cistaceae) Scrub.
Liatris tenuifolia var. *laevigata* (Nutt.) Robinson (Asteraceae) Pine Flatwood.
Licania michauxii Prance (Chrysobalanaceae) Pine Flatwood.
Lippia nodiflora Michx. (Verbenaceae) Disturbed Sites.
Lobelia paludosa Nutt. (Campanulaceae) Wet Prairie.
Ludwigia alata Ell. (Onagraceae) Marsh.
L. peruviana (L.) Hara Marsh.
L. suffruticosa Walt. Marsh, Wet Prairie.
L. virgata Michx. Pine Flatwood.
Lyonia ferruginea (Walt.) Nutt. (Ericaceae) Dry Prairie, Pine Flatwood.
L. lucida (Lam.) K. Koch Pine Flatwood, Dry Prairie.
Lythrum alatum var. *lanceolatum* (Ell.) T. & G. (Lythraceae) Wet Prairie, Marsh.
Mecardonia acuminata (Walt.) Small (Scrophulariaceae) Wet Prairie.
Melaleuca quinquenervia (Car.) Blake (Myrtaceae) Disturbed Sites.
Mikania batatifolia DC. (Asteraceae) Disturbed Sites.
Momordica charantia L. (Cucurbitaceae) Disturbed Sites.
Myrica cerifera L. (Myricaceae) Pine Flatwood, Dry Prairie.
Osmunda regalis L. var. *spectabilis* (Willd.) Gray (Osmundaceae) Marsh.
Oxypolis filiformis (Walt.) Britt. (Apiaceae) Wet Prairie.
Panicum ensifolium Baldw. *ex* Ell. (Poaceae) Pine Flatwood, Dry Prairie.
Parthenocissus quinquefolia (L.) Planchon (Vitaceae) Disturbed Sites.
Paspalum notatum Fluegge (Poaceae) Wet Prairie.
P. urvillei Steud. Disturbed Sites.
Persea borbonia (L.) Spreng. (Lauraceae) Swamp, Marsh.
Petalostemon feayi Chapm. (Fabaceae) Scrub.
Phytolacca americana L. (Phytolaccaceae) Disturbed Sites.
Pinus clausa (Engelm.) Sarg. (Pinaceae) Scrub.
P. elliottii Engelm. Pine Flatwood.
Piriqueta caroliniana (Walt.) Urban (Turneraceae) Dry Prairie, Pine Flatwood.
Pluchea foetida (L.) DC. (Asteraceae) Wet Prairie.
P. rosea R. K. Godfrey Wet Prairie.
Polygala lutea L. (Polygalaceae) Wet Prairie.
P. nana (Michx.) DC. Wet Prairie.

P. ramosa Ell. Wet Prairie.
P. rugelii Shuttlw. Marsh, Wet Prairie.
P. setacea Michx. Wet Prairie.
Polygonella ciliata Meissner (Polygonaceae) Scrub.
P. polygama (Vent.) Engelm. & Gray Scrub.
Polygonum punctatum Ell. (Polygonaceae) Wet Prairie.
Polypremum procumbens L. (Loganiaceae) Disturbed Sites.
Pontederia lanceolata Nutt. (Pontederiaceae) Marsh.
Psidium guajava L. (Myrtaceae) Disturbed Sites.
Pterocaulon pycnostachyum (Michx.) Ell. (Asteraceae) Dry Prairie, Pine Flatwood.
Quercus chapmanii Sarg. (Fagaceae) Scrub.
Q. virginiana Mill. var. *geminata* Sarg. Scrub.
Q. minima (Sarg.) Small Scrub.
Q. myrtifolia Willd. Scrub.
Rhexia cubensis Griseb. (Melastomataceae) Wet Prairie.
R. nuttallii C. M. James Wet Prairie.
Rhynchelytrum repens (Willd.) C. E. Hubbard (Poaceae) Disturbed Sites.
Rhynchospora cephalantha Gray (Cyperaceae) Marsh.
R. megalocarpa Gray Wet Prairie, Marsh.
Sabal palmetto (Walt.) Lodd. *ex* Schultes (Arecaceae) Low Hammock.
Sabatia grandiflora (Gray) Small (Gentianaceae) Wet Prairie.
Sagittaria lancifolia L. (Alismataceae) Marsh.
Salix caroliniana Michx. (Salicaceae) Swamp, Disturbed Sites.
Sarcostemma clausum (Jacq.) R. & S. (Asclepiadaceae) Marsh, Swamp.
Satureja rigida Bartr. *ex* Benth. (Lamiaceae) Dry Prairie, Pine Flatwood.
Schinus terebinthifolius Raddi (Anacardiaceae) Disturbed Sites.
Scoparia dulcis L. (Scrophulariaceae) Disturbed Sites.
Selaginella arenicola Underw. (Selaginellaceae) Scrub.
Serenoa repens (Bartr.) Small (Arecaceae) Dry Prairie, Pine Flatwood.
Setaria geniculata (Lam.) Beauv. (Poaceae) Disturbed Sites.
Sida cordifolia L. (Malvaceae) Disturbed Sites.
S. spinosa L. Disturbed Sites.
Sisyrinchium miamiense Bicknell (Iridaceae) Pine Flatwood, Dry Prairie.
S. solstitiale Bicknell Scrub.
Smilax auriculata Walt. (Smilacaceae) Disturbed Sites.
Solanum americanum Mill. (Solanaceae) Disturbed Sites.
Solidago gigantea Ait. (Asteraceae) Disturbed Sites.
S. microcephala (Greene) Bush Pine Flatwood.
S. stricta Ait. Pine Flatwood.
Stillingia aquatica Chapm. (Euphorbiaceae) Wet Prairie.
Tillandsia recurvata L. (Bromeliaceae) Scrub.
Tradescantia rosea Raf. (Commelinaceae) Scrub.
Urena lobata L. (Malvaceae) Disturbed Sites.
Utricularia fimbriata HBK (Lentibulariaceae) Wet Prairie, Marsh.
U. purpurea Walt. Wet Prairie, Marsh.
U. subulata L. Wet Prairie, Marsh.
Vaccinium myrsinites Lam. (Ericaceae) Dry Prairie, Pine Flatwood.
Vigna luteola (Jacq.) Benth. (Fabaceae) Disturbed Sites.
Vitis rotundifolia Michx. (Vitaceae) Disturbed Sites.
Ximenia americana L. (Olacaceae) Scrub.
Xyris caroliniana Walt. (Xyridaceae) Wet Prairie.
X. elliottii Chapm. Wet Prairie.

2. Estancia Hammock—The word "hammock" in the name for this site is not used in the sense employed elsewhere. The name is a local designation for this habitat complex (Fig. 3).

Before drainage, in the period between 1900 and the late 1920's, Estancia, a Swamp, was the northern branch of the old Hillsboro River. Estancia is largely a Cypress Swamp with an interior Freshwater Marsh. Directly south of the Swamp is a piece of land formerly covered with Low Hammock or scattered islands of pine. The association of pine and hammock occurs in a mosaic pattern dependent upon local elevation and edaphic conditions.

The northeastern corner of the cypress dome has a small Dry Prairie which runs southward a few hundred yd into the hammock. Directly east of the cypress dome is Butts Hammock, an inland Tropical Hammock. Elevations in the Tropical Hammock reach about 25 ft msl, contrasted with the pine forest to the north where elevations range 15-17 ft. Swampy areas are mostly 14-15 ft msl.

By 1940, when the first aerial photographs were taken, the Swamp system had already been drastically altered. Most of the associated wetland communities had been filled and bulldozed up to the margins. In the past, these Swamps underwent water fluctuations as much as 2-3 ft (Harper, 1927), but even by the 1940's much of the swamp flora was dying. With uncontrolled drainage in the early 1900's, the normal period of high water necessary for germination of cypress did not occur. Today virtually no regeneration of cypress is occurring within the stand.

Probably the most dramatic change in the hammock has been along the margins due to urban development which has effectively changed the normal surface water drainage patterns. The Arvida Corporation has reported a drop in the water table of 6-8 ft over a 5 yr period (Lynnwood Stevens, personal communication, 1976). This has allowed the invasion of disturbed site plants: willow, saltbush, and Brasilian pepper around the margins of the hammock (Fig. 3). The presence of these disturbed site plants has retarded the life cycles of some native swamp species, particularly *Psychotria sulzneri*, *Magnolia virginiana*, and *Annona glabra*.

The small Freshwater Marsh that is located centrally in the hammock has undergone a shift to the shrub stage. Many of the marsh plants (*Sagittaria* and *Cladium*) that can survive only during periods of standing water have been replaced by saltbush (*Baccharis halimifolia*) and Brasilian pepper (*Schinus terebinthifolius*).

Many other species can be used as indicators of changing water levels or other types of disturbance. *Blechnum serrulatum* has become prolific in partially drained areas to the south side of the hammock complex. Common ragweed, *Ambrosia artemisifolia*, is frequent along the margins of the hammock and the marsh. *Salix caroliniana*, an indicator of lowered water levels, is found in isolated pockets throughout the southern portion of the hammock.

The small ridge of Dry Prairie has undergone succession to Low Hammock probably due to the lack of fires. The fact that this area is closely associated with the Swamp system may explain why it has not been recently fired.

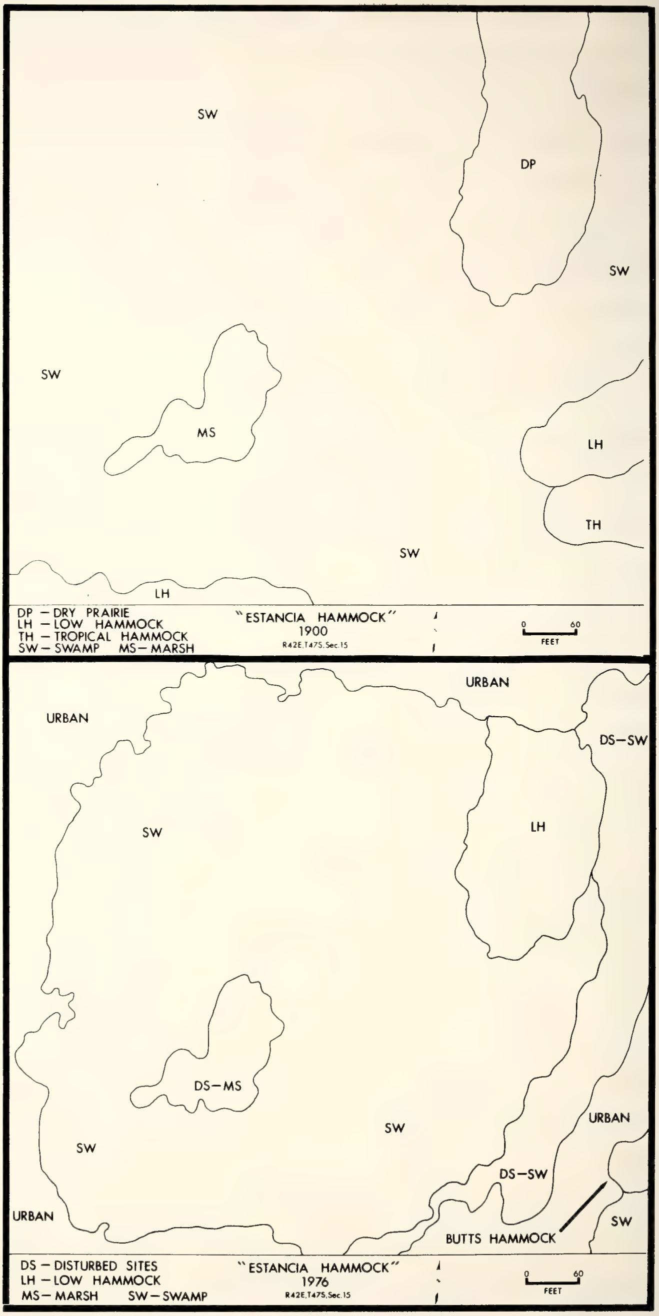


FIG. 3. Estancia Hammock. Upper Map-1900 vegetation patterns. Lower Map-1976 vegetation patterns.

Much of what is now called Butts Hammock has been considerably reduced by development. A small road for the Arvida Nursery removed the western portion of the Tropical Hammock, leaving only a very small portion still intact. The future of the Tropical Hammock has not been decided but the remaining portions of the cypress Swamp have been dedicated as a community park.

The following checklist compiled by D. Austin and D. Richardson (1977) of species from Swamp and associated habitats includes 131 species; 28% of these species were disturbed site plants. Theoretically, the percentage of disturbed site plants is much higher than what the Swamp would have supported during the 1900's. Every community undergoes a shift from pioneer stages to mature climax vegetation. In some cases the proportion of disturbance site plants might be a misleading index if the community is young. However, Estancia is part of a well developed swamp system and the high percentage of disturbance species shows the effects of man's activities.

Acer rubrum L. (Aceraceae) Swamp.
Acrostichum danaeaefolium Langsd. & Fisch. (Pteridaceae) Swamp, Marsh, Mangrove.
Amaranthus spinosus L. (Amaranthaceae) Disturbed Sites.
Ambrosia artemisiifolia L. (Asteraceae) Disturbed Sites.
Ammannia coccinea Rottb. (Lythraceae) Wet Prairie, Marsh.
Ampelopsis arborea (L.) Rusby (Vitaceae). Disturbed Sites.
Andropogon virginicus L. (Poaceae) Pine Flatwood, Dry Prairie, Wet Prairie, Disturbed Sites
Annona glabra L. (Annonaceae) Swamp.
Apios americana Medicus (Fabaceae) Low Hammock.
Ardisia escallonioides Schlecht. & Cham. (Myrsinaceae) Tropical Hammock, Strand.
Baccharis halimifolia L. (Asteraceae) Disturbed Sites.
Bidens pilosa L. (Asteraceae) Disturbed Sites.
Blechnum serrulatum Richard (Blechnaceae) Low Hammock, Swamp.
Boehmeria cylindrica (L.) Swartz (Urticaceae) Swamp, Marsh.
Bursera simaruba (L.) Sarg. (Burseraceae) Tropical Hammock.
Callicarpa americana L. (Verbenaceae) Pine Flatwood, Disturbed Sites.
Campyloneurum phyllitidis (L.) Presl (Polypodiaceae) Swamp, Low Hammock.
Canna flaccida Small (Cannaceae) Swamp, Marsh, Wet Prairie.
Carica papaya L. (Caricaceae) Disturbed Sites, Low Hammock, Tropical Hammock.
Casuarina equisetifolia Forst. (Casuarinaceae) Disturbed Sites.
Catharanthus roseus (L.) G. Don (Apocynaceae). Disturbed Sites.
Cenchrus incertus M. A. Curtis (Poaceae) Strand, Disturbed Sites.
Cephalanthus occidentalis L. (Rubiaceae) Swamp, Marsh.
Chrysobalanus icaco L. (Chrysobalanaceae) Strand, Swamp.
Chrysophyllum oliviforme L. (Sapotaceae) Tropical Hammock.
Cirsium horridulum Michx. (Asteraceae) Disturbed Sites, Wet Prairie.
Citrus paradisi Macf. (Rutaceae) Disturbed Sites.
C. sinensis (L.) Osbeck Disturbed Sites.
Coccoloba diversifolia Jacq. (Polygonaceae) Tropical Hammock.
Commelina diffusa Burm. f. (Commelinaceae) Disturbed Sites.
Conyza canadensis (L.) Cronquist (Asteraceae) Disturbed Sites, Wet Prairie.
Cynoctonum mitreola (L.) Britton (Loganiaceae) Marsh, Wet Prairie.
Cyperus sp. (Cyperaceae) Disturbed Sites.
Dichromena floridensis Britton (Cyperaceae) Wet Prairie, Disturbed Sites.
Diospyros virginiana L. (Ebenaceae) Tropical Hammock, Low Hammock.
Drypetes lateriflora (Swartz) Krug & Urban (Euphorbiaceae) Tropical Hammock.
Echinochloa walteri (Pursh) Heller (Poaceae) Disturbed Sites.
Emelia sonchifolia (L.) DC. *ex* Wight (Asteraceae) Disturbed Sites.

Encyclia tampensis (Lindl.) Small (Orchidaceae) Swamp.
Eugenia axillaris (Swartz) Willd. (Myrtaceae) Tropical Hammock, Strand.
Eupatorium capillifolium (Lam.) Small (Asteraceae) Disturbed Sites.
Exothea paniculata (Juss.) Radlk. (Sapindaceae) Tropical Hammock.
Ficus aurea Nutt. (Moraceae) Swamp, Disturbed Sites.
F. citrifolia Mill. Swamp, Low Hammock.
Hypericum tetrapetalum Lam. (Hypericaceae) Pine Flatwood, Dry Prairie.
Hyptis alata (Raf.) Shinners (Lamiaceae) Wet Prairie.
Ilex cassine L. (Aquifoliaceae) Swamp.
Ipomoea alba L. (Convolvulaceae) Swamp, Strand.
Itea virginica L. (Iteaceae) Swamp, Marsh.
Lantana camara L. (Verbenaceae) Disturbed Sites.
Lippia nodiflora Michx. (Verbenaceae) Disturbed Sites.
Ludwigia octovalvis (Jacq.) Raven (Onagraceae) Marsh, Swamp.
L. peruviana (L.) Hara Marsh, Swamp.
L. repens Forst. Marsh.
Lyonia ferruginea (Walt.) Nutt. (Ericaceae) Pine Flatwood, Dry Prairie.
Magnolia virginiana L. (Magnoliaceae) Swamp, Low Hammock.
Malvaviscus arboreus Cav. (Malvaceae) Disturbed Sites.
Mastichodendron foetidissium (Jacq.) Cronquist (Sapotaceae) Tropical Hammock.
Melothria pendula L. (Cucurbitaceae) Disturbed Sites, Low Hammock.
Mikania scandens (L.) Willd. (Asteraceae) Low Hammock, Tropical Hammock, Disturbed Sites.
Morus rubra L. (Moraceae) Low Hammock, Tropical Hammock, Pine Flatwood.
Myrcianthes fragrans (Swartz) McVaugh (Myrtaceae) Tropical Hammock.
Myrica cerifera L. (Myricaceae) Marsh, Swamp.
Myrsine guianensis (Aubl.) O. Ktze. (Myrsinaceae) Tropical Hammock, Strand, Swamp.
Nephrolepis exaltata (L.) Schott (Davalliaceae) Swamp, Marsh.
Osmunda regalis L. (Osmundaceae) Swamp.
Panicum portoricense Desv. *ex* Ham. (Poaceae) Pine Flatwood, Wet Prairie, Dry Prairie.
P. purpurascens Raddi Disturbed Sites, Wet Prairie.
Parthenocissus quinquefolia (L.) Planchon (Vitaceae) Low Hammock, Tropical Hammock, Disturbed Sites.
Persea borbonia (L.) Sprengel (Lauraceae) Swamp.
Phlebodium aureum (L.) Sm. (Polypodiaceae) Low Hammock, Swamp.
Phytolacca americana L. (Phytolaccaceae) Disturbed Sites.
Pinus elliottii Engelm. var. *densa* Little & Dorman (Pinaceae) Pine Flatwood, Dry Prairie.
Piriqueta caroliniana (Walt.) Urban (Turneraceae) Pine Flatwood, Dry Prairie.
Pluchea purpurascens (Swartz) DC. (Asteraceae) Marsh, Swamp.
Polypodium polypodioides (L.) Watt (Polypodiaceae) Swamp, Low Hammock.
Portulaca oleracea L. (Portulacaceae) Disturbed Sites.
Psidium guajava L. (Myrtaceae) Swamp, Disturbed Sites.
P. littorale Raddi (= *P. cattleianum* Sabine) Disturbed Sites.
Psilotum nudum (L.) Beauv. (Psilotaceae) Low Hammock, Swamp.
Psychotria sulzneri Small (Rubiaceae) Tropical Hammock, Low Hammock, Swamp.
P. undata Jacq. Tropical Hammock, Low Hammock, Swamp.
Pteridium aquilinum (L.) Kuhn (Pteridaceae) Disturbed Sites, Low Hammock.
Pteris tripartita (Sw.) Presl (Pteridaceae) Swamp.
Quercus chapmanii Sarg. (Fagaceae) Scrub, Low Hammock, Dry Prairie.
Q. geminata Small (= *Q. virginiana* var. *geminata* Sarg.) Scrub.
Q. laurifolia Michx. Swamp, Low Hammock.
Q. virginiana Mill. Low Hammock, Tropical Hammock.
Rhus copallina L. (Anacardiaceae) Disturbed Sites, Low Hammock.
Richardia scabra L. (Rubiaceae) Disturbed Sites.

Rivina humilis L. (Phytolaccaceae) Tropical Hammock, Low Hammock.
Sabal palmetto (Walt.) Lodd. *ex* Schultes (Arecaceae) Swamp, Low Hammock.
Salix caroliniana Michx. (Salicaceae) Swamp, Disturbed Sites.
Sambucus simpsonii Rehder (Caprifoliaceae) Marsh, Swamp.
Sarcostemma clausum (Jacq.) Roem. & Schultes (Asclepiadaceae) Tropical Hammock, Swamp, Disturbed Sites.
Saururus cernuus L. (Saururaceae) Swamp, Marsh.
Schinus terebinthifolius Raddi (Anacardiaceae) Disturbed Sites.
Scoparia dulcis L. (Scrophulariaceae) Disturbed Sites.
Senecio glabellus Poir. (Asteraceae) Wet Prairie, Disturbed Sites.
Serenoa repens (Bartr.) Small (Arecaceae) Pine Flatwood, Dry Prairie, Strand.
Setaria magna Griseb. (Poaceae) Marsh, Disturbed Sites.
Sida cordifolia L. (Malvaceae) Disturbed Sites.
S. rhombifolia L. Disturbed Sites.
S. rubromarginata Nash Disturbed Sites.
Smilax bona-nox L. (Smilacaceae) Low Hammock, Tropical Hammock, Disturbed Sites.
S. havanensis Jacq. Disturbed Sites, Pine Flatwood.
S. laurifolia L. Low Hammock, Pine Flatwood, Disturbed Sites.
Solanum americanum Mill. (Solanaceae) Disturbed Sites.
Sonchus oleraceus L. (Asteraceae) Pine Flatwood, Disturbed Sites.
Sporobolus indicus (L.) R. Brown (Poaceae) Disturbed Sites.
Taxodium distichum (L.) Richard (Taxodiaceae) Swamp.
Thelypteris normalis (C. Chr.) Moxley (Aspidiaceae) Swamp, Low Hammock.
T. reticulata (L.) Proctor Low Hammock, Swamp.
T. interrupta (Willd.) Iwatsuki Low Hammock.
Tillandsia balbisiana Schultes (Bromeliaceae) Swamp, Low Hammock.
T. fasciculata Swartz Swamp, Low Hammock.
T. recurvata L. Swamp, Scrub, Low Hammock.
T. usneoides L. Swamp, Low Hammock.
T. utriculata L. Swamp, Low Hammock.
Toxicodendron radicans (L.) Kuntze (Anacardiaceae) Swamp, Low Hammock, Tropical Hammock.
Trema micrantha (L.) Blume (Ulmaceae) Hammocks, Disturbed Sites.
Trichostema dichotomum L. (Lamiaceae) Strand, Tropical Hammock.
Tridax procumbens L. (Asteraceae) Disturbed Sites.
Typha domingensis Pers. (Typhaceae) Marsh.
Urena lobata L. (Malvaceae) Disturbed Sites.
Verbesina virginica L. (Asteraceae) Strand, Disturbed Sites.
Vitis rotundifolia Michx. (Vitaceae) Disturbed Sites.
V. shuttleworthii House Low Hammock, Swamp.
Vittaria lineata (L.) Sm. (Vittariaceae) Swamp, Low Hammock.
Ximenia americana L. (Olacaceae) Scrub, Swamp.
Zanthoxylum fagara (L.) Sarg. (Rutaceae) Tropical Hammock.

3. Yamato Marsh—Yamato Marsh is part of a large freshwater system which today drains southward along the inland scrub ridge. Formerly, this marsh system flowed into the northern extremity of the old Hillsboro River system. Surface flow was sluggish due to extensive aquatic vegetation which formed deep peat deposits. Cores (David McJunkin, personal communication, 1975) and recent mining operations show that peat was at least 8 ft thick in this area. Surveys by MacKay (1845) and Williams (1870) show that this area was sawgrass and openlands draining into the Hillsboro River. Today, this marsh is undergoing rapid deterioration due to fires, drainage and bulldozing (Fig. 4). Aerial photo-

graphs from 1940's reveal that most of the portion north of the present day C-15 canal was bulldozed in the construction of the canal.

Large areas formerly of dense sawgrass, *Cladium jamaicensis*, have been reduced to sparse stands by fires which have become more intense and widespread. A small area of disturbed sawgrass and maidencane still exists in a shallow pond in the southern section, but is rapidly undergoing a change into a *Schinus* thicket. A mixture of sawgrass, saltbush and wax myrtle, probably uncommon prior to the initiation of drainage programs, has become increasingly important. Maidencane, *Panicum hemitomon*, has become a dominant part of the marsh system, particularly in the southeastern portion of the study site. Prior to drainage, it was probably restricted to much drier sites. Willows, *Salix caroliniana*, are more prevalent today than formerly. These trees are good indicators of fires or badly disturbed soil conditions and dominate canal banks and roadside ditches in the study area.

Major changes in the Low Hammocks (Fig. 4) show that communities have been dissected and subdivided by development. Localized disturbance due to construction of a small road has eliminated the periphery of saw palmettos, allowing fires to severely damage the interior of the hammock. Many of the oaks and small trees have extensive fire scars over most of the trunk and a few individuals have been killed. The overall effect has been a reduction in the total number of Low Hammock species and a large increase in disturbed site plants. *Casuarina, Schinus, Catharanthus, Vitis, Crotalaria* and *Callicarpa* are becoming increasingly common understory plants in these Low Hammocks.

A total of 86 species collected by D. Richardson and M. Truitt in 1975-76 are listed for the study area. The portion of disturbance plants was found to be 50.5% indicating a high degree of disturbance caused by man's influences of drainage, increased fires and development. Many indicator species of disturbed conditions, e.g., *Casuarina equisetifolia, Schinus terebinthifolius* and *Melaleuca quinquenervia* are becoming increasingly common throughout the entire study area. The overall effect of these species has been to reduce native species due to encroachment and regression in community development.

Abrus precatorius L. (Fabaceae) Disturbed Sites.
Allamanda cathartica L. (Apocynaceae) Disturbed Sites.
Ambrosia artemisiifolia L. (Asteraceae) Disturbed Sites.
Ampelopsis arborea (L.) Rusby (Vitaceae) Disturbed Sites.
Baccharis halimifolia L. (Asteraceae) Disturbed Sites.
Bacopa monnieri (L.) Pennell (Scrophulariaceae) Marsh, Wet Prairie.
Bidens pilosa L. (Asteraceae) Disturbed Sites.
Boehmeria cylindrica (L.) Swartz (Urticaceae) Wet Prairie, Swamp.
Callicarpa americana L. (Verbenaceae) Pine Flatwoods, Low Hammocks.
Cassia bicapsularis L. (Fabaceae) Disturbed Sites.
C. occidentalis L. Pine Flatwood.
Cassytha filiformis L. (Lauraceae) Scrub.
Catharanthus roseus (L.) G. Don (Apocynaceae) Disturbed Sites.
Cephalanthus occidentalis L. (Rubiaceae) Swamp, Marsh.
Chamaesyce hirta (L.) Millsp. (Euphorbiaceae) Disturbed Sites.
Chenopodium ambrosioides L. (Chenopodiaceae) Disturbed Sites.
Chloris petracea Swartz (Poaceae) Disturbed Sites.

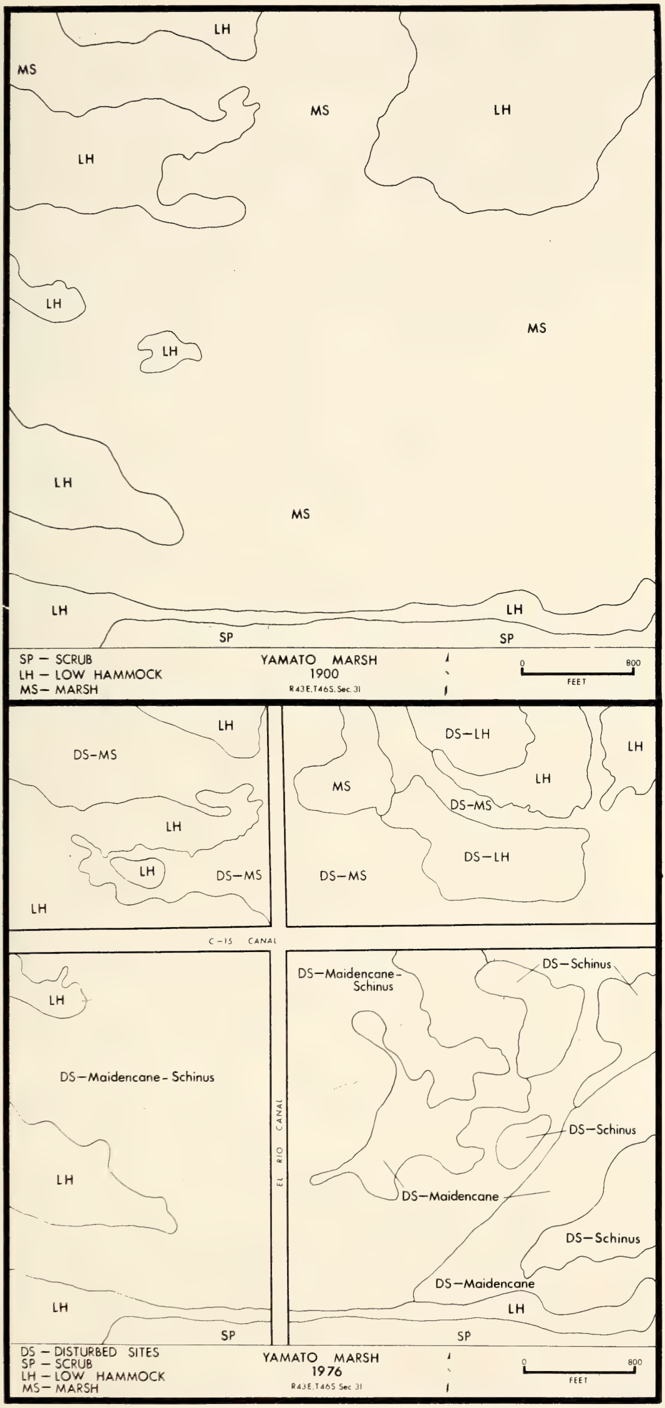


FIG. 4. Yamato Marsh. Upper Map-1900 vegetation patterns. Lower Map-1976 vegetation patterns.

Cladium jamaicensis Crantz (Cyperaceae) Marsh.
Crotalaria incana L. (Fabaceae) Disturbed Sites.
Cyperus haspan L. (Cyperaceae) Disturbed Sites.
C. planifolius Richard Disturbed Sites.
Dactyloctenium aegyptium (L.) Beauv. (Poaceae) Disturbed Sites.
Dichromena floridensis Britton (Cyperaceae) Wet Prairie.
Diodia virginiana L. (Rubiaceae) Disturbed Sites.
Eupatorium capillifolium (Lam.) Small (Asteraceae) Disturbed Sites.
E. coelestinum L. Wet Prairie.
Gaura angustifolia Michx. (Onagraceae) Disturbed Sites.
Gomphrena decumbens Jacq. (Amaranthaceae) Disturbed Sites.
Heliotropium polyphyllum Lehmann (Boraginaceae) Pine Flatwood, Dry Prairie.
Heterotheca graminifolia (Michx.) Shinners (Asteraceae) Pine Flatwood, Dry Prairie.
H. subaxillaris (Lam.) Britt. & Rusby (Asteraceae) Pine Flatwood, Dry Prairie.
Hydrocotyle umbellata L. (Apiaceae) Marsh, Wet Prairie.
Ipomoea carica (L.) Sweet (Convolvulaceae) Disturbed Sites.
Iresene celosia L. (Amaranthaceae) Disturbed Sites.
Kosteletzkya virginica (L.) Presl. *ex* Gray (Malvaceae) Marsh, Wet Prairie.
Lantana camara L. (Verbenaceae) Disturbed Sites.
Liatris tenuifolia var. *laevigata* (Nutt.) Robinson (Asteraceae) Pine Flatwood.
Licania michauxii Prance (Chrysobalanaceae) Pine Flatwood, Scrub.
Lippia nodiflora Michx. (Verbenaceae) Disturbed Sites.
Ludwigia octovalvis (Jacq.) Raven (Onagraceae) Marsh.
L. peruviana (L.) Hara (Onagraceae) Marsh.
Lyonia ferruginea (Walt.) Nutt. (Ericaceae) Pine Flatwood, Dry Prairie.
Lythrum alatum var. *lanceolatum* (Ell.) T. & G. (Lythraceae) Wet Prairie, Marsh.
Melaleuca quinquenervia (Car.) Blake (Myrtaceae) Disturbed Sites.
Mikania scandens (L.) Willd. (Asteraceae) Disturbed Sites.
Momordica charantia L. (Curcurbitaceae) Disturbed Sites.
Myrica cerifera L. (Myricaceae) Pine Flatwood, Dry Prairie.
Palafoxia feayi Gray (Asteraceae) Scrub.
Panicum hemitomon Schultes (Poaceae) Disturbed Sites.
Phleobodium aureum (L.) Sm. (Polypodiaceae) Swamp, Low Hammock.
Phytolacca americana L. (Phytolaccaceae) Disturbed Sites.
Pinus elliottii Engelm. (Pinaceae) Pine Flatwood, Dry Prairie.
Pluchea purpurascens (Swartz) DC. (Asteraceae) Hammocks, Pine Flatwood.
Plumbago scandens L. (Plumbaginaceae) Disturbed Sites.
Poinsettia cyathophora (Murr.) Kl. & Gke. (Euphorbiaceae) Disturbed Sites.
Polypremum procumbens L. (Loganiaceae) Disturbed Sites.
Pontederia lanceolata Nutt. (Pontederiaceae) Marsh.
Pteridium aquilinum (L.) Kuhn var. *caudatum* (L.) Sadebeck (Pteridaceae) Low Hammock, Disturbed Sites.
Pterocaulon pycnostachyum (Michx.) Ell. (Asteraceae) Pine Flatwood, Dry Prairie.
Quercus minima (Sarg.) Small (Fagaceae) Pinelands, Scrub.
Q. virginiana Mill. var. *virginiana* Hammocks.
Rhynchelytrum repens (Willd.) C. E. Hubbard (Poaceae) Disturbed Sites.
Ricinus communis L. (Euphorbiaceae) Disturbed Sites.
Ruellia brittoniana Leonard *ex* Fern. (Acanthaceae) Disturbed Sites.
Sabal palmetto (Walt.) Lodd. *ex* Schultes (Arecaceae) Low Hammock.
Sagittaria lancifolia L. (Alismataceae) Marsh.
Salix caroliniana Michx. (Salicaceae) Swamp, Disturbed Sites.
Sarcostema clausum (Jacq.) R. & S. (Asclepiadaceae) Marsh, Swamp.
Schinus terebinthifolius Raddi (Anacardiaceae) Disturbed Sites.
Scirpus americanus Pers. (Cyperaceae) Swamp.

Scoparia dulcis L. (Scrophulariaceae) Disturbed Sites.
Setaria geniculata (Lam.) Beauv. (Poaceae) Disturbed Sites.
Sida acuta Burm. (Malvaceae) Disturbed Sites.
S. cordifolia L. Disturbed Sites.
S. spinosa L. Disturbed Sites.
Sisyrinchium solstitiale Bicknell (Iridaceae) Scrub.
Thelypteris interrupta (Willd.) Iwatsuki (Aspidiaceae) Swamp, Low Hammock.
Typha domingensis Pers. (Typhaceae) Marsh.
Urena lobata L. (Malvaceae) Disturbed Sites.
Vaccinium myrsinites Lam. (Ericaceae) Pine Flatwood, Dry Prairie.
Vigna luteola (Jacq.) Benth. (Fabaceae) Disturbed Sites.
Vitis rotundifolia Michx. (Vitaceae) Disturbed Sites.
Wedelia trilobata (L.) Hitchc. (Asteraceae) Disturbed Sites.
Ximenia americana L. (Olacaceae) Scrub.

4. Boynton Beach—Located at the southern end of Lake Worth is a remnant of what were at one time extensive tropical hardwood hammocks. This half mile section of hammock is unique since it is the last of its size existing in Palm Beach County. Other scattered remnants of beach hammocks occur in a few areas along the coast but none that is as complex and undisturbed as the Boynton Hammock.

The best developed hammocks occur in Dade County on limestone outcrops, suggesting that the limestone and warmer temperatures favor development of Tropical Hammocks. Most of the hammocks which occur on limestone outcrops, such as Brickell and Matheson hammocks, are located near the coasts, but some do occur at inland sites (Butts Hammock). Comparative studies by D. Austin (personal communication, 1975) show that most inland Tropical Hammocks have a reduced tropical species composition.

Vegetation at Boynton Hammock can be divided into three distinct habitats: Tropical Hammock, Coastal Strand and Beach. Below the high water mark on the beach, no vegetation was apparent because of the unstable soil conditions. Just above this mark, vegetation was sparse with most abundant forms being the grass *Paspalum vaginatum* and the beachstar, *Remirea maritima*. At the base of the primary dune, *Canavalia maritima*, *Ipomoea pes-caprae* and *Suriana maritima* can be found in some abundance. This zone precedes the zone of sea oats, *Uniola paniculata*, which acts as a dune stabilizer throughout southern Florida. From here to the top of the dune ridge, a salt or wind pruned stand of *Coccoloba uvifera* occurs. This zone grades into the hammock where small shrubs and trees of *Metopium*, *Eugenia* and *Psychotria* form the beginning of the Tropical Hammock. The hammock offers the most favorable conditions for luxuriant growth because of reduced wind and salt spray and evenly moderated temperatures.

Maintenance of Tropical Hammocks occurs only if fires are very infrequent or lacking. Harper (1927) mentioned that fires which occur more often than once every 20-50 yr cause considerable damage to the tropical hardwood species. The hammock at Boynton Beach is relatively rich in species, with 102 being collected by Austin and Weise (1972). This is somewhat divergent from the species–poor hammocks described by Harper (1927) for the west coast of Florida.

Probably the most outstanding feature of this Tropical Hammock is that disturbance plants account for only 18% of the total. This is largely due to the lack of coastal fires and minimal disturbance by man. Most of the weed species were introduced with the construction of Highway A1A. The leeward side of the hammock near the road is dominated by Brazilian pepper, *Schinus terebinthifolius.* Since birds spread the seeds of this tree, small seedlings are very abundant throughout the entire hammock. A few stands of *Casuarina equisetifolia* are scattered around the northern end of the hammock. This tree has often been planted as a wind break and has become naturalized on the coastal dunes of southern Florida. It is thought that this plant releases a toxin when the leaves fall, resulting in elimination of almost all native species surrounding the tree. Periwinkles, *Catharanthus roseus*, are usually the only plants that can proliferate under these conditions.

The southern end of the hammock is the most heavily disturbed by footpaths and a small road which allows access to the bathing beach. Disturbed site plants *Bidens pilosa, Catharanthus roseus, Schinus terebinthifolius* and *Poinsettia cyathophora* are common in this area. Today, most of these coastal hammocks are being replaced by condominiums, roads and finger canals (Fig. 5). It is hoped that the few remaining of these unique areas will be set aside so that future monitoring of change will enable us to understand the biological complexities leading to their development. Efforts to save the Boynton Hammock from development were successful and plans to dedicate this site as a park are underway. Species present are:

Acrostichum danaeaefolium Langsd. & Fisch. (Pteridaceae) Swamp, Marsh.
Agave decipens Baker (Agavaceae) Strand, Tropical Hammock.
Alternanthera maritima (Mart.) St. Hil. (Amaranthaceae) Strand, Tropical Hammock.
Amyris elemifera L. (Rutaceae) Tropical Hammock, Low Hammock.
Annona glabra L. (Annonaceae) Swamp.
Ardisia escallonioides Schlecht. & Cham. (Myrsinaceae) Tropical Hammock, Strand.
Bursera simaruba (L.) Sarg. (Burseraceae) Tropical Hammock.
Baccharis halimifolia L. (Asteraceae) Disturbed Sites.
Bidens pilosa L. (Asteraceae) Disturbed Sites.
Caesalpinia bonduc (L.) Roxb. (Fabaceae) Strand.
Canavalia maritima (Aubl.) Thouars. (Fabaceae) Strand.
Capparis cynophallophora L. (Capparidaceae) Tropical Hammock.
C. flexuosa L. Tropical Hammock.
Carica papaya L. (Caricaceae) Disturbed Sites.
Cassytha filiformis L. (Lauraceae) Scrub.
Casuarina equisetifolia Forst. (Casuarinaceae) Disturbed Sites.
Catharanthus roseus (L.) G. Don (Apocynaceae) Disturbed Sites.
Cenchrus echinatus L. (Poaceae) Disturbed Sites.
C. tribuloides L. Disturbed Sites.
Cereus undatus Haw. (Cactaceae) Tropical Hammock, Low Hammock.
Chamaesyce bombensis (Jacq.) Dugand. (Euphorbiaceae) Disturbed Sites.
C. mesembryanthemifolia (Jacq.) Dugand. Strand.
Chiococca alba (L.) Hitch. (Rubiaceae) Tropical Hammock.
Chrysobalanus icaco L. (Chrysobalanaceae) Strand, Swamp.
Cladium jamaicensis Crantz (Cyperaceae) Marsh.
Cnidoscolus stimulosus Jacq. (Euphorbiaceae) Strand.
Coccoloba diversifolia Jacq. (Polygonaceae) Tropical Hammock.

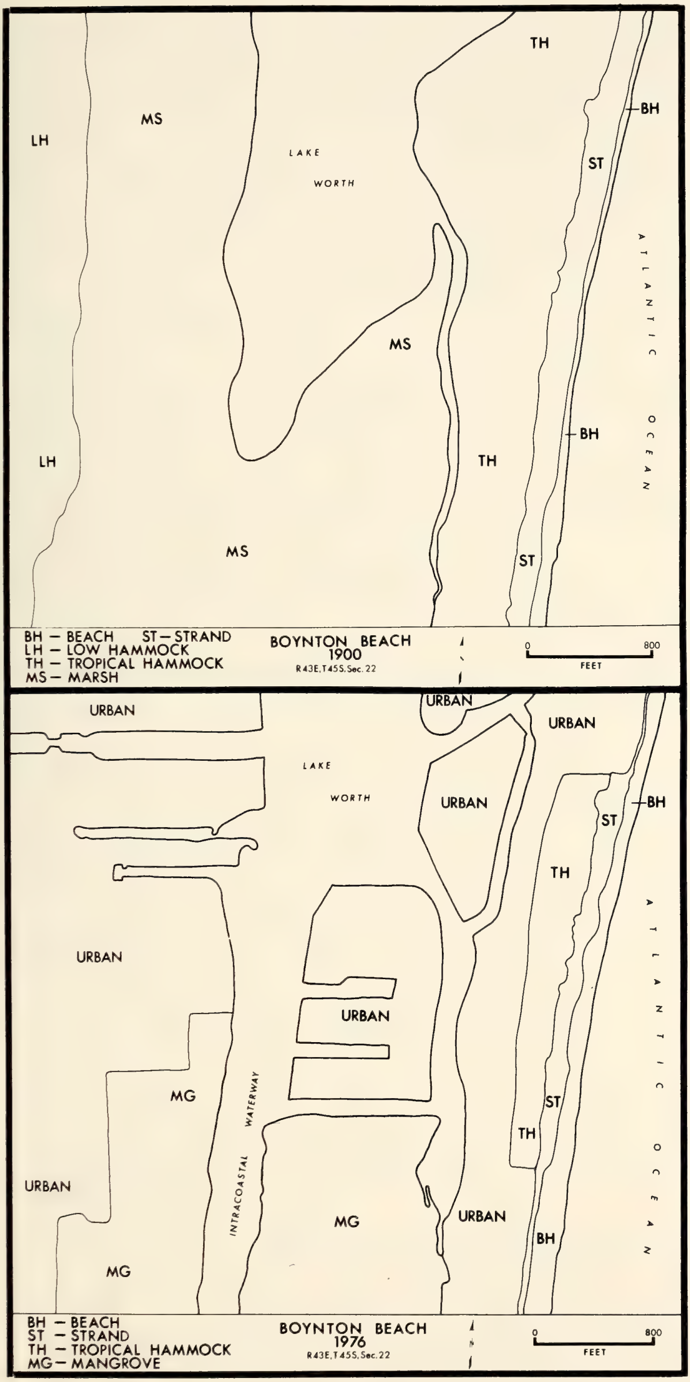


FIG. 5. Boynton Beach Hammock. Upper Map-1900 vegetation patterns. Lower Map-1976 vegetation patterns.

C. uvifera L. Tropical Hammock.
Cocos nucifera L. (Arecaceae) Disturbed Sites.
Commelina erecta L. (Commelinaceae) Disturbed Sites.
Conocarpus erecta L. (Combretaceae) Mangroves.
Crotalaria pumila Ortega (Fabaceae) Disturbed Sites.
Croton punctatus Jacq. (Euphorbiaceae) Scrub, Strand.
Cyperus thyrsiflorus Schlect. & Cham. (Cyperaceae) Disturbed Sites.
Dalbergia ecastophyllum (L.) Taub. (Fabaceae) Mangrove.
Distichilis spicata (L.) Greene (Poaceae) Strand.
Drypetes lateriflora (Swartz) Krug & Urban (Euphorbiaceae) Tropical Hammock.
Ernodea littoralis Swartz (Rubiaceae) Strand.
Erythrina herbacea L. (Fabaceae) Tropical Hammock, Strand.
Eugenia axillaris (Swartz) Willd. (Myrtaceae) Tropical Hammock, Low Hammock.
E. myrtoides Poir. (Myrtaceae) Tropical Hammock.
Exothea paniculata (Juss.) Radlk. (Sapindaceae) Tropical Hammock.
Ficus aurea Nutt. (Moraceae) Swamp, Tropical Hammock, Low Hammock.
Forestiera segregata (Jacq.) G. Don (Apocynaceae) Tropical Hammock.
Helianthus debilis Nutt. (Asteraceae) Strand.
Heliotropium angiospermum Murray (Boraginaceae) Tropical Hammock.
Hymenocallis latifolia (Mill.) Roem. (Amaryllidaceae) Marsh, Wet Prairie.
Ipomoea alba L. (Convolvulaceae) Swamp, Strand.
I. acuminata (Vahl.) Roem. & Schultz Strand, Tropical Hammock.
I. macrantha Roem. & Schultz Strand.
I. pes-capre (L.) R. Br. Strand.
Iresine diffusa Humb. & Bonpl. *ex* Willd. (Amaranthaceae) Tropical Hammock, Wet Prairie.
Iva frutescens L. (Asteraceae) Mangrove, Strand.
I. imbricata Walt. Strand.
Krugiodendron ferreum (Vahl.) Urban (Rhamnaceae) Tropical Hammock.
Lemna valdiviana Phil. (Lemnaceae) Marsh.
Lysiloma latisiligua (L.) Benth. (Euphorbiaceae) Tropical Hammock.
Mastichodendron foetidissium (Jacq.) Cronquist (Sapotaceae) Tropical Hammock.
Mentzelia floridana Nutt. (Loasaceae) Strand.
Metopium toxiferum (L.) Krug & Urban (Anacardiaceae) Tropical Hammock.
Mikania cordifolia (L.) Willd. (Asteraceae) Tropical Hammock, Low Hammock.
Myrsine guianensis (Aubl.) Kuntze (Myrsinaceae) Tropical Hammock, Swamp.
Nectandra coriacea (Swartz) Griseb. (Lauraceae) Tropical Hammock.
Opuntia stricta var. *dillenii* (Ker.) L. Benson (Cactaceae) Strand.
Parthenocissus quinquefolia (L.) Planch. (Vitaceae) Low Hammock.
Paspalum vaginatum Swartz (Poaceae) Strand.
Passiflora suberosa L. (Passifloraceae) Tropical Hammock, Low Hammock.
Pennisetum purpureum Schum. (Poaceae) Disturbed Sites.
Persea borbonia (L.) Spreng. (Lauraceae) Swamp, Low Hammock, Tropical Hammock.
Phlebodium aureum (L.) Sm. (Polypodiaceae) Swamp, Tropical Hammock, Low Hammock.
Phragmites communis Trin. (Poaceae) Disturbed Sites.
Phyllanthus abnormis Baillon (Euphorbiaceae) Strand.
Pithecellobium keyense Britton (Fabaceae) Strand.
Plumbago scandens L. (Plumbaginaceae) Disturbed Sites.
Poinsettia cyathophora (Murr.) Kl. & Gke. (Euphorbiaceae) Disturbed Sites.
Polygala grandiflora Walt. (Polygalaceae) Wet Prairie.
Polypodium polypodioides (L.) Watt. (Polypodiaceae) Swamp, Low Hammock.
Psychotria nervosa Swartz (Rubiaceae) Tropical Hammock, Swamp, Low Hammock.
Randia aculeata L. (Rubiaceae) Tropical Hammock.

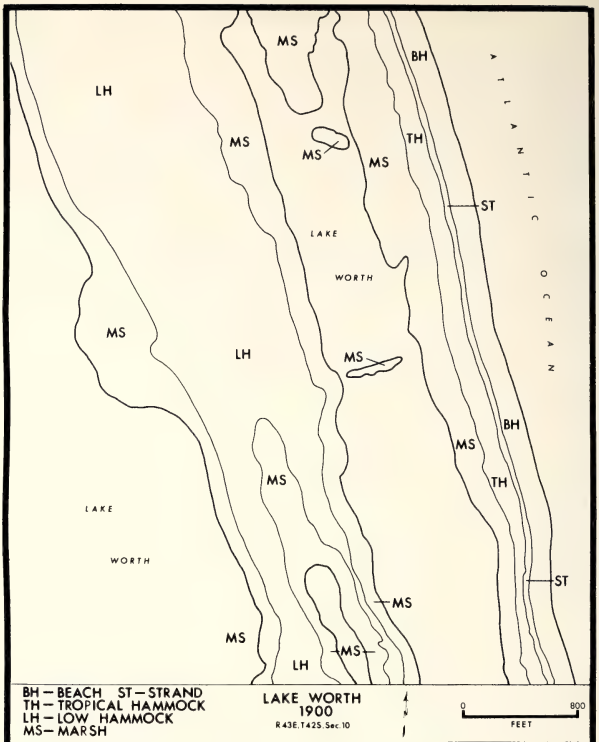
Remirea maritima Aubl. (Cyperaceae) Strand.
Rivina humilis L. (Phytolaccaceae) Tropical Hammock.
Sabal palmetto (Walt.) Lodd. *ex* Schultes (Arecaceae) Low Hammock, Swamp.
Salix caroliniana Michx. (Salicaceae) Swamp, Disturbed Sites.
Sarcostemma clausum Vail (Asclepiadaceae) Tropical Hammock, Low Hammock, Swamp.
Scaevola plumieri Vahl (Goodeniaceae) Strand.
Schinus terebinthifolius Raddi (Anacardiaceae) Disturbed Sites.
Serenoa repens (Bartr.) Small (Arecaceae) Dry Prairie, Pine Flatwood, Strand, Scrub.
Sesuvium portulacastrum L. (Aizoaceae) Strand, Mangrove.
Simarouba glauca DC. (Simaroubaceae) Tropical Hammock.
Smilax bona-nox L. (Smilacaceae) Disturbed Sites.
Solanum bahamense L. (Solanaceae) Strand.
Sophora tomentosa L. (Fabaceae) Strand.
Spartina patens (Ait.) Muhl. (Poaceae) Salt Marsh.
Stenotaphrum secundatum (Walt.) Kuntze (Poaceae) Disturbed Sites.
Suriana maritima L. (Surianaceae) Strand.
Tournefortia gnaphalodes (L.) R. Br. (Boraginaceae) Strand.
Toxicodendron radicans (L.) Kuntze subsp. *radicans* (Anacardiaceae) Tropical Hammock. Swamp, Low Hammock.
Tribulus cistoides L. (Zygophyllaceae) Disturbed Sites.
Typha domingensis Pers. (Typhaceae) Marsh.
Uniola paniculata L. (Poaceae) Strand.
Verbesina laciniata (Poir.) Nutt. (Asteraceae) Strand.
Vitis shuttleworthii House (Vitaceae) Low Hammock, Tropical Hammock, Disturbed Sites.
Yucca aloifolia L. (Agavaceae) Strand.
Zanthoxylum fagara (L.) Sarg. (Rutaceae) Tropical Hammock.

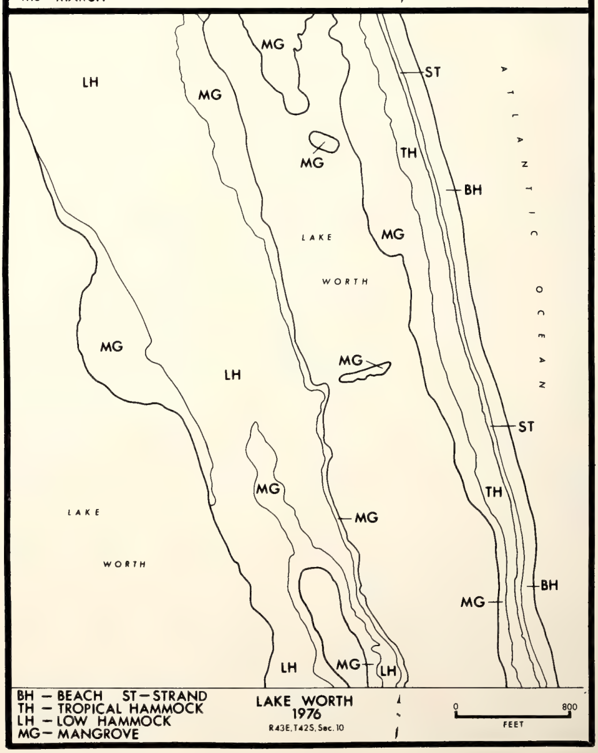
5. North Lake Worth—Situated at the north end of Lake Worth is a small peninsula of land that is primarily composed of three plant communities: Low Hammock, Salt Marsh and Mangroves (Fig. 6). Historical maps and surveys (1770-1900) do not show this small projection of land. This may have been due to the very crude instruments available or the lack of field surveys in this area of Palm Beach County. The first accurate description of this area derives from the Bureau of Soils (1913). Their efforts involved a systematic analysis of the soil types and associated vegetation between West Palm Beach and Ankona in Martin County.

The 1940 aerial photographs showed that the location of the Low Hammock has not changed much over the past 35 yr (Fig. 6). The hammock has probably not changed because few fires have occurred. The proximity of water on both sides accounts for this.

We found 101 taxa of which 32.6% were disturbance site plants. This considerable disturbance was caused by the construction of highway A1A and frequent or heavy use of the area by local fishing parties. Numerous cultivated plants, e.g., *Wedelia* and *Plumbago*, are found scattered throughout the site due to a small road that cuts through the middle of the hammock. It appears that this road has been used as a dump for many years which could account for the presence of cultivated forms.

Margins of the hammock are dominated by disturbance site plants, princi-


BH — BEACH ST — STRAND
TH — TROPICAL HAMMOCK
LH — LOW HAMMOCK
MS — MARSH
LAKE WORTH
1900
R43E, T42S, Sec. 10
0
800
FEET
ATLANTIC OCEAN
LAKE WORTH
LAKE WORTH
LH
MS
BH
TH
ST


BH — BEACH ST — STRAND
TH — TROPICAL HAMMOCK
LH — LOW HAMMOCK
MG — MANGROVE
LAKE WORTH
1976
R43E, T42S, Sec. 10
0
800
FEET
ATLANTIC OCEAN
LAKE WORTH
LAKE WORTH
LH
MG
ST
TH
BH

pally *Schinus terebinthifolius, Casuarina equisetifolia* and *Catharanthus roseus.* Interior portions of the hammock shelter rich populations of *Vittaria* and *Psilotum* which are otherwise quite rare. Some tropical species (*Bursera* and *Metopium*) are scattered throughout the area at slightly higher elevations. These isolated patches of Tropical Hammock are comprised of a majority of small trees 15-29 yr old under scattered trees 70 or more yr old. It appears that the areas which support Tropical Hammock might have been inhabited by American pioneers, which would partially explain the occurrence of several large trees.

In the late 1800's and early 1900's, the Mangrove community replaced a vast Freshwater Marsh that surrounded the Low Hammock (Vignoles, 1823; Tanner, 1823; Williams, 1837; MacKay, 1845; Ives, 1856; Pierce, 1970; Austin, 1976a). The early reports mentioned that large stands of sawgrass could be seen for miles along the lake. Scattered throughout some of these reports are notes which mention the presence of a few mangroves which had probably become established with the opening and closing of the northern inlet. In any case, by 1875 the north inlet was opened to allow small pleasure craft, fishing boats or mail boats to enter Lake Worth. At this time replacement of sawgrass by Mangrove began.

A few Salt Marshes are scattered among the tidal creeks and most of these marshes contain only a few species; *Suaeda linearis, Sesuvium portulacastrum,* and *Spartina alterniflora.* Some erosion is occurring at the mouths of the tidal creeks due to the increased boat traffic.

The following checklist compiled by D. Richardson in 1975-76 for the hammock and associated communities shows the very rich species composition.

Abrus precatorius L. (Fabaceae) Disturbed Sites.
Ambrosia artemisiifolia L. (Asteraceae) Disturbed Sites.
Ampelopsis arborea (L.) Rusby (Vitaceae) Disturbed Sites.
Amphitecna latifolia (Mill.) A. Gentry (Bignoniaceae) Tropical Hammock.
Annona glabra L. (Annonaceae) Swamp.
Ardisia escallonioides Schlecht. & Cham. (Myrsinaceae) Tropical Hammock.
Avicennia germinans L. (Avicenniaceae) Mangrove.
Blechnum serrulatum Richard (Blechnaceae) Low Hammock, Pine Flatwoods.
Borrichia frutescens (L.) DC. (Asteraceae) Mangrove.
Bursera simaruba (L.) Sarg. (Burseraceae) Tropical Hammock.
Caesalpinia bonduc (L.) Roxb. (Fabaceae) Mangrove.
Callicarpa americana L. (Verbenaceae) Low Hammock, Pine Flatwoods.
Canavalia maritima (Aubl.) Thouars (Fabaceae) Strand.
Capparis cynophallophora L. (Capparidaceae) Tropical Hammock.
C. flexuosa L. Tropical Hammock.
Cassia aspera Muhl. (Fabaceae) Disturbed Sites, Pine Flatwoods, Dry Prairie.
Cassytha filiformis L. (Lauraceae) Scrub.
Catharanthus roseus (L.) G. Don (Apocynaceae) Disturbed Sites.
Chiococca alba (L.) Hitchc. (Rubiaceae) Low Hammock.
Chrysobalanus icaco L. (Chrysobalanaceae) Wet Prairie, Swamp, Strand.
Chrysophyllum oliviforme L. (Sapotaceae) Tropical Hammock.
Cladium jamaicensis Crantz (Cyperaceae) Marsh.
Cnidoscolus stimulosus (Michx.) Engelm. & Gray (Euphorbiaceae) Strand.

Fig. 6. North Lake Worth. Upper Map-1900 vegetation patterns. Lower Map-1976 vegetation patterns.

Coccoloba diversifolia Jacq. (Polygonaceae) Tropical Hammock.
C. uvifera L. Strand.
Conocarpus erecta L. (Combretaceae) Mangrove.
Cyperus planifolius Richard (Cyperaceae) Disturbed Sites.
Dalbergia ecastophyllum (L.) Benth. (Fabaceae) Tropical Hammock, Mangrove.
Desmodium canum (J. F. Gmel.) Schinz & Thellung (Fabaceae) Disturbed Sites.
D. tortuosum (Swartz) DC. Disturbed Sites.
Diospyros virginiana L. (Ebenaceae) Low Hammocks, Disturbed Sites.
Dipholis salicifolia (L.) A. DC. (Sapotaceae) Tropical Hammock, Low Hammock.
Emilia javanica (Burm.) C. B. Robinson (Asteraceae) Disturbed Sites.
Erythrina herbacea L. (Fabaceae) Tropical Hammock, Low Hammock.
Eugenia axillaris (Swartz) Willd. (Myrtaceae) Tropical Hammock, Low Hammock.
Exothea paniculata (Juss.) Radlk. (Sapindaceae) Tropical Hammock.
Ficus aurea Nutt. (Moraceae) Low Hammock, Tropical Hammock.
Forestiera segregata (Jacq.) Krug & Urban (Oleaceae) Tropical Hammock, Low Hammock.
Galactia macreei M. A. Curtis (Fabaceae) Dry Prairie, Pine Flatwood.
Galium virginicum Michx. (Rubiaceae) Disturbed Sites, Pine Flatwood.
Gaura angustifolia Michx. (Onagraceae) Disturbed Sites.
Helianthemum corymbosum Michx. (Cistaceae) Scrub.
Hypericum stans (Michx.) P. Adams & N. Robson (Hypericaceae) Pine Flatwood, Low Hammock.
Ipomoea alba L. (Convolvulaceae) Hammocks, Swamp, Strand.
I. indica (Burm.) Merrill Disturbed Sites, Hammock.
I. pes-capre (L.) R. Brown Strand.
Iresine celosia L. (Amaranthaceae) Disturbed Sites.
Kosteletzkya virginica (L.) Presl. *ex* Gray (Malvaceae) Marsh, Wet Prairie.
Krugiodendron ferreum (Vahl.) Urban (Rhamnaceae) Tropical Hammock.
Laguncularia racemosa Gaertn. f. (Combretaceae) Mangrove.
Lepidium virginicum L. (Brassicaceae) Disturbed Sites.
Metopium toxiferum (L.) Krug & Urban (Anacardiaceae) Tropical Hammock.
Mikania cordifolia (L.) Willd. (Asteraceae) Low Hammock.
Morus rubra L. (Moraceae) Low Hammock, Tropical Hammock.
Myrica cerifera L. (Myricaceae) Wet Prairie, Swamp, Hammock.
Nephrolepis cordifolia (L.) Presl. (Davalliaceae) Disturbed Sites.
Parthenocissus quinquefolia (L.) Planchon (Vitaceae) Disturbed Sites, Low Hammock.
Persea borbonia (L.) Spreng. (Lauraceae) Swamp, Low Hammock.
Phlebodium aureum (L.) Sm. (Polypodiaceae) Swamp, Low Hammock.
Pisonia discolor Spreng. (Nyctaginaceae) Low Hammock.
Plumbago scandens L. (Plumbaginaceae) Disturbed Sites.
Poinsettia cyathophora (Murr.) Kl. & Gke. (Euphorbiaceae) Disturbed Sites.
Polygala grandiflora Walt. (Polygalaceae) Wet Prairie, Pine Flatwood.
Polygonum hydropiperiodes Michx. (Polygonaceae) Swamp.
Portulaca oleracea L. (Portulacaceae) Disturbed Sites.
P. pilosa L. Disturbed Sites.
Psilotum nudum (L.) Beauv. (Psilotaceae) Swamp, Low Hammock, Tropical Hammock.
Psychotria sulzneri Small (Rubiaceae) Swamp, Low Hammock, Tropical Hammock.
P. undata Jacq. Swamp, Low Hammock, Tropical Hammock.
Pteridium aquilinum (L.) Kuhn var. *caudatum* (L.) Sadebeck (Pteridaceae) Low Hammock, Disturbed Sites.
Quercus laurifolia Michx. (Fagaceae) Low Hammock, Swamp.
Q. virginiana Mill. Low Hammock.
Randia aculeata L. (Rubiaceae) Low Hammock, Tropical Hammock, Strand.
Rhizophora mangle L. (Rhizophoraceae) Mangrove.
Rivina humilis L. (Phytolaccaceae) Disturbed Sites, Tropical Hammock.

Sabal palmetto (Walt.) Lodd. *ex* Schultes (Arecaceae) Low Hammock.
Schinus terebinthifolius Raddi (Anacardiaceae) Disturbed Sites.
Scleria baldwinii (Torr.) Steud. (Cyperaceae) Low Hammock.
Serenoa repens (Bartr.) Small (Arecaceae) Strand.
Sesuvium portulacastrum L. (Aizoaceae) Mangrove, Beach.
Setaria geniculata (Lam.) Beauv. (Poaceae) Disturbed Sites.
Simarouba glauca DC. (Simaroubaceae) Tropical Hammock.
Smilax auriculata Walt. (Smilacaceae) Disturbed Sites, Low Hammock, Dry Prairie.
S. bona-nox L. Disturbed Sites, Low Hammock.
Solidago stricta Ait. (Asteraceae) Disturbed Sites.
Spartina alterniflora Loisl. (Poaceae) Mangrove, Marsh.
Sporobolus domingensis (Trin.) Kunth (Poaceae) Beach, Strand.
Suaeda linearis (Ell.) Moq. (Chenopodiaceae) Mangrove, Marsh.
Tillandsia usneoides L. (Bromeliaceae) Low Hammock, Swamp.
Tovara virginiana Raf. (Polygonaceae) Disturbed Sites.
Trichostema suffrutescens Kearney (Lamiaceae) Pine Flatwoods.
Verbesina virginica L. (Asteraceae) Strand, Dry Prairie.
Vigna luteola (Jacq.) Benth. (Fabaceae) Disturbed Sites.
Vitis aestavalis Michx. (Vitaceae) Low Hammock, Disturbed Sites.
V. rotundifolia Michx. Disturbed Sites, Low Hammock.
V. shuttleworthii House Low Hammock, Tropical Hammock.
Vittaria lineata (L.) Sm. (Vittariaceae) Swamp, Low Hammock.
Wedelia trilobata (L.) Hitchc. (Asteraceae) Disturbed Sites.
Ximenia americana L. (Olacaceae) Scrub, Low Hammock, Tropical Hammock.
Yucca aloifolia L. (Agavaceae) Disturbed Sites.
Zanthoxylum clava-herculis L. (Rutaceae) Tropical Hammock.
Z. fagara (L.) Sarg. Low Hammock, Tropical Hammock.

GENERALIZED SUCCESSIONAL TRENDS

SCRUB (*Pinus clausa/Quercus* spp.)—Inland from the coastal strip are old relict beach dunes which support Scrub vegetation. Scrub is usually indigenous to these ancient shorelines. Establishment of this community occurred very early when peninsular Florida was beginning to emerge. Successive drops in sea level caused many of the beach species to be eliminated and replaced by species which could tolerate the thoroughly leached soil conditions. Pines and oaks became established, eventually leading to what many people feel is the oldest plant community in southern Florida. A wide range of changes may take place when this community is burned. Normal maintenance of Scrub occurs when fires avg 20-40 yr cycles (Austin, 1976b). Fires more frequent than the normal burning cycle coupled with erosion may shift the habitat in different directions. Annual fires, or fires exceeding one per yr, will cause the habitat to shift to an Oak-Palmetto Scrub. This is occurring in extensive areas between Juno Beach and Jupiter (Map 7). These areas are very similar to Strand vegetation.

Erosion of the scrub ridges or over-burning may eventually lead to Low Hammock formation. Erosion on the margins leads to Low Hammock only if protected from fire. Lack of burning will usually allow *Pinus clausa* to reach senescence, about 70 yr with little regeneration. Most of the scrub ridges in Palm Beach County show few signs of re-seeding, except in badly disturbed areas.

If fires occur too frequently (2-4 yr), Low Hammock formation is retarded because the oaks cannot tolerate increased fires. Apparently a trend in Palm Beach County is an invasion of *Pinus elliottii* when a seed source is nearby. This habitat mixture of slash pines and oaks is called Scrubby Flatwoods. In most cases, the advancement of the slash pine is accelerated by erosion of the sand ridges to elevations which usually overlap mature pinelands. The fact that no new areas of Scrub are forming suggests that many of the well developed ridges, especially in the Jupiter area (Map 7), should be preserved for study as biological museums. Many species of fauna, the Scrub jay particularly, are endemic to these ridges. With the rapid reduction of suitable nesting sites, this bird as well as other animals have become rare and endangered.

Pine Flatwoods (*Pinus elliottii*/*Serenoa repens*)—Early authors of vegetation studies (Harshberger, 1914; Davis, 1943) in southern Florida have called the flatlands between the Atlantic Coastal Ridge and the Everglades a Pine Flatwoods. By use of historical surveys (MacKay, 1845; Williams, 1870) and 1940 aerial photography, my study established the flatlands to be predominantly Wet Prairies with small patches of Dry Prairie (Maps 1-3). Pine Flatwoods historically occurred only as isolated islands within the system and several variations of this pine formation are visible today. Pine Flatwoods may change to Scrubby Flatwoods, Wet Prairies or Dry Prairies.

Reversion of Pine Flatwoods to Wet Prairies is occurring in isolated areas of the county. In most cases, these scattered islands of pines are found bordering Wet Prairie systems that are dominated by herbaceous wildflowers and grasses. With drainage, the pines have encroached upon the Wet Prairie community. Following extensive bulldozing, a few species of grasses, e.g., *Aristida* and *Andropogon*, and some typical Wet Prairie species occur. This habitat will remain at this stage only temporarily until the pines are able to invade. Probably what has occurred more frequently in Palm Beach County has been the formation of extensive Dry Prairies as a result of fires occurring more often than every 2-3 yr.

Dry Prairies (*Serenoa repens*/*Aristida* spp.)—According to Harper (1927) a Dry Prairie is similar in species composition to a Pine Flatwoods, but with one or fewer pines per acre. The most famous Dry Prairies exist in the central part of the state where cattle ranching is of prime importance. Historical accounts (Swanton, 1922) indicate that southern Florida was subjected to fires as early as the time of the Indians. If not burned at frequent intervals, Dry Prairies can eventually develop into Low Hammocks or secondary Pine Flatwoods. In most cases, the associated oaks are kept pruned back as very low shrubs by continued burning. Once fires can be controlled, the oaks begin to mature with eventual formation of a Low Hammock. A good example of Low Hammock formation from Dry Prairies is the Yamato Scrub area (Austin, 1977a). As succession to Low Hammock requires many yr, it is highly improbable that Low Hammock will ever revert back to Dry Prairie, unless there are extensive fires, bulldozing or continued drainage. If fires do occur every 2-4 yr, seeding pines will slowly change the Dry Prairie into a Pine Flatwoods, with its characteristic species composition.

Low Hammock (*Quercus*/*Sabal*)—Although used for a variety of different habitats, the term Low Hammock is used here to describe a habitat dominated by *Quercus* spp. and *Sabal palmetto*. Low Hammocks may originate from three different habitats: Dry Prairie, Scrub or Swamp. If the hammock is associated with the margins of swamps, it may contain *Acer rubrum, Taxodium distichum* or *Quercus laurifolia* as dominant trees. Hammocks that occur from Scrub usually have *Quercus geminata, Q. myrtifolia* and *Persea borbonia*. The transition from Swamp to Low Hammock occurs usually at the margins in areas that are moist, but slightly drier than the swampy areas. This has occurred in Boca Raton (Map 1) and several sites near Jupiter (Map 7).

The lack of fires is of prime importance for the formation of Low Hammocks. Based on 1940 aerial photographs, some Low Hammocks have appeared to enlarge. This is primarily due to drainage which has allowed the Low Hammock species to migrate outwards. Competition has been reduced because the surrounding communities have deteriorated to some extent.

In some cases, especially in the northwestern portions of the county, the transition from Swamp to Low Hammock is difficult to identify. There is usually a slight change in elevation and water conditions as one ascends from swampy areas to what is considered Low Hammock. In the Loxahatchee Slough, for example (Map 6), "tree islands" may be Swamps, Low Hammocks or Tropical Hammocks. Their exact classification as to community type is sometimes difficult to assess without extensive field analysis.

Today, most of the Low Hammocks associated with urban areas have been greatly stressed by fires. Damage has been found to range from a minor degree of burnout to sometimes complete destruction and disappearance of the entire hammock.

TROPICAL HAMMOCKS (*Metopium/Bursera*)—Tropical Hammocks are dominated by tropical hardwood species which are very susceptible to periodic fires. These hammocks occur along the coasts from Dade County northward into Brevard County, but some do occur inland from the barrier islands. Maintenance of these hammocks is dependent upon the lack of fires. Harper (1927) suggested that fires which occur more often than once every 20-50 yr would cause a marked reduction in the number of tropical species.

Normal succession of Tropical Hammocks occurs from either Low Hammocks or Coastal Strand. Formation of these hammocks from Low Hammocks usually occurs on limestone outcrops where a slight increase in elevation has protected these areas from frost. In some areas throughout Palm Beach County, especially north of the city of Palm Beach (Maps 5 and 6), one can find Tropical Hammocks scattered between vast Low Hammocks. However, most Tropical Hammocks have their beginnings from Strand areas that have not been burned. In some isolated areas along the coast, especially in the Boca Raton area, tropical hardwood species of *Bursera* and *Metopium* have increased in numbers over the last couple of yr. However, as soon as there is a fire in the area, these species will be severely pruned back or killed, depending upon the nature of the fire.

STRAND (*Serenoa/Pithecellobium/Eugenia*)—Previously, this term was used to describe the combined habitats of Beach and Strand vegetation. Strand is defined in this text to be the zone between the Beach and Tropical Hammock associations. However, in some cases most of the extensive Tropical Hammocks have been eliminated by the construction of highways and other developments. This association is always dominated by saw palmetto (*Serenoa repens*) with abundant seedlings of tropical shrubs. In many places along the coast in Palm Beach County, large areas of Strand have endured for long periods (Kurz, 1942; Pierce, 1970). Pierce (1970) described such a habitat as extending 2.5 mi north of the Orange Grove House of Refuge and 4 mi to the south. Several remnants of this habitat can still be seen in Palm Beach County.

Apparently, fire is the principal factor keeping Strand vegetation from developing into hammock vegetation. Studies by Austin and Coleman (1977d) show that normal maintenance of Strand occurs when fires occur in 3-4 yr cycle. During a fire, all plants except saw palmetto are killed to ground level. Within one month most of the strand species have begun to recover depending on how badly they were burned. Tropical hardwood species recover more slowly.

Strand vegetation may arise from the Beach community with normal succession, from overburned Scrub or from the burning of Tropical Hammocks. As the dune is invaded with pioneer species, more and more vegetation becomes established. With a large influx of tropical species that are cast ashore by ocean currents, Strand species become established in areas of greater stability.

In many areas throughout Palm Beach County, Scrub is found close to the coast. If fires are too frequent, the scrub pine is eliminated and a low strand-type vegetation is formed. The only difference between the burned over Scrub area and Strand vegetation is the presence of oaks, *Quercus geminata* and *Q. myrtifolia*. This is clearly the case in the Jupiter area where vast acres of Scrub have remained as low lying Strand as a result of burning. Burned over Tropical Hammocks will also cause them to revert to Strand vegetation. Fires will eliminate the tropical hardwood species normally associated with Strand and allow more highly adapted Strand species to flourish.

WET PRAIRIE (*Hypericum/Eriocaulon*)—Wet Prairies are usually the beginning stages for the development of Marsh communities. With continued organic buildup and prolonged wet conditions, the eventual change to a more hydrophytic community will occur. Presently, with drainage and increased drought conditions the normal sequence of events leading to Marsh formation has been short-circuited, being replaced by pure stands of *Melaleuca* or *Pinus elliottii.*

With continued stress caused by the lack of standing water for extended periods of time, most Wet Prairies have been eliminated or reduced to small isolated patches of vegetation on white sandy bottoms. *Melaleuca quinquenervia*, like other exotic species, is rapidly filling the space left behind by native Wet Prairie species. Sapling populations of *Melaleuca* in original Wet Prairie sites can be so thick as to be impenetrable on foot. This has retarded normal succession and eliminated most of the native species which become shaded out with the increased canopy cover. Unfortunately, this is occurring in a wide range of habitats throughout Palm Beach County. Like the Brazilian pepper, *Melaleuca* is salt tolerant and has intermingled with the mangroves in some areas. Many pineland areas have become covered with this plant as a result of seed dispersal. Dense stands and rapid expansion from *Melaleuca* is occurring in the conservation areas as well as the cypress strand systems bordering the Everglades.

Wet Prairies have also been replaced by *Pinus elliottii* since the period of increased drainage and fires. Austin (1976b) has shown this to be the case at the Pine Jog Environmental Sciences Center. In most sites, the Pine Flatwoods are less than 25 yr old.

Drainage is not the only factor that has affected the disappearance of the Wet Prairie community. Fires which have been increasing over the last 70 yr have totally reduced some Wet Prairies to bare sand. The margins of these prairies still retain a few species such as *Lachnanthes* and *Xyris*. In many areas in northern Palm Beach County, the old boundaries of some of these prairies can be delimited by a periphery of *Chrysobalanus icaco*.

MARSH (*Cladium/Sagittaria*)—For the most part, Marshes in Palm Beach County have changed drastically over the past 30 yr. Water level fluctuations and fires have caused most major changes in Marsh communities (McPherson, 1973). Marsh communities normally undergo a change in community structure through different seral stages leading to the formation of a swamp. With a slight reduction in the hydroperiod and amount of standing water, upland shrubs are first to invade a changing Marsh community, eventually leading to the establishment of tree species.

Throughout Palm Beach County shrubs such as *Myrica cerifera*, *Schinus terebinthifolius*, and *Baccharis halimifolia* are replacing sawgrass and other aquatic plants. This has been attributed to ground water levels being depressed more than 6 ft (Thomas, 1974) and increased fires. Usually in areas where shrubs are invading, man has managed the area to control fire. In some localities, increased fires have caused some Marsh systems to revert back to Wet Prairies, that is, prairies dominated by grasses with scattered islands of marsh species. Some of the marshy areas that have deep bottoms have not changed considerably probably because they retained water for longer periods of time.

Other noted changes in the Marsh communities of Palm Beach County have included the invasion of *Salix caroliniana* in marginal areas indicating fires or soil disturbance. Buttonbush, *Cephalanthus occidentalis*, has also increased due to dry down of the entire system. *Panicum hemitomon* (maidencane) is becoming very common in locally bulldozed or disturbed sites. Its increase might be due to drier conditions coupled with other local disturbances such as soil variations or farming.

SWAMP (*Taxodium/Acer* or other related species)—The Swamp community is probably the most complex of the wetland communities. The higher margins often grade into Low Hammocks making the two difficult to distinguish. Most of these communities occur in areas of standing waters that are not significantly salty. With drainage over the past 70 yr, many mixed riverine Swamps are being invaded by the Mangrove community. Salinities of these river systems has increased due to decreased discharge and salt water intrusion. The north branch of the Loxahatchee River has signs of saltwater intrusion demonstrated by the presence of mangroves as understory plants to dead cypress trees.

Nearly all the cypress forests in Palm Beach County had been lumbered by the mid-1930's for use as pasture land or agriculture. Logging, fires and drainage have changed many of these swamps into depauperate marshes, usually *Salix* or *Schinus* thickets.

Because cypress is often associated with other wetland communities, an intermixing of scattered cypress probably occurred when water levels were much higher. As the water table was reduced, the cypress trees were more severely stressed because they are more subject to fires and reduced soil moisture which is inadequate for seed germination. Local residents near the West Palm Beach water catchment area report that most of the cypress in that area are dwarfed because of lowered water levels. Excessive drainage has reduced vigor and growth rate so that many trees 5-6 ft tall are as much as 30-40 yr old.

Most cypress heads are farmed up to the margins today and now have standing water only seasonally. As drying continues, indigenous plants are rapidly being replaced by exotics such as *Melaleuca quinquenervia* which can fill the niche to the exclusion of native species.

Mangroves (*Rhizophora/Laguncularia*)—Mangroves are brackish water Swamps associated with coastal areas. The entire mangrove population in Palm Beach County occurs as a secondary forest invading freshwater Marshes concurrently with marine water intrusion. Austin (1976a) has used mangroves as monitors of historical changes in salinity. Very few studies have been done on successional stages within the Mangrove community, but it appears that in some sites they have changed to Salt Marshes. Salt Marsh formation may be the result of hurricane damage which removes most of the conspicuous trees and herbs.

The remaining Mangrove areas are found scattered along the Intracoastal Waterway. The larger the stand, the more rich and dynamic is the community in functioning as a collecting spot for detritus and food substances for many aquatic organisms. Most of these benefits are still retained in the remaining Mangrove communities, but more and more mangroves have been removed and replaced with finger canals, developments or badly disturbed by the digging of mosquito control ditches. Marsh (1974) reported that 77% of the mangroves have been eliminated from Palm Beach County. In the few remaining areas, boats have degraded and eroded many of the outer margins as a result of increased wave action.

Beach (*Uniola/Ipomoea*)—The Beach community is the primary stage in the development of coastal habitats. It may undergo succession to Strand, Scrub or Mangroves. The normal successional sequence for the Beach community includes the gradual transformation to Strand with increased time and stability. The close proximity to ocean currents accounts for the large influx of many tropical species which are cast ashore. This phenomenon accounts for the considerable similarity among the tropical beaches of the world.

Probably the most marked change in the Beach community involves the transformation to Mangroves on the leeward side of the barrier islands or along tidal creeks where low action areas exist. Virtually no mangrove invasion is occurring on the windward side of the coast because of the temporary beach conditions. However, with the rapid development of coastal areas, many of the Mangrove and Beach communities have been replaced or reduced in diversity due to erosion or construction.

SUMMARY—Main successional sequences for Palm Beach County are summarized in Fig. 7. The diagram illustrates both primary and secondary successional relationships. The boxes represent pioneer or primary communities which will develop into secondary habitats. The relationship lines in the chart are double pointed to reflect the fact that the normal sequence of events is reversible and dependent upon several environmental conditions which are subject to human modification.

The following conclusions are based on data gathered over 2 yr, 1975-76, in eastern Palm Beach County. It is hoped that this study can be continued by monitoring the region on a regular basis with modern remote sensing techniques and occasional ground truth studies in order to enhance and update management practices.

1. Vegetational changes have occurred over the past 76 yr in all of the plant communities studied. In most cases, marked changes can be attributed mainly to anthropogenic factors.

2. All community changes documented in this study were made with reference to dominant species. Follow-up studies to record the total community change in species composition will be useful in establishing management criteria.

3. Hydrologic data show that the most marked community changes resulted

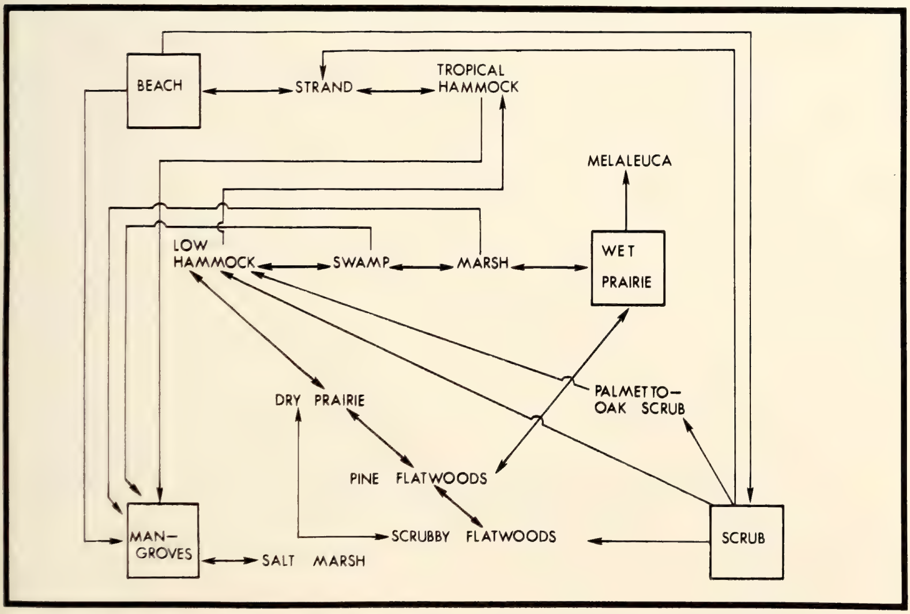


FIG. 7. Successional Relationships between Plant communities in eastern Palm Beach County.

from a 6-9 ft drop in the water table and encroachment of sea water farther inland.

4. A more than 200% increase in fires during 1966-1976 has caused a decline or disappearance of native species in many areas. Fires have completely exterminated some local habitats (Scrub, Low Hammock, Marshes) and substantially reduced others (Wet Prairies).

5. Satisfactory evidence has been found to re-define the habitat referred to by Davis (1943) as sandy pinelands. This area was actually Wet Prairie with scattered islands of pine.

6. Management to preserve much of the historic flora is still possible in selected areas. Partial recovery of present–day communities can be achieved, however, only with strict control measures.

7. Exotic plant species have become a serious threat to the entire system. These species have totally replaced the native species in some habitats, particularly Wet Prairies. Immediate measures should be taken to control and understand the biology of any introduced plant species into the U.S., particularly non–foodcrop species.

8. Substantial evidence exists to show that the Atlantic Coastal Ridge of Palm Beach County will continue to be subjected to expanding urbanization. Already, much of the native vegetation has been replaced due to this population pressure on fragile ecosystems. Regional parks and preserves must be established to halt absolute eradication of these vegetational types and their endangered biota, not to mention the long range impact on human habitability of the region.

Acknowledgments—This study could not have been completed without the willing cooperation and guidance of my major professor, Dr. Daniel Austin. I am grateful for the advice and criticism offered from Drs. Thomas Sturrock, Alex Marsh, Ralph Adams and Roy Lemon. A special note of thanks goes to the Royal Palm Garden Club, Florida Federation of Garden Clubs and the Garden Club of America for financial assistance throughout the course of study. The Joint Center for Environmental and Urban Problems provided the initial grant which helped finance most of this study (D. F. Austin, principal investigator). I am particularly indebted to David Schwartz, Bryan Steinberg, Anthony Arico and Clif Nauman for their advice and field assistance in surveying Palm Beach County. Publication of this research was supported in part by the F.A.U.-F.I.U. Joint Center for Environmental and Urban Problems and the F.A.U.-Pine Jog Environmental Sciences Center.

LITERATURE CITED

Alexander, T. R. 1974. Recent vegetational changes in South Florida. In: Gleason, P. J. ed., Environments of South Florida: Present and Past. Mem. Miami Geol. Survey 2:61-72.

————, and A. G. Crook. 1973. Recent and long-term vegetation changes and patterns in South Florida-Part 1, Prel. Rept. National Technical Information Service, U. S. Department of Commerce, Washington, D.C. Accession No. PB-231-939 (1974).

————, and ————. 1975. Recent and long-term vegetation changes and patterns in South Florida-Part 2, NTIS, U.S. Department of Commerce, Washington, D. C. Accession No. PB-264-462 (1977).

Austin, D. F. 1976a. Mangroves as monitors of change in the Spanish River. Florida Environmental and Urban Issues. 3(3):4-7, 15-16.

————. 1976b. Florida Scrub. Florida Natur. 59(4):2-5.

_________. 1977a. Vegetation of southeastern Florida—I. Pine Jog. Florida Sci. 39:230-235.

_________. 1977b. Vegetation of southeastern Florida—III. Yamato Scrub. Florida Sci. 40:

_________, and K. Coleman. 1977. Vegetation of southeastern Florida—II. Boca Hammock. Florida Sci. 40:

_________, and D. Richardson. 1977. Vegetation of southeastern Florida—IV. Butts Hammock. Florida Sci. 40:

_________, and J. G. Weise. 1972. Annotated checklist of the Boynton Beach Hammock. Quart. J. Florida Acad. Sci. 35:145-154.

_________, and D. M. McJunkin. In Prep. The Legends of Boca Ratones.

Barbour, G. M. 1883. Florida. In: Barbour, G. M. Florida for Tourists, Invalids and Settlers. Appleton. New York.

Bartram, J. 1765. Antiquities of Florida. In Journal of John Bartram of Philadelphia. London.

Black, Crow and Eidsness, Inc. 1974. Engineering Report; Ten-Year Master Plan, Water and Wastewater Facilities for the city of Boca Raton, Boca Raton Water Treatment Plant. Boca Raton, Florida.

Blakey, F. 1975. A Timber Tale. In: Gill, J. and B. Reed, ed. Born of the Sun. Florida Bicentennial Commemorative Journal. Hollywood, Florida.

Bruff, J. D. 1846. The State of Florida. McClelland. Washington.

Bureau of Soils. 1913. Indian River Sheet, Sec. No. 3. Field Operations. Florida.

Butler, G. 1908. Survey of Boca Raton area, Plats of T. 47 S., R. 43 E., Sec. 9.

_________. 1939. Plat of Sec. 9 and part of Sec. 4, T. 47 S., R. 43 E., by Geo. Butler. [Copy from Boca Raton City Hall]

Cooke, C. W. 1939. Scenery of Florida, Interpreted by a Geologist. Florida Geol. Surv. Bull. 17:118p.

Craighead, F. C., Sr. 1974. The Trees of South Florida. Vol. 1. Univ. Miami Press. Coral Gables.

Darby, W. 1921. Map of Florida. In: Darby, W. Memoir on the Geography and Natural and Civil History of Florida. T. H. Palmer Printing. Philadelphia.

Davis, J. H. 1943. The Natural Features of Southern Florida. Accompanied by Vegetation Map of Southern Florida. Fig. 71. Florida State Geol. Surv. Bull. 25:311p.

_________. 1967. General Map of Natural Vegetation of Florida. Agric. Exp. Sta. IFAS Circular S-178. Univ. Florida. Gainesville.

DeBrahm, J. W. 1773. Report of the General Survey in the Southern District of North America and Map of the General Survey of East Florida. L. DeVorsey, ed. Univ. South Carolina Press. Columbia. [Reprint, 1971]

Dickinson, J. 1699. God's Protecting Providence: Being the Narrative of a Journey from Port Royal in Jamaica to Philadelphia. Edited by E. W. Andrews and C. M. Andrews. Yale University Press. New Haven. [Reprint, 1945]

Harper, R. M. 1927. Natural resources of southern Florida. Accompanied by regional map of southern Florida. Ann. Rept. Florida Geol. Surv. 18:27-192.

Harshberger, J. W. 1914. The vegetation of south Florida. Accompanied by phytogeographic map of south Florida. Trans. Wagner Inst. Sci. Phil. 3:51-189.

Henshall, J. A. 1884. Camping and Cruising in Florida. Robert Clarke and Co. Cincinnati.

Hoffmeister, J. E. 1974. Land from the Sea; The Geologic Story of South Florida. Univ. Miami Press. Coral Gables.

Hood, L. 1838. Map of the Seat of War in Florida. Bureau of U. S. Topographical Engineers. Washington, D.C.

Ives, J. C. 1856. Memoirs to Accompany a Military Map of Florida. Wynkoop Co. New York.

Kurz, H. 1942. Florida dunes and scrub, vegetation and geology. Florida Geol. Surv. Bull. 23:15-154.

Leach, S. D., H. Klein and E. R. Hampton. 1972. Hydrologic effects of water control and management of southeastern Florida. U.S. Geol. Surv., Rept. of Investigations, No. 60:43-47. Tallahassee.

Long, G. R. 1921. Subdivision survey of the south half of Govn. Lot 4, Sec. 9, T. 47 S., R. 43 E., by R. Long. [Copy from Boca Raton City Hall]

Long, R. W., Jr. 1974. The vegetation of southern Florida. Florida Sci. 37:33-45.

_________, and O. Lakela. 1976. A Flora of Tropical Florida. Banyan Books. Miami.

Lucas, F. 1822. Geographical, Statistical and Historical Map of Florida. In: Carey, H. C. and I. Lea. A Complete Historical, Chronological and Geographical American Atlas. Sherwood, Jones and Co. London.

MacKay, G. 1845. U.S. Survey Plats of T. 46 S. R. 41 E., T. 47 S. R. 43 E., T. 46 S. R. 43 E., T. 45S. R. 43 E.

_________, and Blake. 1839. Map of the Seat of War in Florida. Washington. [Photograph from the Dept. of Natural Resources, Tallahassee.]

MARSH, G. A. 1974. The Intracoastal Waterway: An ecological perspective. Florida Environ. Urban Issues 2(2):6-7; 13-15.

MARTIN, S. W. 1949. Florida's Flagler. Univ. Georgia Press. Athens.

MCCOY, H. J., AND J. HARDEE. 1970. Ground-water resources of the lower Hillsboro Canal area, southeastern Florida. U.S. Geol. Survey, Rept. Invest. No. 55:1-44.

MCPHERSON, B. F. 1973. Vegetation in relation to water depth in Conservation Area 3, Florida. U.S. Geol. Survey, Open File Report No. 73025. Tallahassee.

MESKINEN, G. F. 1962. A Silvical Study of the *Melaleuca* Tree in South Florida. Masters Thesis. Univ. Florida. Gainesville.

MITHCHELL, A. J., AND M. R. ENSIGN. 1928. The Climate of Florida. Univ. Florida Agric. Exper. Sta. Bull. No. 200.

PARKER, G. G., AND C. W. COOKE. 1944. Late Cenozoic Geology of Southern Florida, with a Discussion of the Ground Water. Florida Geol. Survey Bull. 27:119p.

———, G. E. FERGUSON AND S. K. LOVE. 1955. Water Resources of Southeastern Florida, with Special Reference to the Geology and Ground Water of the Miami Area. U.S. Geol. Surv. Water-Supply Pap. No. 1255:965p.

PIERCE, C. 1970. Pioneer Life in Southeastern Florida. Don Curl, ed. Univ. Miami Press. Coral Gables.

PLACES OF INTEREST MAP. 1907. Lake Worth, West Palm Beach and Palm Beach. Currie Investment Co.

REYES, W. J. 1855. United States Survey Plats of T. 44 S. R. 42 E., T. 43 S. R. 42 E., T. 42 S. R. 42 E., T. 40 S. R. 42 E., T. 44 S. R. 43 E., T. 43 S. R. 43 E., T. 42 S. R. 43 E., T. 41 S. R. 43 E., T. 40 S. R. 43 E.

RICHARDS, P. W. 1966. The Tropical Rain Forest, An Ecological Study. Cambridge Univ. Press. Cambridge.

ROMANS, B. 1775. A Concise History of East and West Florida. Accompanied by maps of part of the Province of East Florida. [R. W. Patrick, ed. Florida Facsimile Reprint Series. Gainesville. Reprint, 1962]

SHALER, N. S. 1890. The topography of Florida. Harvard Coll. Mus. Comp. Zoology Bull. 16(7):139-158.

STEINBERG, B. 1976. Vegetation Analysis of the Atlantic Coastal Ridge of Broward County, Florida. Masters Thesis. Florida Atlantic Univ. Boca Raton.

STEPHENS, J. C. 1956. Subsidence of organic soils in the Florida Everglades. Soil Sci. Soc. Amer. Proc. 20(1):77-80.

SWANTON, J. R. 1922. Early History of the Creek Indians and Their Neighbors. Johnson Reprint Corp. New York. [Reprint, 1970]

TANNER, H. S. 1823 Map Of Florida. In: The American Traveler. No. 22. Philadelphia.

THOMAS, T. M. 1974. A detailed analysis of climatological and hydrological records of South Florida with reference to man's influence upon ecosystem evolution. In: Gleason, P. J., ed. Environments of South Florida: Present and Past. Mem. Miami Geol. Survey 2:82-122.

TOURSON, W. 1556. One of several interpretations for the use of the word "Hammock". In: Oxford English Dictionary. Oxford Univ. Press, Anem House. London.

U. S. COAST AND GEODETIC SURVEY. 1884. East coast of Florida, between the south end of Lake Worth and Hillsboro Inlet. Surveyed by: T. P. Borden, Register No. 1657.

UNITED STATES DEPARTMENT OF AGRICULTURE. 1940, 1973. Aerial Photographs. Palm Beach County, Florida.

———. 1946, 1973. Soil Surveys. Palm Beach County, Florida.

U.S.D.C., COASTAL MAPPING DIVISION. 1945. Aerial Photographs. Coastal Palm Beach County, Florida.

U. S. DEPARTMENT OF INTERIOR. 1969, 1973. Topographic Quadrangles. Palm Beach County, Florida.

VIGNOLES, C. 1823. Observations upon the Floridas. Accompanied by Map of Florida. New York.

WILLIAMS, J. L. 1837. Map of Florida. In: Williams, J. L. The Territory of Florida. New York.

WILLIAMS, M. H. 1870. U. S. Survey Plats of T. 46 S. R. 41 E., T. 47 S. R. 42 E., T. 45 S. R. 42 E., T. 45 S. R. 43 E., T. 46 S. R. 43 E. with the outline of the sections established.

WINSTON, J. T., AND C. J. BLANFORD. 1975. Open Space for Boca Raton, and Open Space and Recreation Master Plan. Ecological Research in Planning and Design, Department of Landscape, Architecture and Regional Planning. Univ. Pennsylvania. Philadelphia. [On file Boca Raton City Courthouse]

Florida Sci. 40(4):281-330. 1977.

Ecosystem Studies

VEGETATION OF SOUTHEASTERN FLORIDA—II-V

Daniel F. Austin, Katherine Coleman-Marois and Donald R. Richardson

Department of Biological Sciences, Florida Atlantic University, Boca Raton, Florida 33431

Abstract: *II. Boca Raton Hammock on the barrier island was originally bordered on the west with a freshwater sawgrass marsh which became overgrown by mangroves following drainage. The tropical hammock has remained since the mid-1800's. Strand vegetation dominated by saw palmetto has persisted for at least a century. III. Yamato Scrub has undergone few successional changes for the past century despite its near extirpation because of agriculture and subsequent urbanization. Even undeveloped sites show evidence of substantial disturbance. IV. Butts Hammock is an inland hammock with 73% tropical species present. After the region was drained in 1921 farming and urbanization eliminated many surrounding communities but most of the hammock itself seems to have remained. V. Boca Raton Inlet has undergone several changes in physiography and vegetation in the past with three major changes within the past 100 yr. Increased salinity has resulted in spread of mangroves and disturbance has resulted in establishment of exotic plants. Dredging, draining and jetty installations have further modified natural habitats. The four areas studied from early survey records, 1940 aerial photographs and recent aerial photography and site visits document significant vegetational shifts correlated with some natural phenomena as well as the much greater change associated with human impact.*[*]

II. Boca Raton Hammock Site, *Daniel F. Austin and Katherine Coleman-Marois.*

The Boca Raton Hammock site is a complex of coastal communities on the barrier island system of southeastern Palm Beach County, Florida. Although the presence of various plant communities in the area has been generally known for many years (Small, 1929; Davis, 1943), only two detailed studies of coastal sites have been made (Alexander, 1958; Austin and Weise, 1972). Even the recent studies dealt only with existing vegetation and no attempt was made to record changes over the past several decades. The Boca Raton Hammock tract is the second area studied to document successional changes (Austin, 1976c).

History—The site, named after the tropical hammock whose appellation dates from the 1870's (Pierce, 1970), is found in Township 47S, Range 43E, Sections 16 and 21. This parcel borders the east side of Lake Wyman, part of the Intracoastal Waterway basin.

The first record of settlement near the tract was shortly after the establishment of Delray in 1895. T. M. Rickards is thought to be the first resident of the area (Lineham, 1973). By 1936 there were several owners of the various parcels of the land, but little had been done to alter its natural state. Parcels 3, 4 and 5 on the northern end were part of the "Cocoanut Park Company." The company had few trees on this tract of land but had large plantations to the north.

Several roads show cutting through the area in the 1940 aerial photographs and some of these remain. Remnants of the old A-1-A (formerly Ocean Boule-

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

vard) show in the photography from the 1940's and some parts still exist. Four buildings have been on the eastern part of the site, these dating from the 1940's and 1950's. *Casuarina* marks the location of these buildings.

Mosquito control canals were dug in the mangroves in the 1950's. Later two large spoil mounds were filled on the lake side of the hammock. These appear in the 1964 and 1965 photographs, but their origin has not been determined. Spoil sites for the Intracoastal Waterway were not part of the area.

South of the major part of the remaining hammock, the Sun and Surf Club and its associated building on the coastal golf course appeared by the last half of the 1960's. Between 1965 and 1970 the beach building on the north end of the golf course was destroyed.

With the beginning of the land boom in the 1950's the land found its way to the Schine group. Speculators in the northeast, Schine and Associates controlled the land for several years. After long negotiations the city of Boca Raton purchased the present land in 1974. Locally it had become known as the Schine Tract, and included the golf course and artificial harbor on the southern end.

Physiography—Elevations on the tract range upward from sea level at the margin of Lake Wyman and the ocean shore. Near the edge of the lake the elevations are between 0-5 ft msl, this area being influenced by tides and supporting mangroves. From this zone the land slopes upward toward the crest of the dune where the maximum elevations are 25 ft (U.S.D.A., 1969). Most of the hammock vegetation is between 5-15 ft msl; the strand between 10-25 ft. The beach zone is between 0-25 ft.

Although there is some local variation, the soils are of three types. The mangrove zone has soils of the Tidal Swamp type (U.S.D.A., 1973) or, in former terminology, Mangrove Peat. Hammock and strand zones occupy soils called Palm Beach Sand. The third soil is on the beach zone, the most recent classification (U.S.D.A., 1973) being simply Beach Sand. On the Boca Raton Hammock site this sand is little different from the Palm Beach series.

In the past there have been numerous shifts in local drainage and the Intracoastal Waterway has varied considerably in salinity. Only a few of these changes have been documented on maps or in historical accounts. The available records of change are summarized elsewhere (Austin, 1976; Austin and McJunkin, in prep.).

Since completion of the Intracoastal Waterway in 1912, the opening of the Palm Beach Canal in 1917, the Hillsboro Canal in 1921, and the reopening of the Boca Raton Inlet in the 1920's, the salinity of the coastal waterways has increased drastically (Austin, 1976). The salinity change was enhanced by the lowering of the fresh water head. Thomas (1974) suggested that the fresh water table has been dropped 6 ft. This figure is probably correct, but the past existence of fresh water springs on the beach north of Boca Raton (DeBrahm, 1773), fresh water in Lake Worth prior to 1866 (Pierce, 1970), and former sawgrass marshes in the Intracoastal Basin suggest that the drop may have been greater.

Vegetation: We have found four early descriptions of the vegetation on the site (MacKay, 1845; Ives, 1856; Williams, 1870; Butler, 1939). The earliest records we have seen were made by surveyors and recorded as field notes or on maps. In addition to these sources we have used maps by Bruff (1846) and Ives (1856). Subsequent are the studies by Harshberger (1914) and Davis (1943). The study by Davis was based in large part on the 1940 aerial photography which we also have used.

Original Associations: With one exception, the original plant associations on the site were the same as the modern. One zone has been added, the roadside flora. While this is not a true association in the same sense as the others, there are many distinctive plants. Before drainage began around 1900, the plant associations on the site were: sawgrass marsh, tropical hammock, strand and beach (Fig. 1).

All of the accounts preceding the turn of the century show that the vegetation in the present Intracoastal Waterway basin was a fresh water sawgrass marsh (MacKay, 1845; Bruff, 1846; Ives, 1856; Williams, 1870; U.S.G.S., 1884; Pierce, 1970). This community persisted after the turn of the century (Butler, 1908) for about 20 yr (Long, 1921). The rapid drop in the fresh water level following the completion of canals in southern Florida and concurrent salt water intrusion initiated changes in the marshes which continue to present (Austin, 1976a).

The next zone east of Lake Wyman was the tropical hammock. Species composition in this hammock was similar to the present hammock (Williams, 1870). Boca Raton Hammock was one of the longest on this coast. At one time the hammock extended unbroken from north of the present Jap Rock (Section 9) south through the study site (Section 16) to the northern edge of Lake Boca Raton (Section 21) and down the eastern edge of the lake to the Boca Raton Inlet (Section 28). The hammock extended in a strip at least 3 miles long. Throughout its length the hammock varied in width, being narrowest at Jap Rock (ca. 50 ft) and widest on the north shore of Lake Boca Raton (over 0.25 mi).

East of the hammock zone was the strand. As used here, the term strand does not completely conform with other authors. We have used "strand" to describe a plant community between the actual beach and, in this case, hammock. This community has classically been dominated by saw palmettos (*Serenoa repens*) with abundant seedlings or root sprouts of a variety of tropical shrubs and trees (Williams, 1870; Pierce, 1970).

Most of the strand communities on this coast have persisted for at least a century. Pierce (1970: 72) described a strand extending from 2.5 miles north of the Orange Grove House of Refuge (previously in the present city of Delray Beach) and south for 4 miles. Several remnants of this strand may still be seen scattered between developed sites. For the past 6 yr (1970-1976) several of these strand sites have been monitored in the Boca Raton region. Apparently fire is the factor keeping the sites from growing up into hammock vegetation. This study suggests that fires avg 4-5 yr cycles in the strand.

Outside of the strand was the beach zone. No mention of plant species was made in early reports of the area.

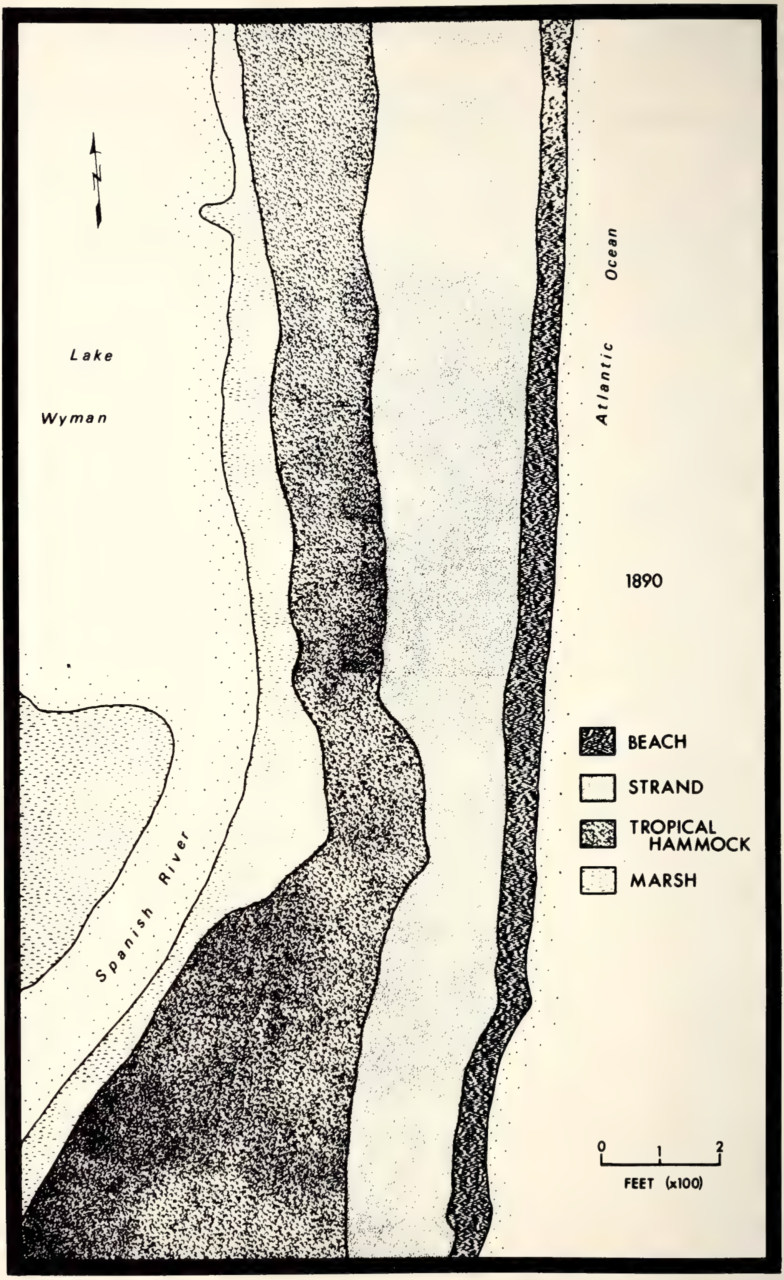


FIG. 1. Interpretation of the plant associations on the Boca Hammock region in 1890. Based on 1845 and 1870 surveys and 1940 aerial photography.

PRESENT ASSOCIATIONS—The fresh water marsh that previously existed in the Intracoastal Waterway basin no longer exists. A mangrove association has replaced this fresh water community. Mangrove invasion took place largely after 1921 (Long, 1921) when the Hillsboro Canal was opened. A survey by Butler in

1939 showed the mangroves in part of their present location. By 1940 mangroves had moved inland, undoubtedly from the Boca Raton Inlet, and were found in most sites along Lake Wyman where they occurred in 1945.

Subsequent photographs show the continued invasion of the mangroves inland up the Hillsboro Canal. From all available evidence the mangroves in the Lake Wyman region are less than 55 yr old (Fig. 2). At present 10 species grow in the mangrove community: *Avicennia germinans, Caesalpinia bonduc, Dalbergia ecastophyllum, Distichlis spicata, Ipomoea macrantha, Laguncularia racemosa, Rhizophora mangle, Sesuvium portulacastrum, Suaeda linearis,* and *Thespesia populnea.*

The tropical hammock occupies part of the original location as it has since the 1800's (Williams, 1870). All of the remaining hammock is now found on the west side of highway A-1-A. Formerly there were extensions of the hammock east, but these have been destroyed and are now strand vegetation or Australian pines (*Casuarina equisetifolia*). The spoil mounds were almost free of vegetation in 1965 but are now dominated by *Casuarina* and *Schinus*. Eight hundred to 1000 ft of the southern end of the hammock was removed by the Sun and Surf Club.

There are now 32 species growing in the tropical hammock. Dominant trees are *Mastichodendron foetidissimum, Bursera simaruba, Simarouba glauca,* and *Eugenia axillaris* and *E. myrtoides*. Cabbage palms (*Sabal palmetto*) dominate in lower elevations and between the hammock and mangroves.

With a few exceptions (Fig. 1-2) the strand occupies the same areas it did in the 1800's (Williams, 1870). Saw palmetto *(Serenoa repens)* still dominates the community. Of the 50 species in the strand the most common are *Ardisia escallonioides, Myrsine guianensis, Coccoloba uvifera, Psychotria nervosa, Eugenia axillaris* and *E. myrtoides, Pisonia discolor, Pithecellobium keyense* and *Lantana involucrata*. Endangered *Jacquemontia reclinata* is frequent.

One of the most disrupting features of the strand has been the modern highway A-1-A. This right-of-way varies from 80-100 ft wide, the majority of which is used for high maintenance clean road shoulder. The activities of building and maintaining this Department of Transportation facility, and the activity of local citizens visiting the beach have given rise to a flora distinct from the other habitats. Some of these weedy plants, such as *Tridax procumbens,* were first collected on mainland Florida in the early 1900's (Small, 1910). Since their date of entry they have spread, mostly along roads. Thirty–nine species occur in disturbed sites. Most common are *Andropogon virginicus, Bidens pilosa, Catharanthus roseus, Dactyloctenium aegyptium, Gomphrena decumbens, Rhynchelytrum repens* and *Tribulus cistoides.*

The beach is the area of highest activity and changes seasonally depending on the severity of weather patterns. Single hurricanes have been reported to change coastlines drastically. In addition to seasonal changes is a trend of erosion. The exact cause of this erosion is obscure, but it may have been started by an attempt to maintain a road at the dune crest. There are several places where the bases of saw palmettos (*Serenoa repens*) are hanging free over the east side of the dune crest. These plants are rooted only in the youngest parts of their stems

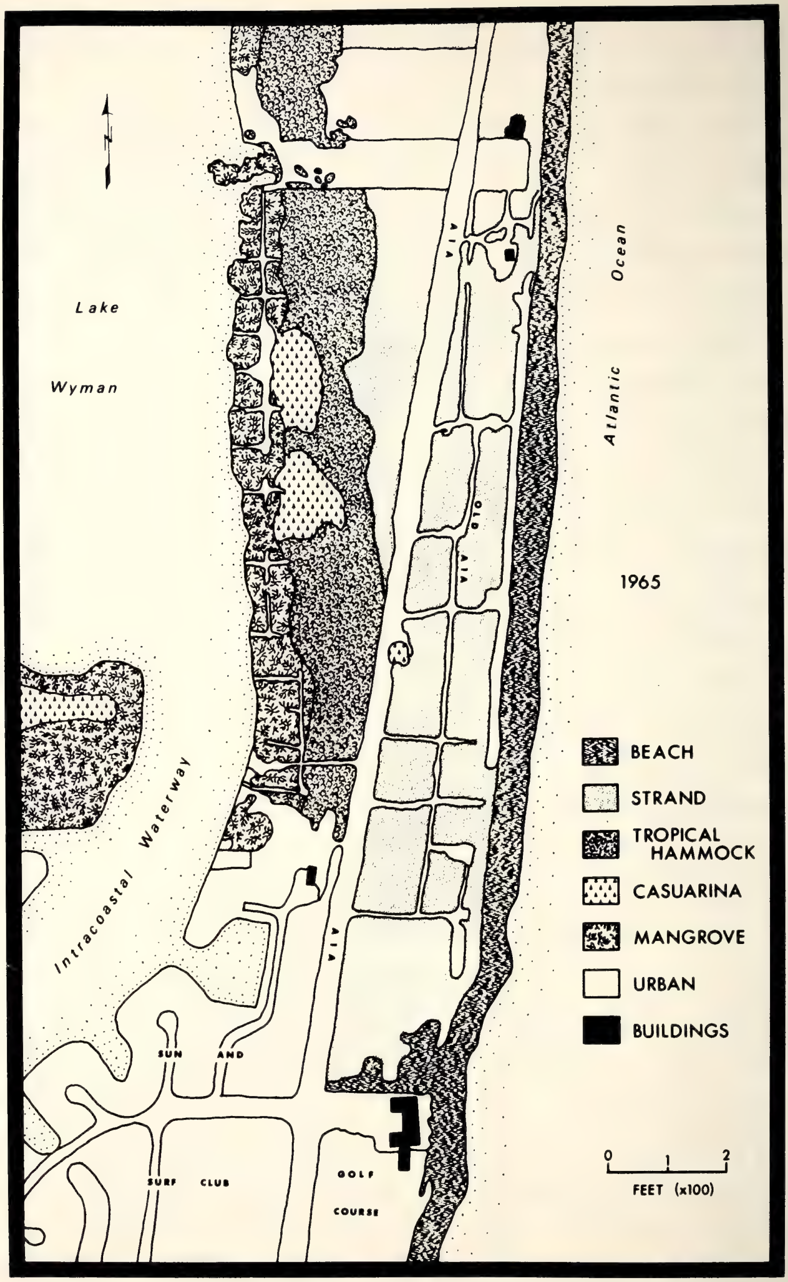


FIG. 2. Present plant associations on the Boca Hammock region with the major cultural features added. Based on 1965 aerial photography.

at the crest of the dune. Furthermore, the dune slopes gently toward the inland side, but slopes at a sharp angle on ocean side. There are some places where fires have burned up from the lower beach to the dune crest. Such burns eliminated the sea oats (*Uniola paniculata*) and opened the sites to faster erosion. One of the first plants to invade these sites is the beach star (*Remirea maritima*). Due to the sharp degree of the slope other pioneer beach plants may have difficulty in becoming established.

Many beaches have been divided into subzones (Sauer, 1967; Austin and Weise, 1972), and these appear to be successional stages. Usually recognized are the open beach, the *Ipomoea pes-caprae/Canavalia maritima* band, the *Uniola paniculata* region, and the prickly shrub zone. The first of these is well formed at the Boca Raton Hammock beach; the second is unusually narrow and crowded up the dune slope; the third is contracted and shifted up the dune slope; and the fourth is absent. These characteristics combined with the other data are indicators of an eroding beach.

Nineteen species have been found growing on the beach. In addition to the species named above, the following are common: *Alternanthera ramosissima, Cenchrus incertus, Chamaesyce mesembryanthemifolia, Helianthus debilis, Iva imbricata, Paspalum vaginatum, Scaevola plumieri* and *Sesuvium portulacastrum.*

Exotics—Most of the exotic plants on the tract are indicators of old homesites. Between 1940 and 1945 the Australian pine (*Casuarina equisetifolia*) appeared on several sites. Virtually all of the trees in the 1945 photography are still present as are many younger seedlings. Other plants growing near former buildings are *Bryophyllum pinnatum, Carissa grandiflora, Vitex trifolia,* and *Wedelia trilobata.*

At present, the pepper tree (*Schinus terebinthifolius*) is abundant in the strand and outer margins of the hammock. This South American weed tree is also abundant on the two spoil mounds. Since there is no way to distinguish this species from others in aerial photography, the date of introduction to the site and the manner remains obscure. Often the trees are planted for ornament near buildings and this manner of introduction is possible. The plants have been spread through the state by birds and this is another possibility at the hammock.

Colubrina asiatica has formerly been known only from Dade and Monroe Counties (Lakela & Craighead, 1965). Small (1933) included it as a naturalized species, but the date of introduction into the United States has not been determined. These plants also occur on the grounds of the Boca Raton Hotel & Club.

Acknowledgments—This study was supported in part by a grant from the Joint Center for Environmental and Urban Issues. We wish particularly to thank William Woodman, and other members of the City Parks and Environmental Divisions for various assistance with this project. The Boca Raton City Attorney's office helped in locating legal documents, old survey maps and descriptions, and various historical documents. James Marois was of great help in assisting the second author locate and select legal and historical materials pertinent to our study. Donald Vandergrift graciously made unpublished soil maps available for the study, and Patrick Gleason and James Milleson, Central and Southeastern Flood Control District, aided in gathering materials and dates on several aspects

of geology and hydrology. A full report and checklist of the site has been deposited at Florida Atlantic University and with the City of Boca Raton.

III. YAMATO SCRUB, *Daniel F. Austin.*

SINCE at least the middle 1800's the term "scrub" has been used to refer to a particular plant community in Florida (MacKay, 1845; Ives, 1856). Variations occur but the habitat is characteristically dominated by oaks (*Quercus* spp.), pine trees (mostly *Pinus clausa*) and saw palmetto (*Serenoa repens*). This habitat has been in Florida for at least 5000 yr (Watts, 1971). Many believe that the association has a much longer history, probably dating from the late Pleistocene (Cooke, 1939; Kurz, 1942; Laessle, 1958, 1967; Long, 1974).

Formerly a narrow band of scrub extended down Florida's east coast through Palm Beach, Broward and into northern Dade County (Small, 1913, 1921, 1924; Lakela and Craighead, 1965). As late as 1940 this habitat was widespread in northern Dade County (U.S.D.A., 1940). Increasing development from the 1950's to present has all but eliminated scrub in many places. In others scrub is so restricted that its flora and fauna are extirpated or at least decadent (Layne, 1974; Robertson and Kushlan, 1974). At present no preserved scrub has been set aside in Dade, Broward or Palm Beach Counties. Jonathan Dickinson State Park in southern Martin County is the only park of any kind in the area containing sufficient scrub to remain healthy.

Little is known of the ecology of this pineland, and virtually all of the past studies have been made of the concentration farther north in the state (Harper, 1927; Mulvania, 1931; Kurz, 1942; Davis, 1943; Laessle, 1958). Even the recent Sand Pine Symposium (U.S.D.A., 1973) contained little data on the southern reaches of the community. Data from the Yamato Scrub suggest that there are certain minor differences between the limits of the scrub community and the central Florida sites (Austin, 1976b).

HISTORY—Yamato Scrub takes its name from the former town of Yamato, now the northern part of Boca Raton. This town was located in Township 47S, Range 43E, for the most part in Sections 5, 6, 7 and 8. As the name of the town implies, the settlement was a Japanese colony. "Yamato" is said to be a 3000 yr old name for Japan (Malear, 1975). Before the land owned by the town was acquired by Joseph Sakai in 1903, it was part of Henry M. Flagler's domain. Flagler fell heir to this land as he did much of the land on the east coast because of his Florida East Coast Railway (Pozzetta, 1975). Settlers began arriving in Yamato in 1904 and by 1907 there were 200 in the colony. Supposedly most of them had worked for Flagler in building the FEC Railroad (Malear, 1975).

The settlers in the town were agriculturists. They grew a variety of crops including silk, tea, tobacco, rice and peppers, but their first cash crop was pineapples. The town thrived until it had a station on the Seaboard Railway. This station was formerly where the railroad is now crossed by 51st Street or Yamato Road. There was also a post office in the town during its height. Eventually the community was forced out of the pineapple business, largely by competition from Cuban farms, but one of the Japanese-owned farms produced and marketed the "Villa Rica" peppers for many years.

World War II had drastic effects on the town since the Japanese were removed to California and placed in concentration camps. By 1945 the Yamato colony had been vacated. The train station on the Seaboard Railway was still standing but apparently was not in use. Personnel stationed at the military base in Boca Raton used the siding farther south at Glades Road (T. T. Sturrock, personal communication). Most of the area in what is now Boca Raton between the FEC Railroad tracks and the Seaboard Railway tracks was part of the military installation. Yamato appears on aerial photography of 1945 as an abandoned area south of the westward bend in the Seaboard Railway tracks (Fig. 3). The area between the FEC Railway and the cultivated fields east of U.S. 1 had been subdivided by bulldozing roads and storm sewers had been installed in several areas. Active fields were being cultivated along the Intracoastal Waterway. Fields in other areas were mostly fallow.

After World War II the Japanese had apparently lost or sold most of their holdings in Yamato. Various tracts of land moved from one development group to

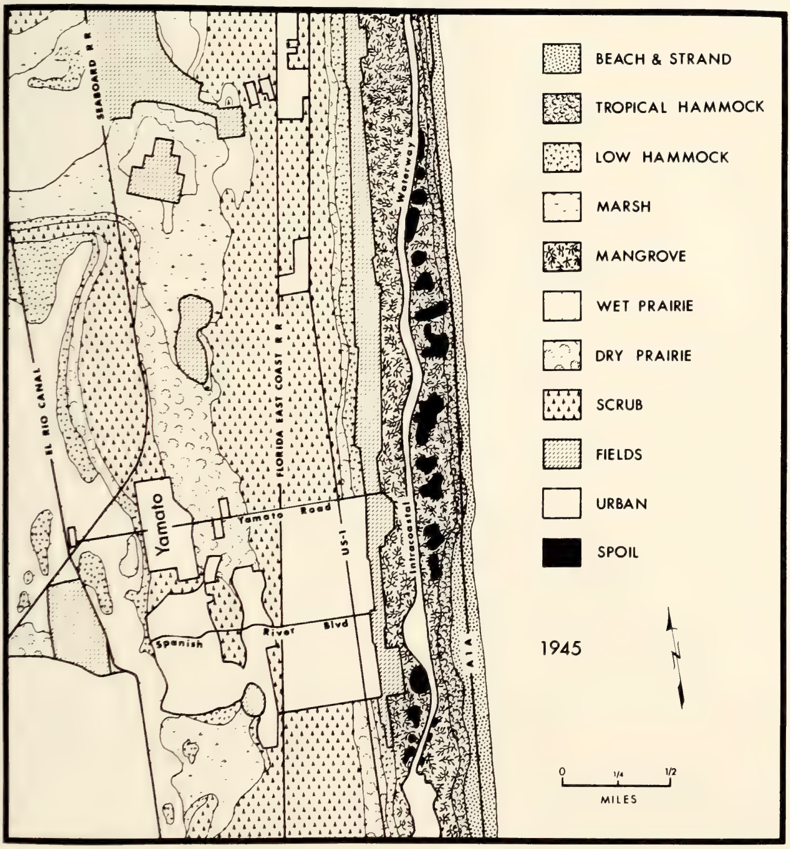


FIG. 3. Plant communities in the Yamato region in 1945 with the major cultural features added. Based on 1945 aerial photography.

another. Some of these speculators succeeded in establishing successful tracts, others did not. Various plats of defunct development plots are recorded in the Boca Raton court house. Probably the most famous is the "Villa Rica" development that was planned for the old Villa Rica pepper farm. It existed only on paper.

Eventually modern speculators bought up different parts of Yamato and some succeeded in establishing various settlements. Modern Boca Teeca, Lake Rogers Isle, Caribbean Key, Bel Marre and Boca Harbour subdivisions are built on the old Yamato sites. Today there are a few descendants of the original settlers but most have moved to other areas. The most famous in the area until recently was the late Mr. George Morikami (Fortner, 1976). He gave the state 40 acres of land for the Agricultural Experiment Station in Delray, and an additional 40 acres was donated for a regional park.

Physiography—Elevations in the Yamato region range from sea level to 30 ft. The beach ridge rises from sea level to above 15 ft; from Jap Rock south it reaches 20 ft. Behind this first dune the land slopes down into the Intracoastal Waterway where the elevation is mostly below 5 ft. Formerly this part of the Intracoastal Waterway was the headwater of the Spanish River, known from the 1800's to the early 1900's as Boca Ratones Lagoon or Sound (Austin and McJunkin, in prep.). West of this wetland the land rises to 16-18 ft on the first major ridge. An irregular break is found west of this rise, the present Hidden Valley subdivision occupying the northern portion, the Boca Teeca Golf Course the middle, and the Second Avenue marsh the south. Rising sharply to the west of this irregular depression is the major ridge or Yamato hill. This ridge rises sharply from 10 ft in the Second Avenue marsh to 20 ft and reaches 30 ft just northwest of the curve in the Seaboard Railroad. Varying somewhat between 25 and 30 ft northward, the ridge drops abruptly into the Yamato Marsh which is northwest of the Hidden Valley area. To the west of the Yamato hill is the drained wet prairie system in the El Rio Canal depression.

Soils in the region (Fig. 4) have been grouped into eleven types (U.S.D.A., 1973b). The beaches and a large part of the barrier island are made up of Palm Beach sands. These sands are of recent origin and consist of fragments of shells. There is a small triangle of Mangrove Peat or Tidal Swamp soil near Jap Rock, but most of the Intracoastal basin is covered with Okeelanta Muck. This same muck is the dominant soil in the Hidden Valley branch of the Yamato Marsh. Bordering the western side of the Intracoastal swale is a narrow band of Immokalee Fine Sand. This sand type is also scattered in other low areas and supports either low hammock vegetation or pine flatwoods or dry prairie.

The two ridges behind the Intracoastal basin are dominated by St. Lucie Fine Sand. Geologists generally agree that these quartzose sands originated in the southern Appalachians and were brought south to Florida on long-shore currents. During their movement they acquired many of their present characteristics: rounded grains, white color due to leaching. These sands are piled in deep ridges along the east coast as elsewhere and are characteristic of scrub associations. Geologists do not agree on the time of deposition of these sands or the

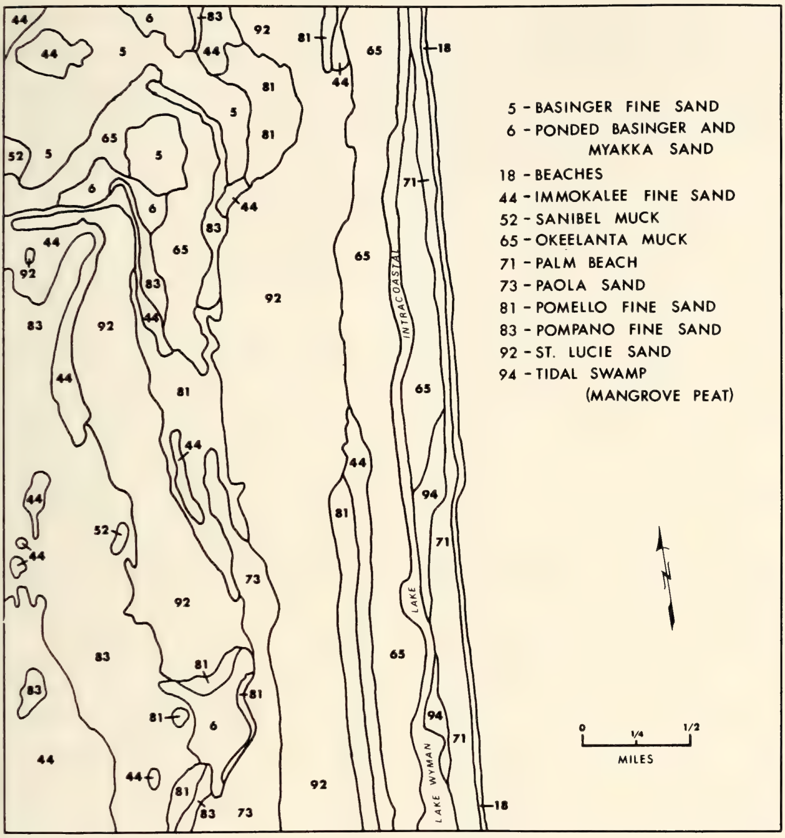


FIG. 4. Soil types and their distribution in the Yamato region.

manner (Cooke, 1939; Hoffmeister, 1974; Fairbridge, 1974), but most geologists believe that the ridges are ancient dunes associated in some manner with sea level fluctuation during the Holocene.

Regardless of the exact time or origin of these "fossil dunes" (Kurz, 1942), there are indications of at least five ridges in the Boca Raton-Yamato area. Most of these are badly eroded, and either coalescent or dissected. The ridges are undoubtedly of considerable age and their plant communities are considered the oldest in the area.

Another soil, the Paola Fine Sand, is reasonably extensive in the swale between the two major ridges in Yamato. This soil appears to differ little from St. Lucie, largely in its lower elevation (U.S.D.A., 1973b). Grain size is, from the examples examined at Yamato, identical. Both these grains and those of St. Lucie are frosted due to an aeolian history (Hoffmeister, 1974).

The most common soils in the marsh systems to the north and south of the Yamato Scrub are Okeelanta and Sanibel Mucks. These are freshwater organic soils several ft deep. Just south of the C-15 canal to the north of Yamato the Okeelanta Muck is as much as 7 ft deep. Presence of this freshwater muck in the Intracoastal basin is ample evidence that it was fresh in the recent past (Austin, 1976a).

Bordering the marshes and west of the highest Yamato ridge are flat areas with soils of Pompano, Basinger and Basinger-Myakka ponded types. These again are similar to the St. Lucie sands, but at lower elevations. Perhaps they are eroded features where the sands of the St. Lucie soils have been deposited near the surface. Pompano and Basinger soils almost always support wet prairies.

VEGETATION—Three early descriptions of parts of the Yamato region have been found (MacKay, 1845; Ives, 1856; Williams, 1870). Another report shows good detail for Section 7 (Butler, 1908). These sources, along with fragmentary descriptions elsewhere, and aerial photographs provide the basis for the early interpretations (Fig. 5).

Original Associations: In the region of Yamato there are habitats other than scrub. While the scrub is the main emphasis of this discussion, a brief description of the other communities is in order. The barrier island east of the Intracoastal Waterway was not part of the Japanese community, at least with regard to ownership. Beach vegetation spread along the coastal portion of the island. Behind the beach was a narrow strip of tropical hammock. This hammock continued south to join the Boca Hammock (Austin and Coleman, 1977).

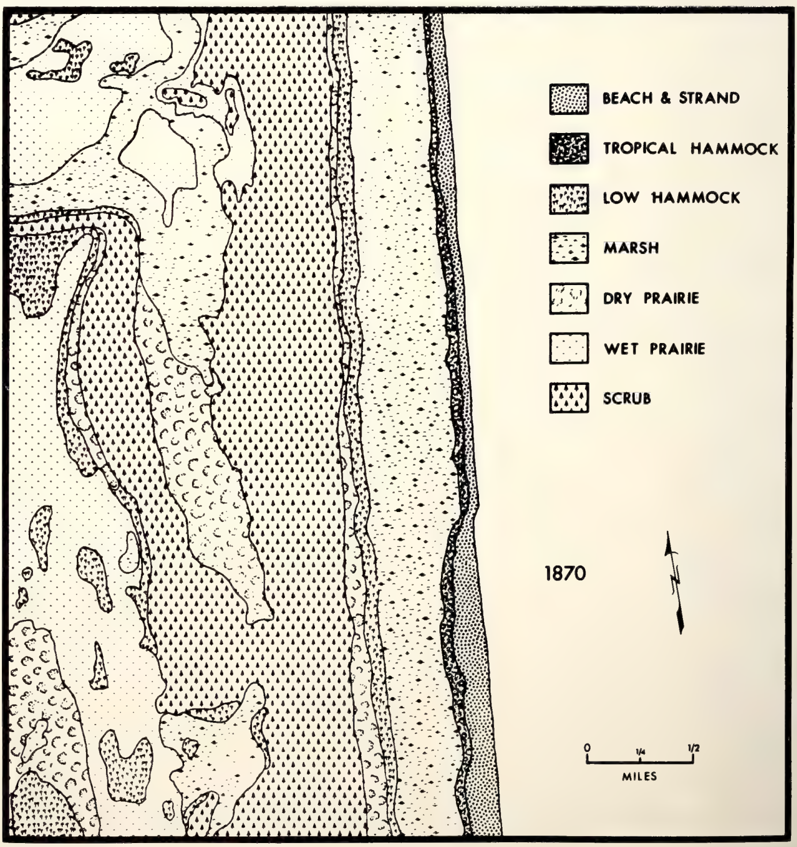


FIG. 5. Interpretation of the plant communities in the Yamato region in 1870. Based on 1845 and 1870 surveys and 1940 aerial photography.

West of the beach ridge the present Intracoastal basin existed. For most of its recent history this wetland was fresh. Data from DeBrahm (1773), Romans (1775), Tanner (1823), MacKay (1845), Ives (1856), Williams (1870), the Coastal Geodetic Survey (1884), Butler (1908) and others detail the condition of the water and the vegetation. From the earliest accounts until the 1920's the lowland was dominated by a freshwater sawgrass marsh (Austin, 1976a).

Butler (1908) showed a narrow strip of low hammock along the western margin of the Intracoastal basin. This hammock appears on the earliest photography in the same configuration and remains today in small fragments. To the west of the low hammock was a narrow strip of land dominated by saw palmetto (*Serenoa repens*) and slash pine (*Pinus elliottii*). This strip of vegetation had such a sparse covering of pines in 1940 that it best fits Harper's (1927) definition of dry prairie. Perhaps the pines had been cut off to feed Flagler's trains on the Florida East Coast Railroad, but no record has been found. For the purpose of this study, this and other areas along the coast with widely scattered slash pines, few or no remnants of stumps that would suggest logging, and no historical record of logging will be considered dry prairies.

The higher lands behind the dry prairie were covered with scrub. Two major dunes or hills support the scrub in Yamato. The eastern hill is lower, reaching only 17-18 ft. For most of its length the scrub is separated from the western hill. A small area connects the two dunes southeast of the Yamato settlement. In most respects these two scrub hills have a similar species composition. *Sabal etonia*, however, is not known from the eastern ridge. Other differences may have existed in the past but they are now obscured by development.

Through most of the length of these scrub hills they are separated by a lower region covered with other vegetation types. On the northern fringe of Yamato a marsh system enters from the northwest and reaches a terminus between the hills. South of the break in this marsh system another ponded marsh existed. Although the slight rise in elevation kept these two separated most of the yr, they were connected for short periods by moving surface water. A large part of the central depression was covered with dry prairie. Both of these marshes connected to a large wet prairie system on the western side. This wet prairie system was dissected by islands of dry prairie, low hammocks and occasional ponded marshes.

Present Associations: By the 1940's many changes had been made in the Yamato vegetation. Most of the changes fragmented the previously continuous communities or eliminated portions where the land was invaded by disturbance plants. The only community shift that had occurred was in the Intracoastal basin. As early as 1895 the Intracoastal Canal had been dredged past Yamato (Handbury, 1896). This and other drainage and dredging operations had changed the water in the Intracoastal from fresh to brackish and allowed mangrove intrusion to occur. By the time the 1940 aerial photographs were made the entire basin was covered with mangroves. Soils in this part of the basin were classified as Okeelanta Muck in the 1940's (U.S.D.A., 1946) and continue to be called the same today (U.S.D.A., 1973b). Mangroves have covered the area for over 30 yrs and the soils have not changed appreciably.

Digging the Intracoastal Canal produced another site for disturbance plants in the area, the spoil mounds. These mounds were rapidly invaded by a variety of herbaceous species and later by oaks and palmettos. They are now dominated by two exotic trees, *Schinus terebinthifolius* and *Casuarina equisetifolia.*

Numerous fields were either in cultivation in the 1940's or had just become fallow. The fields that were cultivated by the Japanese before the war are not known, but they grew peppers and other commercial food plants along the western side of the Intracoastal wetland shortly after World War II. Croplands to the north and south of the town appear on the 1940 and 1945 photography.

Prior to the war pineapples were the main crop of the area. Where these plants were grown has not been determined, but photographs of the Boca Raton croplands show pineapples in scrub pinelands (Curl, 1975).

Creation of the military base southwest of Yamato obliterated most of the communities in that area. The 1940 photographs show the remains of a large low hammock just north of what is now the Biology Building on the Florida Atlantic University campus. By 1945 a complex of barracks and roads laced the scrub south of Yamato between the FEC Railroad and the El Rio Canal. East of the FEC Railroad a large tract of land had been subdivided but the pine trees were still standing between the sand roads. This area still shows remnants of the old roads near Yamato Road and storm sewers are scattered through the area. Curiously one of the earliest areas to be prepared for development in the 1940's has been one of the last to be developed. Reasonably large stands of pines exist in this old development, but most of the ground layer species have been eliminated by constant mowing.

In the 1908 survey by Butler an Indian mound is shown near the Intracoastal Canal on the south boundary of section eight. This mound was southwest of Lake Rogers, called then Little Lake Wyman. When the subdivision called Lake Rogers Isle was built the mound was eliminated. No mounds are shown north of this on the 1908 survey.

Occupying a large part of what was formerly Yamato is the present Boca Teeca Country Club. This country club sits on the western slope of the east scrub ridge. The golf course is laid out on the dry prairie that was formerly between the two ridges. To the north of this complex, the Hidden Valley subdivision has been built on what was formerly a marsh. This marsh was not adequately drained until the C-15 Canal was built in the 1960's.

The city of Boca Raton has spread in the last few years onto the former town site of Yamato. Interstate Highway 95 cuts across the northwestern corner of Yamato and most of the scrub south of the Seaboard Railroad track has been eliminated or fragmented so badly that what remains is negligible. Only north of the Seaboard track is there a good stand of scrub remaining on Yamato hill. The scrub on Yamato hill is a healthy stand. Various disturbance features exist, but the stand is large enough that it maintains much of the original diversity. Clint Moore Road, connecting Boca Teeca with Congress Avenue has bisected the scrub from east to west. Within the scrub, old subdivision roads are frequent and first appear on the aerial photographs of the early 1960's. Dumping has cluttered some of the old roads, but this has been hidden in most by the vegetation.

Exotics: Many of the plants on the disturbance site list are exotics. The degree to which they are influencing native vegetation varies with the different species. Within the scrub there seems to be little real competition between natives and exotics. *Schinus* and *Casuarina* may be found scattered throughout the area. From the observations made in the area over the past six years (1970-1976), these exotic trees compete with native plants only in badly disturbed sites. Where disturbance is recent or continual, as on roadsides, railroad beds, yards, cultivated fields, the exotics eliminate many native species. On the other hand, in the scrub where the disturbance is not repeated and happened some distance in the past, the scrub plants appear able to hold their own against the exotics.

ACKNOWLEDGMENTS—This study was supported in part by a grant from the Joint Center for Environmental and Urban Issues. Students in several of my classes have helped in preparing voucher specimens. A full report and checklist of the site has been deposited at Florida Atlantic University.

IV. BUTTS HAMMOCK, *Daniel F. Austin and Donald R. Richardson.*

MOST LITERATURE on the plant associations of southern Florida recognizes two basic types of hammocks: tropical or high hammocks and low or temperate hammocks. Variations of these categories have been used by Harshberger (1914), Harper (1927), Davis (1943), Alexander (1955, 1967), Craighead (1971, 1974) and others. In some areas the distinction between these two types is clear; in others the definition is more difficult. Basically the question seems to be how tropical a hammock must be to be "tropical." On the basis of species composition, must the line of distinction be 90% tropicals, 80% tropicals, or perhaps 70%. For the majority of hammocks previously studied the problem is not great. Costellow Hammock has an 82% tropical composition (Phillips, 1940); Matheson Hammock has 84% (Avery, 1968); the former Pompano Beach Hammock had about 87% (Alexander, 1959); and Boynton Hammock has 85% (Austin and Weise, 1972). Most Florida botanists appear to agree that these are tropical hammocks, but when the percentage falls below these figures opinions are more diverse.

Simpson (1920) drew the line of tropical limits on the southeastern coast near Ft. Lauderdale. Still, along the coast from Ft. Lauderdale to Cape Canaveral hammocks may be found that qualify as tropical. From Simpson's Line northward inland hammocks are not common. Most of those known are clearly low hammocks with a strong temperate or palm composition. Apparently unique on the southeastern coast is the small hammock on the southern edge of the old Butts Farm near Boca Raton. Not only is this hammock unusual in its tropical composition at this latitude, but it is also of interest because of its association with the former Hillsboro River system. The Butts Hammock, with its 73% tropical species composition, is found almost 5 miles from the nearest point on the coast.

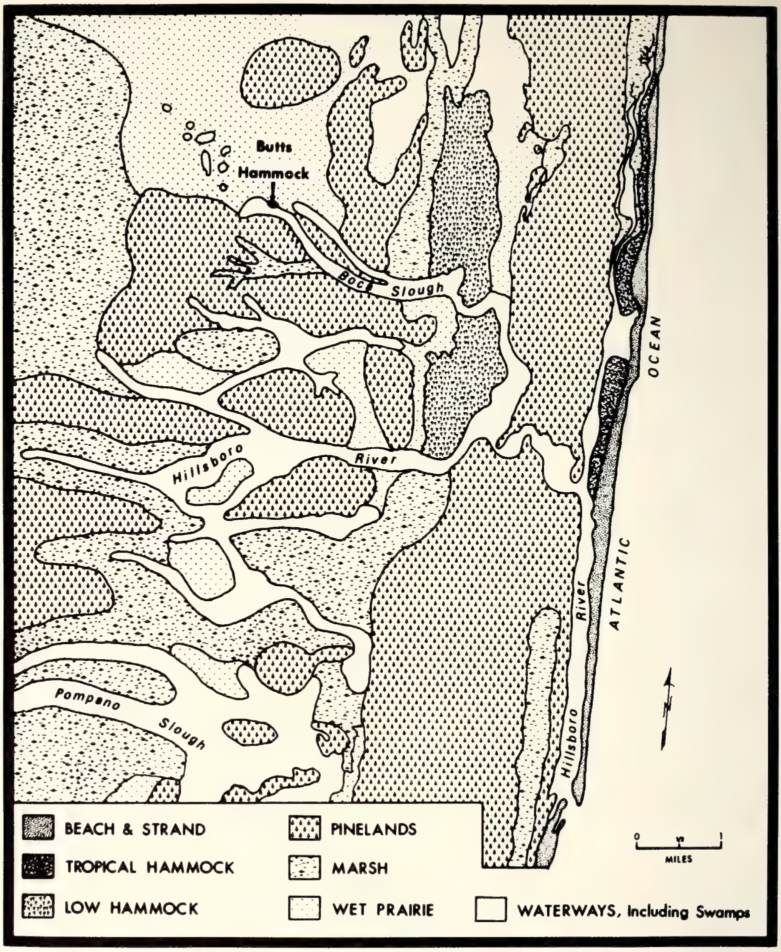


Fig. 6. Generalized vegetation map of the Butts Hammock region before drainage. Interpreted and adapted from MacKay (1845), Williams (1870) and U. S. G. S. (1940).

Similar composition is not known for any other inland hammock on this coast near this latitude (Fig. 6).

History—Butts Hammock and the associated wetlands are found in the southwestern corner of Section 15, Range 42E, Township 47S. In 1890 this land and the surrounding area belonged to the State of Florida, being held by the Internal Improvement Fund. By 1892 the land had been transferred to the Boston & Florida Atlantic Coast Land Company. This northeastern based land company held the property until it was obtained in 1924 by two local speculation offices: Lake Webster Land Company and the Model Land Company. Eventually most of the land was obtained by the Model Land Company, a Henry M. Flagler enterprise. This Flagler company held the property until the Lake Worth Drainage District took control in 1930. There are no records that any of these early owners changed the land in any way.

The first members of the farming families, A. H. Butts and later his son, Harold, bought the land in 1933. For most of its history, the Butts farm occupied as much as 6 sections or nearly 4200 acres. The land remained within the Butts family for the next two decades, with most of the active parts being to the north of the tropical hammock. This farm was an important regional producer of beans, citrus and a variety of other truck crops for about the next 30 yr.

Arthur Vining Davis owned much of the land east of the Butts farm by the early 1960's. In 1963 Davis purchased most of the farm, with the remaining portions being sold within the Butts family or to close relatives. The late Thomas Fleming, a banker in Boca Raton and former sales manager on the Butts farm, maintained a home adjacent to the east side of the Butts Hammock/Swamp system until the 1970's. Portions west of modern Powerline Road remained in the family for several more years and as late as 1975 the Butts family still owned one of the original sections.

In the same year that he bought the majority of the farm (1963), Davis transferred it to the Arvida Corporation. Arvida has controlled the land since, but there was little new development until the late 1960's. Near the hammock the major activity before the 1970's was the Arvida Nursery. This nursery extended from the northern fringe of the tropical hammock to Glades Road (about 250 m), and during its height had several thousand kinds of plants in cultivation. In 1975 the nursery was moved. From about 1973 to present a 7 acre portion of the swamp west of the Butts Hammock has been dedicated as a preserve. More recently the construction of the Los Paseos development on the northern fringe of Butts Hammock has begun. In 1976 plans were not final for the tropical hammock, but recent discussions call for a nature walk through its center.

Physiography—Perhaps the most important factor in the development of the Butts Hammock was its elevation. At the center of the hammock the altitude is 25 ft msl. This contrasts with the area to the north which, until recently, supported flatwoods at near 17 ft. The swamp system on the south side of the hammock is 14-15 ft in elevation. Such a comparatively high elevation of the hammock perhaps caused the colder air to flow down from the heights and mediate a milder climate within the hammock. Another factor affecting the hammock must have been the ponded swamp where the water had an ameliorating effect on the potential for the ridge to support tropical vegetation.

Within the hammock there is little soil, the substrate being mostly an outcrop of limestone. The limestone is largely of the Ft. Thompson association (Cooke, 1945). Stone outcrops in the area are rare since most bedrock is overlain with several ft of sand. The wet prairie/pine flatwoods system north of the hammock is underlain with Pompano Fine Sand and Immokalee Fine Sand (U.S.D.A., 1973b), with wet prairie being confined to the former and flatwoods to the latter.

The most recent soil maps list the swamp system as having Pompano Fine Sand (U.S.D.A., 1973b), but closer examination shows that the soils are actually Okeelanta Muck. This soil has about 8 inches of black muck on the surface. Below the surface is a layer of dark reddish brown muck extending down to as much as 31 inches. The second layer is subtended by sandy materials to depths of as much as 65 inches.

To the south of the Boca Slough Swamp system was an expanse of land formerly covered with scattered pine woods or palmetto/oak woods. These communities occurred in a mosaic apparently dependent on local slope and proximity of the limestone to the surface. Boca Fine Sand covered most of the area.

Before drainage began with the opening of the Hillsboro Canal in 1921, the Boca Slough swamp system to the south of Butts Hammock was a northern branch of the Hillsboro River system. This and the several swamps to the south were mentioned by Motte (1963) during the 1838 military campaign in the Second Seminole War. Motte did not mention the Boca Slough specifically but commented on the army having to cross ". . . several cypress swamps with deep streams flowing through their center. . . ." (Motte, 1963: 220). Similar descriptions of swamps and riverine conditions were given by MacKay (1845) and Williams (1870) during the first surveys of the region.

Before it was drained the Hillsboro River reached from the eastern side of the Everglades across the Atlantic Coastal Ridge to spill excess water from the inland swamps (Fig. 7). In 1921 this normal cycle was eliminated and the Hillsboro Canal began dumping fresh water into the Atlantic Ocean constantly. The salinity dams that were later added, and the Lake Worth Drainage District have some control on water losses, but the surface drainage patterns have been so badly altered through levees, canals, filling for urban development and similar disruptions that the old Hillsboro River functions only during severe storms.

The numerous depressions crossing or partially crossing the Atlantic Coastal Ridge in the Hillsboro River system appear superficially like the transverse valleys or glades noted in the Everglades National Park (Hoffmeister, 1974). Perhaps the origin of these depressions on the southeastern coast was different from those in the Everglades Keys. Although fragmentary, the geologic literature on the region suggests that the Hillsboro River functioned from about the post-Wisconsin times to present in draining the Everglades basin (Cooke, 1945; Scholl et al., 1969; Fairbridge, 1974). Since the dune and swale topography of the area was formed during the same time period, the various transverse depressions may be old channels for the Hillsboro River. The Boca Slough would be a former channel that emptied into the ocean before the three ridges east of it were formed. Formation of these eastern ridges blocked the water flow through the Boca Slough and a new channel appeared as the pre-canalization Hillsboro River. Other sloughs may be explained as contemporary with other ridge systems.

Vegetation—The earliest records of vegetation in the Butts Hammock area come from Motte (1963) and the surveys by MacKay (1845) and Williams (1870). Neither of these is very detailed, but general patterns are clear. There appear to be no records from the late 1800's until the 1940 photography, and then aerial photographs are available at regular intervals.

Original Vegetation: Before drainage and farming began after the turn of the century there were five habitats associated with the Butts Hammock: wet prairie, swamp, dry prairie, pine flatwoods, low hammock and the tropical hammock itself. Butts Hammock was never large, probably never more than 35 m long and 10-15 m wide. Surrounding most of the tropical hammock was a low ham-

FIG. 7. Pre-1900 surface drainage patterns in the Hillsboro River area. Arrows indicate direction of flow in the wetlands. Upland areas occupied by pinelands and hammocks probably showed a general trend like the lowlands.

mock dominated by oaks (*Quercus* spp.) and saw palmetto (*Serenoa repens*). This low hammock extended several hundred yards to the east along a low limestone ridge. A similar low hammock ridge paralleled this on the south side of the Boca Slough swamp.

Boca Slough was dominated throughout its length with swamp vegetation although there were scattered low hammocks in various areas. The ponded swamp just west of Butts Hammock was the western terminus of the continuous low slough. West of this the swamp system broke into scattered cypress heads or domes. Perhaps these ponded swamps lie in a former channel of some previous Hillsboro River. Most of the area north of the hammocks and swamps was wet prairie. To the south the land was covered with pine flatwoods and dry prairies.

Several of the original habitats began to change as soon as the Hillsboro Canal was opened in 1921. By the 1930's when the Butts family moved to the area, the canal had dropped the water table and fires had increased throughout the region. Much of the wet prairie system north of the hammock had begun to change to pinelands. Drying reduced the hydroperiod (Thomas, 1974), so that by the 1940's slash pines (*Pinus elliottii* var. *densa*) were scattered throughout. By this time most of the former wet prairies had been changed to cultivated fields. Some road clearing had taken place south of the swamp system by 1949, but most of the pinelands and dry prairies were not disturbed.

In the 1949 photography the land adjacent to the low and tropical hammock had recently been cleared. This clearing eliminated much of the low hammock vegetation on the north side of Butts Hammock. For several yr occupants of the house built in this clearing maintained fields nearby, and used the hammock for a variety of purposes. Barrel hoops and crock fragments are scattered in the hammock; two large papayas (*Carica papaya*) on the northern edge of the hammock also date from this period.

The Butts farm remained active in more or less the same areas, with little clearing of new hammock or swamp lands until large parcels of land were sold to the Arvida Corporation. From the time the land was sold until Arvida started urbanization, the former farmland lay fallow. Bean fields with windscreen rows of oranges in the nearly half-section north of the hammock were neglected, and signs of the former farm began to disappear. In the last half of the 1960's Arvida began to develop the Boca West Estates north of Glades Road. This marked the beginning of the recent changes near the hammock.

In 1969 the new route of Powerline Road was cut through the western edge of the tropical hammock. Four years later, in 1973, large tracts of land west of the swamp system and bordering the new Powerline Road right-of-way began being bulldozed for the Estancia development. In 1975 the plant nursery Arvida had maintained for several yr was moved to begin construction of the Los Paseos community east of Estancia.

Present Associations: Due to urbanization of the area all of the wet prairie formerly north of Butts Hammock has disappeared. The majority of the swamps west of the hammock and all of the dry prairies are gone. One 7 acre piece of the upper end of the Boca Slough swamp has been set aside by Arvida as a community park called the "Estancia Hammock." This is actually a complex of habitats with the center being dominated by swamp and the fringes either disturbed swamp, low hammock or urbanized.

A small part of the Butts Hammock remains, with the Boca Slough still extending for some distance along the southern edge. The tropical hammock is bordered on the north, east and south by low hammock. Powerline Road has replaced the low hammock and part of the tropical hammock on the western side. Only about 25-30 m of tropical hammock remains.

Of the 132 species of plants in the hammock and swamp systems, 8% are marsh/wet prairie species and 30% are swamp plants. About 28% of the plants grow in disturbed sites. Some 70 species of plants are found in the hammocks. Of these 66% in the low and tropical parts of the hammock have tropical affinity, but 73% of the plants growing in the highest hammock are tropical.

Exotics: Within the hammock itself, 11 species are exotics. There are five trees, two shrubs, one vine, one fern and two herbs. Each of these has had a different effect on the ecosystem.

The most important in terms of human and habitat health is the pepper tree, *Schinus terebinthifolius*. These relatives of poison ivy cause contact dermatitis in many people and have been implicated in respiratory problems in others (Morton, 1971). Various attempts by different people to eliminate single trees have been less than successful. When disturbance of any kind occurs in the hammock these trees invade, lasting for several yr, inhibiting growth of native plants underneath by shading and perhaps allelopathy, and keeping native hammock trees from reproducing.

Guavas (*Psidium guajava*) have been naturalized in the state longer than the pepper tree, but would appear to be less of a problem ecologically. Little major damage is caused by these trees in the hammock since it is mostly too high and dry for them. These trees usually invade disturbed swamps.

Papaya (*Carica papaya*) has been naturalized in Florida from Cape Canaveral to the Keys since at least 1769 when Romans (1775) found them. These plants invade open sites but do not persist when the canopy begins to close.

Three species are persistent from cultivation. Oranges (*Citrus sinensis*) and grapefruits (*Citrus paradisi*) are on the northwestern edge of the hammock and there is a single clump of sleeping hibiscus (*Malvaviscus arboreus*) on the northeastern edge.

Caesar's weed (*Urena lobata*), a shrub introduced from the East Indies as a fiber source, has become widely naturalized. Almost any disturbed margin in the hammock will be dominated by these plants for over a year after the initial disruption.

The other exotic plants, *Sarcostemma clausa*, *Nephrolepis exaltata*, *Emelia sonchifolia* and *Tridax procumbens*, are seasonally and locally abundant but do not appear to have sufficient biomass or other traits to severely alter the hammock. Records are not available on all of these species regarding dates of introduction, but *Nephrolepis exaltata* was first recorded in 1859 and *Tridax procumbens* was found on the mainland in 1903.

CHECKLIST OF PLANTS IN BUTTS HAMMOCK

TH = Tropical Hammock; LH = Low Hammock.

Trees

1. *Bursera simaruba* (L.) Sarg. Gumbo Limbo; TH; Tropical
2. *Carica papaya* L. Papaya; TH, LH; Tropical
3. *Chrysophyllum oliviforme* L. Satin Leaf; TH, LH; Tropical
4. *Citrus paradisi* Macf. Grapefruit; LH; Tropical
5. *Citrus sinensis* (L.) Osbeck. Sweet Orange; LH; Tropical
6. *Diospyros virginiana* L. Persimmon; LH; Temperate
7. *Drypetes laterifolia* (Sw.) Krug & Urban. Guiana Plum; TH; Tropical
8. *Exothea paniculata* (Juss.) Radlk. Inkwood; TH; Tropical
9. *Ficus aurea* Nutt. Strangler Fig; TH, LH; Tropical

10. *Mastichodendron foetidissimum* (Jacq.) Cronquist. Mastic; TH; Tropical
11. *Morus rubra* L. Mulberry; TH, LH; Temperate
12. *Nectandra coriacea* (Sw.) Griseb. Lancewood; TH; Tropical
13. *Pinus elliottii* Engelm. Slash Pine; LH; Temperate
14. *Psidium guajava* L. Guava; TH, LH; Tropical
15. *Quercus chapmanii* Sarg. Chapman's Oak; LH; Temperate
16. *Quercus geminata* Small. Scrub Live Oak; LH; Temperate
17. *Quercus virginiana* Mill. Live Oak; TH, LH; Temperate
18. *Sabal palmetto* (Walt.) Lodd ex Schultes. Cabbage Palm; TH, LH; Tropical
19. *Schinus terebinthifolius* Raddi. Pepper Tree; TH, LH; Tropical
20. *Trema micrantha* (L.) Blume. Florida Trema; TH, LH; Tropical

SHRUBS

1. *Ardisia escallonioides* Schlecht. & Cham. Marlberry; TH; Tropical
2. *Baccharis halimifolia* L. Saltbush; TH, LH; Temperate
3. *Callicarpa americana* L. Beauty Berry; TH; Tropical
4. *Coccoloba diversifolia* Jacq. Pigeon Plum; TH; Tropical
5. *Eugenia axillaris* (Sw.) Willd. White Stopper; TH; Tropical
6. *Lantana camara* L. Lantana; TH; Tropical
7. *Lyonia ferruginea* (Walt.) Nutt. Staggerbush; TH, LH; Temperate
8. *Malvaviscus arboreus* Cav. Sleeping Hibiscus; TH; Tropical
9. *Myrcianthes fragrans* (Sw.) McVaugh. Simpson's Stopper; TH; Tropical
10. *Myrsine guianensis* (Aublet) O. Ktze. Myrsine; TH; Tropical
11. *Psychotria nervosa* Sw. Wild Coffee; TH; Tropical
12. *Psychotria sulzneri* Small. Wild Coffee; TH; Tropical
13. *Rhus copallina* L. Dwarf S. Sumac; LH; Temperate
14. *Serenoa repens* (Bartr.) Small. Saw Palmetto; TH, LH; Temperate
15. *Urena lobata* L. Caesar's Weed; TH, LH; Tropical
16. *Ximenia americana* L. Tallow Wood; TH; Tropical
17. *Zanthoxylum fagara* (L.) Sarg. Wild Lime; TH; Tropical

EPIPHYTES

1. *Tillandsia balbisiana* Schult. Reflexed Wild Pine; TH, LH; Tropical
2. *Tillandsia fasciculata* Sw. Cardinal Wild Pine; TH, LH; Tropical
3. *Tillandsia recurvata* L. Ball Moss; TH, LH; Tropical
4. *Tillandsia utriculata* L. Giant Wild Pine; TH, LH; Tropical

VINES

1. *Ampelopsis arborea* (L.) Rusby. Pepper Vine; TH, LH; Temperate
2. *Ipomoea alba* L. Moonflower; LH; Tropical
3. *Melothria pendula* L. Creeping Cucumber; TH, LH; Tropical
4. *Mikania scandens* (L.) Willd. Hemp Vine; LH; Temperate
5. *Parthenocissus quinquefolia* (L.) Planchon. Virginia Creeper; TH, LH; Temperate
6. *Sarcostemma clausa* (Jacq.) Roem. & Schultes. White Vine; LH; Tropical
7. *Smilax bona-nox* L. Greenbriar; LH; Temperate
8. *Smilax havanensis* Jacq. Sawbriar; LH; Tropical
9. *Smilax laurifolia* L. Bamboo Vine; LH; Temperate
10. *Toxicodendron radicans* (L.) Ktze. Poison Ivy; TH, LH; Temperate
11. *Vitis rotundifolia* Michx. Muscadine Grape; TH, LH; Temperate
12. *Vitis shuttleworthii* House. Calusa Grape; TH, LH; Temperate

FERNS

1. *Campyloneuron phyllitidis* (L.) Presl. Strap Fern; TH; Tropical
2. *Nephrolepis exaltata* (L.) Schott. Boston Fern; TH, LH; Tropical

3. *Phlebodium aureum* (L.) Sm. Cabbage Palm Fern; TH, LH; Tropical
4. *Polypodium polypodioides* (L.) Watt. Resurrection Fern; TH; Tropical
5. *Psilotum nudum* (L.) Beauv. Whisk Fern; LH; Tropical
6. *Pteridium aquilinum* (L.) Kuhn. Bracken Fern; TH, LH; Temperate
7. *Thelypteris kunthii* (Desv.) Morton. Marsh Fern; TH, LH; Tropical
8. *Vittaria lineata* (L.) Sm. Shoestring Fern; TH; Tropical

HERBS

1. *Emelia sonchifolia* (L.) DC. ex Wight. Tassel Flower; TH; Tropical
2. *Lippia nodiflora* Michx. Creeping Charlie; TH, LH; Tropical
3. *Panicum portoricensis* Desv. ex Ham. Panic Grass; TH; Tropical
4. *Rivina humilis* L. Rouge Plant; TH; Tropical
5. *Sida acuta* Burm. f. Indian Mallow; TH; Temperate
6. *Trichostema suffrutescens* Kearney. Blue Curls; LH; Temperate
7. *Tridax procumbens* L. Tridax; LH; Tropical
8. *Verbesina virginica* L. Frostweed; LH; Temperate

ACKNOWLEDGMENTS—This study was partially supported by a contract to the first author with the Arvida Corporation. We wish to thank Donald Vandergrift of the Soil Conservation Office (West Palm Beach) for providing soils maps. Marshall DeWitt, presently of the Sun Banks, Inc., formerly Supervisor of the Lake Worth Drainage District (1945-1956) and in a management position on the Butts farm (1948-1963), gave us much historical information and read a draft version of the historical section. Roy Lemon (Department of Geology, Florida Atlantic University) checked identification of the limestone.

V. BOCA RATON INLET, *Daniel F. Austin.*

MOST of the inlets in Florida have a long, complex, and only partially recorded history. Reports of inlets closing or opening are scattered through the literature, although not many have been studied in detail (see, for example, DuBois, 1960). In Florida few of the relationships between inlets, coastal vegetation and dune stabilization have been documented even though there have been a number of studies (e.g., Kurz, 1942; Davis, 1943, 1975). Some of the relationships between changes in the Boca Raton Inlet and vegetation are presented in the following discussion.

HISTORY—Modern Lake Boca Raton and the associated inlet are in the southeastern part of Township 47S, Range 43E, in Sections 28 and 29. Early names of this inlet near latitude 26°21'N have been discussed elsewhere (Austin and McJunkin, in prep.). The first time an inlet in this area was recorded was on the Freducci map of 1514-1515. This map is thought to have been drawn from the notes of the voyage of Ponce de Leon (True, 1954). Records of physical change, however, began with the surveys by DeBrahm (1773) and Romans (1775) in the 1760's. During those surveys DeBrahm and Romans recorded that the inlet was on the northeastern corner of the lake that later became known as Boca Raton. Several maps copy the 1760's configuration with little change (Sayer and Bennett, 1776; Hinton et al., 1832; Illman and Pilbrow, 1837) although the map by Gauld (1794) was supposedly based on actual surveys. The next accurate record was provided by MacKay (1845) who surveyed the lines of the township. In his field notes of one of the southern lines this surveyor recorded ". . . bog becomes impassible—compelled to abandon line—set high post—not any inside passage —we were obliged to remove provisions around by boat to Boca Rattones—hauled boat over—followed sound north about 4 miles and made landing, by hauling boat 1/4 of a mile thru mud 3 feet deep—3 inches water—head of navigation for small boats . . ." This was written on April 2, the dry season.

During the Second Seminole War Lt. J. C. Ives of the U.S. Topographical Engineers gave another account of the lake and the inlet. After discussion of the passage from the Orange Grove Haulover, Ives said of Lake Boca Ratones: ". . . this sheet of water is a mile and a half wide and three quarters of a mile long. The sand bank which separates it from the sea is, in one place, only a hundred yards wide. Here there was once an inlet. The timbers of a ship lie buried in what was formerly the channel. It is said by the Indians that many years ago a wrecked vessel drifted on to the bar, and, being left there by the receding tide, formed a nucleus about which sand collected and closed the mouth of the river" (Ives, 1856: 15).

The sections were first surveyed by M. A. Williams in 1870. Field notes and sketch maps recorded in Tallahassee that year show no inlet at "Boca Ratoones Lagoon" during the wet season in August, and provide the first detailed map of the area. Ives' (1856) map was one of the first general maps of the southern end of the peninsula to show vegetation patterns accurately, but it lacked the local detail of the Williams survey. A coastal survey was made again in 1883 (U.S.G.S., 1884) and a similar account was recorded by one of the barefoot mailmen for the 1890's (Pierce, 1970). The East Coast Canal Company dug the first "Intracoastal Waterway" past the Boca Raton Inlet in 1895 (Handbury, 1896). This canal had some local effect on vegetation, but little compared to the changes caused by the opening of the Hillsboro Canal in 1921. Mangroves were scattered through the lake margins prior to the opening of the Hillsboro canal, but drastic reduction in fresh water allowed a dramatic invasion by the 1940's (Austin, 1976a).

Some time between 1906 and 1926 the Boca Raton Inlet was opened by the new town of Boca Raton (U.S.G.S., 1906; Mizner, 1926). Late in 1926 the Mizner Development Corporation planned a new inlet about 1200 ft north of the old one in almost the modern configuration. Two years later the devastating 1928 hurricane swept through littering the beaches and burying the section corner posts so deeply that they were not found by later survey teams (U.S.G.S., 1929). The present inlet was opened some time between 1926 and 1932; reports vary on the year (Wymbs, 1976).

In 1934 the corner was again surveyed and this time the posts were found under 2-5 ft of sand. Reference mark no. 3 was covered with "junk and mangroves" (U.S.G.S., 1934). That same year a new point was established, Boca Raton 2, some 38 m north of the old section corner.

From 1940 to present no major changes in the inlet are recorded (U.S.G.S., 1940; C.G.S., 1945; U.S.D.A., 1964; Palm Beach County, 1973). The 1947 hurricane took out the jetties and caused general filling and litter, but no damage to

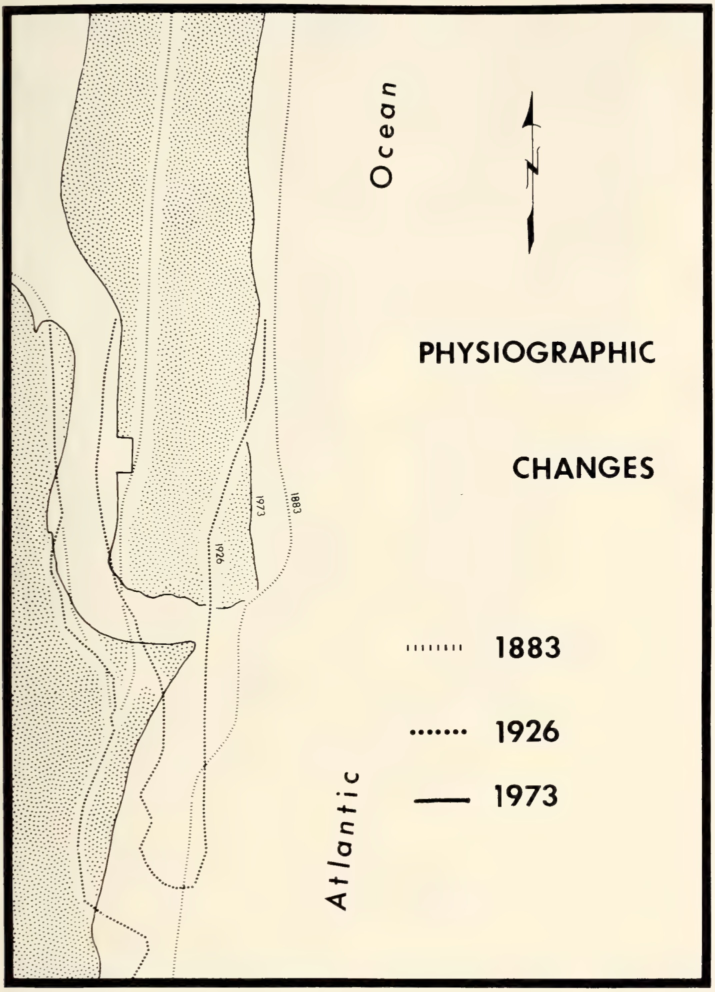


FIG. 8. Physiographic changes in the Boca Raton Inlet in the past 90 years. Based on U. S. G. S. (1884), Mizner (1926) and Palm Beach County (1973).

the inlet occurred. Jetties on the inlet were not fully repaired until the 1970's. During the last 50 yr erosion and deposition changed the area considerably (Fig. 8).

PHYSIOGRAPHY—North of the inlet a steep sand dune dominates the landscape. This dune reaches over 25 ft msl elevation for much of the eastern side of Lake Boca Raton. To the east it slopes down to about 10 ft where the natural dune is replaced by a parallel artificial ridge. This ridge slopes gently to the seashore. Inland the ridge drops abruptly to 5-10 ft east of highway A1A and then slopes gently to the edge of the lake and the inlet. A similar but lower ridge system occurs south of the inlet. There are a few places south of the inlet that are over 10 ft msl. The ridge that now supports hammock on the inner edge of the beach on the south side of the inlet is the only ridge with a known date of origin.

This ridge was not there in the 1883 survey but appeared in the data from 1926. Inlet changes in the interim caused the ridge to form.

Throughout the barrier island system in southeastern Florida there is scattered evidence of two or more ridge systems. Although only two occur with frequency on topographic maps, three are common and four sometimes occur (U.S.G.S., 1969). No local geologic studies have been made of these ridge systems and the sea level changes recorded by MacNeil (1949) farther north in the state does not include them.

Soils throughout the coastal dune system at the Boca Raton Inlet are the Palm Beach series (U.S.D.A., 1973b). Fringing the ocean are the more recent beach sands. On the margins of Lake Boca Raton and in some places along the upper parts of the inlet channel are Arents-Urban land soils. These are composed of about 1 m of sand fill over a base layer of native organic soils. In the Boca Raton area these base layers were derived from the original freshwater sawgrass marsh (MacKay, 1845; Williams, 1870; U.S.G.S., 1884; Austin, 1976).

Material taken from the digging of the modern inlet was used to fill the old inlet. Over the years material pumped from the seasonally clogged inlet was added to the old channel until there is little hint that an alteration was ever made. Sands on the fill are different from the natural beaches and have numerous pieces of concrete mixed in.

VEGETATION—The earliest accurate records of vegetation in the area of the inlet come from the surveys by MacKay (1845), Williams (1870) and the Coastal Geodetic Survey (1884). A few comments are made in the Coastal Geodetic Surveys in the early 1900's (U.S.G.S., 1906-1934). Remaining data have come from aerial photography (U.S.D.A., 1940; Palm Beach County, 1973) and other scattered sources.

Original Vegetation: During the township survey George MacKay (1845) found a closed inlet and a sawgrass passage up the "Boca Rattones Sound" for 4 miles. No other mention of plant cover near the inlet is given. When Williams (1870) surveyed the section lines he gave additional data on vegetation, and also found freshwater sawgrass marsh in the same places as had MacKay. This marsh was in the same configuration in the 1880's (U.S.G.S., 1884).

North of the post in the southeastern corner of section 29 Williams (1870) found a "first rate hammock." This hammock followed the crest of the dune past the northeastern corner of Lake Boca Raton. A tropical hammock was also found on the south and west side of the marsh that fringed the old inlet channel (Fig. 9).

Most of the area toward the ocean from these hammocks was recorded in the late 1800's as "sandy land" but saw palmettos (*Serenoa repens*) are also listed. Data from the surveys show that palmetto strand vegetation has been on these dunes for about 100 yr (Williams, 1870; U.S.G.S., 1884). Fire has been cited as necessary to stabilize this habitat (Austin and Coleman, 1977), and periodic wildfires are implied by an early record of land clearing near the inlet to "serve as a firebreak" (U.S.G.S., 1906). Beach communities were outside the palmetto strand in several areas but varied in size annually.

Present Associations: Urbanization has replaced most of the vegetation on

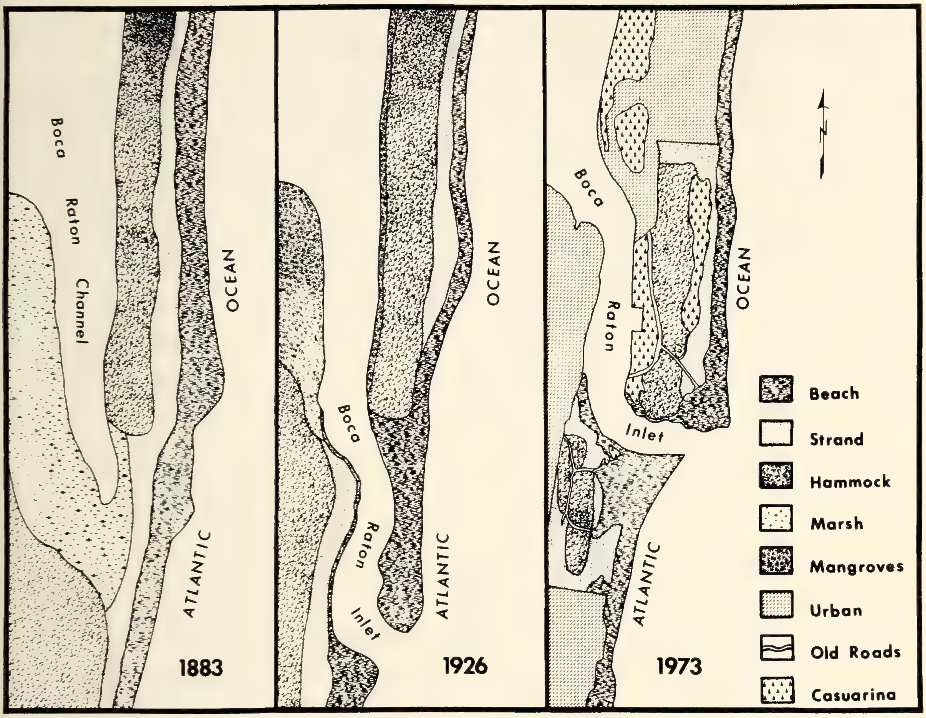


FIG. 9. Interpretation of the changing plant communities near the Boca Raton Inlet. Based on U. S. G. S. (1884), Mizner (1926) and Palm Beach County (1973).

the barrier island system east of Lake Boca Raton and further development promises to remove the remainder. For the most part, high-rise condominiums have replaced the beach and dune vegetation. No major hurricane has hit this coast since these structures were built and the result of removing the dune-stabilizing plants has not been tested.

Two remnants of former native plant communities remain near the Boca Raton Inlet. Both of the sites have been badly disturbed over the last 50-70 yr, but both give some indication of natural succession processes (Fig. 9).

On the north side of the inlet the property named "Sabal Point" by the Arvida Corporation is still (December 1976) covered by part of the "first rate hammock" reported by Williams (1870). The southern tip of this hammock borders the present Boca Raton Inlet, and is now dominated by Pepper trees (*Schinus terebinthifolius*). Several Gumbo Limbo (*Bursera simaruba*) remain as do many Cabbage Palms (*Sabal palmetto*) although all are young. Concrete foundations of former buildings are on the southern fringe. From the inlet north patches of tropical hammock remain on the ridge, all invaded by Pepper trees. West of the ridge the land is dominated by Australian pines (*Casuarina equisetifolia*) as it has been since the middle 1960's.

The beach side of Sabal Point has most of the strand zone replaced by a spoil ridge. This ridge parallels the original dunes and is almost completely dominated by Australian pines. Several herbs and shrubs grow on this artificial ridge, but no native trees. The beach zone is healthy through most of the region.

South of the inlet the vegetation shows less recent disturbance and provides more data on beach succession. The survey reports of Williams (1870) and the U.S.G.S. (1884) show a closed inlet and extensive marsh near the coast (Fig. 9). There was at that time no ridge near the western edge of the Boca Raton Channel and consequently no tropical hammock. The ridge and hammock appear, however, in the 1920's (Mizner, 1926) and early photography (U.S.D.A., 1940), indicating that the ridge was formed near the turn of the century. From formation of the ridge near 1900 until 1940 (U.S.D.A., 1940) the dune progressed through all early stages of succession and passed to incipient hammock. Remaining fragments of this hammock contain only young trees, probably all less than 30 yr old.

Not only have areas that were beach in the 1920's changed to hammocks, but several sites that were hammocks have been degraded to beach and strand (Fig. 9). Most of these sites are the result of urbanization attempts. On the north side of the inlet the area between the hammock and the urbanized area has beach and strand vegetation extending across the major dunes in an area that was tropical hammock from at least 1870 until after the 1964 aerial photography (U.S.D.A., 1964). Preparation for building eliminated this forest. A similar situation exists on the south side of the inlet. South of the remaining hammock an area is covered with remains of old Ocean Boulevard and trails leading to the beach that were, in part, associated with an old pumping station.

Both hammock remnants contain 23% of the total 121 species, with composition by species being similar. There are, however, Paradise Trees (*Simarouba glauca*) on the northern side of the inlet and not on the south. Forty percent of the species are in the beach and strand zones (Fig. 9). Thirty-five percent of the plants indicate disturbance and the remaining 2% are mangrove species.

Exotics: About 13% of the species are naturalized. Some of these (e.g. *Agave sisalana, Casuarina equisetifolia, Ricinus communis, Sanseveria thyrsiflora, Schinus terebinthifolius,* and *Tridax procumbens*) have been recorded in the state since before or near the turn of the century. Others (e.g. *Phoenix* sp., *Wedelia trilobata*) have become naturalized only recently.

Two of the naturalized species are worthy of further comment because of their abundance throughout the area. *Casuarina* dominates several areas on both sides of the inlet, but they are mostly restricted at present to those sites of fill. They were planted for ornament near the old bridge which was used from about 1918 until the early 1960's. This bridge was at the southern end of the remnant of Ocean Boulevard. From these plantings the trees have spread naturally into all other filled sites. Several trees are also scattered through the remaining tropical hammock.

The Pepper tree (*Schinus terebinthifolius*) is probably the most common species in the whole area. While these plants are concentrated on the fringes of the present hammock, they are also common on the interior of some sites. These trees are also beginning to invade the hammocks that were degraded to beach and strand.

A third species is rarely considered naturalized in Florida, *Phoenix*. Over a dozen seedlings of this genus are established in the hammock on the south side of the inlet. Since the plants are juveniles, an exact species determination is not possible but they are probably *P. reclinata* or a hybrid of that species (Stevenson, 1974). This plant, usually called the Senegal Date, has been in Florida since about the turn of the century. Only future study will show if the plants persist near the Boca Raton Inlet.

ACKNOWLEDGMENTS—Thanks are due Donald Vandergrift (Soil Conservation Office, West Palm Beach) for providing the recent soil maps and to David Schwartz (Department of Transportation, Broward County) for the older maps. Hugh Boiter (State Forester, Boca Raton) checked through many city documents to verify dates of changes in the inlet. Voucher specimens were collected by several students in my classes and are deposited at Florida Atlantic University.

LITERATURE CITED

ALEXANDER, T. R. 1955. Observations on the ecology of the low hammocks of southern Florida. Quart. J. Florida Acad. Sci. 18:21-27.

———. 1958. Ecology of the Pompano Beach Hammock. Quart. J. Florida Acad. Sci. 21:299-304.

———. 1967. A tropical hammock on the Miami (Florida) Limestone—a twenty-five year study. Ecology 48:863-867.

AUSTIN, D. F. 1976a. Mangroves as monitors of change in the Spanish River. Florida Environ. Urban Issues 3(3):4-7, 15-16.

———. 1976b. Florida scrub. Florida Natural. 49(4):2-5.

———. 1976c. Vegetation of southeastern Florida—I. Pine Jog. Florida Sci. 39:230-235.

———, AND K. COLEMAN. 1977. Vegetation of southeastern Florida—II. Boca Raton Hammock site. Florida Sci. 40:330-337.

———, AND D. M. MCJUNKIN. In prep. The legends of Boca Ratones.

———, AND J. G. WEISE. 1972. Annotated checklist of the Boyton Beach Hammock. Quart. J. Florida Acad. Sci. 35:145-154.

AVERY, G. 1968. Preliminary checklist of the plants in Matheson Hammock, Dade Co., Florida. (Mimeographed)

BRUFF, J. G. 1846. The State of Florida. Map published by D. McClelland. Washington, D. C.

BUTLER, G. O. 1908. Plat of Sections 4, 8 & 17, Twp. 47S, Rge. 43E, State of Florida.

———. 1939. Plat of Sections 16 & 21, Twp. 47S, Rge. 43E, State of Florida.

COASTAL AND GEODETIC SURVEY. 1945. Aerial photography.

COOKE, C. W. 1939. Scenery of Florida as interpreted by a geologist. Florida Geol. Surv. Bull. 17:1-118.

———. 1945. Geology of Florida. Florida Geol. Surv. Bull. 29:1-339.

CRAIGHEAD, F. C. 1971. The Trees of South Florida, Vol. 1. Univ. Miami Press. Coral Gables.

———. 1974. Hammocks of south Florida. In P. J. Gleason (ed.). Environments of South Florida: Present and Past. Mem. Miami Geol. Soc. 2:53-60.

CURL, D. W. 1975. The Pioneer Cook in Southeast Florida. Boca Raton Historical Soc.

DAVIS, J. H. 1943. The natural features of southern Florida. Florida Geol. Surv. Bull. 25:6-301.

———. 1975. Stabilization of beaches and dunes by vegetation in Florida. Florida Sea Grant Program Rept. 7:1-52.

DEBRAHM, J. W. G. 1773. Report of the General Survey in the Southern District of North America. L. DeVorsey (ed.). Univ. S. Carolina Press. Columbia. [1971 reprint]

DUBOIS, B. W. 1968. Jupiter Inlet. Tequesta 28:19-36.

FAIRBRIDGE, R. W. 1974. The Holocene sea-level record in south Florida. In P. J. Gleason (ed.) Environments of South Florida: Present and Past. Mem. Miami Geol. Soc. 2:223-232.

FORTNER, L. 1976. George Morikami: concern was genuine. Boca Raton News, Monday, March 1, 1976.

Gauld, G. 1794. A Chart of the Gulf of Florida, etc. London.

Handbury, T. H. 1896. Report on a preliminary examination of Biscayne Bay. 1895 Rept. U. S. Comm. Fish & Fisheries Pt. 21:189-191.

Harper, R. M. 1927. Natural resources of southern Florida. Ann. Rept. Florida Geol. Surv. 18:22-206.

Harshberger, J. W. 1914. The vegetation of south Florida. Trans. Wagner Free Inst. Sci. Phila. 3:51-189.

Hinton, I. T., et al. 1832. Map of the State of Florida. London.

Hoffmeister, J. E. 1974. Land from the Sea. Univ. Miami Press. Coral Gables.

Illman, and Pilbrow. 1837. Map of the Territory of Florida. Florida Historical Society Collection.

Ives, J. C. 1856. Memoirs to Accompany a Military Map of Florida. Wynkoop Co. New York.

Kurz, H. 1942. Florida dunes and scrub, vegetation and geology. Bull. Florida Geol. Surv. 23:1-154.

Laessle, A. M. 1958. The origin and successional relationship of sandhill vegetation and sand-pine scrub. Ecol. Monogr. 28:361-387.

__________. 1967. Relationship of sand pine scrub to former shore lines. Quart. J. Florida Acad. Sci. 30:269-286.

Lakela, O., and F. C. Craighead. 1965. Annotated Checklist of the Vascular Plants of Collier, Dade and Monroe Counties, Florida. Fairchild Tropical Gard. and Univ. Miami Press. Coral Gables.

Layne, J. N. 1974. The land mammals of south Florida. In P. J. Gleason (ed.) Environments of South Florida: Present and Past. Mem. Miami Geol. Soc. 2:386-413.

Lineham, M. 1973. Highlights of the History of Palm Beach County Communities. (Mimeographed)

Long, G. R. 1921. Subdivision survey of the south half of Government Lot 4, Section 9, Twp. 47S, Rge. 43E, State of Florida.

Long, R. W., Jr. 1974. Origin of the vascular flora of south Florida. In P. J. Gleason (ed.) Environments of South Florida: Present and Past. Mem. Miami Geol. Soc. 2:28-36.

MacKay, G. 1845. Survey notes of the United States Survey of Twp. 47S, Rge. 43E, State of Florida.

MacNeil, F. S. 1949. Pleistocene shore lines in Florida and Georgia. Geol. Surv. Prof. Pap. 221-F:94-107.

Malear, J. 1975. Ancient America. Part II. Yamato. Fiesta 17:20-21.

Mizner, A. 1926. Plat of the Boca Raton Inlet. City Hall, Boca Raton.

Morton, J. F. 1971. Plants Poisonous to People. Hurricane House. Miami.

Motte, J. R. 1963. Journey into Wilderness. J. F. Sunderman (ed.) Univ. Florida Press. Gainesville.

Mulvania, M. 1931. Ecological survey of a Florida scrub. Ecology 13:528-540.

Palm Beach County. 1973. Aerial photography of Twp. 47S, Rge. 43E, Sect. 28, 29. Palm Beach Court House.

Phillips, W. S. 1940. A tropical hammock on the Miami (Florida) Limestone. Ecology 21:166-175.

Pierce, C. 1970. Pioneer Life in Southeast Florida. Don Curl (ed.) Univ. Miami Press. Coral Gables.

Pozzetta, G. E. 1975. Japanese Floridians. In J. E. Gill and B. R. Read. Born of the Sun. Worth Internat. Commun. Corp. Hollywood.

Robertson, W. B., Jr. and J. A. Kushlan. 1974. The south Florida avifauna. In P. J. Gleason (ed.) Environments of South Florida: Present and Past. Mem. Miami Geol. Soc. 2:414-452.

Romans, B. 1775. A Concise Natural History of East and West Florida. R. W. Patrick (ed.) Floridiana Facsimile Reprint Series. Gainesville. [1962 issue]

Sauer, J. 1967. Geographic Reconnaissance of Seashore Vegetation along the Mexican Gulf Coast. Louisiana State Univ. Press. Baton Rouge.

Sayer, and Bennett. 1776. East Florida. 15 October. London.

Scholl, D. W., F. C. Craighead, and M. Stuiver. 1969. Florida submergence curve revised: its relation to coastal sedimentation rates. Science 163:562-564.

Simpson, C. T. 1920. In Lower Florida Wilds. G. P. Putnam's Sons. New York.

Small, J. K. 1910. Additions to the flora of peninsular Florida. Bull. Torrey Bot. Club 37:513-518.

__________. 1913. Flora of Miami. Publ. Author. New York.

__________. 1921. Historic trails, by land and water. A record of exploration in Florida in December 1919. J. New York Bot. Gard. 22:193-222.

__________. 1924. The land where spring meets autumn. A record of exploration in Florida in December 1921. J. New York Bot. Gard. 25:53-94.

__________. 1929. From Eden to Sahara. Science Press. Lancaster, Pennsylvania.

__________. 1933. Manual of the Southeastern Flora. Univ. No. Carolina Press. Chapel Hill.

Stevenson, G. B. 1974. Palms of South Florida. Publ. Author. Coral Gables.

Tanner, N. S. 1823. Map of Florida, No. 22. In: A New American Atlas, etc. Philadelphia.

Thomas, T. M. 1974. A detailed analysis of climatological and hydrological records of south Florida with reference to man's influence upon ecosystem evolution. In P. J. Gleason (ed.) Environments of South Florida: Present and Past. Mem. Miami Geol. Soc. 2:82-122.

True, D. O. 1954. Some early maps relating to Florida. Image Mundi 73-84.

U. S. D. A. 1940. Aerial photography. Washington, D. C.

__________. 1946. Soil Survey, Palm Beach County, Florida. Soil Conserv. Serv.

__________. 1964. Aerial photography. Washington, D. C.

__________. 1969. Topographic quadrangle "Boca Raton." Washington, D. C.

__________. 1973a. Sand pine symposium proceedings. Southeast. For. Exp. Sta. U.S.D.A. For. Serv. Gen. Tech. Rept. SE-2:1-253.

__________. 1973b. Soil Survey Special Report, Maps and Interpretations, Palm Beach County, Florida. Soil Conservation Service.

U. S. G. S. 1884. East Coast of Florida between Hillsboro and New River Inlets. Reg. No. 1657.

__________. 1884. East Coast of Florida between South End of Lake Worth and Hillsboro Inlet. Reg. No. 1657.

__________. 1906-1934. Survey Notes of Coastal Geodetic Surveys. Washington, D. C.

Watts, W. A. 1971. Postglacial and interglacial vegetational history of southern Georgia and central Florida. Ecology 52:676-690.

Williams, M. A. 1870. Survey notes on the United States Survey of Twp. 47S, Rge. 43E, with outlines of sections established, State of Florida.

Wymbs, N. 1976. Letter to editor: Arvida must keep inlet open. Boca Raton News, Thursday, 20 October, 1976.

Florida Sci. 40(4):331-361. 1977.

REVIEW

Stevenson, Henry M. *Vertebrates of Florida—Identification and Distribution.* University Presses of Florida, Gainesville, Florida 32611. 1977. 607 pp. Clothbound. $35.00.

This considerable tome is a very complete guide to the identification and distribution of vertebrate animals in Florida. The book is divided into two major sections: the first is an extensive key to all Florida vertebrates, except for saltwater fishes, and the second is an account of the species found naturalized in Florida including 880 taxa—208 freshwater fishes, 53 amphibians, 98 reptiles, 428 birds and 93 mammals. Additionally, a helpful chapter on preserving vertebrate animals is provided along with an excellent bibliography and a glossary of scientific terms used in the text.

The strength of this contribution lies in the fact that, in a single source, an investigator has at his fingertips information on every Florida vertebrate. The text is very up-to-date with species names current with the latest nomenclature. Each species is presented with a brief description of its distinguishing characteristics followed by details of its range. In some cases figures and maps augment the text (in all, 66 maps and 21 text figures or plates). In many cases, the reader is referred to specialized treatments in the literature for additional information.

The weakness of the work from this reviewer's point of view is that, despite its size, it can be only a starting point. The information is limited to the distribution and identification of species with no notes on biological attributes of the organism. The value of the work is thus decreased for all but the working scientist and the most dedicated amateur. *Vertebrates of Florida* is not a field guide, nor is it intended to be, and so the user must already know something about the organisms he seeks to identify before starting. The figures placed in the text to assist with identification are, regretfully, not of professional quality and, in some cases, are of doubtful value.

In conclusion, the work is a well done, up-to-date, guide to Florida vertebrates. It summarizes much useful information and provides leads to the appropriate scientific literature for each organism. However, the lack of information about the ecology, behavior and natural history of the individual species limit the book's usefulness to the hard-core scientist or amateur and the need for a field guide to Florida vertebrates for use by interested laymen remains unfilled.—*Mark E. Sinclair,* Educational Director, John Young Museum and Planetarium, Orlando, Florida 32803.

Ecosystem Studies

VEGETATION OF CENTRAL FLORIDA'S EAST COAST[1]; A CHECKLIST OF THE VASCULAR PLANTS[2]

James E. Poppleton, Allen G. Shuey[3] and Haven C. Sweet

Department of Biological Sciences, Florida Technological University, Orlando, Florida 32816

Abstract: *A checklist of plants found on the Merritt Island peninsula and the offshore barrier island complex encompassing Cape Canaveral is presented. Located midway along Florida's east coast, the region covered by the checklist extends about 70 mi north to south and includes about 225 sq mi. Although much of the original vegetation present in the southern half was destroyed as a consequence of rapid development in the 1960's, a diverse flora still exists. A total of 943 native or naturalized taxa plus 124 plants persisting from cultivation around abandoned homesites are listed. The flora represents approximately 25% of all the taxa estimated to be native to the state of Florida.*[*]

Florida has one of the most interesting and varied floras in the United States, and as a result, has been the focus of attention for numerous botanists for over 250 years. The state's climatic range (from nearly tropical in southern Florida to temperate in northern and panhandle Florida), geographical position, geological uniqueness, and varied topography have resulted in a remarkably diverse and large flora of 3,000 to 3,500 vascular plant species.

The state was first explored botanically by Mark Catesby in 1722 (Hume, 1938). Unfortunately this and other early botanizing in the state was often scanty and non-comprehensive until the uniqueness of Florida's flora caught the attention of John K. Small who was most prolific botanically. Small's work in Florida began in 1901 and continued for 35 yr. His monumental *Manual of the Southeastern Flora* (Small, 1933) remains as the only single work applicable to the entire state. However, the usefulness of Small's manual is somewhat limited due to the numerous taxonomic changes made in subsequent yr, and his utilization of the now obsolete American Code of Botanical Nomenclature.

North central and panhandle Florida are fairly well known botanically because of research by various botanists at the state's two oldest institutions, the University of Florida in Gainesville and Florida State University in Tallahassee. Although this northern flora is well represented in both herbaria, few checklists covering large regions of northern Florida have been published recently; one exception is Mitchell's account of the flora of Florida Caverns State Park (Mitchell, 1963).

Due primarily to efforts of botanists at the University of South Florida in Tampa over the last 10 yr, adequate checklists are now available for the vegeta-

---

[1]Research supported in part by NASA Grant NGR 10-019-004 and FTU 18-2000-026.

[2]Merritt Island Ecosystem Studies Contribution No. 6.

[3]Current address: Conservation Consultants, Inc., Palmetto, Florida.

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "advertisement" solely to indicate this fact.

tion of southern Florida (Lakela and Craighead, 1965) and the Tampa Bay Area (Lakela et al., 1976). Furthermore, a comprehensive manual of south Florida's flora (Long and Lakela, 1971) has been prepared; in addition to taxonomic keys, their volume contains ecological and biosystematic information.

Much of central Florida, which is floristically rich and with a significant endemic element, is inadequately known and in need of a comprehensive checklist. Although Conard (1969) wrote a useful key to many of the plants of Central Florida, its emphasis is on those growing on the "highlands" in the vicinity of Lake Wales. In addition, most of eastern Florida, especially coastal areas, has not been extensively studied floristically. Existing studies of this region have been limited to small areas, usually individual hammocks, such as those analyzed by Alexander (1953, 1955, 1958a, 1958b) and Austin (1976) on the southeast coast. Most recently Norman (1976) published the results of a floristic and ecological study of Turtle Mound in Volusia County, the best known and interesting of the Indian mounds along the coast because it sustains a predominantly tropical flora.

The area involved in the current study is located about midway along Florida's east coast and spans approximately 1° of latitude (27° 52′ N to 28° 52′ N) or about 75 air mi north to south. It includes all of Merritt Island and much of the barrier island complex encompassing Cape Canaveral (Fig. 1). Botanical interest in the area effectively dates from 1919 when J. K. Small began publishing accounts of his travels along the coast in the *Journal of the New York Botanical Garden* (Small, 1919, 1920, 1921). He was especially intrigued by the presence of several unique plants (particularly *Peperomia humilis, Cereus eriophorus* var. *fragrans* and other cacti), and "islands" of tropical vegetation situated upon Indian mounds. Little further attention was paid to this region until 1954 when a lengthy list of plants collected on the southern end of Merritt Island was prepared, purportedly by Dr. George Cooley. Although this unpublished list was deposited in the herbarium library of the University of South Florida, the voucher specimens have not been located. Until our study, no more floristic or ecological studies were made in the area.

Our survey is an outgrowth of a 3-yr, NASA sponsored, investigation of the ecology of Merritt Island. The initial investigation for NASA was limited to northern Merritt Island; the resulting data provided the nucleus of a floristic study which was expanded to include all of coastal Brevard County east of the Indian River, and that portion of Volusia County included in the recently created Canaveral National Seashore.

Merritt Island was apparently first settled in 1830 when Dummit planted the first of the now famous groves of Indian River citrus (Fix, 1967). The villages which sprouted on the island during the remainder of the 19th century were dependent upon an economy based on cattle, pineapple, sugarcane and citrus. Until 1923 when the first bridge to Merritt Island was constructed, access was only by boat. However, development in this part of Florida was meager, and large areas of natural vegetation remained until the late 1950's and early 1960's. During this time, the Federal Government purchased and became the sole occupant of most of Merritt Island and Cape Canaveral for use by NASA and the Air

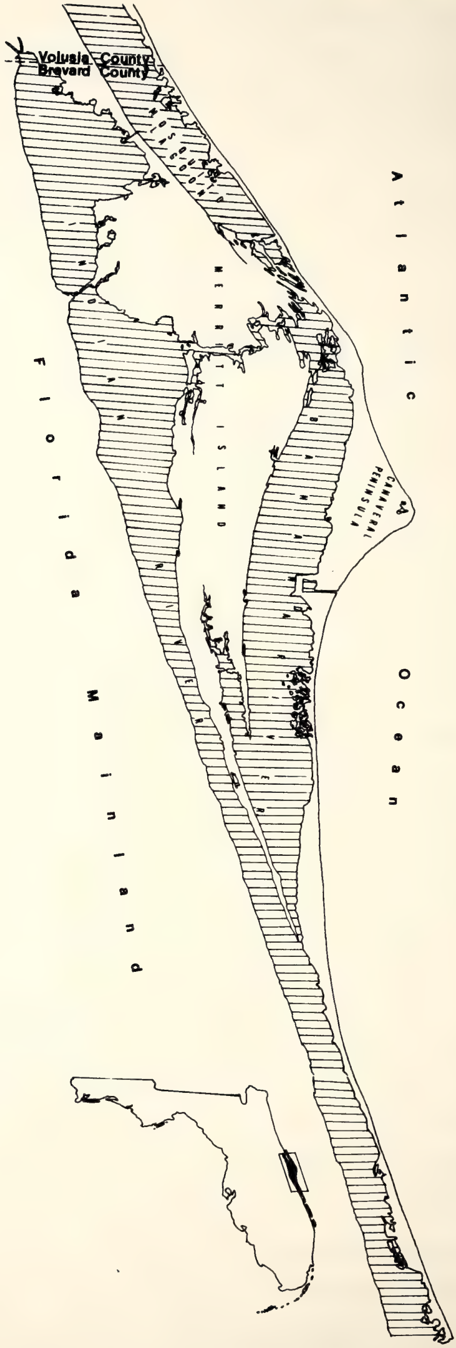


FIG. 1: Map of Merritt Island, barrier island complex encompassing Cape Canaveral and lagoonal system included within study. Inset shows relative size and position of area to the rest of Florida.

Force. The budding space industry caused a growth boom which changed the formerly quiescent development drastically. The cities just south of the government installation on Merritt Island and the barrier island all experienced an unprecedented, rapid growth; consequently, much of the natural vegetation on the southern end of both Merritt Island and the barrier island was destroyed. In addition to the damage caused by urban growth, the construction and operation of the government installations was responsible for severely modifying or destroying large areas of vegetation on central Merritt Island and Cape Canaveral. Finally, county attempts to control saltwater-breeding mosquitoes resulted in drastic alteration of much of the marsh region bordering the western portion of northern Merritt Island. These marshes have been seriously modified since they no longer receive tidal flux; rather they are permanently flooded due to an extensive network of dikes. Fortunately, many areas of northern Merritt Island which were not in direct use by NASA were put under the direction of the Department of the Interior and became the Merritt Island National Wildlife Refuge. All of the barrier island north of Cape Canaveral to Turtle Mound was later included in the National Seashore program as the Canaveral National Seashore. Thus, we have a situation where many portions of north Merritt Island have original vegetational associations while much of the southern end is disturbed with few extensive tracts of natural vegetation remaining. Most of the barrier island north of Cape Canaveral to Turtle Mound and south of Melbourne Beach to Sebastian Inlet remains almost intact.

It is unfortunate that the urban end of Merritt Island has only a few remnants of the original vegetation since it is apparent that this area supported a primarily tropical association which never occurred farther north in the now protected areas. It was possible, however, by studying the few remaining areas of original vegetation, to reconstruct the composition of the natural communities that used to exist. Even with the rapid development of the southern region and the partial disturbance of northern Merritt Island and Cape Canaveral, a remarkably diverse and biogeographically interesting flora still remains.

Collections were made during the period 1972-1975. Vouchers of most species present in the following list were deposited in a special collection within the herbarium of Florida Technological University (FTU). Additional vouchers and many duplicates were placed in the herbarium of the University of South Florida (USF). In addition, specimens of species which were collected by other workers but not found by the authors in this study were recorded from the herbaria of the University of Florida (FLAS) and the University of South Florida (USF). Collection data for each specimen, as well as information concerning the species in general, was stored and processed by computer (Sweet and Poppleton, 1977).

A total of 943 native or naturalized taxa is presented. In addition, 124 exotic plants persisting at least 10 yr from cultivation (designated by an * preceding the name) are included as they were often encountered around former homesites. They are not considered a part of the flora as they do not extensively naturalize. Plants which were apparently cultivated at one time but now appear well established in the area are listed and designated by double asterisks (**). Authenticated species records of taxa which have been collected in the area but appear to be no longer present are designated by a dagger (†). Of the 943 native or naturalized plants presented, some 105 are taxa which were introduced into other parts of Florida in previous times and have become subsequently widely naturalized in the state. Thus, about 840 species are indigenous to the area.

Several manuals were utilized for identification. Nomenclature generally follows that of Radford et al. (1964), Long and Lakela (1971), Lakela et al. (1976) and, for monocots, Ward (1968). Wherever possible, names used conform with results presented in recent monographs of particular groups. Systematic sequence of families follows that of the Dalla Torre and Harms (1900-1907) in *Enumeratio Familiarium Siphonogamarum.*

LIST OF TAXA

PSILOTACEAE

Psilotum nudum (L.) Beauv.

LYCOPODIACEAE

Lycopodium alopercuroides L.
L. adpressum (Chapm.) Lloyd & Underw.
L. carolinianum L.

SELAGINELLACEAE

Selaginella arenicola Underw.

OPHIOGLOSSACEAE

Ophioglossum palmatum L.
O. petiolatum Hook.

OSMUNDACEAE

Osmunda cinnamomea L.
O. regalis L. var. *spectabilis* (Willd.) Gray

VITTARIACEAE

Vittaria lineata (L.) Sm.

POLYPODIACEAE

Campyloneurum phyllitidis (L.) Presl.
Phlebodium aureum (L.) Sm.
Polypodium plumula Humb. & Bonpl. *ex* Willd.
P. polypodioides (L.) Watt.

DAVALLIACEAE

**Nephrolepis biserrata* Schott var. *furcans* Horton
***N. cordifolia* (L.) Presl.
N. exaltata (L.) Schott

PTERIDACEAE

Acrostichum aureum L.
A. danaeaefolium Langsd. & Fisch.
Pteridium aquilinum (L.) Kuhn var. *caudatum* (L.) Sadebeck

BLECHNACEAE

Blechnum serrulatum Richard
Woodwardia areolata (L.) Moore
W. virginica (L.) Sm.

ASPLENIACEAE

Asplenium platyneuron (L.) Oakes

ASPIDIACEAE

Dryopteris ludoviciana (Kunze) Small

Thelypteris interrupta (Willd.) Iwatsuki
T. normalis (C. Chr.) Moxley
T. palustris Schott var. *haleana* Fern.
T. quadrangularis (Fee) Schelpe var. *versicolor* (R. St. John) A. R. Smith

SALVINIACEAE

Azolla caroliniana Willd.
Salvinia rotundifolia Willd.

CYCADACEAE

°*Cycas revoluta* Thunb.
Zamia integrifolia Ait.

PINACEAE

Pinus clausa (Engelm.) Sarg.
P. elliottii Engelm. var. *densa* Little & Dorman
°*P. elliottii* Engelm. var. *elliottii*
P. palustris Mill.
P. serotina Michx.

TAXODIACEAE

°*Taxodium ascendens* Brongn.

CUPRESSACEAE

Juniperus silicicola (Small) Bailey

PODOCARPACEAE

°*Podocarpus macrophyllus* D. Don var. *maki* Sieb.

TYPHACEAE

Typha angustifolia L.
T. domingensis Pers.
T. latifolia L.

RUPPIACEAE

Ruppia maritima L.

NAJADACEAE

Najas guadalupensis (Spreng.) Mangus var. *floridana* R.R. Haynes & Wentz
N. marina L.
N. wrightiana A. Br.

CYMODOCEACEAE

Cymodocea filiformis (Kuetz.) Correll
Halodule beaudettei (den Hartog) den Hartog

ALISMATACEAE

Sagittaria lancifolia L.
S. subulata (L.) Buch.

HYDROCHARITACEAE

Halophila baillonis Ascher
H. engelmanii Ascher
Limnobium spongia (Bosc.) Steud.
Thalassia testudinum Koenig & Sims

POACEAE

Amphicarpum muhlenbergianum (Schultes) Hitchc.
Andropogon brachystachys Chapm.
A. cabanisii Hack.
A. capillipes Nash
A. elliottii Chapm.
A. glomeratus (Walt.) BSP
A. longiberbis Hack.
A. perangustatus Nash
A. ternarius Michx.
A. virginicus L. var. *virginicus*

A. virginicus L. var. *glaucopsis* (Ell.) Hitchc.
Aristida patula Chapm. *ex* Nash
A. purpurascens Poir.
A. spiciformis Ell.
A. stricta Michx.
A. virgata Trin.
Arundinaria tecta (Walt.) Muhl.
°*Arundo donax* L.
Axonopus affinis Chase
°*Bambusa multiplex* (Lour.) Raeusch
°*B. vulgaris* Schrad.
Brachiaria subquadripara (Trin.) Hitchc.
Calamovilfa curtissii (Vasey) Scribn.
Cenchrus echinatus L.
C. incertus M. A. Curtis
C. pauciflorus Benth.
C. tribuloides L.
Chasmanthium sessiliflorum (Poir.) Yates
Chloris glauca (Chapm.) Wood
C. petraea Sw.
°*Cortaderia selloana* (Schultes) Aschers. & Graebn.
Cynodon dactylon Pers.
Dactyloctenium aegyptium (L.) Beauv.
Digitaria adscendens (HBK) Henr.
D. diversiflora Sw.
D. sanguinalis (L.) Scopoli
D. villosa (Walt.) Pers.
Distichlis spicata (L.) Greene
Echinochloa colonum (L.) Link
E. crusgalli (L.) Beauv.
E. walteri (Pursh) Heller
Eleusine indica (L.) Gaertn.
Eragrostis acuta Hitchc.
E. ciliaris (L.) R. Br.
E. elliottii Wats.
E. refracta (Muhl.) Scribn.
E. spectabilis (Pursh) Steud.
Eremochloa ophiuroides Hack.
Erianthus giganteus (Walt.) Muhl.
Eriochloa michauxii (Roem. & Schult.) Hitchc.
Festuca elatior L.
Heteropogon melanocarpus (Ell.) Benth.
Imperata cylindrica (L.) Beauv.
Leersia hexandra Sw.
L. virginica Willd.
Leptochloa fascicularis (Lam.) Gray
Manisuris rugosa (Nutt.) Kuntze
Monanthocloe littoralis Engelm.
Muhlenbergia capillaris (Lam.) Trin. var. *capillaris*
M. capillaris (Lam.) Trin. var. *filipis* (M.A. Curtis) Chapm. *ex* Beal
Oplismenus setarius (Lam.) Roem. & Schult.
Panicum agrostoides Spreng. var. *condensum* (Nash) Fern.
P. albomarginatum Nash
P. amarum Ell.

P. anceps Michx. var. *anceps*
P. bartowense Scribn. & Merrill
P. breve Hitchc. & Chase
P. caerulescens Hack. *ex* Hitchc.
P. chamaelonche Trin.
P. ciliatum Ell.
P. commutatum Schult.
P. ensifolium Baldw. *ex* Ell.
P. equilaterale Scribn.
P. fasciculatum Sw.
P. fusiforme Hitchc.
P. glabrifolium Nash.
P. hemitomon Schult.
P. hians Ell.
P. huachucae Ashe
P. joorii Vasey
P. lancearium Trin.
P. lanuginosum Ell.
P. malacon Nash
P. maximum Jacq.
P. nitidum Lam.
P. patentifolium Nash
P. patulum (Scribn. & Merrill) Hitchc.
P. polycaulon Nash
P. portoricense Desv. *ex* Ham.
P. purpurascens Raddi
P. repens L.
P. rhizomatum Hitchc. & Chase
P. roanokense Ashe
P. tenerum Beyr.
P. trifolium Nash
P. virgatum L.
P. webberianum Nash
P. wrightianum Scribn.
P. xalapense HBK
Paspalum bifidum (Bertol.) Nash
P. conjugatum Bergius
P. distchum L.
P. floridanum Michx.
P. giganteum Baldw. *ex* Vasey
P. laeve Michx.
P. langei (Fourn.) Nash
P. notatum Fluegge var. *saurae* Parodi
P. plicatulum Michx.
P. praecox Walt. var. *curtisianum* (Steud.) Vasey
P. setaceum Michx.
P. urvillei Steud.
P. vaginatum Sw.
Pennisetum purpureum Schum.
Phragmites australis (Cav.) Trin. *ex* Steud.
Polypogon monspeliensis (L.) Desf.
Rhynchelytrum repens (Willd.) C. E. Hubbard
Sacciolepsis striata (L.) Nash
Schizachyrium littorale Bicknell

S. scoparium (Michx.) Nash
S. stoloniferum Nash
Setaria corrugata (Ell.) Schultes
S. geniculata (Lam.) Beauv.
S. glauca (L.) Beauv.
S. macrosperma (Scribn. & Merrill) Schum.
S. magna Griseb.
Sorghastrum elliottii (Mohr) Nash
S. secundum (Ell.) Nash
Sorghum halepense (L.) Pers.
**S. vulgare* Pers.
Spartina alterniflora Loisel.
S. bakerii Merrill
S. patens (Ait.) Muhl.
Sphenopholis filiformis (Chapm.) Scribn.
S. obtusata (Michx.) Scribn.
Sporobolus domingensis (Trin.) Kunth
S. floridanum Chapm.
S. indicus (L.) R. Brown
S. poiretii (Roem. & Schultes) Hitchc.
S. virginicus (L.) Kunth
***Stenotaphrum secundatum* (Walt.) Kuntze
Tridens chapmanii (Small) Chase
T. flavus (L.) Hitchc.
Triplasis purpurea (Walt.) Chapm.
Tripsacum dactyloides L.
Uniola paniculata L.
**Zea mays* L.
***Zoysia tenuifolia* Willd. *ex* Trin.

CYPERACEAE

Bulbostylis barbata (Rottb.) Clarke
B. ciliatifolia (Ell.) Fern.
B. stenophylla (Ell.) Clarke
Carex alata Torr.
C. arenaria L.
C. lupuliformis Sartwell *ex* Dewey
C. stipata Muhl. *ex* Schk.
Cladium jamaicensis Crantz
Cyperus articulatus L.
C. brevifolius (Rottb.) Hassk.
C. compressus L.
C. distinctus Steud.
C. esculentus L.
C. filiculmis Vahl
C. flavescens L.
C. globulosus Aubl.
C. haspan L.
C. ligularis L.
C. nashii Britt.
C. odoratus L.
C. ovularis (Michx.) Torr.
C. planifolius Rich.
C. polystachyos Rottb. var. *texensis* (Torr.) Fern.
C. retrorsus Chapm. var. *retorsus*

C. retrorsus Chapm. var. *deeringianus* (B & S) Fern. & Griseb.
C. strigosus L.
C. surinamensis Rottb.
C. tetragonus Ell.
Dichromena colorata (L.) Hitchc.
D. floridensis Britt.
D. latifolia Baldw.
Eleocharis albida Torr.
E. atropurpurea (Retz.) Kunth
E. baldwinii (Torr.) Chapm.
E. cellulosa Torr.
E. geniculata (L.) R & S
E. montevidensis Kunth
E. parvula (R & S) Link
Fimbristylis caroliniana (Lam.) Fern.
F. dichotoma (L.) Vahl
F. spadicea (L.) Vahl
F. spathacea Roth
Fuirena scirpoidea Michx.
F. squarrosa Michx.
Hemicarpha micrantha (Vahl) Pax *in* Engl. & Prantl
Rhynchospora caduca Ell.
R. ciliaris (Michx.) Mohr
R. debilis Gale
R. divergens Chapm.
R. fascicularis (Michx.) Vahl
R. filifolia Gray
R. globularis (Chapm.) Small var. *pinetorum* (Small) Gale
R. globularis (Chapm.) Small var. *globularis*
R. intermedia (Chapm.) Britt.
R. intermixta C. Wright
R. inundata (Oakes) Fern.
R. megalocarpa Gray
R. microcarpa Baldw. *ex* Gray
R. miliacea (Lam.) Gray
R. odorata C. Wright *ex* Griseb.
R. plumosa Ell.
R. wrightiana Boeckler
Scirpus americanus Pers.
S. robustus Pursh
S. validus Vahl
Scleria curtissii Britt.
S. oligantha Michx.
S. pauciflora Muhl. *ex* Willd.
S. reticularis Michx. var. *pubescens* Britt.
S. triglomerata Michx.

ARECACEAE

**Arecastrum romanzoffianum* Becc.
**Cocos nucifera* L.
**Phoenix canariensis* Horton
**P. dactylifera* L.
**P. reclinata*
**P. sylvestris*
Sabal palmetto (Walt.) Lodd. *ex* Schultes

Serenoa repens (Bartr.) Small
°*Washingtonia robusta* Wendl.

ARACEAE

Arisaema dracontium (L.) Schott
A. triphyllum (L.) Schott
°°*Colocasia esculentum* (L.) Schott
Peltandra virginica (L.) Schott & Endl.
Pistia stratiotes L.
°*Syngonium podophyllum* Schott

LEMNACEAE

Lemna minor L.
L. perpusilla Torr.
Spirodela polyrhiza (L.) Schleiden
Wolfiella floridana (J. G. Smith) Thompson

XYRIDACEAE

Xyris brevifolia Michx.
X. caroliniana Walt.
X. elliottii Chapm.
X. fimbriata Ell.
X. jupicai Richard
X. smalliana Nash

ERIOCAULACEAE

Eriocaulon compressum Lam.
Lachnocaulon anceps (Walt.) Morong
L. minus (Chapm.) Small
Syngonanthus flavidulus (Michx.) Ruhland

BROMELIACEAE

Tillandsia recurvata L.
Tillandsia simulata Small
Tillandsia usneoides L.
Tillandsia utriculata L.

COMMELINACEAE

Callisia cordifolia (Sw.) Anderson & Woodson
Commelina diffusa Burm. f.
C. erecta L. var. *angustifolia* (Michx.) Fern.
Cuthbertia ornata Small
°*Setcreasea purpurea* Boomhour
Tradescantia ohiensis Raf.
°*Zebrina pendula* Schniz

PONTEDERIACEAE

Eichhornia crassipes (Mart.) Solms
Pontederia cordata L. var. *lancifolia* (Muhl.) Torr.
P. cordata L. var. *cordata*

JUNCACEAE

Juncus acuminatus Michx.
J. biflorus Michx.
J. dichotomus Ell.
J. effusus L.
J. marginatus Rostk.
J. megacephalus M. A. Curtis
J. polycephalus Michx.
J. roemerianus Scheele
J. scirpioides Lam.
J. trigonocarpus Steud.

LILIACEAE

Allium cuthbertii Small
°*Asparagus plumosus* Baker
Lilium catesbaei Walt.
°*L. longiflorum* var. *eximium* Baker
Schoenocaulon dubium (Michx.) Small

SMILACACEAE

Smilax auriculata Walt.
S. *bona-nox* L.
S. *glauca* Walt.
S. *laurifolia* L.

AGAVACEAE

°*Agave americana* L.
°A. *angustifolia* Haw.
°A. *decipiens* Baker
°A. *sisalana* Perrine
°*Sansevieria aubrytiana* Auth.
°S. *guineensis* (L.) Britt.
Yucca aloifolia L.
Y. *filamentosa* L. var. *filamentosa*

HAEMODORACEAE

Lachnanthes caroliniana (Lam.) Dandy

AMARYLLIDACEAE

Aletris lutea Small
Crinum americanum L.
°*C. bulbispermum* (Burm.) Milne-Redhead & Schweicki
Hymenocallis crassifolia Herb.
H. latifolia (Mill.) Roem.
H. palmeri Wats.
Hypoxis juncea L.

DIOSCOREACEAE

Dioscorea bulbifera L.

IRIDACEAE

°*Gladiolus* × *gandovensis* Van Houtte
Iris hexagona Walt. var. *savannarum* (Small) Foster
Sisyrinchium arenicola Bicknell
S. *atlanticum* Bicknell

MUSACEAE

°*Musa sapientum* L.

ZINGIBERACEAE

°*Alpinia officinarum* Hance
°A. *zerumbet* (Pers.) Burtt & Sm.

CANNACEAE

Canna flaccida Small
°*C.* × *generalis* Bailey

MARANTACEAE

Thalia geniculata L.

ORCHIDACEAE

Calopogon multiflorus Lindl.
C. tuberosus (L.) Britt.
Encyclia tampensis (Lindl.) Small
Epidendrum conopseum R. Brown
Eulophia alta (L.) Fawc. & Rendle
E. ecristata (Fern.) Ames

Habenaria odontopetala Reichen. f.
H. repens Nutt.
Harrisella porrecta (Reichen. f.) Fawc. & Rendle
Hexalectris spicata (Walt.) Barnhart
Malaxis spicata Sw.
Pogonia ophioglossoides (L.) Ker.
Ponthieva racemosa (Walt.) Mohr
Spiranthes laciniata (Small) Ames
Zeuxine strateumatica (L.) Schltr.

CASUARINACEAE

***Casuarina cunninghamiana* Miq.
***C. equisetifolia* Forst.
**C. glauca* Sieb.

PIPERACEAE

Peperomia humilis Vahl
**P. obtusifolia* (L.) Dietr.

SALICACEAE

**Salix babylonica* L.
S. caroliniana Michx.

MYRICACEAE

Myrica cerifera L. var. *cerifera*
M. cerifera L. var. *pumila* Michx.

JUGLANDACEAE

Carya aquatica (Michx. f.) Nutt.
C. floridana Sarg.
C. glabra (Mill.) Sweet
**C. illinoensis* (Wang) K. Koch

BATACEAE

Batis maritima L.

BETULACEAE

**Carpinus caroliniana* Walt.

FAGACEAE

Quercus chapmanii Sarg.
Q. incana Bart.
Q. laevis Walt.
Q. laurifolia Michx.
Q. minima (Sarg.) Small
Q. myrtifolia Willd.
Q. pumila Walt.
Q. virginiana Mill. var. *maritima* (Michx.) Sarg.
Q. virginiana Mill. var. *virginiana*

ULMACEAE

Celtis laevigata Willd.
C. occidentalis var. *georgiana* (Small) Ahles
Ulmus americana L.

MORACEAE

**Broussonetia papyrifera* (L.) Vent.
Ficus aurea Nutt.
**F. carica* L.
**F. elastica* Roxb.
**Maclura pomifera* (Raf.) Schneid.
**Morus nigra* L.
M. rubra L.

URTICACEAE

Boehmeria cylindrica (L.) Sw. var. *cylindrica*
B. cylindrica (L.) Sw. var. *drummondiana* Wedd.
Parietaria floridana Nutt.
P. praetermissa Hinton

PROTEACEAE

**Grevillea robusta* Cunn.

LORANTHACEAE

Phoradendron serotinum (Raf.) M. C. Johnston var. *macrotomum* M. C. Johnston

OLACACEAE

Schoepfia chrysophylloides (A. Rich.) Planchon
Ximenia americana L.

ARISTOLOCHIACEAE

**Aristolochia elegans* Masters

POLYGONACEAE

***Antigonon leptopus* Hook. & Arn.
Coccoloba diversifolia Jacq.
C. uvifera (L.) L.
Polygonella ciliata Meissner
P. gracilis (Nutt.) Meissner
P. polygama (Vent.) Engelm. & Gray
Polygonum hirsutum Walt.
P. hydropiperodes Michx. var. *hydropiperoides*
P. hydropiperoides Michx. var. *opelousanum* Stone
P. persicaria L.
P. punctatum Ell.
Rumex pulcher L.
R. verticillatus L.

CHENOPODIACEAE

Atriplex arenaria Nutt.
Chenopodium album L.
C. ambrosioides L.
Salicornia bigelovii Torr.
S. virginica L.
Salsola kali L.
Suaeda linearis (Ell.) Moq.

AMARANTHACEAE

Alternanthera philoxerides (Mart.) Griseb.
A. ramosissima (Mart.) Chodat
Amaranthus cannabinus (L.) Sauer
A. hybridus L.
A. spinosus L.
Froelichia floridana (Nutt.) Moq.
Gomphrena decumbens Jacq.
Iresine diffusa Humb. *ex* Bonpl. *ex* Willd.
Philoxerus vermicularis (L.) R. Brown

NYCTAGINACEAE

Boerhavia diffusa L.
**Bougainvillea glabra* Choisy
Guapira discolor (Spreng.) Little var. *discolor*
**Mirabilis jalapa* L.

PHYTOLACCACEAE

Phytolacca americana L.
Rivina humilis L.

AIZOACEAE

Sesuvium maritimum (Walt.) BSP
S. portulacastrum L.
Trianthema portulacastrum L.

PORTULACACEAE

Portulaca oleracea L.
P. pilosa L.

CARYOPHYLLACEAE

Arenaria lanuginosa (Michx.) Rohrb. ssp. *lanuginosa*
Drymaria cordata (L.) Willd. *ex* Roem. & Schultes
Paronychia americana (Nutt.) Fenzl *ex* Walp.
Stellaria media (L.) Cyr.
Stipulicida setacea Michx.

NYMPHAEACEAE

Nuphar luteum (L.) Sibth. & Sm. ssp. *macrophyllum* Beal
Nymphaea × *daubeniana* O. Thomas
N. mexicana Zucc.
N. odorata Ait. var. *gigantea* Tricker

CERATOPHYLLACEAE

Ceratophyllum demersum L.
C. echinatum Gray

RANUNCULACEAE

Clematis baldwinii T & G var. *baldwinii*

MAGNOLIACEAE

Magnolia grandiflora L.
M. virginiana L.

ANNONACEAE

Annona glabra L.
Asimina obovata (Willd.) Nash
A. parviflora Michx.
A. pygmaea (Bartr.) Dunal
A. reticulata Shuttlew. *ex* Chapm.

LAURACEAE

Cassytha filiformis L.
**Cinnamomum camphora* (L.) Nees & Frefrm.
Nectandra coriacea (Sw.) Griseb.
**Persea americana* Mill. var. *americana*
P. borbonia (L.) Spreng. var. *borbonia*
P. borbonia (L.) Spreng. var. *humilis* (Nash) Kopp
P. palustris (Raf.) Sarg.

PAPAVERACEAE

Argemome mexicana L.

BRASSICACEAE

Cakile fusiformis Greene
Descurainia pinnata (Walt.) Britt.
Lepidium virginicum L.
Raphanus raphanistrum L.

CAPPARACEAE

Capparis cynophallophora L.
C. flexuosa L.
Polanisia tenuifolia T & G

DROSERACEAE

Drosera capillaris Poir.
D. leucantha Shinners
D. rotundifolia L.

CRASSULACEAE

°*Kalanchoe daigremontiana* Hamet & Perr.
°*K. fedtschenkoi* Hamet & Perr.
°°*K. grandiflora* A. Richard
°°*K. pinnata* (Lam.) Pers.

HAMAMELIDACEAE

Liquidambar styraciflua L.

ROSACEAE

°*Eriobotrya japonica* Lindl.
Prunus augustifolia Marsh.
P. caroliniana Ait.
°*P. persica* (L.) Batsch
P. serotina Ehrhart
°*Pyrus communis* L.
Rubus cuneifolius Pursh
R. trivialis Michx.

CHRYSOBALANACEAE

Chrysobalanus icaco L. var. *icaco*
Licania michauxii Prance

FABACEAE

Abrus precatorius L.
Acacia farnesiana (L.) Willd.
Aeschynomene americana L. var. *americana*
°*Albizia julibrissin* (Willd.) Durazz.
°*A. lebbeck* (L.) Benth.
Alysicarpus vaginalis (L.) DC
Amorpha fruiticosa L.
Apios americana Medicus
Baptisia lecontei T & G
°*Bauhinia variegata* L.
Caesalpinia bonduc Roxb.
°*Calliandra haematocephala* Hassk.
Canavalia rosea (Sw.) DC
°*Cassia alata* L.
C. aspera Muhl.
°°*C. bicapsularis* L.
C. fasciculata Michx.
C. obtusifolia L.
C. occidentalis L.
Centrosema virginianum (DC) Benth.
Clitoria mariana L.
Crotalaria lanceolata E. Mey.
C. mucronata Desv.
C. rotundifolia (Walt.) Poir. var. *rotundifolia*
C. spectabilis Roth
C. pumila Ortega
C. retusa L.
Dalbergia ecastophyllum (L.) Benth.
Desmodium canum (J. F. Gmel.) Schinz & Thellung
D. floridanum Chapm.
D. paniculatum (L.) DC
D. strictum (Pursh) DC
D. tenuifolia T & G
D. tortuosum (Sw.) DC
D. triflorum (L.) DC

**Enterolobium cyclocarpum* Griseb.
Erythrina herbacea L.
Galactia elliottii Nutt.
G. macreii M. A. Curtis
G. volubilis (L.) Britt.
Indigofera caroliniana Mill.
I. hirsuta Harv.
I. spicata Forsk.
I. suffruticosa Mill.
Lespedeza striata (Thunb.) H & A
***Leucaena leucocephala* (Lam.) de Wit
Lupinus diffusus Nutt.
Medicago lupulina L.
Melilotus alba Desr.
M. indica (L.) All.
**Parkinsonia aculeata* L.
Petalostemon carneum Michx.
P. feayi Chapm.
Phaseolus lathyroides L.
P. polystachios (L.) BSP
Pithecellobium unguis-cati (L.) Benth.
Rhynchosia cinerea Nash
R. difformis (Ell.) DC
R. lewtonii (Vail) Small
R. minima (L.) DC
Sesbania exaltata (Raf.) Rydberg *ex* A. W. Hill
**S. *punicea* (Cav.) Benth.
S. vesicaria DC
Sophora tomentosa L.
Strophostyles helvola (L.) Ell.
Tephrosia curtissii (Small) Shinners
Vicia acutifolia Ell.
V. floridana S. Wats.
V. luteola (Jacq.) Benth.
**Wisteria sinensis* (Sims) Sweet

GERANIACEAE

Geranium carolinianum L.
**Pelargonium* × *hortorum* Bailey

OXALIDACEAE

Oxalis dillenii Jacq.
O. violacea L.

ZYGOPHYLLACEAE

Tribulus cistoides L.
T. terrestris L.

RUTACEAE

Amyris elemifera L.
**Citrus aurantium* L.
***C. paradisi* Macf.
**C. paradisi* Macf. × *C. reticulata* Blanco
**C. reticulata* Blanco
***C. sinensis* (L.) Osbeck
Zanthoxylum clava-herculis L.
Z. fagara (L.) Sarg.

SIMAROUBACEAE

Simarouba glauca DC

SURIANACEAE

†*Suriana maritima* L.

BURSERACEAE

Bursera simaruba (L.) Sarg.

MELIACEAE

***Melia azedarach* L.

POLYGALACEAE

Polygala baldwinii Nutt.
P. cruciata L.
P. grandiflora Walt. var. *angustifolia* T & G
P. grandiflora Walt. var. *grandiflora*
P. incarnata L.
P. lutea L.
P. nana (Michx.) DC
P. polygama Walt.
P. rugelii Shuttlw.
P. setacea Michx.

EUPHORBIACEAE

Acalypha gracilens Gray
A. ostryaefolia Riddell
Chamaesyce blodgettii (Engelm. *ex* Hitchc.) Small
C. bombensis (Jacq.) Dugand
C. hirta (L.) Millsp.
C. hypericifolia (L.) Small
C. hyssopifolia (L.) Small
C. maculata (L.) Small
C. mesembryanthemifolia (Jacq.) Dugand
C. opthalmica (Pers.) Burch
Cnidoscolus stimulosus (Michx.) Engelm. & Gray
Croton glandulosus L. var. *glandulosus*
C. punctatus Jacq.
†*Drypetes lateriflora* (Sw.) Krug & Urban
Euphorbia trichotoma HBK
**Jatropha curcas* L.
**Pedilanthus tithymaloides* (L.) Poit. ssp. *smallii* (Millsp.) Dressler
Phyllanthus abnormis Baillon
P. tenellus Roxb.
Poinsettia cyathophora (Murray) Kl. & Gke.
***Ricinus communis* L.
**Sapium sebiferum* (L.) Roxb.
Stillingia sylvatica L. ssp. *sylvatica*
Tragia urens L.

EMPETRACEAE

Ceratiola ericoides Michx.

ANACARDIACEAE

**Mangifera indica* L.
Rhus copallina L. var. *leucantha* (Jacq.) DC
***Schinus terebinthifolius* Raddi
Toxicodendron radicans (L.) Kuntze ssp. *radicans*

CYRILLACEAE

Cyrilla racemiflora L.

AQUIFOLIACEAE

Ilex ambigua (Michx.) Chapm. var. *ambigua*
I. cassine L.
I. glabra (L.) Gray
I. vomitoria Ait.

ACERACEAE

Acer negundo L.
A. rubrum L. var. *tridens* Wood

SAPINDACEAE

Dodonaea viscosa (L.) Jacq.
Exothea paniculata (Juss.) Radlk.
°*Koelreuteria elegans* (Seem.) A. C. Smith ssp. *formosana* (Hayata) F. G. Meyer
°*Litchi chinensis* Sonn.
Sapindus marginatus Willd.

RHAMNACEAE

Berchemia scandens (Hill.) K. Koch
Krugiodendron ferreum (Vahl) Urban
Sageretia minutiflora (Michx.) Mohr.

VITACEAE

Ampelopsis arborea (L.) Koehne
Cissus trifoliata L.
Parthenocissus quinquefolia (L.) Planchon
Vitis aestivalis Michx.
V. rotundifolia Michx.
V. shuttleworthii House

MALVACEAE

Hibiscus furcellatus Desr.
H. grandiflorus Michx.
°*H. rosa-sinensis* L.
°*H. schizopetalus* (Mast.) Hook. f.
°*H. tiliaceus* L.
Kosteletzkya althaeifolia (Chapm.) Rusby
K. pentasperma (Bertero *ex* DC) Griseb.
Malvastrum corchorifolium (Desc.) Britt. ex Small
M. coromandelianum (L.) Garcke
°*Malvaviscus arboreus* Cav. var. *mexicanus* Schlecht.
Pavonia spinifex (L.) Cav.
Sida acuta Burm.
S. cordifolia L.
S. rhombifolia L.
Urena lobata L.

BOMBACACEAE

°*Salmalia malabarica* Schott & Grell.

BYTTNERIACEAE

°*Dombeya wallichii* D. Jackson

HYPERICACEAE

Hypericum cistifolium Lam.
H. gentianoides (L.) BSP
H. hypericoides (L.) Crantz var. *hypericoides*
H. mutilum L.
H. reductum P. Adams
H. stans (Michx.) P. Adams & Robson
H. tetrapetalum Lam.

CISTACEAE

Helianthemum corymbosum Michx.
H. nashii Britt.
Lechea cernua Small
L. mucronata Raf.
L. patula Leggett
L. torreyi Leggett *ex* Britt.

VIOLACEAE

Viola floridana Brainerd
V. lanceolata L.
V. primulifolia L.

TURNERACEAE

Piriqueta caroliniana (Walt.) Urban var. *tomentosa* Urban

PASSIFLORACEAE

Passiflora incarnata L.
P. lutea L.
P. suberosa L.

CARICACEAE

Carica papaya L.

LOASACEAE

Mentzelia floridana Nutt.

CACTACEAE

Cereus eriophorus Pfeiffer var. *fragrans* (Small) L. Benson
°*C. pterantha* Link & Otto
°*C. undatus* Haw.
°*Nopalea cochinellifera* Salm-Dyck
Opuntia compressa (Salisb.) Macbride var. *austrina* (Small) L. Benson
O. stricta Haw. var. *dillenii* (Ker.) L. Benson
O. stricta Haw. var. *stricta*
°*Pereskia aculeata* Mill.

LYTHRACEAE

Ammannia teres Raf.
°*Lagerstroemia indica* L.
Lythrum alatum Pursh var. *lanceolatum* (Ell.) T & G
L. lineare L.
Rotala ramosior (L.) Koehne

RHIZOPHORACEAE

Rhizophora mangle L.
Conocarpus erecta L. var. *erecta*
C. erecta L. var. *sericea* Forst. *ex* DC
Laguncularia racemosa Gaertn. f.
°*Quisqualis indica* L.

MYRTACEAE

°*Eucalyptus robusta* Sm.
Eugenia axillaris (Sw.) Willd.
E. foetida Pers.
°*E. uniflora* L.
°*Melaleuca quinquenervia* (Cav.) Blake
Myrcianthes fragrans (Sw.) McVaugh
°°*Psidium cattleianum* Sabine
°°*P. guajava* L.
°*Syzygium cumingii* (L.) Skeels
°*S. jambos* Alston

MELASTOMATACEAE

Rhexia mariana L. var. *mariana*
R. nuttallii C. M. James
R. petiolata Walt.

ONAGRACEAE

Gaura angustifolia Michx.
Ludwigia alata Ell.
L. decurrens Walt.
L. hirtella Raf.
L. maritima F. Harper
L. microcarpa Michx.
L. octovalvis (Jacq.) Raven ssp. *octovalvis*
L. peruviana (L.) Hara
L. repens Forst.
L. suffruticosa Walt.
Oenothera humifusa Nutt.
O. laciniata Hill var. *laciniata*

HALORAGACEAE

Proserpinaca palustris L.
P. pectinata Lam.

ARALIACEAE

* *Tetrapanax papyriferum* Koch

APIACEAE

Apium leptophyllum (Pers.) F. Muell.
Centella asiatica (L.) Urban
Cicuta maculata L.
Eryngium aromaticum Baldw.
E. baldwinii Spreng.
E. prostratum Nutt.
E. yuccifolium Michx. var. *synchaetum* (Gray) C & R
Hydrocotyle bonariensis Lam.
H. umbellata L.
H. verticillata Thunb.
Oxypolis filiformis (Walt.) Britt.
Ptilimnium capillaceum (Michx.) Raf.
Sanicula canadensis L.
Spermolepis divaricata (Walt.) Raf.

CORNACEAE

Cornus foemina Mill.

ERICACEAE

Befaria racemosa Vent.
Gaylussacia dumosa (Andrews) T & G
Leucothoe populifolia (Lam.) Dippel
Lyonia ferruginea (Walt.) Nutt.
L. fruticosa (Michx.) G. A. Torr.
L. lucida (Lam.) K. Koch
Monotropa uniflora L.
Vaccinium arboreum Marsh.
V. darrowi Camp
V. myrsinites Lam.
V. stamineum L. var. *caesium* (Greene) Ward

MYRSINACEAE

Ardisia escalloniodes Schlecht. & Cham.
Myrsine guianensis (Aubl.) Kuntze

PRIMULACEAE

Samolus ebracteatus HBK
S. parviflorus Raf.

PLUMBAGINACEAE

Limonium carolinianum Britt. var. *carolinianum*
**Plumbago capensis* Thunb.
P. scandens L.

SAPOTACEAE

Bumelia reclinata (Michx.) Vent. var. *reclinata*
B. tenax (L.) Willd.
Chrysophyllum oliviforme L.
Mastichodendron foetidissimum (Jacq.) Cronquist

EBENACEAE

**Diospyros kaki* Horton
D. virginiana L.

OLEACEAE

Forestiera segregata (Jacq.) Krug & Urban var. *segregata*
Fraxinus tomentosa Michx. f.
**Jasminum sambac* Solander
**Ligustrum lucidum* Ait.
**Olea europeae* L.
Osmanthus americanus (L.) Gray var. *americanus*
O. americanus (L.) Gray var. *megacarpa* Small

LOGANIACEAE

**Buddleja madagascariensis* Lam.
Gelsemium sempervirens (L.) Ait. f.
Mitreola petiolata (J. F. Gmel.) Torr.
M. sessilifolium (J. F. Gmel.) G. Don
M. succulentum R. W. Long
Polypremum procumbens L.

GENTIANACEAE

Bartonia verna (Michx.) Muhl.
Eustoma exaltatum (L.) Griseb.
Sabatia brevifolia Raf.
S. campanulata (L.) Torr.
S. difformis (L.) Druce
S. grandiflora (Gray) Small
S. stellaris Pursh

APOCYNACEAE

**Allamanda cathartica* L.
Apocynum cannabinum L.
***Catharanthus roseus* (L.) G. Don
Echites umbellata Jacq. var. *umbellata*
**Ervatamia coronaria* Willd.
**Nerium oleander* L.
**Thevetia peruviana* (Pers.) Schum.
**Vinca minor* L.

ASCLEPIADACEAE

Asclepias curtissii Gray
A. incarnata L. ssp. *incarnata*
A. lanceolata Walt.
A. pedicellata Walt.
A. tomentosa Ell.
A. tuberosa L. ssp. *rolfsii* (Britt.) Woodson

Cynanchum laeve (Michx.) Pers.
C. palustre (Pursh) Heller
C. scoparium Nutt.
Matelea suberosa (L.) Shinners
Morrenia odorata Lindl.

CONVOLVULACEAE

Calystegia sepium (L.) R. Brown
Cuscuta campestris Yuncker
C. compacta Juss.
Dichondra caroliniensis Michx.
Ipomoea acuminata (Vahl.) R & S
I. alba L.
I. cairica (L.) Sweet
I. coccinea L.
I. hederacea (L.) Jacq. var. *hederacea*
I. panduranta (L.) Meyer
I. pes-caprae (L.) R. Brown var. *emarginata* Hall
I. purpurea (L.) Roth
I. sagittata Lam.
I. stolonifera (Cyr.) J. F. Gmel.
I. trichocarpa Ell.
Merremia dissecta (Jacq.) Hall

POLEMONIACEAE

Gilia rubra L.
Phlox drummondii Hook.

BORAGINACEAE

Heliotropium angiospermum Murray
H. curassavicum L.
Tournefortia gnaphalodes (L.) Brown
T. poliochros Spreng.

VERBENACEAE

Callicarpa americana L.
Citharexylum fruticosum L.
°*Clerodendrum indicum* Kuntze
°*C. speciosum* D'Ombrain
°*C. umbellatum* Poir.
Lantana camara L.
L. involucrata L.
L. montevidensis (Spreng.) Briq.
L. ovatifolia Britt. var. *ovatifolia*
Lippia nodiflora Michx.
Verbena maritima Small
V. scabra Vahl.
V. tampensis Nash
°*Vitex trifolia* L. var. *variegata* Moldenke

AVICENNIACEAE

Avicennia germinans (L.) L.

LAMIACEAE

Conradina grandiflora Small
Hyptis alata (Raf.) Shinners var. *alata*
H. mutabilis (A. Richard) Briq. var. *spicata* Briq.
°*Mentha* sp.
Monarda punctata L.
Prunella vulgaris L.

Salvia coccinea L.
S. lyrata L.
Satureja rigida Bartr. *ex* Benth.
Scutellaria integrifolia L.
Teucrium canadense L. var. *canadense*
T. canadense L. var. *hypoleucum* Griseb.
Trichostema dichotomum L.
T. suffrutescens Kearney

SOLANACEAE

Capsicum annum L. var. *minimum* (Mill.) Heiser
°*Cestrum nocturnum* L.
Lycium carolinianum Walt.
Physalis pubescens L. var. *pubescens*
P. viscosa L. ssp. *maritima* (Curtiss) Waterfall
Solanum americanum Mill.
S. erianthum D. Don
S. seaforthianum Andr.

SCROPHULARIACEAE

Agalinis fasciculata (Ell.) Raf.
A. filifolia (Nutt.) Raf.
A. harperi Pennell
A. linifolia (Nutt.) Britt.
A. maritima (Raf.) Raf.
A. setacea (J. F. Gmel.) Raf.
Bacopa caroliniana (Walt.) Robinson
B. monnieri (L.) Pennell
Buchnera americana L.
B. floridana Gandoger
Gratiola ramosa Walt.
G. subulata Baldw.
Linaria floridana Chapm.
Mecardonia acuminata (Walt.) Small
Micranthemum glomeratum (Chapm.) Shinners
Penstemon multiflorus Chapm. *ex* Benth.
°*Russelia equisetiformis* Schlecht. & Champ.
Scoparia dulcis L.
Seymeria pectinata (Pursh) Kuntze

BIGNONIACEAE

°*Bignonia capreolata* L.
Campsis radicans (L.) Seem.
°*Jacaranda acutifolia* H & B
°*Kigelia pinnata* (Jacq.) DC
°*Podranea ricasoliana* Sprague
°*Pyrostegia ignea* Presl.
°*Tecoma stans* (L.) Juss.
°*Tecomaria capensis* (Thunb.) Spach

LENTIBULARIACEAE

Pinguicula caerulea Walt.
P. lutea Walt.
P. pumila Michx.
Utricularia biflora Lam.
U. foliosa L.
U. inflata Walt. var. *inflata*
U. inflata Walt. var *minor* Chapm.
U. purpurea Walt.

ACANTHACEAE

Asystasia gangetica (L.) Anders.
Dicliptera assurgens (L.) Juss. var. *vahliana* (Nees) Gomez
Justicia brandegeana Wasshausen & Smith
Odontonema strictum Kuntze
**Ruellia brittoniana* Leonard *ex* Fern.
R. caroliniensis (J. F. Gmel.) Steud. ssp. *caroliniansis* var. *caroliniensis*
R. caroliniensis (J. F. Gmel.) Steud. ssp. *ciliosa* (Pursh) R. W. Long var. *heteromorpha* R. W. Long
Thunbergia alata Bojer *ex* Sims
T. fragrans Roxb.

PLANTAGINACEAE

Plantago lanceolata L.
P. virginica L.

RUBIACEAE

Borreria laevis (Lam.) Griseb.
B. verticillata (L.) Meyer
Cephalanthus occidentalis L.
Chiococca alba (L.) Hitchc.
Diodia rigida (Willd.) Champ. & Schlecht.
D. teres Walt.
D. virginiana L.
Ernodea littoralis Sw.
Galium aparine L.
G. hispidulum Michx.
G. obtusum Bigel. var. *floridanum* (Wieg.) Fern.
G. pilosum Ait. var. *laevicaule* Weatherby & Blake
Hedyotis corymbosa (L.) Lam.
H. procumbens (J. F. Gmel.) Fosberg
H. uniflora (L.) Lam. var. *fasciculata* (Bertoloni) W. H. Lewis
Morinda royac L.
Psychotria nervosa Sw.
P. sulzneri Small
Randia aculeata L.
Richardia brasiliensis (Moq.) Gomez

CAPRIFOLIACEAE

Sambucus canadensis L. var. *laciniata* Gray
Viburnum obovatum Walt.

VALERIANACEAE

Valeriana scabra L. var. *scabra*

CUCURBITACEAE

**Citrullus vulgaris* Schrad. *ex* Ecklon & Zeyher
Melothria pendula L. var. *crassifolia* (Small) Cogn.
M. pendula L. var. *pendula*
Momordica charantia L.

CAMPANULACEAE

Campanula floridana Wats.
Lobelia feayana Gray
L. glandulosa Walt.
L. paludosa Nutt.
L. puberula Michx.

GOODENIACEAE

Scaevola plumieri (L.) Vahl

ASTERACEAE

Ambrosia artemisiifolia L.
A. hispida Pursh
Aster carolinianus Walt.
A. dumosus L. var. *subulaefolius* T & G
A. elliottii T & G
A. reticulatus Pursh
A. subulatus Michx. var. *ligulatus* Shinners
Baccharis angustifolia Michx.
B. glomeruliflora Pers.
B. halimifolia L. var. *angustior* DC
Balduina angustifolia (Pursh) C. B. Robinson
Berlandiera humilis Small
B. subacaulis (Nutt.) Nutt.
Bidens bipinnata L.
B. pilosa L. var. *pilosa*
Borrichia frutescens (L.) DC
Cacalia floridana Gray
C. lanceolata Nutt. var. *elliottii* Kral & R. K. Godfrey
Carphephorus corymbosus (Nutt.) T & G
C. odoratissimum (J. F. Gmel.) Herb.
C. paniculata (J. F. Gmel.) Herb.
Cirsium horridulum Michx. var. *elliottii* T & G
C. nuttallii DC
Conyza canadensis (L.) Cronquist var. *pusilla* (Nutt.) Cronquist
Coreopsis gladiata Walt.
C. leavenworthii T & G
Eclipta alba (L.) Hassk.
Elephantopus elatus Bertoloni
Emilia javanica (Burm.) C. B. Robinson
Erechtites hieracifolia (L.) Raf. var. *hieracifolia*
Erigeron quercifolius Lam.
E. strigosus Mohl. var. *strigosus*
E. vernus (L.) T & G
Eupatorium aromaticum L.
E. capillifolium (Lam.) Small var. *capillifolium*
E. capillifolium (Lam.) Small var. *leptophyllum* (DC) Ahles
E. coelestinum L.
E. compositifolium Walt.
E. mikanioides Chapm.
E. recurvans Small
E. rotundifolium L.
E. serotinum Michx.
Flaveria linearis Lag.
F. × *latifolia* (J. R. Johnston) Rydberg
Gaillardia pulchella Foug.
Gnaphalium obtusifolium L. var. *obtusifolium*
G. falcatum Lam.
Helenium amarum (Raf.) H. Rock
H. vernale Walt.
°*Helianthus annuus* L.
H. debilis Nutt. ssp. *debilis*
H. simulans E. Wats.
Heterotheca graminifolia (Michx.) Shinners var. *graminifolia*

H. graminifolia (Michx.) Shinners var. *tracyi* (Small) R. W. Long
H. hyssopifolia (Nutt.) R. W. Long var. *hyssopifolia*
H. mariana (L.) Shinners
H. nervosa (Willd.) Shinners
H. subaxillaris Britt. & Rusby var. *subaxillaris*
H. trichophylla (Nutt.) Shinners
Hieracium gronovii L.
Iva frutescens L.
I. imbricata Walt.
I. microcephala Nutt.
Krigia virginica (L.) Willd.
Kuhnia eupatorioides L. var. *eupatorioides*
Lactuca floridana (L.) Gaertn.
L. graminifolia Michx.
Liatris chapmanii T & G
L. gracilis Pursh
L. graminifolia Willd.
L. tenuifolia Nutt. var. *tenuifolia*
L. tenuifolia Nutt. var. *laevigata* (Nutt.) Robinson
Lygodesmia aphylla (Nutt.) DC
Melanthera aspera Jacq. var. *aspera*
Mikania cordifolia (L.) Willd.
M. scandens (L.) Willd.
Palafoxia integrifolia (Nutt.) T & G
Phoebanthus graniflora (T & G) Blake
Pluchea camphorata (L.) DC
P. foetida (L.) DC
P. longifolia Nash
P. purpurascens (Sw.) DC
P. rosea R. K. Godfrey
Polymnia uvedalia L.
Pterocaulon pycnostachyum (Michx.) Ell.
Pyrrhopappus carolinianus (Walt.) DC. var. *georgianus* (Shinners) Ahles
Rudbeckia hirta L. var. *floridana* (Moor.) Perdue
* *Senecio confusus* Britt.
S. glabellus Poir.
Sericocarpus bifoliatus (Walt.) Porter
Solidago arguta Ait.
S. chapmanii T & G
S. fistulosa Mill.
S. leavenworthii T & G
S. microcephala (Greene) Bush
S. sempervirens L. var. *mexicana* (L.) Fern.
S. stricta Ait.
S. tenuifolia Pursh
S. tortifolia Ell.
Sonchus asper (L.) Hill
S. oleraceus L.
Spilanthes americana (Mutis) Hieron.
Verbesina laciniata (Poir.) Nutt.
Vernonia angustifolia Michx. var. *angustifolia*
V. gigantea (Walt.) Trel.
** *Wedelia trilobata* (L.) Hitchc.
* *Xanthium strumarium* L. var. *glabratum* (DC) Cronquist

ACKNOWLEDGMENTS—The authors thank the curators of the herbaria of the University of Florida, Gainesville, and the University of South Florida, Tampa, for permission to examine their collections. Special thanks are due to Dr. Richard Wunderlin, Director of the University of South Florida Herbarium, for his helpful comments on nomenclatural changes and for correcting numerous identification errors. Various personnel of the Merritt Island National Wildlife Refuge are thanked for permission to collect on Merritt Island. We express gratitude to Mrs. Felecia Hammond for typing several versions of the checklist, a thankless task for those not familiar with Latin binomials.

LITERATURE CITED

ALEXANDER, T. R. 1953. Plant succession on Key Largo, Florida, involving *Pinus caribaea* and *Quercus virginiana*. Quart. J. Florida Acad. Sci. 16:133-138.

———. 1955. Observations on the ecology of the low hammocks of southern Florida. Quart. J. Florida Acad. Sci. 18:21-27.

———. 1958a. High hammock vegetation of the southern Florida mainland. Quart. J. Florida Acad. Sci. 21:293-298.

———. 1958b. Ecology of the Pompano Beach hammock. Quart. J. Florida Acad. Sci. 21:299-304.

AUSTIN, D. F. 1976. Vegetation changes in the Spanish River area of Boca Raton. Florida Sci. 39 (Suppl. 1):7.

CONARD, H. S. 1969. Plants of Central Florida. Golden Rule Press. Orlando.

FIX, J. 1967. Royal relic of Merritt Island. Florida Wildlife 20:30-31.

HUME, H. H. 1938. Advancing knowledge of Florida's vast plant life. Proc. Florida Acad. Sci. 2:5-12.

LAKELA, O., AND F. C. CRAIGHEAD. 1965. Annotated checklist of vascular plants of Collier, Dade and Monroe Counties, Florida. Univ. Miami Press. Coral Gables.

———, R. W. LONG, G. FLEMING AND P. GENELLE. 1976. Plants of the Tampa Bay Area (Revised Edition). Banyan Books. Miami.

LONG, R. W., AND O. LAKELA. 1971. A Flora of Tropical Florida. Univ. Miami. Press. Coral Gables.

MITCHELL, R. S. 1963. Phytogeography and floristic survey of a relic area in the Marianna Lowlands, Florida. Amer. Midl. Nat. 69:328-366.

NORMAN, E. M. 1976. An analysis of the vegetation of Turtle Mound. Florida Sci. 39:19-31.

RADFORD, A. E., H. E. AHLES AND C. R. BELL. 1964. Manual of the Vascular Flora of the Carolinas. Univ. North Carolina Press. Chapel Hill.

SMALL, J. K. 1919. Coastwide dunes and lagoons a record of botanical exploration in Florida in the spring of 1918. J. N.Y. Bot. Gard. 20:191-207.

———. 1920. Of grottoes and ancient dunes, a record of exploration in Florida in December, 1918. J. N.Y. Bot. Gard. 21:25-54.

———. 1921. Historic trails, by land and by water. A record of exploration in Florida in December, 1919. J. N.Y. Bot. Gard. 22:193-222.

———. 1933. Manual of the Southeastern Flora. Reprint. Univ. North Carolina Press. Chapel Hill.

SWEET, H. C. AND J. E. POPPLETON. 1977. An EDP technique designed for the study of a local flora. Taxon 26:12-21.

WARD, D. B. 1968. Checklist of the vascular flora of Florida—Part I. Bull. 726. Agric. Exper. Sta. IFAS Bull. 726. Gainesville.

Florida Sci. 40(4):362-389. 1977.

Outstanding Service Award

CITATION FOR CLARENCE C CLARK

UNSELFISH DEVOTION cannot exceed that of Clarence C Clark to Science Education, to the activities of the youth of Florida in the sciences, and to all the programs of the Florida Academy of Sciences. Coming to Florida in 1959 as Professor and Course Chairman of Physical Sciences at the University of South Florida, Dr. Clark has served continuously on the Council of the Florida Academy of Sciences since 1962 and was President in the year 1967-68. Since his presidency he has voluntarily and graciously given public service to science practically his undivided attention, with no expectation of glory or reward.

Dr. Clark's imagination and leadership have been major factors in Florida's meteoric rise to "overall first state in the world" in Science for Florida in the National Science Talent Search, he has so promoted the program in Florida that the state for many years has consistently had many times its share of highest performers at every phase of the competition. Similar records have been maintained in the Science Fair Program. Both programs have been sponsored by the Academy.

Somehow, with no recognition, Dr. Clark always seems to be the one behind the arrangements which make things like these go. Early in his Florida career Dr. Clark obtained support from the National Science Foundation for the Florida Academy to operate a Visiting Scientist Program in which arrangements are made for many of the State's leading scientists to visit high schools and make talks on request, without compensation. When NSF support for all such programs through learned societies was discontinued, Dr. Clark offered the Academy his services to conduct the program single-handed, with the Academy paying only some of his few out-of-pocket expenses in publicizing and arranging the visits, usually made without even payment of travel expenses of the visitors. Florida is only one of five states continuing the program at the present time. After conducting the program for eleven years Dr. Clark is now offering to train a successor he has found, whom the Council of the Academy has approved.

It is most appropriate at this time that the Academy is honoring *Dr. Clarence C Clark.*

Outstanding Service Award

CITATION FOR HARVEY ALFRED MILLER

WHEN THE FLORIDA ACADEMY OF SCIENCES seized a new and willing Editor for its Quarterly Journal in 1973, it little realized that in addition to getting an experienced and qualified man of letters and a very accomplished botanist, it was also bringing to its administration a superb imaginative manager. The new Editor, Dr. Harvey Alfred Miller, picked up a Journal with scores of accepted, but yet unpublished, papers and even more papers which had been neither accepted nor rejected and with the forthcoming issue of the Journal nearly two years behind its specified date of publication. Subscribers were refusing to continue payments, and discouraged Academy members were dropping their memberships.

In less than three years Dr. Miller brought the publication schedule up to date, cleared all the backlog of manuscripts, greatly strengthened the refereeing of papers submitted, revolutionized the processes of preparation, reproduction and distribution and, incidentally, added "*Florida Scientist*" to the title of the Quarterly Journal. All this was accomplished at a lower current cost to the Academy than when the output of the Journal was miniscule.

Dr. Miller saw the need for revisions of the administrative and fiscal procedures of the Academy interfacing with its biggest single operation, the publication and distribution of the Journal. In his endeavors to effect these revisions, he took on increasing responsibilities in connection with memberships, dues, and multifarious other secretarial needs of the Academy, some of which had never before been met. Dr. Miller soon found that he had become the first Executive Secretary of the Academy, despite zero salary for this position or the editorship.

Typical of the vision and bold statesmanship of this dedicated servant, he cultivated the John Young Museum of Orlando with the result that the Museum has provided the Academy with its first permanent headquarters at practically no expense to the Academy and with enhancement to the prestige of both organizations. For the past four years he has represented the Academy in the American Association for the Advancement of Science.

Having put the Quarterly Journal on a firm operating basis, Dr. Miller has declared that he is now ready to groom a successor to edit the Journal.

It is most appropriate at this time that the Academy is honoring *Dr. Harvey Alfred Miller.*

ERRATA—Corrections to: *The Marco Island Estuary; A Summary of Physicochemical and Biological Parameters* by MICHAEL P. WEINSTEIN, CHARLES M. COURTNEY AND JAMES C. KINCH. *Florida Scientist* 40(2):97-124. Page 97 for Matuskey *read* Matusky; p. 102 for physiochemical *read* physicochemical; p. 104, TABLE 1, insert the following headings to the columns of numbers, from left to right, PO_4^1 (mg/1), PO_4^2 (mg/1), NO_3 (mg/1), NO_2 (mg/1), NH_3 (mg/1), SiO_3 (mg/1), Chlorophyll *a* (mg/m^3); p. 106, Table 2, for *Branciostoma* read *Branchiostoma*, for *Tubonilla* read *Turbonilla*; p. 109 for *Toxeuma carolinese* read *Tozeuma carolinense*; p. 110 column 1, for *Nassorius uibex* read *Nassarius vibex*, for *spicina* read *apicina*, for *Andara traversa* read *Anadara transversa*; p. 110 column 3, for *Branchistoma* read *Branchiostoma*, for *Brachiostoma* read *Branchiostoma*; p. 114 for TABLE 1 *read* TABLE 5; p. 116 for *Sygnathus* read *Syngnathus*, for *nephalus* read *nephelus*.

OCCURRENCE OF *ESOX NIGER* IN SANTA ROSA SOUND, FLORIDA[1]

—*Larry R. Goodman,* U. S. Environmental Protection Agency, Environmental Research Laboratory, Sabine Island, Gulf Breeze, Florida 32561

ABSTRACT: *An immature chain pickerel was collected in Santa Rosa Sound, Florida, at a salinity of 3 °/oo after heavy rain storms.*

CHAIN PICKEREL, *Esox niger* LeSueur, occur east of the Appalachians from the St. Lawrence River southward and in drainage systems along the Gulf Coast to Texas. The chain pickerel is known to be common in the littoral areas of Chesapeake Bay at salinities as great as 12.6 °/oo and Carlander (1969) reported that it may live in brackish water as high as 15 °/oo. In our area, this species inhabits freshwater streams that flow into Pensacola Bay (Bailey et al., 1954). Chain pickerel comprise 0.1% of the catch in the lower Escambia River by sportsfishermen (Hixson et al., 1971).

This note is the first report of *E. niger* collected from the normally saline portion of the lower Pensacola estuary. A 109 mm standard length chain pickerel was seined by Walter Burgess, Edward Matthews, and me on 7 August 1975 from Santa Rosa Sound, in Santa Rosa County, Florida, from *Thalassia* beds about 300 m W. of the N. end of State Highway 399 bridge. The specimen is in the Environmental Research Laboratory Museum as catalog No. GBERL–1914. Associated fishes either collected or observed were *Menidia* sp., *Eucinostomus* sp., *Orthopristis chrysoptera, Lagodon rhomboides, Leiostomus xanthurus, Mugil cephalus,* and *Chasmodes saburrae.* Water temperature was 26°C and salinity was an unusually low 3 °/oo near the collection site. The low salinity is attributed to a three-day total rainfall (29-31 July 1975) recorded by the U. S. Geological Survey for the following stations in the Escambia–Blackwater watershed: Pensacola, 29.54 cm; Crestview, 42.16 cm; Milton, 35.33 cm. Salinity recorded at the Environmental Research Laboratory on Sabine Island dropped from 23 °/oo on 28 July to a 25-year low of 1 °/oo on 12 August 1975.

LITERATURE CITED

BAILEY, R. M., H. E. WINN, AND C. L. SMITH. 1954. Fishes from the Escambia River, Alabama and Florida, with ecologic and taxonomic notes. Proc. Acad. Nat. Sci. Phila. 106:109-161.

CARLANDER, K. D. 1969. Handbook of Freshwater Fishery Biology. Iowa State Univ. Press. Ames.

HIXSON, W. C., J. I. NIVEN, AND T. S. HOPKINS. 1971. Results of a creel census of the lower Escambia River sports fishery. Bream Fishermen Association, 1333 N. Spring St., Pensacola, Florida. 18 pp.

Florida Sci. 40(4):392. 1977.

[1]Contribution No. 282, Gulf Breeze Environmental Research Laboratory.

Biological Sciences

DENSITY DEPENDENT AGGRESSIVE ADVANTAGE IN MELANISTIC MALE MOSQUITOFISH *GAMBUSIA AFFINIS HOLBROOKI* (GIRARD)

Randy G. Martin[1]

School of Forest Resources and Conservation, University of Florida, Gainesville, Florida 32611

Abstract: *At high laboratory densities, specifically 10 pair (= one pair per 1.65 l water), melanistic male mosquitofish* (Gambusia affinis holbrooki), *which are extremely rare in nature, were highly aggressive to normal males and had a clear dominance advantage over normals. Although their sexual activity at the 10-pair level was also significantly higher than normals, it was unclear whether there was an actual mating advantage or any female choice involved. If it can be subsequently shown that females respond selectively to melanistics by exhibiting receptive behavior, particularly at higher densities, a case for sexual selection will have been established.*[*]

Functional significance of color patterning in fishes is commonly related, directly or indirectly, to social behavior, i.e., courtship and agonistic behavior (Baerends and Baerends-van Roon, 1950; Baerends et al., 1955; Baggerman, 1957; Barlow, 1974; Bergman, 1968; Bleick, 1970; Blum, 1968; George, 1960; McAlister, 1958; Neil, 1964; and Seitz, 1940, 1942, 1948). Di- or poly-chromatism occurs in some species of fishes, including the families Poeciliidae, Cichlidae, Cyprinidae, Centrarchidae, Serranidae, Lepisosteidae, Anguillidae, Gadidae, Pomadasyidae, and Soleidae. It undoubtedly has a significant role during various forms of signalling, such as mate and resource competition, sexual solicitation, mimicry. However, examples demonstrating a functional significance are rare. Only the findings of McPhail (1969), Semler (1971), Barlow (1973), and Barlow et al. (1975) on *Gasterosteus aculeatus* and *Cichlasoma citrinellum* provide clear evidence of the selective role of different color morphs (predator avoidance in *G. aculeatus* and competition for food in *C. citrinellum*).

Male dichromatism is occasionally seen in populations of the live-bearing mosquitofish, *Gambusia affinis holbrooki* (Girard). Normally pigmented males contain two types of micromelanophores, one type in the epidermis and another in the dermis, while the dermis of melanistic males possesses macromelanophores with thick, varicose projections, in addition to the normal micromelanophores (Regan, 1961). In most natural populations, only normally pigmented males are found; in those with melanism, the melanistic males are always rare relative to normally pigmented males. The expression of melanism may be slight (spotted males), moderate (mottled), or strong (jet black).

To establish a possible functional significance of the melanism with regard to social behavior, I observed aggressive and sexual behavior of mosquitofish under laboratory conditions.

---

[1]Present address: Department of Biology, North Carolina A. & T. State University, Greensboro, N.C. 27411.

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

Materials and Methods—Populations of all normal males, mixed, and all melanistic males, with equal numbers of females, were established in aquaria measuring 61 × 17 × 21 cm, 16.5 l capacity. Population sizes were one, two, five, and ten pairs. Although "all normal," "mixed," and "all melanistic" populations were observed at the one and two pairs level, only "all normal" and "mixed" populations were observed at the five and ten pairs level due to insufficient numbers of melanistic individuals. A fifteen pair "all normal" population, seriously overcrowded, was also observed.

Sexual activity data were computed using only the category "orient," a basic unit of male sexual activity in which "typical" poeciliid lateral or frontal display is absent. During "orient," a male positions himself behind a female (from 1-10 fish lengths in the 16.5 l aquaria) and maneuvers to remain behind the female prior to making a gonopodial thrust. Gonopodial thrusts and gonopodial swings (which covaried significantly) were recorded but not included in computations of sexual activity, as their contribution remained relatively constant for each population level.

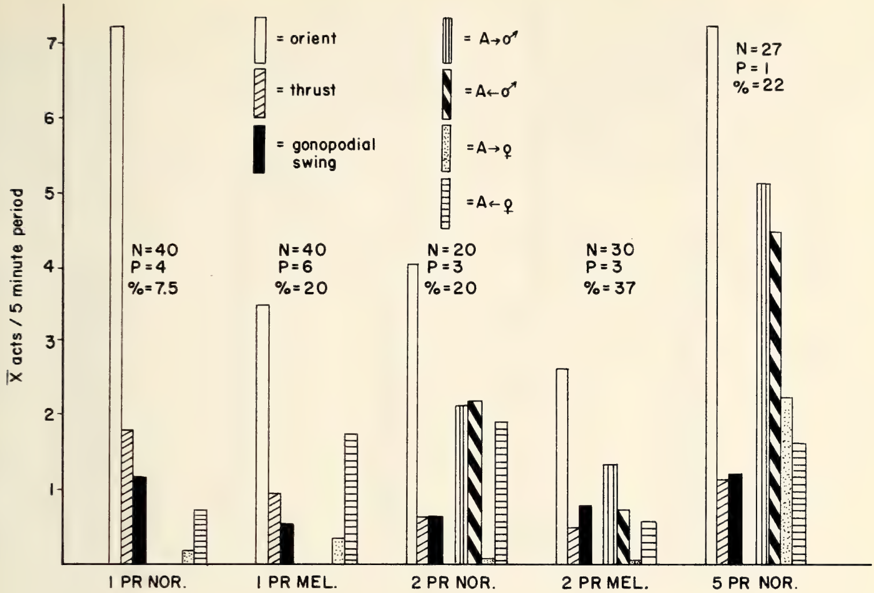
Aggression, consisting mostly of chases and occasional lateral displays, was recorded as "male to male," "male from male," "female to male," or "male to female." Lateral displays were infrequent, and almost always initiated by a dominant individual. Nipping, biting, and other categories of aggression were also infrequent, constituting a minor part of the behavioral repertoire. For a more complete description of mosquitofish behavior, see Itzkowitz (1971), Peden (1970, 1972), and Martin (1975a, 1975b).

Aquaria were kept on racks in a windowless laboratory with fluorescent lighting of approximately 100 lux, set on a 12-12 light-dark photoperiod. Water temperature of the aquaria remained at 22.5° C ± 1.° Fish were fed daily to satiation with Tetramin flakes, the amount depending on population size.

Observations were recorded with either an 8-channel event recorder, a 20-channel event recorder, or on notebooks using a behavioral code. Each observation period lasted 5 min.

Results—*One pair*: Normal males engaged in about twice as much sexual activity as did melanistic males; conversely, melanistic males received about twice as much aggression from the female of a pair (Fig. 1). These differences are significant at 0.05, suggestive of a basic difference between normal male and melanistic sexual activity. However, isolated pairs do not occur in nature.

Two pair: There were no significant differences in sexual activity among 2 pair normal, 2 pair melanistic, and 2 pair half melanistic. There were differences in aggression, however. Two melanistic males engaged in aggression less frequently than 2 normal males, but in mixed populations, a melanistic male had a significant advantage over the normal male (Fig. 2). Large differences occurred in male-female aggressive interactions in the mixed populations when compared to 2 pair normal and 2 pair melanistic. For example, melanistic males received nine times more aggression from females than they did in 2 pair melanistic populations, while normal male aggression to females was 8 times the rate of the 2 pair normal level (Fig. 1a,b).



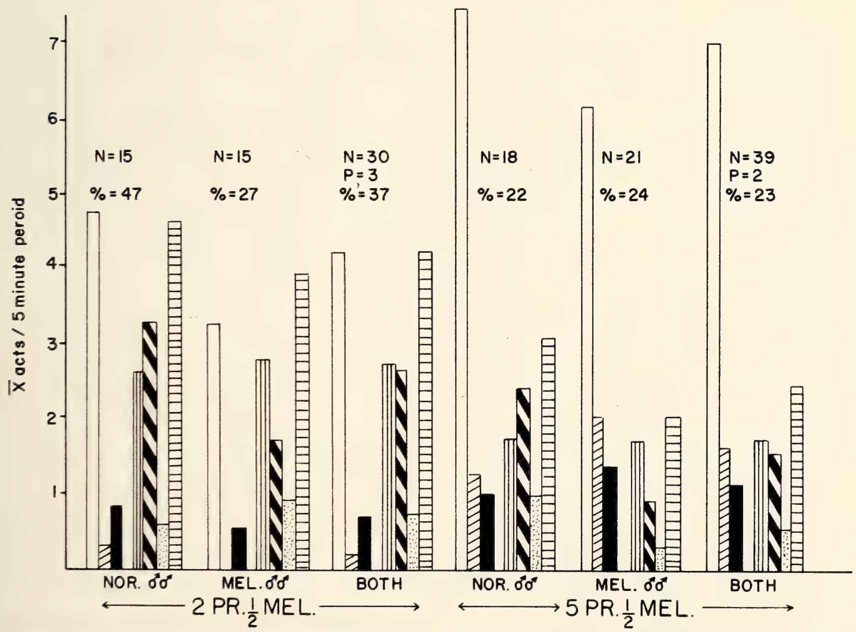


Fig. 1. (above) Sexual and aggressive activity of normal and melanistic mosquitofish, *Gambusia affinis holbrooki.* N = total number of five minute observation periods. P = total number of populations observed. % = percent of observations in which no sexual activity was observed.

Fig. 2. (below) Sexual and aggressive activity of normal and melanistic mosquitofish, *G. a. holbrooki.* N = total number of observation periods of five minutes each. P = total number of populations observed. % = percent of observations in which no sexual activity was observed.

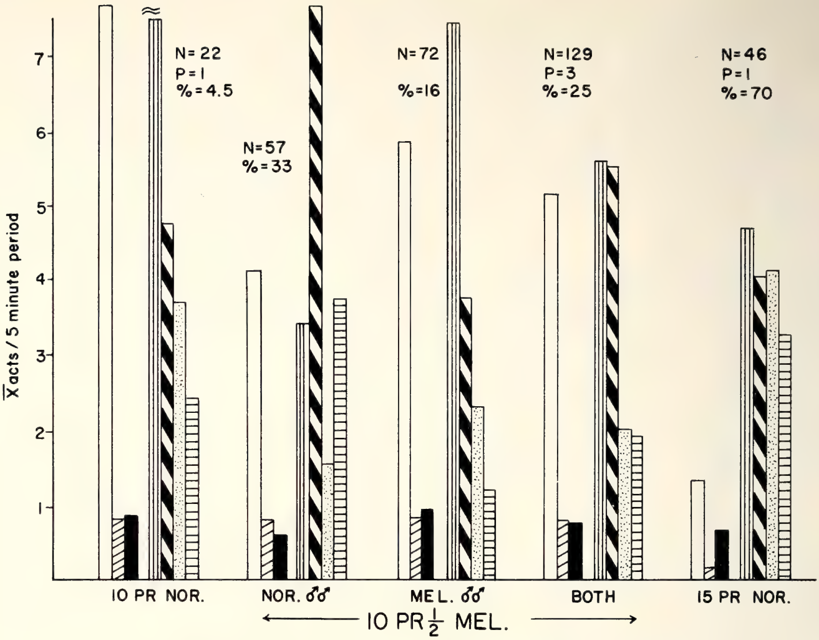


FIG. 3. Sexual and aggressive activity of normal and melanistic mosquitofish, *G. a. holbrooki.* N = total number of five minute observation periods. P = total number of populations observed. % = percent of observations in which no sexual activity was observed.

Five pair: The population of interest was the half melanistic one (3 melanistic males and 2 normals in one population, vice versa in a replicate), in which there was no significant difference in sexual or aggressive activity between normal and melanistic males (Fig. 2). Aggression from females was high for both types of males, although not as high as 2 pair half melanistic (Fig. 2).

Ten pair: Sexual and male-male aggressive activity were higher for 10 pair normal populations than for all other population sizes, but the most notable results occurred at the half melanistic level (Fig. 3). Results for the original population showed that aggression sent by melanistics nearly doubled aggression sent by normals (X = 7.38 vs. X = 4.13, N = 24). In two replicates the interactions of individually recognizable males were recorded, clearly showing that most melanistic aggression was directed at normals (Table 1). The total aggressive activity of each individual with each type of male, and the significance level based on binomial probability of deviation from equal amounts of aggression, are shown in Table 1.

Although not significantly aggressive over other melanistics, "alpha" melanistic in R1 was so named for his complete dominance over normals (93 acts sent, 1 received, Table 1). "Alpha" melanistic in R2 was dominant over both melanistics and normals (Table 1). Some of the melanistics reacted infrequently to other melanistics, e.g., "black" and "small" in R1. Most importantly, aggression received by normals from melanistics in R1 and R2 was always greater than aggression sent, significant at the .01 level for every normal fish (Table 1).

Discussion—Although mosquitofish live in all types of aquatic habitats, including brackish water, melanistic males are most commonly encountered in clear, spring-fed areas. Visual and photographic observations of social behavior in these areas have not shed light on the aquarium studies since aggression occurs very infrequently in the field (Martin, 1975a, 1975b). However, questions concerning the functional significance of higher aggressiveness of melanistic males in the laboratory may be posed.

Sexual selection: Although very high aggression may conceivably limit the time spent in reproductive activities, the clear dominance advantage of melanistic males over normals at the 10 pair level raises the question of whether the aggressive advantage confers an advantage in sexual activity. Aggressive dominance as a factor in reproductive success has been verified for other livebearing fishes by Gandolfi (1971), McKay (1971), and Constantz (1975). In the three 10 pair half melanistic populations observed, sexual activity varied considerably from individual to individual, with dominant melanistics and large and medium-sized normals having, in general, the highest rates. Overall, melanistic sexual activity for all three 10 pair half melanistic populations was significantly higher than normal activity. However, there was no overall significant sexual advantage (based on activity) for melanistic males for all population levels combined. Thus, whether or not melanistic males had an overall sexual advantage was unclear.

Of course, even a sexual advantage does not imply superior reproductive fitness, since greater reproductive activity does not necessarily lead to greater mating success. Copulation, indicating mating success, occurs infrequently and is difficult to detect in mosquitofish. Other measures of sexual selection besides the indirect one of sexual activity, such as female choice and male conflict, were unfortunately difficult to apply. The factor of female choice, one of the most likely mechanisms of sexual selection (Maynard-Smith, 1958), is very hard to detect in mosquitofish. Carlson (1969) used male thrusts as a measure of female receptivity in mosquitofish on the supposition that "there should be a correlation between the two," but this requires substantiation. Male conflict in mosquitofish occurs mostly during lulls in sexual activity, and the outcomes of individual bouts are frequently unrelated to sexual activity. Thus, the question of sexual selection, one of considerable general theoretical interest (see Campbell, 1972, Gadgil, 1972, and Charlesworth and Charlesworth, 1975), appears difficult to ascertain in *Gambusia affinis*.

Growth rate; *predation*: Selective pressures other than sexual may contribute to dimorphism. The discovery of Barlow (1973) and Barlow et al. (1975) that gold morphs of *Cichlasoma citrinellum* have a faster growth rate due to an aggressive advantage over normal morphs is especially interesting in comparison to my *Gambusia* work. Although I have not studied growth rate, melanistic males are generally larger than normals, and an analogous situation may exist.

Barlow also postulated that predation may operate as a counterselective force against the colored cichlid morphs. A definite answer to this possibility for melanistic mosquitofish has not been reached, but preliminary laboratory observa-

TABLE 1. Aggressive interactions of individual fish in replicate populations #1 and 2, ten pair ½ MEL. population level. The first number of a pair is aggression sent, the second number aggression received. Italicized pairs deviate from a binomial probability of 0.5:0.5 at the 0.01 significance level.

	Total aggression with melanistic males	Total aggression with normal males	Total aggression with females
REPLICATE #1			
"Alpha" mel.	27-19	*93-1*	*56-9*
"Dark" mel.	*30-1*	18-6	2-3
"Black" mel.	0-3	12-8	6-1
"Intersex" mel.	*0-14*	14-4	7-7
"Small" mel.	2-7	*19-5*	11-4
Large normal	*11-40*	*31-7*	*8-24*
Medium normal 1	*4-37*	12-11	*2-17*
Medium normal 2	*3-54*	*7-21*	15-25
Small normal 1	*5-19*	6-1	*22-5*
Small normal 2	*0-32*	5-14	*3-26*
REPLICATE #2			
"Alpha" mel.	*60-3*	*44-2*	*21-7*
"Fine" mel.	*3-36*	*32-4*	12-10
"Blotchy" mel.	*10-27*	*14-0*	7-12
"Small" mel.	*2-16*	*35-0*	10-12
Large normals (2)	*4-20*	*38-7*	*8-39*
Medium normal	*0-34*	*25-3*	12-21
Small normals (2)	*0-47*	*0-41*	*0-9*

tions, in which sunfish (*Lepomis* spp.) predators in 38 l aquaria with free access to equal numbers of melanistic and normal fish ate more normals than melanistics, indicate that the obverse of Barlow's observation may be occurring. In the field, mottled melanistics appeared camouflaged in vegetation but were conspicuous over open water. Jet black individuals were conspicuous in either type of habitat. I observed these melanistics at only 3 areas out of some 30 known mosquitofish habitats. At these 3 areas (all springs) more melanistics were collected in vegetation than in open water, but since they were always very rare (usually only 3 or 4 seen per collecting trip) an experimental field approach to the predation question was infeasible.

SUMMARY—At high laboratory densities, specifically 10 pair (= one pair per 1.65 l of water), melanistic male mosquitofish (*Gambusia affinis holbrooki*), which are extremely rare in nature, were highly aggressive to normal males and had a clear dominance advantage over normals. Although their sexual activity at the 10 pair level was also significantly higher than normals, it was unclear whether there was an actual mating advantage or any female choice involved. If it can be subsequently shown that females respond selectively to melanistics by exhibiting receptive behavior, particularly at higher densities, the melanistic genome would then have a definite advantage, and a case for sexual selection will have been established. If female choice were to occur particularly at higher

densities, the melanistic advantage would be density-dependent, and one would expect higher ratios of melanistics in dense populations unless an outside force (e.g., predation) were operating. Concerning predation, laboratory observations indicate that sunfish (*Lepomis* spp.) prefer normals over melanistics. Additional studies on female choice, predator preference, and other aspects of melanism (e.g., mechanisms of inheritance) are needed.

ACKNOWLEDGMENTS—I appreciate the helpful criticisms and advice of James A. Farr and William F. Herrnkind. This work is based upon part of my Ph.D. dissertation from Florida State University.

LITERATURE CITED

BAERENDS, G. P., AND J. M. BAERENDS-VAN ROON. 1950. An introduction to the study of the ethology of cichlid fishes. Behaviour Suppl. 1:1-242.

———, R. BROUWER, AND H. TJ. WATERBOLK. 1955. Ethological studies on *Lebistes reticulatus* (Peters). I. An analysis of the male courtship pattern. Behaviour 8:249-335.

BAGGERMAN, B. 1957. An experimental study of the timing of breeding and migration in the three-spined stickleback (*Gasterosteus aculeatus* L.). Arch. Neerl. Zool. 12:105-318.

BARLOW, G. W. 1973. Competition between color morphs of the polychromic Midas cichlid *Cichlasoma citrinellum*. Science 179:806-807.

———. 1974. Contrasts in social behavior between Central American cichlid fishes and coral-reef surgeon fishes. Amer. Zool. 14:9-34.

———, D. H. BAUER, AND K. R. MCKAYE. 1975. A comparison of feeding, spacing, and aggression in color morphs of the Midas cichlid. I. Food continuously present. Behaviour 54:72-96.

BERGMANN, H. H. 1968. Eine deskriptive Verhaltensanalyse des Segelflossers (*Pterophyllum scalare* Cuv. & Val.; Cichlidae, Pisces). Z. Tierpsychol. 25:559-587.

BLEICK, C. R. 1970. The behavior of the Central American fish, *Cichlasoma managuense*, and the function of its color patterns: a laboratory and field study. Masters thesis. Univ. California. Berkeley.

BLUM, V. 1968. Das Kämpfverhalten des braunen Diskusfishes, *Symphysodon aequifasciata axelrodi* L. P. Schultz (Teleostei, Cichlidae). Z. Tierpsychol. 25:395-408.

CAMPBELL, B. (ed.). 1972. Sexual Selection and the Descent of Man 1871-1971. Aldine. Chicago.

CARLSON, D. R. 1969. Female sexual receptivity in *Gambusia affinis* (Baird and Girard). Texas J. Sci. 21:167-173.

CHARLESWORTH, D., AND B. CHARLESWORTH. 1975. Sexual selection and polymorphism. Amer. Nat. 109:465-470.

CONSTANTZ, G. D. 1975. Behavioral ecology of mating in the male Gila topminnow. Ecology 56:966-973.

GADGIL, M. 1972. Male dimorphism as a consequence of sexual selection. Amer. Nat. 106:574-580.

GANDOLFI, G. 1971. Sexual selection in relation to the social status of males in *Poecilia reticulata* (Teleostei: Poeciliidae). Boll. di Zoologia 38:35-48.

GEORGE, C. 1960. Behavioral interaction of the pickerel (*Esox niger* LeSueur and *Esox americanus* LeSueur) and the mosquito fish (*Gambusia patruelis* (Baird and Girard)). Ph.D. dissert. Harvard Univ. Cambridge.

ITZKOWITZ, M. 1971. Preliminary study of the social behavior of male *Gambusia affinis* (Baird and Girard) (Pisces: Poeciliidae) in aquaria. Chesapeake Sci. 12:219-224.

MARTIN, R. G. 1975a. The social behavior of the mosquitofish, *Gambusia affinis holbrooki* (Girard), in the field and laboratory. Ph.D. dissert. Florida State Univ. Tallahassee.

———. 1975b. Sexual and aggressive behavior, density and social structure in a natural population of mosquitofish, *Gambusia affinis holbrooki*. Copeia 1975:445-454.

MAYNARD-SMITH, J. 1958. Sexual selection. *In* Barnett, S. A. (ed.). A Century of Darwin. Harvard Univ. Press. Cambridge.

MCALISTER, W. H. 1958. The correlation of coloration with social rank in *Gambusia hurtadoi*. Ecology 39:477-482.

MCPHAIL, J. D. 1969. Predation and the evolution of a stickleback (*Gasterosteus*). J. Fish. Res. Bd. Canada 26:3183-3208.

NEIL, E. H. 1964. An analysis of color changes and social behavior of *Tilapia mossambica*. Univ. Calif. (Berkeley) Publ. Zool. 75:1-58.

PEDEN, A. E. 1970. Courtship behavior of *Gambusia* (Poeciliidae) with emphasis on isolating mechanisms. Ph.D. dissert. Univ. Texas. Austin.

————. 1972. The function of gonopodial parts and behavioral pattern during copulation by *Gambusia* (Poeciliidae). Canada J. Zool. 50:955-968.

REGAN, J. D. 1961. Melanism in the poeciliid fish, *Gambusia affinis* (Baird and Girard). Amer. Midl. Nat. 65:139-143.

SEITZ, A. 1940. Die Paarbildung bei einigen Cichliden. I. *Astatotilapia strigena* Pfeffer. Z. Tierpsychol. 4:40-84.

————. 1942. Die Paarbildung bei einigen Cichliden. II. *Hemichromis bimaculatus* Gill. Z. Tierpsychol. 5:74-101.

————. 1948. Verhaltensstudien an Buntbarschen. Z. Tierpsychol. 6:230-233.

SEMLER, D. E. 1971. Some aspects of adaptation in a polymorphism for breeding colours in the threespine stickleback (*Gasterosteus aculeatus*). J. Zool. Lond. 165:291-302.

Florida Sci. 40(4):393-400. 1977.

STATEMENT OF OWNERSHIP, MANAGEMENT AND CIRCULATION (Act of August 12, 1970: Section 3685, Title 39, United States Code). 1. *Title of Publication*: FLORIDA SCIENTIST. 2. *Date of Filing*: 1 December 1976. 3. *Frequency of Issue*: Quarterly. 4. *Location of known office of publication*: Florida Academy of Sciences, Inc., 810 East Rollins Street, Orlando, Florida 32803. 5. *Location of the headquarters or general business offices of the publisher*: Same as above. 6. *Names and addresses of publisher and editor*: *Publisher*: Florida Academy of Sciences, 810 East Rollins Street, Orlando, Florida 32803. *Editor*: Harvey A. Miller, Department of Biological Sciences, Florida Technological University, Orlando, Florida 32816. 7. *Owner*: Florida Academy of Sciences, Inc., 810 East Rollins Street, Orlando, Florida 32803—a nonprofit professional scientific organization incorporated in the state of Florida. Current officers are: President, Robert A. Kromhout; President-Elect, Harris B. Stewart; Secretary, H. Edwin Steiner, Jr.; Treasurer, Anthony F. Walsh. 8. *Known bondholders, mortgagees, and other security holders owning or holding 1% or more of total amount of bonds, mortgages or other securities*: None. 9. *For completion by nonprofit organizations authorized to mail at special rates*: The purpose, function, and non-profit status of this organization and the exempt status for Federal income tax purposes have not changed during preceding 12 months. 10. *Extent and Nature of Circulation*:

	Avg. No. Copies Ea. Issue During Preceding 12 months	Single Issue Nearest to Filing Date
A. Total No. Copies Printed	1300	2200
B. Paid Circulation:		
1. Through membership only	700	700
2. Mail Subscriptions (Institutional Subscriptions)	400	400
C. Total Paid Circulation	1100	1100
D. Free Distribution	0	0
E. Total Distribution	1100	1100
F. Office Use, leftover, unaccounted, spoiled after printing	200	900
G. Total:	1300	2200

I certify that the statements made by me above are correct and complete. (*signed*) *Harvey A. Miller, Editor.*

Biological Sciences

A NEW SUBSPECIES OF *ANOLIS BALEATUS* (SAURIA: IGUANIDAE) FROM ISLA SAONA, REPUBLICA DOMINICANA

ALBERT SCHWARTZ

Miami-Dade Community College North, Miami, Florida 33167

ABSTRACT: *A new subspecies of* Anolis baleatus, *one of the three species of Hispaniolan giant anoles, is described from a single specimen taken on Isla Saona off the extreme southeastern end of Hispaniola; comparisons of the new taxon are made with the two adjacent mainland subspecies. A brief discussion of the Saonan herpetofauna reveals high incidence of subspecific endemism.**

ISLA SAONA, off the extreme southeastern coast of the Dominican portion of Hispaniola, has revealed an increasingly large herpetofauna. Schwartz (1974) noted the occurrence of *Anolis baleatus* Cope, one of the three Hispaniolan species of giant anoles, on Isla Saona, but the single animal observed in 1971 could not be collected. On 18-19 February 1975, a field party composed of Howard W. Campbell, Ronald I. Crombie, Roy W. McDiarmid, and Fred G. Thompson collected on Isla Saona, and among other material they succeeded in securing an adult male *A. baleatus*. This animal, through the courtesy of Mr. Crombie, has been lent me for study, and a color transparency of the head (with dewlap extended) has likewise been afforded me by Dr. McDiarmid. The lizard is so very distinctive, not only from the adjacent mainland subspecies but from all other subspecies of *Anolis baleatus* that I have no doubts as to the differentiation of this insular population. Mr. Crombie's field notes likewise suggest that these lizards are not uncommon in the xeric woodlands of Isla Saona, but they are there, as elsewhere, difficult to secure except at night. Since there is no foreseeable chance that anyone will be visiting Isla Saona in the near future to secure more material, this seems an appropriate time to name this population. A certain amount of risk is obviously involved in such an action, since it is always possible that the single Saona specimen is not representative of the Isla Saona population as a whole (see, however, comments below). Yet it is so distinctive that, even if the population is more variable than this specimen, the population is nameworthy.

In allusion to the striking neck streaking in the adult male, I propose, from the Latin for "streaked" and "neck" that it be called

Anolis baleatus lineatacervix, new subspecies

Holotype. USNM 197325, an adult male, from between kms 7 and 8 on the Mano Juan road, just east of the navy base, west end of Isla Saona, La Altagracia Province, República Dominicana, collected 18 February 1975 by Howard W. Campbell and Ronald I. Crombie. Original number USNM 040169.

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

Definition. A subspecies of *A. baleatus* characterized by the combination of 3 snout scales between second canthal scales, 5 vertical rows of loreal scales, 2 scales between the supraorbital semicircles, low number (16) of vertical dorsal scales, nuchal crest scales very high, body crest scales low, subocular scales separated from supralabial scales by 1 row of scales; adult male basically medium brown (although apparently capable of a very pale green phase at least at night) with faint indications of 3 widely separated pale grayish crossbands, sides of neck prominently streaked or blotched with white, including a white supra-axillary white stripe; throat streaked with green to brown, the green extending onto the supra- and infra-labial scales; casque dull brownish, eyeskin ashy gray; dewlap yellowish peach.

Description of holotype. An adult male with a snout-vent length of 145 mm, tail length about 230 mm; snout scales on level of second canthals 3, 5 vertical rows of loreal scales, scales between the supraorbital semicircles 2, 5/5 scales between the interparietal and the supraorbital semicircles, vertical dorsals 16, horizontal dorsals 19, ventrals 22, 1 row of scales between the suboculars and supralabials, fourth toe lamellae on phalanges II and III 32, nuchal crest scales very high, body crest scales low (for methods of taking measurements and counts, see Schwartz, 1974); coloration (based on preserved specimen, color transparency of head and anterior end, and field notes) medium brown, with 3 widely spaced faint pale grayish crossbands on the back; tail concolor with dorsum and only very vaguely crossbanded; limbs patternless brown; casque dull brownish (more reddish than dorsum, as preserved); sides of neck (including region of auricular opening) with broad and conspicuous white streaking, consisting of a white preauricular spot, a white streak from above the auricular opening dorsally to parallel the midline of the back, its posterior portion broken as a separate blotch; a second lower white streak from anterior to the auricular opening posteriorly to above the insertion of the forelimb; a white blotch near the middorsal crest scales at about mid-neck; and a white streak from the forelimb insertion posteriorly for about the anterior quarter of the body, this last line the least conspicuous of the nuchal pattern (Fig. 1); venter whitish, chin, supra- and infralabials green, the chin with green longitudinal streaking which posteriorly becomes brownish at the anterior end of the dewlap; dewlap yellowish peach; eyeskin ashy gray in contrast to the brown casque and loreal and temporal regions of head.

COMPARISONS—*A. b. lineatacervix* is so distinctive that it requires no comparisons with any of the other 9 subspecies of *A. baleatus* (see Schwartz and Thomas, 1975, for distributions of other subspecies; Schwartz, 1974, for a review of the entire complex; and Schwartz, 1975, for the description of another subspecies). No other subspecies has males with a boldly lineate neck; although occasional females of various subspecies may have some neck streaking, this streaking is dark (usually very dark green to black) and never so obvious as the white streaking in male *A. b. lineatacervix*.

The 2 subspecies that occur nearest to *A. b. lineatacervix* (*A. b. scelestus* Schwartz, *A. b. litorisilva* Schwartz) are not known from the immediately adjacent mainland; *A. b. scelestus* occurs some 40 km to the northwest (13.4 km NE La Romana) and *A. b. litorisilva* some 30 km to the northeast (9.8 km NW Boca de Yuma). There are no records from the adjacent mainland (between El Peñón and Punta Aljibe) and in fact this southern mainland extremity is very poorly known herpetologically. As far as scutellation is concerned, *A. b. lineatacervix* falls within the known parameters of all counts of the adjacent subspecies except that no (of 15) *A. b. litorisilva* has 5 vertical loreal rows (range 6-9; $M_o = 7$). *A. b. lineatacervix* appears to be much smaller than the other 2 subspecies; the holotype has a snout-vent length of 145 mm, whereas maximally sized male *A. b. litorisilva* are 158 mm and *A. b. scelestus* are 180 mm.

Field notes on the holotype and other *A. b. lineatacervix* (Crombie, *in litt.*, 4 April 1975 and 31 May 1977) stated that "All the ones . . . missed and the one we got were medium brown, with the vermiculations quite pronounced. All were seen at night, however, while [the animals were] sleeping high in the trees. During the day, the one we collected was varying shades of brown (never any greens apparent . . .)." However, Crombie's later letter stated that the lizards were very pale green. These data suggest that *A. b. lineatacervix* has limited metachrosis and achieves a green phase at night; some other subspecies are green both diurnally and nocturnally. Male *A. b. litorisilva* are basically blotched lizards (not crossbanded), the dorsum varying from light blue-brown to light greenish brown in males, the dewlap bright orange, and the chin and throat (including the lips) bright orange; nuchal vermiculations or stripes are never present. Male *A. b. scelestus* may be either blotched or crossbanded, the dorsum either green with 3 pastel green crossbands, dark green flecked with light green, or cream with some greenish to brownish green smudges; the dewlap in males is deep yellow to deep orange, streaked or smudged with dark brown to charcoal. The basic ground color in *A. b. scelestus* is green to greenish, and even *A. b. litorisilva* has greenish tints. In dorsal pattern (crossbanding) *A. b. lineatacervix* most closely resembles *A. b. scelestus*, but that subspecies likewise lacks white nuchal streaking or vermiculations. The yellowish peach dewlap of *A. b. lineatacervix* likewise differs from those of both *A. b. scelestus* and *A. b. litorisilva*.

Remarks—Crombie (*in litt.*) noted that "All the individuals we saw were sleeping 10-20′ up on slender limbs of trees along the road leading east from the navy base on the west end of the island. All were in forest and we saw none in cut-over or agricultural areas. . . . They were about as abundant as *Uromacer* [*oxyrhynchus*] but considerably more difficult to get. Most tolerated considerable jostling of the tree in our clumsy efforts to nab them. Their tails dangling down made them fairly obvious." Crombie returned to Isla Saona in 1976 and attempted to collect more specimens in the same canopied forest. None was observed in 3 nights of collecting. This may have been due to high winds and rain squalls. In addition, the road had been widened, and cultivation and goats had resulted in clearing the scrubby forest and destroying most of the lower levels of the remaining forest. I gather that *A. b. lineatavervix* is not rare in the proper habitat (forest) on Isla Saona, but collecting specimens may be subject to the vagaries of weather. Although I spent 4 days on the island in 1968 and traveled fairly widely from the village of Mano Juan (both at night and during the day), *A. baleatus* was never encountered nor did local residents bring in specimens. The previous example noted above was seen at night as it slept and shot (not retrieved) by Danny C. Fowler and Bruce R. Sheplan in November 1971; this was the only individual they encountered in a stay of less than 1 day (including night collecting). The site was on the northwest corner of the island, near Puesto Catuán.

Isla Saona has an area of 111 km^2 and is separated from the mainland by a channel 2 km wide; its avifauna, herpetofauna, and their comparisons with those of other Hispaniolan satellite islands have been discussed by Schwartz (1970, 1971). The known herpetofauna consists of 1 amphibian (*Osteopilus dominicen-*

FIG. 1. Lateral view of head and anterior portion of holotype (USNM 197325) of *Anolis b. lineatacervix*; snout-vent length 145 mm.

sis Tschudi), 10 lizards (*Ameiva chrysolaema richardthomasi* Schwartz and Klinikowski, *A. taeniura rosamondae* Cochran, *Anolis baleatus lineatacervix* Schwartz, *A. ch. chlorocyanus* Duméril and Bibron, *A. cybotes* Cope, *A. distichus sejunctus* Schwartz, *Cyclura cornuta cornuta* Bonnaterre—no specimens but reported, *Celestus costatus saonae* Schwartz, *Leiocephalus lunatus louisae* Cochran, *Sphaerodactylus savagei juanilloensis* Shreve), and 6 snakes (*Antillophis parvifrons styqius* Thomas and Schwartz, *Epicrates striatus striatus* Fischer, *Hypsirhynchus ferox exedrus* Schwartz, *Typhlops pusilla* Barbour, *Uromacer catesbyi inchausteguii* Schwartz, *U. oxyrhynchus* Duméril and Bibron). Of these taxa, 9 are endemic Saona subspecies. In addition, the specimens of *A. cybotes* are very obviously a nameworthy population. Thomas (1976) noted that southeastern Hispaniolan *T. pusilla* (including specimens not only from the mainland but also from Isla Saona and Isla Catalina) have the highest counts of dorsal scales for this widely ranging species, and that these same specimens are pallid but in addition are truly bicolor. It seems likely that the southeastern *T. pusilla* likewise represent an undescribed subspecies. Of the species that do not have endemic Saonan subspecies (*O. dominicensis, A. chlorocyanus, Cyclura cornuta, S. savagei, E. striatus, U. oxyrhynchus*), all except *O. dominicensis* and *S. savagei* have subspecies elsewhere and, with the exception of *S. savagei,* all are broadly distributed geographically on the mainland. *S. savagei,* on the other hand, has a restricted distribution on extreme eastern Hispaniola, including Isla Saona and Isla Catalinita (with 2 poorly defined mainland subspecies involved) and an outlier population to the west in San Cristóbal Province, near Sabana Grande de Palenque. In summary, well over half of the Isla Saona amphibians and reptiles have subspecies that are often very distinct from their mainland relatives.

The above list indicates what species are found on Isla Saona; equally important are those animals that are *not* (or have not as yet been found) there. The most striking omission is the frog genus *Eleutherodactylus*. Admittedly, overseas transport of even frogs with direct development (where eggs rather than adults or tadpoles may be the mode of transport) is fraught with difficulties and additionally southeastern Hispaniola has a poor *Eleutherodactylus* fauna; still, one might expect that some member of the genus occurs there. Secondly, the absence of amphisbaenids (Family Amphisbaenidae) is puzzling; one species (*A. manni* Barbour) occurs in southeastern Hispaniola, and it seems likely that it should occur on Isla Saona. Among the snakes, the dwarf boas (*Tropidophis*) remain uncollected (or are absent) from Isla Saona. These small snakes are rather ubiquitous in lowland situations, either mesic or xeric, and their absence from the island is puzzling. Collectors who visit Isla Saona should pay especial attention to the possibility of finding representatives of these groups.

Acknowledgments—I am very grateful to Ronald I. Crombie of the National Museum of Natural History for making the single Saona anole available to me for study. Financial assistance to Howard W. Campbell for the field work, during which the holotype was collected, was from the National Fish and Wildlife Laboratory. The Fundación Gulf + Western Dominicana, Inc., provided indispensable logistical support, including the boat which made the trip to Isla Saona possible. Thanks are also due to Alfredo Carta for permission to use the facilities; Campos S. de Moya, Christina Baber, and Nicholas I. Tawill were all of great assistance to the party in handling the arrangements on the island. Thomas Scanlon, the Gulf + Western Corporation agent in Washington, was instrumental in making the original basic arrangements. The drawing of the lateral view of the head of *A. b. lineatacervix* is from the pen of Steven A. Fagan, to whom I am once more in debt.

LITERATURE CITED

Schwartz, A. 1970. Land birds of Isla Saona, República Dominicana. Quart. J. Florida Acad. Sci. 32:291-306.

————. 1971. A systematic review of the Hispaniolan snake genus *Hypsirhynchus*. Stud. Fauna Curaçao and Caribbean Is. 35(128):63-94.

————. 1974. An analysis of variation in the Hispaniolan giant anole, *Anolis ricordi* Duméril and Bibron. Bull. Mus. Comp. Zool. 146(2):89-148.

————. 1975. A new subspecies of *Anolis baleatus* Cope (Sauria: Iguanidae) from the República Dominicana. Florida Sci. 38:30-36.

————, and R. Thomas. 1975. A check-list of West Indian amphibians and reptiles. Carnegie Mus. Nat. Hist. Spec. Publ. 1:216 pp.

Thomas, R. 1976. Systematics of Antillean blind snakes of the genus *Typhlops* (Serpentes: Typhlopidae). Ph. D. dissert. Louisiana State Univ. Baton Rouge.

Florida Sci. 40(4):401-405. 1977.

CAVE DWELLING FISHES IN PANHANDLE FLORIDA—*Karen A. Brockman and Stephen A. Bortone*, Faculty of Biology, University of West Florida, Pensacola, Florida 32504

ABSTRACT: *Explorations in Ellis Cave, Jackson Co., Florida revealed 2 species of cave dwelling fishes: the pirate perch,* Aphredoderus sayanus *and the redeye chub,* Hybopsis harperi. *Their presence in the cave is probably facultative and transitory.*

WE EXPLORED Ellis Cave, Jackson Co., Florida on 20-21 December 1975 and 5 March 1977 to follow up on a rumor among local residents concerned with the presence of "blind cave fishes." While our examination of the cave did not reveal any "blind" fish, we did collect and observe 2 fish species, one of which is previously unreported from Florida caves. Previously known Florida cave fishes are all from the central portion of the state and include *Hybopsis harperi* and the yellow bullhead *Ictalurus natalis* (Hobbs, 1942; Hubbs, 1956; Relyea and Sutton, 1973).

Ellis Cave is located in an exposed limestone outcrop 0.4 km W of the Chipola River and 2.9 km N of Marianna, Florida. The cave has two entrances and other smaller openings which border the Chipola River flood plain. Ellis Cave consists of alternating narrow passages and wide "rooms", many of which contain quiet, silt bottomed pools. On 20-21 December 1975 the air temperature was 18°C and water temperature was 21°C. On 5 March 1977 air and water temperatures were 23° and 19°C, respectively.

Aphredoderus sayanus—Three pirate perch, 40-53 mm standard length (University of West Florida Catalog No.: UWF 2586) were collected by dipnet and minnow trap baited with Vienna sausage on 20-21 December 1975. One of the specimens was taken from a shallow (0.5 m deep) pool just inside the cave entrance. The remaining specimens (and at least 4 other fish seen, but not captured) were located in deeper, larger pools (3 m × 5 m × 0.1-3 m deep) 50 m or more from a cave entrance. In situ observations indicated that the pirate perch were relatively inactive and did not respond to light or human activity. Pigmentation was slightly reduced on the ventral surface of cheeks, opercles, mandibles, belly and caudal peduncle but otherwise appeared as epigean pirate perch. Summarizing biological data on the three specimens: 1) 40 mm SL male, stomach filled with *Cambarus cryptodytes* parts and some shrimp and cladocerans; 2) 43 mm SL female, ovary mature, stomach with exoskeleton and mud; 3) 53 mm SL female, ovary mature, stomach with a cladoceran and mud, a vestigial unsegmented anal ray present on right side of anal fin. The occurrence of *A. sayanus* in a cave calls for a comparison with its closest living relatives, the North American blind cave fishes of the Amblyopsidae. Rosen and Patterson (1969) based this relationship, in part, on the presence of an expanded parasphenoid bone in extant Amblyopsidae and fossil Oligocene and Miocene Aphredoderidae. Both families have genital papilla in the jugular position in adults. Several features of *A. sayanus* make it a likely candidate for a cave existence: the cephalic lateral line system is well developed, the species is nocturnal (Parker and Simco, 1975) and it consumes insects as well as a wide variety of food items (Flemer and Woolcott, 1966).

Hybopsis harperi—Five redeye chubs were observed in the larger pools on 5 March 1976 and one specimen (31 mm SL, UWF 2587) was captured by dipnet. The fish were inactive when first observed but became active when approached and seemed negatively phototaxic. The captured tuberculate male had enlarged testes and its gut was empty. Pigmentation was pale but apparently normal with pale orange on the snout and dorsal caudal peduncle surfaces. The present distribution of both subterranean and epigean *H. harperi* closely follows the karst topography and often occurs in areas where underground springs emerge (McLane, 1955). Marshall (1947) noted that *H. harperi* can eat a variety of small animals. McLane collected juvenile specimens all yr long and attributed the lack of a well defined breeding season to almost constant cave water temperatures. Our discovery of a tuberculate male lends support to the speculation by Relyea and Sutton (1973) that *H. harperi* may spawn in caves.

It is apparent that *A. sayanus* and *H. harperi* enter (and leave) Ellis Cave during flooding of the nearby Chipola River. Their preadaptation or potential affinity for subterranean existence may insure their survival as facultative cave residents. Other fish species may also enter the cave during flooding but lack the morphological, feeding, and behavioral features necessary for survival.

Ellis Cave supports a variety of other troglophilic vertebrates such as: the slimy salamander, *Plethodon glutinosus*; the long-tailed salamander, *Eurycea longicauda*; and the leopard frog, *Rana pipiens.* Also found living in the cave were several blind crayfish, *Cambarus cryptodytes,* and a "white" arachnid, *Spermophora meridionalis.*

ACKNOWLEDGMENTS: We thank C. Wilcox, J. S. Williams, D. Adkison, P. A. Hastings, M. Jeffries, D. Trescott, G. Donahue for aid in collecting the specimens. James Farr identified the arachnid.

LITERATURE CITED

FLEMER, D. A., AND W. S. WOOLCOTT. 1966. Food habits and distribution of the fishes of Tuckahoe Creek, Virginia, with special emphasis on the bluegill, *Lepomis m. macrochirus* Rafinesque. Chesapeake Sci. 7:75-89.

HOBBS, H. H. 1940. Seven new crayfishes of the genus *Cambarus* from Florida, with notes on other species. Proc. U.S. Natl. Mus. 89:387-423.

HUBBS, C. L. 1956. Preliminary analysis of the American cyprinid fishes, seven new, referred to the genus *Hybopsis,* subgenus *Erimystax.* Occ. Pap. Mus. Zool. Univ. Michigan 578:1-18.

MARSHALL, N. 1947. The spring run and cave habitats of *Erimystax harperi* (Fowler). Ecology 68-75.

MCLANE, W. M. 1955. The Fishes of the St. John's River System. Ph.D. dissert. Univ. of Florida. Gainesville.

PARKER, N. C., AND B. A. SIMCO. 1975. Activity patterns, feeding and behavior of the pirate perch, *Aphredoderus sayanus.* Copeia 1973:572-574.

RELYEA, K., AND B. SUTTON. 1973. Cave dwelling yellow bullheads in Florida. Florida Sci. 36:22-30.

ROSEN, D. E., AND C. PATTERSON. 1969. The structure and relationships of the paracanthopterygian fishes. Bull. Amer. Mus. Nat. Hist. 141:357-474; pl. 54-78.

Florida Sci. 40(4):406-407. 1977.

ACKNOWLEDGMENT OF REVIEWERS

For the past five years, a growing number of helping hands has been extended by specialists in many fields. They have helped to strengthen our journal and have often given freely to assist authors in need of sympathetic guidance in manuscript development. Sometimes they have helped us find just the right person to provide a learned and effective review. As our new editorial team assumes responsibility for volume 41, they will surely call upon those loyal members and friends for aid and be seeking new names representing new skills to assist them. Should you wish to volunteer, please let our new editors know of your willingness. Meanwhile, my sincerest thanks are extended to the courteous and cooperative authors whose papers have appeared in these pages and to those unseen and unnamed reviewers who have done so much to assist me during my term. If I have overlooked any reviewer in the following list, my apology is profound and my thanks undiminished.—*H. A. Miller*, retiring editor.

John H. Armstrong
Walter Auffenberg
Daniel Austin
Ronald C. Baird
J. E. Bartholic
Mondell L. Beach
Stephen A. Bortone
John C. Briggs
John Brookbank
Robert C. Bullock
George H. Burgess
Robert L. Chew
Samuel F. Clark
Andre Clewell
Glenn M. Cohen
Ida J. Cook
Thomas J. Costello
Walter R. Courteney, Jr.
Bruce C. Cowell
Ernest H. Davis
Joseph S. Davis
Thomas R. Dye
Llewellyn M. Ehrhart
Leslie L. Ellis
John Ewel
Andrew Feinstein
Phyllis Fleming
David E. Flinchbaugh
Eldon H. Franz
F. E. Friedl
George Fritz
Robert N. Gennaro
Carter R. Gilbert
Robert B. Grimm
Dannie A. Hensley
Wm. F. Herrnkind
John E. Hodgin
Arthur J. Hicks
Ronald Hofstetter
Robin Huck
Harold J. Humm
A. Blair Irvine
Ray Iverson
John W. Jolley, Jr.
Albert C. Jones
L. S. Karably
Tom Lee
Robert W. Long, Jr.
Lowell D. Kispert
John J. Koran, Jr.
Frank B. Kujawa
Robert J. Laird
James Layne
R. R. H. Lemon
Robert J. Livingston
Kathleen A. Manchip
Alex Marsh
Donald Marszaleck
Dean F. Martin
Karl Mattox
James A. McArthur
George A. Maul
William M. McCord
David Mook
David Nicol
Daniel K. Odell
Guy C. Omer
George Y. Onada
James D. Orcutt
John A. Osborne
J. K. Osmond
Hans S. Plendl
James E. Poppleton
Peter Pritchard
Anthony F. Randazzo
George K. Reid
C. Richard Robins
Thomas N. Russo
George E. Schaiberger
John W. Sheldon
Joseph L. Simon
Franklin F. Snelson
Janice B. Snook
Stephen E. Stancyk
H. Edwin Steiner, Jr.
Don C. Steinker
I. Jack Stout
Michael J. Sweeney
Haven C. Sweet
William H. Taft
Walter K. Taylor
Howard J. Teas
Daniel B. Ward
Linda Ward-Williams
David W. Washington
S. David Webb
Roseanne S. White
Henry O. Whittier
Rudy J. Wodzinski
Richard P. Wunderlin
Yousef A. Yousef
S. G. Zam

INSTRUCTIONS TO AUTHORS

Rapid, efficient, and economical transmission of knowledge by means of the printed word requires full cooperation between author and editor. Revise copy before submission to insure logical order, conciseness, and clarity.

MANUSCRIPTS should be typed double-space throughout, on one side of numbered sheets 8½ by 11 inch, smooth, bond paper.

A CARBON COPY will facilitate review by referees.

MARGINS should be 1½ inches all around.

FOOTNOTES should be avoided. Give ACKNOWLEDGMENTS in the text.

ADDRESS should be given following the author's name.

ABSTRACTS should be typed double-spaced immediately following the address.

LITERATURE CITED follows the text. Double-space every line and follow the form in the current volume.

TABLES are charged to authors at $25.00 per page or fraction. Titles must be short, but explanatory matter may be given. Type each table on a separate sheet, double-space, unruled, to fit normal width of page, and place after Literature Cited.

LEGENDS for illustrations should be grouped on a sheet, double-spaced, in the form used in the current volume, and placed after Tables. Titles must be short but may be followed by explanatory matter.

ILLUSTRATIONS are charged to authors ($20.00 per page or fraction). Drawings should be in India ink, on good board or drafting paper, and lettered by lettering guide or equivalent. Plan linework and lettering for reduction, so that final width is 4 5/8 inches, and final length does not exceed 7 inches. Do not submit illustrations needing reduction by more than one-half. Photographs should be of good contrast, on glossy paper. Do not write heavily on the backs of photographs.

PROOF must be returned promptly. Leave a forwarding address in case of extended absence.

REPRINTS may be ordered when the author returns corrected proof.

Membership applications, subscriptions, renewals, changes of address, and orders for back numbers should be addressed to the Executive Secretary, Florida Academy of Sciences, 810 East Rollins Street, Orlando, Florida 32803.

Florida Scientist

QUARTERLY JOURNAL
of the
FLORIDA ACADEMY OF SCIENCES

VOLUME 41

Editors
WALTER K. TAYLOR
HENRY O. WHITTIER

Published by the

FLORIDA ACADEMY OF SCIENCES, INC.
Orlando, Florida
1978

The Florida Scientist continues the series formerly issued as the Quarterly Journal of the Florida Academy of Sciences. The Annual Program Issue is published independently of the journal and is issued as a separately paged Supplement.

CONTENTS OF VOLUME 41

NUMBER 1

NUMBER 2

Number 3

Number 4

Florida Scientist 40(4) was mailed on April 11-12, 1978.
Florida Scientist 41(1) was mailed on June 14, 1978.
Florida Scientist 41(2) was mailed on August 25, 1978.
Florida Scientist 41(3) was mailed on October 30, 1978.

ISSN: 0098-4590

Florida Scientist

Volume 41 | Winter, 1978 | No. 1

CONTENTS

(*Continued on back*)

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

FLORIDA SCIENTIST

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Editors: Walter K. Taylor and Henry O. Whittier
Department of Biological Sciences
Florida Technological University
Orlando, Florida 32816

The FLORIDA SCIENTIST is published quarterly by the Florida Academy of Sciences, Inc., a non-profit scientific and educational association. Membership is open to individuals or institutions interested in supporting science in its broadest sense. Applications may be obtained from the Executive Secretary. Both individual and institutional members receive a subscription to the FLORIDA SCIENTIST. Direct subscription is available at $13.00 per calendar year.

Original articles containing new knowledge, or new interpretation of knowledge, are welcomed in any field of Science as represented by the sections of the Academy, viz., Biological Sciences, Conservation, Earth and Planetary Sciences, Medical Sciences, Physical Sciences, Science Teaching, and Social Sciences. Also, contributions will be considered which present new applications of scientific knowledge to practical problems within fields of interest to the Academy. Articles must not duplicate in any substantial way material that is published elsewhere. Contributions are accepted only from members of the Academy and so papers submitted by non-members will be accepted only after the authors join the Academy. Instructions for preparation of manuscripts are inside the back cover.

Published by the Florida Academy of Sciences, Inc.
810 East Rollins Street
Orlando, Florida 32803

Printed by the Storter Printing Company
Gainesville, Florida

Florida Scientist

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Walter K. Taylor, *Editor* Henry O. Whittier, *Editor*

Volume 41 Winter, 1978 No. 1

Biological Sciences

MORTALITY OF FISHES DUE TO COLD ON THE EAST COAST OF FLORIDA, JANUARY, 1977[1]

Franklin F. Snelson, Jr. and William K. Bradley, Jr.

Department of Biological Sciences, Florida Technological University, Orlando, Florida 32816

Abstract: *The unusually cold weather during January, 1977, resulted in fish mortality in waters of the Indian River Lagoon system, Brevard County, Florida. Air and water temperatures for the area are presented, and 30 fish species affected by the cold are listed. Since 1856, 16 cold-induced fish kills have been reported from Florida waters, averaging one per decade. Ecological aspects of cold weather fish mortality vary according to species.*[*]

Winter of 1976-77 was one of the coldest on record in Florida. The news media widely publicized the unusual series of cold weather fronts that resulted in freezing conditions, even snowfall, throughout most of the State. The coldest period, 17-22 January, broke all low temperature records and had a devastating effect on many subtropical components of the biota. This report documents the effects of the January cold period on marine fishes in the Indian River Lagoon system in Brevard County, Florida. Cold-related fish mortality occurred in other areas throughout the State during this same time.

There have been 15 previous occasions when marine fishes have been reported stunned or killed by severe low temperatures somewhere in the coastal waters of peninsular Florida:

1856. Fishes were killed in the vicinity of Key West, where air temperatures of 44°F (6.6°C) occurred 24 and 25 December (Packard, 1871).

1868. An intense cold front on 25 December resulted in frost and ice at Key West and the destruction of many fishes. The kill apparently was more severe than that of 1856 (Packard, 1871).

1886. A severe cold wave on 12 January killed fishes along the entire west coast of the Florida peninsula, from Cedar Key to Key West. Destruction of fishes

[1]Contribution No. 8, Merritt Island Ecosystem Studies.

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

and other aquatic organisms was massive. An air temperature of 41°F (5.0°C) was recorded at Key West (Willcox, 1887; Finch, 1917).

1894-95. Destruction of fishes was recorded at Sanibel Island on the west coast and Oak Lodge (in southern Brevard County) on the east coast in the period 29-30 December, 1894. In addition to fishes, manatee (*Trichechus manatus*) and green sea turtles (*Chelonia mydas*) were numbed or killed. An air temperature of 28°F (–2.2°C) was recorded at Sanibel Island. The second fish-killing cold of the winter occurred in the period 9-12 February, 1895. At Sanibel Island, the lowest air temperature recorded was 34°F (1.1°C). Air temperature at Oak Lodge reached a low of 20°F (–6.7°C). In addition to fishes, manatee were killed at Oak Lodge (Bangs, 1895; Storey and Gudger, 1936).

1898. A cold period in January paralyzed and/or killed fishes at Sanibel Island. An air temperature of 26°F (–3.3°C) was recorded on the 3rd of the month (Storey and Gudger, 1936).

1899. Fishes were numbed (but apparently not killed) in the vicinity of Sanibel Island during February. A low air temperature of 28°F (–2.2°C) was recorded on 14 February (Storey and Gudger, 1936).

1905. Fishes were killed at Sanibel Island either in December (1904) or January. Minimum reported air temperature was 30°F (–1.1°C) at Sanibel Island (date unspecified) and 27°F (–2.8°C) at nearby Fort Myers on 26 January (Storey and Gudger, 1936).

1917. Extensive mortality of fishes (and mollusks) occurred along both coasts of Florida from about Cedar Key south to Key West during the period 2-4 February. Air temperatures reached 29-30°F (–1.1 to +1.6°C) at Cedar Key and 43.5°F (6.4°C) at Key West (Finch, 1917; Storey and Gudger, 1936).

1928. A sudden drop in air temperature from 70 to 32.5°F (21.1 to 0.3°C) caused extensive mortality among fishes at Sanibel Island. The exact date of the cold period is in question, either 4 January or 15-16 January (Storey and Gudger, 1936).

1934. Fishes were killed at Sanibel Island, where air temperatures of 28-30°F (–1.1 to –2.2°C) were recorded on 12 December (Storey and Gudger, 1936).

1940. Between 27 and 29 January, fishes were killed from Miami to Key West and around Charlotte Harbor by a cold wave that dropped air temperatures to 31°F (–0.6°C) at Miami and either 50°F (10.0°C) (Miller, 1940) or 43°F (6.1°C) (Galloway, 1941) at Key West. Lowest recorded water temperatures were 51°F (10.6°C) at Coconut Grove (Miami) and 57°F (13.9°C) at Key West (Miller, 1940; Galloway, 1941).

1957-58. Several incidents of cold-caused fish mortality occurred during the winter of 1957-58. During the period 13-14 December, 1957, fish kills were reported in Florida Bay and Tampa Bay. Lowest recorded water temperatures were 14-16°C for Florida Bay and 13.0°C for Tampa Bay (Springer and Woodburn, 1960; Tabb, Dubrow, and Manning, 1962). Gunter and Hall (1963) did not mention a December fish kill, but mentioned several such events in January and February, 1958. They documented a cold-related kill during 24-26 February in the St. Lucie estuary and noted that fishes were killed in Tampa Bay and Biscayne Bay during this same period. Apparently, some fishes were killed in Brevard County during this winter (personal communications with area residents).

1962. Eleven species of marine fishes were killed in small numbers at Matecumbe Key and Green Mangrove Key in Florida Bay. A low water temperature of 11.7°C was recorded 14 December, the day of the kill (Starck and Schroeder, 1971). Rinckey and Saloman (1964) recorded 19 fish species killed on December 13 and 14 at several localities in the Tampa Bay area. Water temperatures ranged from 9.6 to 11.8°C. Local residents have told us that substantial numbers of fishes were killed in Brevard County during the 1962 cold wave, but no details are published.

Discounting February, 1899, when fishes apparently were stunned but not killed (Storey and Gudger, 1936), the intervals between winters cold enough to destroy significant numbers of fishes have ranged from 3 to 18 yr, with an avg interval of 10.0 yr. Gunter (1945) reported fish-killing cold spells along the Texas coast as occurring in 1856, 1868, 1899, 1917, 1930, and 1940. He incorrectly derived an avg interval of 14 yr; in fact it is almost 17 yr. Including the subsequently reported cold kills of 1942, 1947, and 1951 (Gunter, 1945, 1947a; Gunter and Hildebrand, 1951), the avg interval between cold kills along the Texas coast is 11.9 yr. As noted by Gunter (1945), mild cold waves, resulting in limited fish kills or brief periods of stunning, affect the Texas coast at more frequent intervals. Furthermore, the 31 yr interval between 1868 and 1899 probably is an artifact of scientific reporting and does not represent an absence of fish kills during the period. These factors considered, the records from Florida and Texas are quite similar, with cold-induced fish mortality occurring on the avg about once every decade.

Study Area—The Indian River Lagoon system extends along the east coast of Florida from St. Lucie Inlet near Stuart (Martin County) to Ponce de Leon Inlet near New Smyrna Beach (Volusia County), a distance of about 220 km. Three interconnected lagoons, Indian River, Banana River, and Mosquito Lagoon, compose the system. The lagoons are long, narrow bodies of water separated from the ocean by barrier banks of varying widths. Ocean connections consist of four small, geologically ephemeral inlets spaced at wide intervals. In most areas the lagoons are no more than 2.5 km wide, but increase to over 9 km in northern sections of Indian River. Average depth is near 1.5 m, with depths greater than 3 m primarily confined to dredged basins and the channel of the Intracoastal Waterway. Most of the lagoonal system is composed of shallow "grass flats" supporting dense growths of rooted seagrasses, primarily *Cymodocea filiforme* (manatee grass), *Thallasia testudinum* (turtle grass), and *Halodule wrightii*. The waters are mesohaline, but salinity varies considerably with rainfall, evaporation, and proximity of runoff sources and ocean inlets. Most salinity values in our study region range between 20-32 ppt, in general agreement with data presented by Grizzle (1974). Turbidity is usually low, reflecting the minimal influence of fresh water runoff except at a few localities (Gunter and Hall, 1963). Except near ocean inlets, lunar tidal cycles do not occur; and water movements are primarily wind-driven (Chew, 1956; Schneider, et al., 1974). A more detailed description of the area is given by Gilmore (1977).

That part of the lagoonal system around Merritt Island (the location of Kennedy Space Center) in northern Brevard County is the subject of a continuing ichthyological survey being conducted by the authors and other Florida Technological University personnel. This region is the focus of our observations on fishes affected by the cold of 17-22 January, 1977.

Isolated instances of numbed or dead fishes were first reported to us on 19 January. Our first observations were on 20 January and intermittent field studies were continued through 23 January. Most of our attention was directed to three areas, either because they were convenient and accessible or because substantial mortality had occurred: (1) the southwest shore of Mosquito Lagoon south of Haulover Canal (lat. 28° 43′N, long. 80° 44′W); (2) Eddy Creek, a semi-isolated bay at the extreme southern end of Mosquito Lagoon (lat. 28° 40′ 30″N, long. 80° 39′ 00″W); and (3) a dredged barge basin, near the Kennedy Space Center Vehicle Assembly Building (VAB), connected by a canal with the extreme northern end of the Banana River (lat. 28° 35′ 00″N, long. 80° 38′ 30″W). Scattered observations were made elsewhere.

RESULTS—*Temperature*: Climatological data collected at Kennedy Space Center on Merritt Island, Brevard County, Florida, yield 10-yr (1966-1976) summary statistics for the month of January as follows: avg maximum 21.9°C, avg minimum 12.9°C, overall mean 17.3°C, extreme maximum 29.4°C, extreme minimum −1.7°C. For January, 1977, the same measurements were: avg maximum 16.0°C, avg minimum 5.6°C, overall mean 10.8°C, extreme maximum 21.6°C, extreme minimum −3.9°C. The overall mean air temperature for January, 1977, was 6.5°C lower than the monthly mean for the preceding 10 yr.

A temperature summary for the month of January, 1977, is shown in Figure 1. Air temperature was recorded hourly each day at Kennedy Space Center. These data are the source of daily maximum, minimum, and avg air temperatures. A continuous record was made of surface water temperature in a brackish-water mosquito control impoundment near the center of Merritt Island. A submersible, chart-recording thermograph was suspended below a floating platform. The platform was anchored in the center of a dredged hole that measured about 6 × 15 m and had a maximum depth of about 1.5 m. The site was moderately protected from the wind and had no overhanging vegetation to shade it from insolation. The instrument had a lower limit of 4.5°C. The maximum temperature recorded on 19 January was 8°C; the minimum value for that day was below the limit of the chart so no median could be determined.

Lagoonal water temperatures were taken at the surface in open areas of Indian River (near Titusville) or in the southern half of Mosquito Lagoon. Measurements made in very shallow or protected waters were rejected as possibly being extreme or unrepresentative. Lagoonal temperatures were taken with an electronic temperature probe or laboratory thermometer and represent scattered, isolated observations. Measurements were taken during daylight at different hours and from different localities. When the maximum and minimum temperatures noted on a day varied by 1°C or more, high and low values were plotted. The rather wide temperature ranges shown for some days can be accounted for by time and place of measurement.

On several occasions, temperature profiles were taken in open waters of Mosquito Lagoon. In all cases, temperatures varied less than 1°C from surface to bottom. The wind blew briskly all during the coldest days, probably keeping the water column nearly isothermal. It seems likely, therefore, that most or-

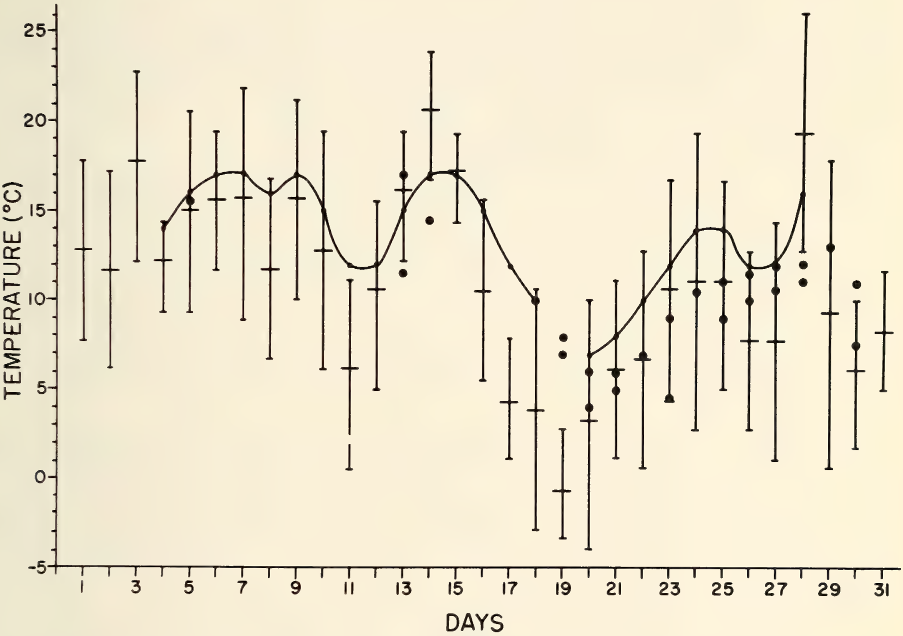


FIG. 1. Summary of air and water temperatures for the month of January, 1977, at Merritt Island, Brevard County, Florida. Vertical bars show daily minimum, average, and maximum air temperature. The curve represents daily median surface water temperature in a mosquito control impoundment. The dots represent ranges in surface temperature of open waters of Mosquito Lagoon and Indian River. See text for additional explanation.

ganisms in open lagoonal waters were exposed to water temperatures at or near 4°C, recorded at the surface at 0910 hours on 20 January in the southern end of Mosquito Lagoon.

Fishes: A checklist of fishes in the Indian River region was presented by Gilmore (1977). He noted the transitional nature of the fauna, including elements of both the tropical Caribbean and the temperate Carolinian provinces. Our continuing ichthyological survey in the Indian River Lagoon system in northern Brevard County has documented the presence of 106 fish species (Snelson, unpubl.). Thirty species were recorded during the January cold period. Twenty-seven of these clearly were either killed or stunned by the low water temperature. Three species (*Brevoortia smithi*, *Cynoscion nebulosus*, and *Trichiurus lepturus*) were recorded among dead fish on the basis of only one specimen, and it is possible that death resulted from commercial fishing operations.

Carcharhinus leucas (BULL SHARK). Two individuals with an estimated total length of 1.5 m were found dead at the VAB barge basin on 21 January. Bull sharks in this size range were commonly encountered in the lagoonal system in summer and fall months. During cold weather, a substantial number of sharks concentrated around the heated effluents of electricity generating stations, but they were seldom encountered elsewhere in the lagoons.

Megalops atlantica (TARPON). The tarpon has a distinctly tropical-subtropical distribution and has been reported in all major cold-related kills in Florida. We encountered the species only at the VAB barge basin. It was not in evidence at this site on 19 or 21 January. On 22 January, 8-10 dead tarpon were observed in shallow water and another 15-20 were seen swimming feebly, without equilibrium, in deep water. These apparently died subsequently, and on 23 January an estimated 100 dead or comatose tarpon were observed. Relative to all fishes killed, it appeared to rank fourth in abundance at this site. Size ranged from 39 to about 100 cm standard length (SL).

Elops saurus (LADYFISH). The ladyfish is another species with distinctly tropical-subtropical affinities often recorded in Florida cold kills. We noted no concentrated kill in the study area. A few individuals were recorded at the VAB barge basin, along the southwestern shore of Mosquito Lagoon, and at scattered canals and mosquito-control impoundments around Merritt Island. Most specimens ranged from about 18-41 cm SL.

Brevoortia smithi (YELLOWFIN MENHADEN). A single specimen 17.6 cm SL was found dead at Eddy Creek on 20 January. It is possible that its death was coincidental, resulting from entanglement in commercial gill nets being fished in the area. This species has not previously been recorded in Florida cold-related fish kills. It was the only clupeid noted during the cold period.

Arius felis (SEA CATFISH). Although this species is very common in the region, we encountered it only once during the cold period. Four specimens about 30 cm SL were found at the Hwy. 3 bridge over Banana Creek, near the center of Merritt Island. Storey (1937) suggests that this species is "always hurt" during cold kills, and we have reliable reports of this species being affected further south in Brevard County around Cocoa and Melbourne.

Bagre marinus (GAFFTOPSAIL CATFISH). Storey (1937) classified this species as being "always hurt" during cold kills in Florida. We encountered it only at the VAB barge basin, but there it was the second most abundant species among dead fish. Several hundred individuals were observed. Most were in the size range 20-25 cm SL, but a few larger adults had been killed.

Strongylura notata (REDFIN NEEDLEFISH). This species was killed or stunned in small to moderate numbers throughout the study region. Greatest concentrations were noted in dredged finger canals along the southwestern shore of Mosquito Lagoon. Some individuals were dead when found, but most were swimming feebly at the surface in a moribund state. In such individuals, the fins were partly eroded, the skin had discolored lesions, and some hemorrhaging was present on the head and around the eyes. This was the only species observed during the kill in which any measure of general deterioration preceded death. Dead specimens ranged from 18-40 cm SL. *Strongylura marina* is also present in the study region, but it is much less common than *S. notata*. Of the 37 needlefish preserved and the many additional specimens examined in the field and discarded, none were *S. marina*.

Centropomus undecimalis (SNOOK). The snook has an essentially tropical-subtropical distribution and has been noted for its susceptibility to cold in Florida (Storey, 1937; Springer and Woodburn, 1960). We encountered a few dead or dying snook at the VAB barge basin and in finger canals on the southwest shore of Mosquito Lagoon. Reliable reports suggest that snook were killed in moderate numbers throughout the region. Many snook, however, were not killed outright by the cold but simply became very lethargic. Many were observed alive in the VAB barge basin on both 22 and 23 January. Although they swam slowly, they maintained normal posture and avoidance responses. Fish in such condition were easily caught from canals and bridges with dipnets and gigs. It seems likely that many, if not most, lethargic snook would have been capable of recovery as water temperatures warmed. Specimens encountered during the kill ranged from about 0.5 to 7 kg.

Echeneis naucrates (SHARKSUCKER). Three living sharksuckers were observed to be associated with the carcasses of two *Carcharhinus leucas* at the VAB barge basin on 21 January. On 23 January, one specimen was found dead along the shore. It measured 49.4 cm SL.

Caranx hippos (CREVALLE JACK). This species was killed in great numbers and its sensitivity to cold was noted by Storey (1937). On 21 January, an estimated 300-400 dead or dying crevalle jack were observed along the shore at the VAB barge basin and others were observed swimming weakly just beneath the surface. On 23 January an estimated one thousand specimens were blown up in windrows along the shore. Some of these were as small as 18 cm SL; but the vast majority were rather uniform in size, weighing an estimated 2.5 kg. This was the most abundant fish killed at this locality.

Caranx crysos (BLUE RUNNER). A large proportion of the dead *Caranx* were examined closely in the field and only a single specimen of *Caranx crysos* (30.8 cm SL) was found. It was the first record of the species in the region under study. *Caranx latus* also is uncommonly encountered in the study area, but none were found among the many dead *Caranx* examined.

Selene vomer (LOOKDOWN). A single dead specimen, 23 cm SL, was found at the VAB barge basin on 21 January. This species appears to be uncommon in the lagoonal system around Merritt Island.

Trachinotus carolinus (FLORIDA POMPANO) and *T. falcatus* (PERMIT). A large number of pompano and permit were killed at the VAB barge basin, but we did not hear reports of these species being affected elsewhere. Unfortunately, the two species were not recognized and distinguished in the field. The mistake was noted after study of a small, preserved sample. The site was revisited on 1 February, and dorsal fin rays were counted in all carcasses remaining intact in order to check identification (Fields, 1962). All 27 specimens counted were permit. This, plus our photographs and recollections, suggests that permit were far more abundant than pompano among the dead *Trachinotus,* being the third most abundant fish killed at the site. Our preserved sample of *T. carolinus* are all small, in the range of 19-27 cm SL. Some of the *T. falcatus* were as small as 21 cm SL; but the vast majority were larger, averaging an estimated 2.5 kg in weight.

Lutjanus griseus (GRAY SNAPPER). Single specimens of this species were encountered at the VAB barge basin and in a finger canal on the southwest shore of Mosquito Lagoon. Both individuals were alive and swimming normally but slowly when dip-netted. Like snook, the gray snapper observed probably could have recovered from the effects of the cold. They measured 15-21 cm SL. Starck and Schroeder (1971) report observations on the behavior of this species during the cold wave of 1962.

Diapterus olisthostomus (IRISH POMPANO). About 25 large adults (19-27 cm SL) were found dead along shore at the VAB barge basin. Although we did not observe mortality elsewhere, reliable reports indicate that it was killed in small numbers throughout the area. Stressed but living juveniles were observed and collected in a finger canal off Mosquito Lagoon on 20 January when the surface water was 9°C.

Diapterus plumieri (STRIPED MOJARRA). About 10 adults (20-28 cm SL) were found at the VAB barge basin. We did not see the species elsewhere nor were any reported.

Eucinostomus argenteus (SPOTFIN MOJARRA) and *E. gula* (SILVER JENNY). We did not find either species among dead fish at any locality. Several were seen and a few collected at two sites where they were swimming slowly and erratically just beneath the surface. It is uncertain if these individuals were moribund or could have recovered later.

Lagodon rhomboides (PINFISH). Pinfish were killed in large numbers at Eddy Creek but were not observed elsewhere. A sample of dead specimens ranged from 7-15 cm SL. We estimate that several hundred individuals were blown up along the shores.

Bairdiella chrysura (SILVER PERCH). Silver perch are regularly reported from cold-related fish kills in Florida (Storey, 1937) and elsewhere (Gunter, 1941; Gunter and Hildebrand, 1951; Dahlberg and Smith, 1970). We collected a few dead or dying individuals at several scattered sites throughout the study area; but a very large kill occurred at Eddy Creek, where dead of this species substantially outnumbered pinfish. We estimate that several thousand specimens were blown up in windrows along shore. A small sample of the dead ranged from 7-16 cm SL.

Cynoscion nebulosus (SPOTTED SEATROUT). Our observations are in agreement with Storey (1937) who treats this species as one "seldom hurt during freezes". We encountered only two affected specimens during the cold period. One was a gill-net escapee, still partially entangled in a piece of webbing. Although it was further weakened by the cold, it avoided several attempts to dip it from the water of a Mosquito Lagoon finger canal where the surface temperature was 6°C. One other specimen was found dead at Eddy Creek; but it, too, may have been killed in a gill netting operation. The cold had a noticeable effect on the wariness and swimming speed of *C. nebulosus*, and this was taken advantage of by commercial net fishermen. There is little doubt that most spotted seatrout recovered from the effects of the cold.

Leiostomus xanthurus (SPOT). A single large adult (28 cm SL) was found dead at the State Highway 3 bridge over Banana Creek on Merritt Island. This species has not been reported previously from cold-related fish kills in Florida, but has been noted in Texas (Gunter, 1941; Gunter and Hildebrand, 1951).

Mugil curema (WHITE MULLET). The white mullet is especially susceptible to cold kills in Florida (Storey, 1937; Springer and Woodburn, 1960) and was found dead or dying in small to moderate numbers at scattered localities throughout the study area. A large school was encountered in a finger canal on the southwestern shore of Mosquito Lagoon. Several thousand individuals milled about slowly just below the surface, swimming weakly with normal equilibrium but minimal avoidance response. The surface temperature at the time was 9°C. It is unclear if these fish subsequently died or recovered. All *M. curema* found in a nearby canal, where the surface temperature was 6°C, were dead or clearly moribund. Individuals encountered during the kill were of rather uniform size, about 9-15 cm SL. The related striped mullet, *Mugil cephalus*, was minimally affected by the cold. Although a few dead individuals were found at the VAB barge basin, they had been dead for several days; and their death clearly was not related to the cold. *M. cephalus* observed in schools in shallow water appeared to have their swimming ability and avoidance response only moderately impaired.

Trichiurus lepturus (ATLANTIC CUTLASSFISH). A single specimen 69 cm SL was found dead at the water's edge at Eddy Creek. It may have been caught and later discarded by gill net fishermen working in the area. This species has not been reported previously as a victim in cold weather mortality in Florida.

Scomberomorus maculatus (SPANISH MACKEREL). Two large individuals (52-53 cm SL) were found dead at the VAB barge basin and a third was seen swimming without equilibrium. The species was not seen or reported elsewhere. It appears to be rare, perhaps sporadic, in the lagoonal system around Merritt Island.

Monacanthus hispidus (PLANEHEAD FILEFISH). Two individuals 15 and 18 cm SL were found dead at the VAB barge basin. It was not seen or reported elsewhere.

Sphoeroides spengleri (BANDTAIL PUFFER). A single specimen 12.4 cm SL was found dead at the VAB barge basin. It was the first time this species had been encountered in the region under study.

Sphoeroides nephelus (SOUTHERN PUFFER). This species is common in the study region but did not appear to be seriously affected by the cold. One dead individual was found at the VAB barge basin and another along the southwest shore of Mosquito Lagoon. The specimens were 17.5 and 18.8 cm SL. This species appears not to have been noted in other cold-related fish kills in Florida.

Chilomycterus schoepfi (STRIPED BURRFISH). Large numbers of burrfish were killed by the cold. On 20 January, many were observed immobilized or nearly so at the surface in open waters of Mosquito Lagoon. The water temperature was 5.5°C. Large numbers of dead *C. schoepfi* blew ashore for about 2 wk after the cold spell, and decomposing carcasses were trawled from the bottom on 10 February. Apparently, many of those individuals not killed immediately by the cold were weakened and subsequently died of other causes. Specimens sampled from those killed ranged between 12-23 cm SL.

Discussion—Various authors have suggested that the physiological impact of cold on shallow-water marine fishes might be caused by the low temperature attained, the duration of the low temperature, or to the rapidity of the temperature drop (Storey and Gudger, 1936; Gunter, 1945; Gunter and Hildebrand, 1951; Springer and Woodburn, 1960; Dahlberg and Smith, 1970). Unfortunately, the nature of the phenomenon usually does not permit one to distinguish between these three interrelated causes. It is impossible to determine which was the most significant factor in the kill described here. Air temperature dropped 14.5°C (15.6 to 1.1) in 17 hr on 16-17 January and 13.3°C (10.0 to –3.3) in 13 hr on 18-19 January. Avg air temperature remained below 5°C for four consecutive days (17-20 January), and surface temperatures in open lagoonal waters probably were in the range of 4-6°C for at least 48 hr.

Observations throughout the southwestern portion of Mosquito Lagoon indicated that a few species were stressed and/or killed throughout the area. The most notable of these were *Chilomycterus schoepfi* and *Strongylura notata*. Most observations indicated, however, that different assemblages of species were affected at different localities. It is not known whether such local differences were due to differential distribution and concentration of fishes, local variations in temperature, or varying degrees of resistance or acclimatization.

All three sites where large kills were noted are deep relative to surrounding areas. The VAB barge basin is dredged, and soundings revealed a maximum depth of 11.6 m. Eddy Creek is a natural deep depression in the otherwise rather shallow southern end of Mosquito Lagoon. Maximum depth is 3.0 m. The dredged finger canals along the southwestern shore of Mosquito Lagoon are, likewise, deep relative to the adjacent seagrass flats. The canal where most observations were made averages 1.7 m deep. It seems likely that fishes, especially large ones, concentrated in deep areas seeking warmer water and were then trapped when the temperature fell below lethal limits. Since there are no nearby ocean inlets, no avenue for offshore escape was available.

Our observations are in general agreement with the results reported from other cold kills in Florida and elsewhere (Gunter, 1941, 1945, 1947a; Gunter and Hildebrand, 1951; Dahlberg and Smith, 1970). In her summary of nine cold-related fish kills occurring at Sanibel Island, Florida, between 1886 and 1936, Storey (1937) listed 19 fish species "always hurt during freezes". Twelve of these species are known to occur in the lagoonal waters in northern Brevard County, and all were killed during the 1977 cold wave. Of the 10 species listed as "often hurt during freezes" (Storey, 1937), nine are known to occur within our study region; and three of these are known to have been killed in 1977. Storey (1937) lists 8 species as "seldom hurt during freezes", and all eight of these occur within our study region. Mortality clearly related to the cold occurred in three of these species.

Gunter (1947b) presented limited data to suggest that large individuals of a species are more susceptible to the effects of cold water than small individuals. Our observations in the Indian River lagoonal system suggest the same conclusion, although we are able to offer no data comparing the size of fishes killed with those in the available population. We did note, however, the distinctive absence of small fish species among those killed. No cyprinodontids, poeciliids, gobiids, engraulids, or atherinids were found among dead fish, and all are common or abundant in the study region. The literature suggests that the first three families are rarely involved in cold-related mortality. Fishes in the first two families are notoriously hardy, and it might be argued that members of all three families could be easily overlooked among dead fishes due to their small size and cryptic coloration. Engraulids and atherinids, however, are silvery and usually occur in large schools. Any significant mortality should not pass unnoticed in clear, shallow waters. A small number of atherinids (*Menidia beryllina)* and a vast number of engraulids (*Anchoa mitchilli)* have been reported in cold-related kills in Texas (Gunter, 1941, 1945, 1947a; Gunter and Hildebrand, 1951). Anchovies (unidentified) have been reported only once in Florida (Galloway, 1941), and atherinids have not been reported. The smallest fishes collected during the period were 2 specimens of *Eucinostomus argenteus* and one *E. gula* that ranged between 48 and 70 mm SL. These were still alive, although obviously stressed, when they were dipped from the water.

We agree with Dahlberg and Smith (1970) that the apparent ultimate factor in mortality, at least in some species, is loss of equilibrium or permanent impairment of swimming ability. Moribund *Chilomycterus schoepfi* and *Sphoeroides nephelus* maintained an upright posture but floated at the surface, feebly moving their fins. Moribund *Elops saurus, Megalops atlantica, Scomberomorus maculatus*, and *Trachinotus falcatus* were noted swimming on their sides or belly-up, usually in an irregular path. Although they often exhibited normal avoidance behavior on being approached, they usually resumed their atypical movements in a short while. We had the impression that the loss of equilibrium or bouyancy control was irreversible. Atypical swimming was noted in tarpon, ladyfish, and spanish mackerel at the barge basin site after water temperature had risen to 9°C on 23 January. Apparently many such moribund fishes died as a result of suffocation, drying, or exposure to cold air temperatures after swimming or being blown into shallows where they were stranded. One interesting phenomenon reported by Gunter (1941) was corroborated in our observations. Fishes picked up from shallow water alive but in a numbed and weakened state (feeble and irregular opercular and fin movements) became quite lively after being removed from the water and placed in the sun for a few minutes. It seemed that they revived from the cold faster than they succumbed from suffocation.

The short-term consequences of fish kills of the type described here are clear. Populations of many species are reduced, at least locally. Mortality seems to be concentrated among larger fish species and among larger individuals within a species. Consequently, both local community composition and population age structure are immediately affected. The long term consequences of such incidents are more difficult to assess, but they probably are limited (Rinckey and Saloman, 1964; Dahlberg and Smith, 1970). Our data from quantitative trawling operations in the area do not show appreciable differences in total catches before (December) and after (February) the cold period. In April, trawl catches were at levels comparable to November, 1976.

Gunter (1947) indicated that cold kills along the Texas coast seriously affected commercial fishing success, and that up to 3 yr might be required for complete recovery to "normal" catch levels. The effects of the 1976-77 winter fish kill on commercial fisheries in the lagoonal waters of Brevard County, if any, will be difficult to distinguish from the general decline in the fishery that seems to have occurred in recent yr, for example in mullet catch (Cato et al., 1976). We are conducting a commercial fishing census in the area, but our data are insufficient to address this problem directly.

ACKNOWLEDGMENTS—We thank all of our co-workers, especially Mark J. Provancha and Jeffrey D. Wetherington, for assisting in the field under adverse circumstances. Dr. Llewellyn M. Ehrhart made his water temperature data available, and Dr. James L. Baker provided notes on his observations during the fish kill. Richard J. Demmer drew the graph. Financial support was provided by a contract with the John F. Kennedy Space Center, National Aeronautics and Space Administration (NAS 10-8986). Finally, we acknowledge the staff of the Merritt Island National Wildlife Refuge, especially Mr. Robert G. Yoder, for generous support in many facets of our work.

LITERATURE CITED

BANGS, O. 1895. The present standing of the Florida manatee, *Trichecus latirostris* (Harlan), in Indian River waters. Amer. Natur. 29:783-787.

CATO, J. C., P. B. YOUNGBERG AND R. RAULERSON. 1976. Production, prices, and marketing: an economic analysis of the Florida mullet fishery. Pp. 11-62. *In* CATO, J. C. AND W. E. MCCULLOUGH (eds.) Economics, biology, and food technology of mullet. Florida Sea Grant Report No. 15:1-158.

CHEW, F. 1956. The probable lowest average salinity in the Indian River. Quart. J. Florida Acad. Sci. 19:241-250.

DAHLBERG, M. D., AND F. G. SMITH. 1970. Mortality of estuarine animals due to cold on the Georgia coast. Ecology 51:931-933.

FIELDS, H. M. 1962. Pompanos (*Trachinotus* spp.) of south Atlantic coast of the United States. Fish. Bull. 62:189-222.

FINCH, R. H. 1917. Fish killed by the cold wave of February 2-4, 1917, in Florida. Monthly Weather Rev. 45:171-172.

GALLOWAY, J. C. 1941. Lethal effects of the cold winter of 1939-40 on marine fishes at Key West, Florida. Copeia 1941(2):118-119.

GILMORE, R. G., JR. 1977. A regional description and checklist of fishes of the Indian River Lagoon and adjacent waters, Florida. Bull. Florida St. Mus. 22(3):101-148.

GRIZZLE, R. E. 1974. The estuarine decapod crustaceans in Brevard County, Florida. Florida Sci. 37:129-141.

GUNTER, G. 1941. Death of fishes due to cold on the Texas coast, January, 1940. Ecology 22:203-208.

———. 1945. Studies on marine fishes of Texas. Publ. Inst. Marine Sci. 1(1):1-190.

———. 1947a. Differential rate of death for large and small fishes caused by hard cold waves. Science 106(2759):472.

———. 1947b. Catastrophism in the sea and its paleontological significance, with special reference to the Gulf of Mexico. Amer. J. Sci. 245:669-676.

———, AND G. E. HALL. 1963. Biological investigations of the St. Lucie estuary (Florida) in connection with Lake Okeechobee discharges through the St. Lucie canal. Gulf Res. Rept. 1(5):189-307.

———, AND H. H. HILDEBRAND. 1951. Destruction of fishes and other organisms on the south Texas coast by the cold wave of January 28-February 3, 1951. Ecology 32:731-736.

MILLER, E. M. 1940. Mortality of fishes due to cold on the southeast Florida coast, 1940. Ecology 21:420-421.

PACKARD, A. S., JR. 1871. An account of a recent trip to Key West and the Tortugas, Florida. Bull. Essex (Mass.) Inst. 2:44.

RINCKEY, G. R., AND C. H. SALOMAN. 1964. Effect of reduced water temperature on fishes of Tampa Bay, Florida. Quart. J. Florida Acad. Sci. 27:9-16.

SCHNEIDER, W. K., P. S. DUBBELDAY, AND T. A. NEVIN. 1974. Measurement of wind-driven currents in a lagoon. Florida Sci. 37:72-78.

SPRINGER, V. G., AND K. D. WOODBURN. 1960. An ecological study of the fishes of the Tampa Bay area. Florida St. Bd. Conserv., Mar. Lab. Prof. Pap. Ser. 1:1-104.

STARCK, W. A., II, AND R. E. SCHROEDER. 1971. Investigations on the gray snapper, *Lutjanus griseus*. Stud. Trop. Oceanogr. 10:1-224.

STOREY, M. 1937. The relation between normal range and mortality of fishes due to cold at Sanibel Island, Florida. Ecology 18:10-26.

__________, AND E. W. GUDGER. 1936. Mortality of fishes due to cold at Sanibel Island, Florida, 1886-1936. Ecology 17:640-648.

TABB, D. C., D. L. DUBROW AND R. B. MANNING. 1962. The ecology of northern Florida Bay and adjacent estuaries. Florida Bd. Conserv. Tech. Ser. 39:1-81.

WILLCOX, J. 1887. Fish killed by cold along the Gulf of Mexico and coast of Florida. Bull. U. S. Fish Comm. 6:123.

Florida Sci. 41(1):1-12. 1978.

Earth Sciences

A SUPERNUMERARY TOOTH IN THE GROUND SLOTH, *MEGALONYX* (EDENTATA MAMMALIA)—*H. Gregory McDonald*, Florida State Museum, Gainesville, Florida 32611

ABSTRACT—*Six left upper teeth were found in an adult cranium of* Megalonyx *collected from the Ringold Formation, Blancan, late Pliocene of Washington instead of the usual five.**

THE ground sloth, *Megalonyx*, has been found throughout North America and the genus is known from the Hemphillian (middle Pliocene) to the late Rancholabrean (Pleistocene). During the past 125 yr, a large amount of material has been collected; over 20 complete skulls and many partial ones are known. It is now possible to assess the variability of the skull in *Megalonyx*.

An extra tooth occurred in the anterior portion of an adult cranium, (Idaho State University Museum 75001/6), collected by Larry Richards in the Ringold Formation (Blancan, late Pliocene) of Washington. Normally in *Megalonyx* the tooth formula is 5/4 with the first tooth in the upper and lower series modified into a tusklike structure, the caniniform, and is separated from the molariform cheek teeth by a diastema. The Ringold specimen has six left upper teeth, the extra tooth is located in the diastema immediately behind the caniniform. (Fig. 1.). No dental anomalies have been reported in any previous studies of *Megalonyx* crania, including Leidy (1855), Lindahl (1892), Lyon (1938), and Stovall (1940).

---

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

Several types of dental anomalies have been reported for many mammalian orders: Phillips and Jones (1968), Miller and Tessier (1971), Meyer (1975) and Hall (1940). Colyer (1936) recorded dental anomalies for most of the mammalian orders but did not list any for edentates. Edmund and Hoffstetter (1970) discussed a dental anomaly in the giant ground sloth, *Megatherium americanum*, in which two molariform teeth in both sides of the maxillae and mandibles had fused reducing the dental formula, but this appears to be the first record of a supernumerary tooth in any gravigrade edentate.

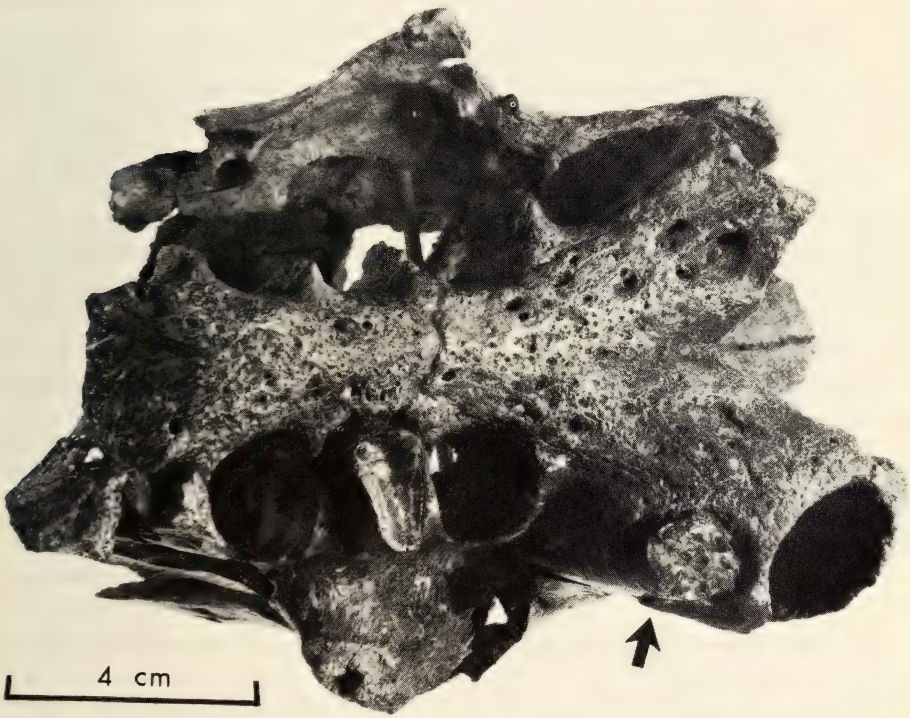


FIG. 1. Palatal view of anterior portion of cranium of *Megalonyx* sp. ISUM 75001/6 from the late Pliocene (Blancan) of Washington showing the supernumerary tooth.

In the specimen at hand, the left maxillary includes alveoli for all of the teeth, but only the second molariform and the extra tooth are still present. There is no sign of the occurrence of an extra tooth in the right side of the cranium, but in other respects, the right and left sides are perfect mirror images of one another. The left second molariform tooth closely resembles other *Megalonyx* second molariform teeth. There are no osteological abnormalities of the maxilla associated with the extra tooth. The extra tooth is located 7 mm posterior to the left caniniform tooth. The left diastema is 35 mm long, only 2 mm longer than the right.

The supernumerary tooth is oval in cross section. Its shape thus resembles that of the caniniform and is not triangular as are the cheek teeth in *Megalonyx*.

The crown of the tooth measures 16 mm transversely and 13 mm anteroposteriorly. It is about half the size of the caniniform. The long axis of the supernumerary lies transversely whereas the long axis of the caniniform is anteroposterior. A similar condition of the supernumerary tooth erupting at a right angle to the original tooth was reported by Hall (1940) for an upper fourth premolar in the fox, *Vulpes macrotis,* and 90 degree rotation was also described for a caribou molar by Miller and Tessier (1971). The root of the tooth curves slightly posteriad as does the alveolus of the caniniform. The supernumerary tooth possesses an open root as do all the other teeth in *Megalonyx.* Unfortunately, the occlusal surface has been broken off so that it is not possible to determine if the wear on the tooth was similar to the caniniform in *Megalonyx.* Conceivably it may have formed an inclined shearing surface as in the anterior teeth of the ground sloth, *Glossotherium,* but it is more likely that there was no wear at all. This would depend, of course, on whether there had been an occluding tooth in the mandible.

The presence of the additional tooth may be explained by either of two hypotheses. First, it could be a deciduous tooth that was not lost during the development of the animal. Hirschfeld and Webb (1968), however, note the total absence of deciduous teeth in immature specimens of *Megalonyx* and modern sloths they have examined. The second hypothesis is that the extra tooth was produced by a twinning of the caniniform germ cells and rotation of the second twin during embryonic development. The close proximity of the extra tooth to the caniniform and its similar oval shape favor this latter hypothesis.

ACKNOWLEDGMENTS—I thank Dr. John A. White of the Idaho State University Museum of Natural History for permission to study the specimen in his care and to Dr. S. David Webb for helpful suggestions. The translation of the paper by Edmund and Hoffstetter from Spanish was very generously done by Evelyn K. Peterson.

LITERATURE CITED

COLYER, F. 1936. Variations and Diseases of the Teeth of Animals. John Bale, Sons and Danielson, Ltd. London.

EDMUND, A. G. AND R. HOFFSTETTER. 1970. *Essonodontherium gervaisi* es un Sinonimo de *Megatherium americanum* Cuvier (Xenarthra, Mammalia) Ameghiniana 7(4):317-328.

HALL, E. R. 1940. Supernumerary and missing teeth in wild mammals of the Orders Insectivora and Carnivora, with some notes on disease. J. Dental Res. 19(2):103-143.

HIRSCHFELD, S. E. AND S. D. WEBB. 1968. Plio-Pleistocene megalonychid sloths of North America. Bull. Florida St. Mus. Bio. Sci. 12(5):213-296.

LEIDY, J. 1855. A memoir on the extinct sloth tribe of North America. Smithson. Contrib. Knowl. 7:1-68; 16 pls.

LINDAHL, J. 1892. Description of the skull of *Megalonyx leidyi* n. sp. Trans. Amer. Phil. Soc. 17:1-10.

LYON, G. M. 1938. *Megalonyx milleri,* a new Pleistocene ground sloth from southern California. San Diego Soc. Nat. Hist. Trans. 9:15-30.

MEYER, P. 1975. Double anomaly of teeth in the European Roe Deer. Z. Jagdwiss. 21:133-135.

MILLER, F. L. AND G. D. TESSIER. 1971. Dental anomalies in caribou, *Rangifer tarandus.* J. Mamm. 52:164-174.

PHILLIPS, C. J. AND J. K. JONES, JR. 1968. Dental abnormalities in North American bats. 1. Emballonuridae, Noctilionidae and Chilonycteridae Trans. Kansas Acad. Sci. 71:509-520.

STOVALL, J. W. 1940. *Megalonyx hogani,* a new species of ground sloth from Gould, Oklahoma. Amer. J. Sci. 238:140-146.

Florida Sci. 41(1):12-14. 1978.

Earth Sciences

CALCULATED X-RAY POWDER DIFFRACTION DATA FOR THE CRANDALLITE-GOYAZITE SERIES

Frank N. Blanchard

Department of Geology, University of Florida, Gainesville, Florida 32611

Abstract: *Calculated X-ray powder diffraction patterns for the crandallite-goyazite series compare reasonably well with observed patterns and serve to identify minor indexing errors. Minor deviations between the calculated pattern for crandallite and observed patterns are due in part to the prevalence of Sr-substitution in natural crandallite. Intensity variations associated with substitution between Ca and Sr serve as a means of determining specific composition in the crandallite-goyazite series. Computed absolute scale factors allow the calculated patterns to be used in quantitative analysis of crandallite-bearing sediments.**

Computer-simulated diffractometer charts and calculated *d*-spacings and relative intensities have been obtained for crandallite, Sr-substituted crandallite, goyazite, and Ca-substituted goyazite. The charts and calculations were obtained by using the FORTRAN IV program for calculating X-ray powder diffraction patterns—version 5 (Clark, Smith, and Johnson, 1973) and crystal structure data for crandallite (Blount, 1974) and for goyazite (Kato, 1971). The results are useful for identification standards, for evaluating the quality of existing powder diffraction data, in determining effects on the diffraction pattern of diadochic substitution, in determining absolute intensities for quantitative analysis, and (although not specifically discussed in this report) in evaluating the effects of preferred orientation on the powder diffraction pattern, as well as in evaluation of the reliability of the crystal structure determination.

Crandallite and goyazite (along with several other minerals) belong to the crandallite group (Fleischer, 1975). These minerals are considered to be isostructural, with an alunite-type structure, and have a general formula $XAl_3(PO_4)_2$-$(OH)_5 \cdot H_2O$, where X = Ca, Sr, Ba, and Ce; in crandallite X = Ca, in goyazite X = Sr. It is only within the last few years that formal crystal structure determinations have been published for crandallite (Blount, 1974) and goyazite (Kato, 1971). Both authors give the space group $R\bar{3}m$, a unit-cell content of 3, the formula cited above, and atomic coordinates for Sr or Ca, Al, P, and O that are very nearly the same. Because of these close similarities, because of the similarity in the ionic radii of Sr^{+2} and Ca^{+2}, and because Ca is commonly found in analyses for goyazite and Sr is commonly found in crandallite, it seems likely that there is a complete series from crandallite to goyazite. From the refined crystal structure data it is possible to calculate not only the powder diffraction pattern for each end-member but also for intermediate members of the series.

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

The chemical formula, cell dimensions, space group, cell content, density, positional and thermal parameters of Blount (1974) were used to compute the X-ray powder diffraction pattern for crandallite. Similar computations were made for goyazite using data from Kato (1971). Modifications of the pattern for 10, 20, . . . 90, 100% Sr substituting for Ca were obtained by adjusting the chemical formula, density, cell constants, and atomic parameters. Table 1 gives the calculated *d*-spacings and relative intensities for crandallite and for goyazite. Column (1) is integrated intensity corrected for flat-plate absorption while column (2) is integrated intensity corrected for Debye-Scherrer absorption. Reflections with intensity less than 0.1 have been omitted. Although it is likely that many of the listed reflections will not actually be observed, it is not likely that reflections not listed will be observed.

TABLE 1. Calculated powder diffraction data for crandallite and for goyazite.

Crandallite				Goyazite				Crandallite				Goyazite			
d(Å)	(1) I/I_o	(2) I/I_o	hkl	d(Å)	(1) I/I_o	(2) I/I_o	hkl	d(Å)	(1) I/I_o	(2) I/I_o	hkl	d(Å)	(1) I/I_o	(2) I/I_o	hkl
5.6809	23.4	21.1	101	5.7055	55.4	46.7	101	1.3866	0.5	0.8	321	1.4264	3.6	5.9	404
5.3973	0.1	0.1	003	5.5017	2.4	2.1	003	1.3735	1.2	1.7	045	1.3900	2.4	3.9	321
4.8548	31.9	29.0	012	4.8952	2.0	1.7	012	1.3716	4.0	5.8	232	1.3754	0.4	0.6	232
3.5025	33.4	32.0	110	3.5105	40.4	37.9	110	1.3607	2.6	3.8	137	1.3754	0.3	0.4	0012
3.3672	0.4	0.3	104	3.4143	4.7	4.4	104	1.3494	0.1	0.2	0012	1.3717	5.2	8.7	137
2.9814	43.4	43.2	021	2.9899	7.5	7.5	021	1.3441	5.7	8.4	039	1.3599	0.7	1.1	309
2.9381	100.0	100.0	113	2.9594	100.0	100.0	113	1.3441	0.2	0.3	309	1.3599	3.9	6.6	039
2.8568	3.8	3.9	015	2.9011	0.1	0.1	015	1.3243	2.1	3.0	2011	1.3455	0.2	0.3	2011
2.8404	2.3	2.4	202	2.8528	7.1	7.3	202	1.3238	2.3	3.4	410	1.3406	1.6	2.8	2110
2.6987	12.9	13.2	006	2.7508	10.6	10.9	006	1.3161	0.8	1.2	324	1.3268	3.7	6.5	410
2.4274	3.5	3.7	024	2.4476	8.9	9.7	024	1.2939	0.8	1.3	318	1.3215	0.1	0.1	324
2.2138	3.7	4.1	205	2.2762	4.3	4.9	211	1.2857	2.2	3.4	143	1.3057	0.1	0.1	318
2.2062	12.6	13.9	122	2.2363	7.1	8.1	205	1.2857	6.1	9.2	413	1.2899	6.7	12.0	413
2.1614	42.5	47.2	107	2.2139	17.0	19.7	122	1.2787	1.0	1.5	235	1.2899	3.6	6.5	143
2.1377	1.3	1.4	116	2.1984	35.6	41.4	107	1.2683	0.8	1.3	407	1.2806	0.7	1.2	1112
1.9951	1.4	1.7	214	2.1653	4.9	5.7	116	1.2591	0.6	0.9	1112	1.2564	0.2	0.4	1211
1.9200	0.1	0.2	018	2.0268	1.5	1.9	300	1.2549	0.7	1.2	229	1.2428	2.0	3.8	1013
1.8936	0.5	0.6	303	2.0078	5.6	6.9	214	1.2387	0.3	0.5	1211	1.2238	0.3	0.6	048
1.8936	38.2	45.0	033	1.9537	1.1	1.4	018	1.2201	1.3	2.1	1013	1.2128	0.1	0.3	051
1.8713	0.3	0.3	125	1.9018	2.5	3.2	303	1.1999	0.4	0.6	502	1.2031	0.9	1.7	502
1.8393	2.8	3.3	027	1.9018	30.6	39.1	033	1.1925	8.6	13.9	327	1.2006	8.4	16.2	327
1.7991	1.8	2.2	009	1.8861	2.1	2.7	125	1.1885	0.1	0.1	146	1.1951	0.4	0.7	416
1.7512	29.9	36.8	220	1.8339	0.7	0.9	009	1.1675	4.2	7.0	330	1.1951	0.8	1.6	146
1.6836	1.4	1.8	208	1.7553	23.8	32.3	220	1.1667	2.6	4.3	1310	1.1796	4.0	7.9	1310
1.6658	0.1	0.1	223	1.7072	2.7	3.8	208	1.1622	0.1	0.2	054	1.1716	0.2	0.5	0213
1.6474	4.2	5.3	312	1.6777	1.2	1.7	131	1.1468	0.1	0.2	238	1.1702	3.8	7.6	330
1.6284	1.6	2.0	217	1.6722	0.7	1.0	223	1.1436	2.1	3.5	241	1.1665	0.6	1.1	054
1.6183	0.2	0.2	036	1.6522	0.1	0.1	312	1.1411	1.6	2.7	333	1.1574	0.4	0.7	0114
1.6183	0.2	0.3	306	1.6458	4.1	5.8	217	1.1362	0.1	0.2	505	1.1556	0.4	0.7	238
1.6004	5.4	7.0	119	1.6317	1.2	1.7	306	1.1351	0.3	0.5	422	1.1463	0.1	0.2	241
1.5644	0.8	1.1	1010	1.6317	1.1	1.6	036	1.1224	2.5	4.2	3012	1.1446	2.6	5.2	333
1.5537	2.1	2.8	134	1.6255	4.9	7.1	119	1.1079	0.1	0.1	3111	1.1381	0.9	1.9	422
1.5174	6.3	8.4	128	1.5929	2.0	3.0	1010	1.1069	2.5	4.4	4010	1.1381	1.8	3.7	3012
1.5100	3.6	4.8	401	1.5352	0.5	0.7	128	1.1031	1.4	2.4	244	1.1210	0.2	0.5	3111
1.4930	3.3	4.4	315	1.5137	0.2	0.4	401	1.0945	3.3	5.8	2113	1.1181	3.1	6.5	4010
1.4907	3.4	4.7	042	1.5018	5.2	8.1	315					1.1113	4.8	10.1	2113
1.4690	10.0	13.8	226	1.4949	3.8	5.8	042					1.1070	2.7	5.6	244
1.4305	0.1	0.2	0111	1.4797	10.2	16.1	226					1.1003	0.1	0.3	0015
1.4284	18.7	26.2	0210	1.4568	0.3	0.5	0111					1.0992	0.5	1.0	2014
1.4202	2.8	4.0	404	1.4505	16.6	26.5	0210					1.0897	0.1	0.3	511

IDENTIFICATION STANDARDS—Because this study was initiated prior to publication of the 1975 edition of the Powder Diffraction File[1], part of the purpose was to evaluate data for crandallite in the file and in the literature. In the 1974 edition of the Powder Diffraction File there were two cards for crandallite (#5-615 and #16-162). In the 1975 edition card #5-615 was deleted and two new cards were added (#25-119 and #25-1457). Comparisons with the calculated patterns of this report (Table 1) indicate that the data on card #5-615 were

[1]Selected Powder Diffraction Data for Minerals.

inferior. The data for the possible triclinic dimorph of crandallite (card #16-162) bear little resemblance to the calculated pattern. Data on cards #25-119 and #25-1457 appear to be substantially of high reliability in spite of at least two indexing errors. On card #25-119 the reflection at $d=2.21$ should be indexed as 122 rather than 205 (the contribution from 205 is of minor significance). On both cards the reflection at $d \sim 1.89$ should be indexed as 033 rather than 303 (the contribution from 303 is negligible).

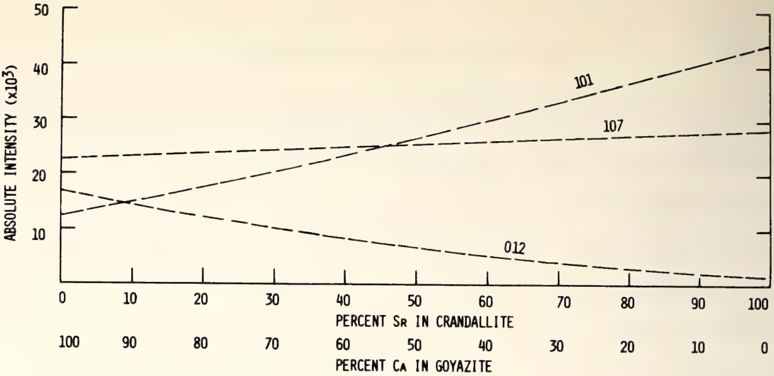
In addition to the crystal structure refinement for crandallite, Blount (1974) also gives partial calculated powder diffraction data for deltaite (=crandallite). In her tabulation (p. 43) the reflection at $d=2.70$, incorrectly indexed as 202, should be 006, and the reflection at $d=2.21$ should be indexed as 122 rather than 205.

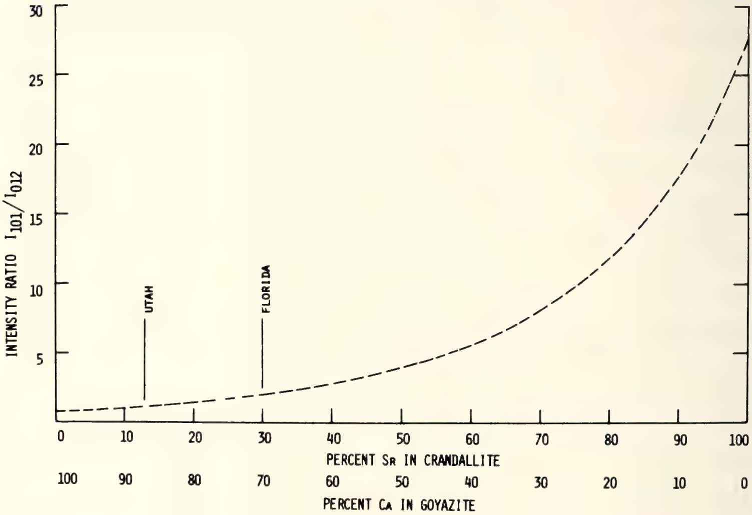
Many natural crandallites (eg., Florida and Fairfield, Utah) contain significant concentrations of Sr, and substitution of Sr has a considerable influence on the intensity of many of the diffraction lines. Because the calculated powder diffraction pattern for crandallite (Table 1) is based on input data obtained from a single crystal containing only 0.08% Sr, this pattern may be useful as an identification standard.

Comparison of the calculated pattern for goyazite with the data on card #11-194 indicates the following indexing errors on the card: the reflection at $d=2.20$ should be indexed 107,122 (rather than 107 alone), the reflection at $d=1.89$ should be 033 rather than 303,125, the reflection at $d=1.66$ should be 131,223 (rather than 223 alone), the reflection at 1.64 should be 217 (alone) rather than 312,217, and the reflection at $d=1.62$ should be 119,306+ rather than 306,119. The card for goyazite (#11-194) gives visual estimates of intensity and hence the pattern was probably recorded on a film. Because of better resolution and more accurate intensity measurements obtainable with the diffractometer, it is probable that the calculated pattern for goyazite presented in this report (Table 1) will correspond more closely with observed diffractometer data than will the data on card #11-194.

Intensity Variations in the Crandallite-Goyazite Series—Powder diffraction intensities and d-spacings may be used in some instances to determine the amount of substitution of certain elements in a crystal structure. Because of the close similarity of ionic radii, the substitution of Sr^{+2} for Ca^{+2} in crandallite has only a very small influence on the dimensions of the unit cell. The atomic weights of these elements are considerably different and because of this the atomic scattering factors are very different. This difference is responsible for a considerable variation in the intensity of some of the diffraction lines where Sr^{+2} substitutes for Ca^{+2}. Figure 1 is a plot of the intensity of selected diffraction lines through the crandallite-goyazite series. These intensities were obtained using estimates of parameters intermediate between those of crandallite and those of goyazite.

For some diffraction lines the intensity varies considerably with variations in composition, while for other lines the variation is slight. For some lines the intensity increases with Sr-substitution in crandallite, while for other lines the





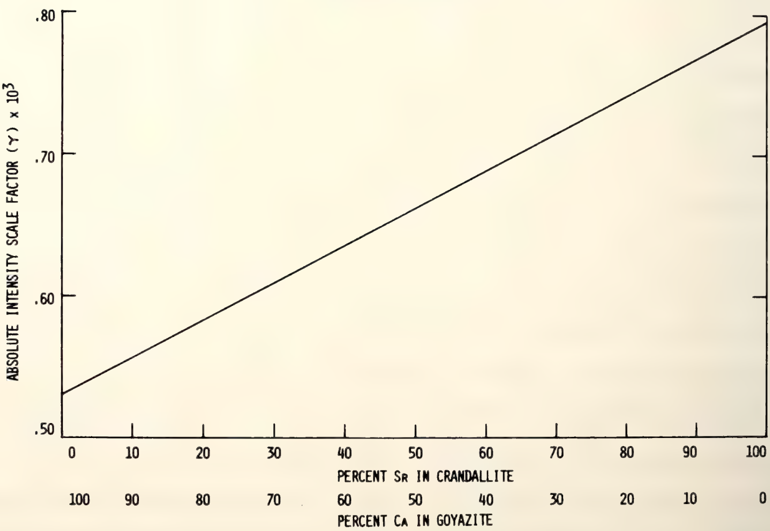


FIG. 1. (upper) Calculated intensities for selected powder diffraction lines through the crandallite-goyazite series.

FIG. 2. (middle) Calculated variations in the intensity ratio I_{101}/I_{012} through the crandallite-goyazite series.

FIG. 3. (lower) Calculated variation in the absolute intensity scale factor through the crandallite-goyazite series.

intensity decreases. To use intensity variations as a measure of substitution it is desirable to use an intensity ratio, and preferably one which varies rapidly with substitution. The intensity ratio I_{012}/I_{101}, and the ratio I_{113}/I_{012} both change rapidly with Sr-Ca substitution. The 012 and 101 reflections are within $3°2\theta$ of each other (with Cu $K\alpha$ radiation) while the angular distance of either of these to the 113 reflection is more than $22°2\theta$; therefore the intensity ratio I_{012}/I_{101} is considered to be the best for determining Sr content in Sr-substituted crandallite (Fig. 2). On this graph the observed intensity ratios (2.05 and 1.17) for crandallite from Florida and from Fairfield, Utah correspond to 30 and 13 mole percent Sr substitution for Ca, respectively (measurements of intensity are from Blanchard, 1972). The figure of 30 mole percent is in close agreement with the chemical determination of Sr for the Florida crandallite (30% by wet chemical methods and 31.5% by X-ray fluorescence, Blanchard, 1972). The correlation between X-ray intensities and Sr content seems to be good and it is planned that this relationship will be used in analyses for Sr contained in crandallite (as opposed to being contained in other minerals) in samples from the aluminum phosphate zone of phosphate deposits in Florida.

Quantitative Analysis for Crandallite (and Goyazite)—In order to use X-ray line intensity measurements for quantitative analysis it is necessary to scale the powder diffraction pattern to some absolute scale. Hubbard, Evans, and Smith (1976) recommend reporting a standard scale factor (γ) with calculated powder diffraction patterns. This practice will permit conversion from relative intensity to absolute/relative intensity. They also point out that the scale factor, γ, may be used with appropriate data for corundum to calculate "the reference intensity ratio" I/I_c. I/I_c is the integrated intensity ratio of the strongest line of a sample to the strongest line of corundum. For crandallite $\gamma = 0.530 \times 10^{-3}$ and $I/I_c = 1.41$. For goyazite $\gamma = 0.795 \times 10^{-3}$ and $I/I_c = 2.37$. These reference intensity ratios were computed using values of γ, linear absorption coefficient, and density for corundum given by Hubbard et al. (1976). Figure 3 is a graph showing the variation in the scale factor γ through the crandallite-goyazite series. By using the intensity ratio I_{012}/I_{101} the Sr content in crandallite may be obtained and by applying this value to the graph of Fig. 3 the scale factor γ for a particular crandallite may be obtained and used in quantitative analysis. It is planned that this relationship will be used in semi-quantitative analysis for crandallite in the aluminum phosphate zone of phosphate deposits of Florida.

Acknowledgments—Calculation of the powder diffraction patterns was done with facilities of the Northeast Regional Data Center of the State University System of Florida. R. A. Wicker adapted the program of Clark et al. (1973) to the NRDC computer and wrote the plot routine.

LITERATURE CITED

Blanchard, F. N. 1972. Physical and chemical data for crandallite from Alachua County, Florida. Amer. Mineral. 57:473-484.

Blount, A. M. 1974. The crystal structure of crandallite. Amer. Mineral. 59:41-47.

Clark, C. M., D. K. Smith, and G. G. Johnson. 1972. A FORTRAN IV program for calculating x-ray powder diffraction patterns—version 5. Pennsylvania State Univ. University Park.

Fleischer, M. 1975. 1975 Glossary of Mineral Species. Mineralogical Record, Inc. Bowie, Maryland.

Hubbard, C. R., E. H. Evans, and D. K. Smith. 1976. The reference intensity ratio, I/I_c, for computer simulated powder patterns. J. Appl. Crystallogr. 9:169-174.

Kato, T. 1971. The crystal structure of goyazite and woodhouseite. Neues Jahrb. Min. Mh. 1971:241-247.

Palache, C., H. Berman, and C. Frondel. 1951. The System of Mineralogy of . . . Dana 7th Ed., vol. 2, Wiley, New York.

Florida Sci. 41(1):15-20. 1978.

Earth Sciences

THE OCCURRENCE OF CAECIDAE IN THE MIOCENE OF FLORIDA

Hugh J. Mitchell-Tapping

Department of Geology, Florida State University, Tallahassee, Florida 32306

Abstract: *Fossil specimens of* Caecum *have been recovered in well-cuttings from the Miocene of Florida. The specimens are identified and described primarily by their microarchitectural patterns.**

Treatment of the *Caecidae* in the fossil record of Florida has been neglected since the publication of Dall (1890) on the Tertiary fauna of Florida. This may be due in part to both scarcity and difficulty in identification, particularly since research on *Caecums*, from the Pliocene and Pleistocene (Grant and Gale, 1931) and the Eocene-Oligocene (Meyer, 1886), has added confusion by vague descriptions and no clear illustrations. Bartsch (1920) proposed an artificial key to the genera which caused further confusion. In descriptions of Recent *Caecidae* this confusion has been continued (Olsson et al., 1953). In 1972, Moore, in his systematic notes on the *Caecidae* from St. Croix, U. S. Virgin Islands, clarified the situation considerably by grouping many previously described species into synonomy with one species and by placing the genus *Meioceras* in synonomy with *Caecum*. In the present well-cuttings study conducted by the Bureau of Geology, Department of Natural Resources of Florida, only a small number of specimens of *Caecum* have been found. However, preservation was good, enabling examination by scanning electron microscopy.

Methods—The specimens of *Caecum* found in the well-cuttings were from the Hawthorn Formation in Flagler, Volusia, and Orange counties, and from the Tamiami Formation in Hendry County. In addition, samples were obtained during the construction of a new canal one mile west of Lake Wales in Polk County. Micrographs were taken on an ISI Supermini I scanning electron microscope. The identification of each species was based on its microarchitectural pattern.

---

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "advertisement" solely to indicate this fact.

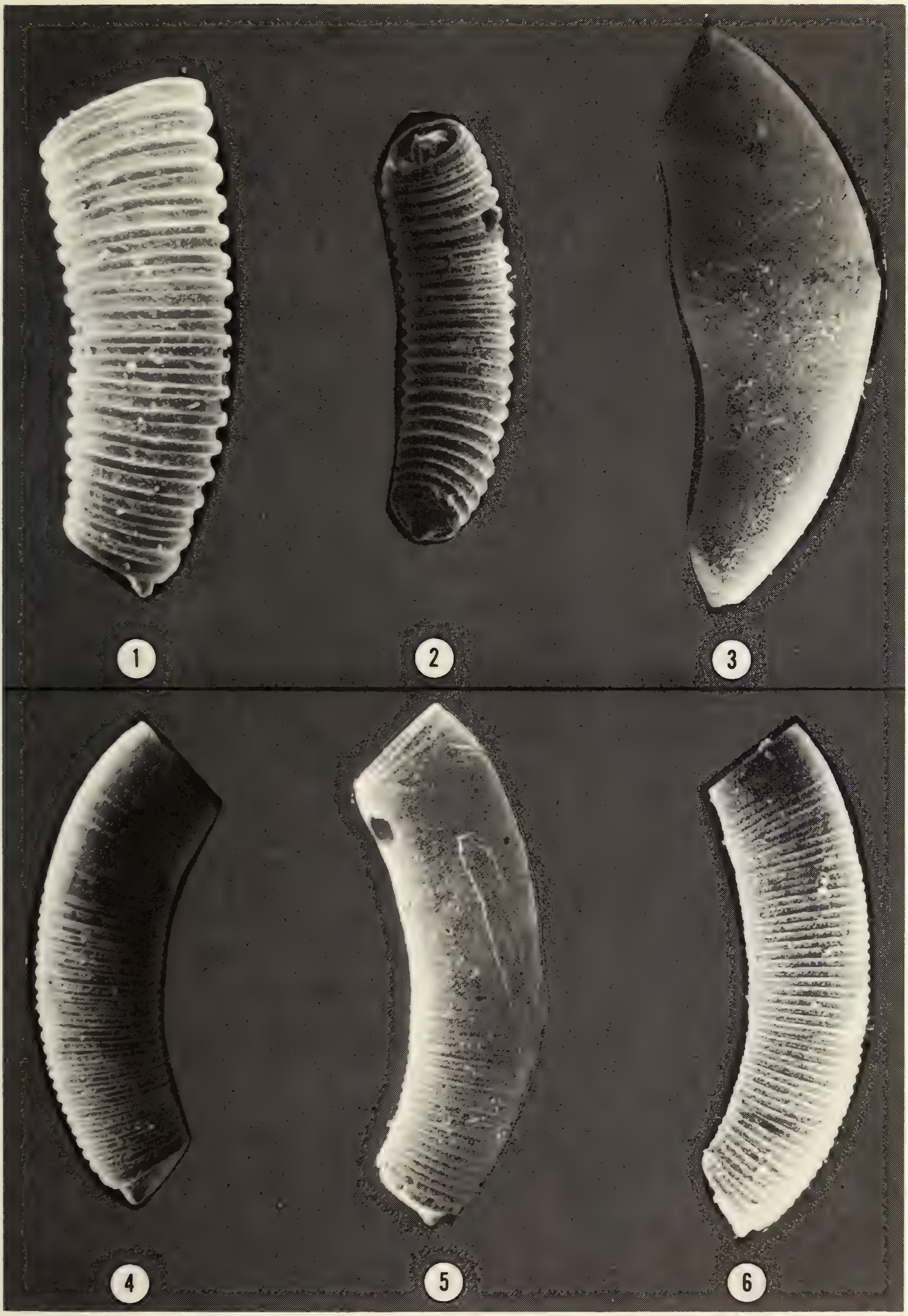


FIG. 1. *C. regulare* Carpenter ×48
FIG. 2. *Caecum* cf. *C. gurgulio* Folin ×16
FIG. 3. *C. cingulatum* Dall ×32
FIG. 4. *Caecum* cf. *C. regulare* Carpenter ×32
FIG. 5. *Caecum* cf. *C. regulare* Carpenter ×32
FIG. 6. *Caecum* cf. *C. regulare* Carpenter ×32

Discussion—A sample from a canal near Lake Wales (Fig. 3) contained one species described by Dall (1890) as *Meioceras cingulatum* and placed in synonomy with *Caecum (Meioceras) nitidum* Stimpson by Moore (1972). I consider it to be *C. cingulatum* (Fig. 3), and feel it should be treated as a separate species on account of the strongly inflated middle. Further, recognizable *C. nitidum* (Fig. 8) and *C. cingulatum* occur together, both in the Pliocene (Olsson et al., 1953), and in Miocene deposits we investigated. Other specimens found in the same sample are similar to *C. regulare* as shown in Fig. 4, 5, and 6. The posterior

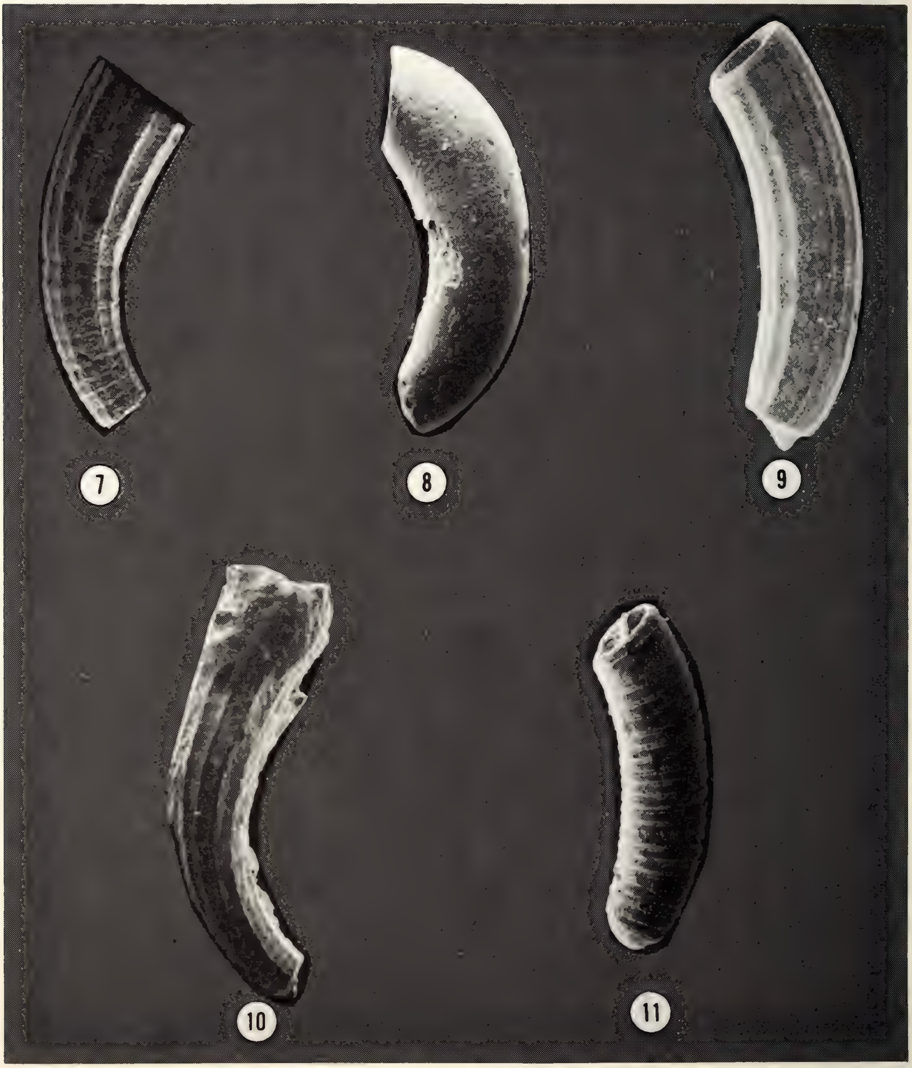


Fig. 7. *C. imbricatum* Carpenter ×32
Fig. 8. *C. nitidum* Stimpson ×32
Fig. 9. *Caecum* sp. ×32
Fig. 10. *C. imbricatum* Carpenter ×32
Fig. 11. *C. textile* Folin ×32

end of each specimen has circular ridges similar to *C. regulare* (Fig. 1) and then changes to a smooth surface within the space of two ridges. The length of the smooth anterior end varies with each specimen. At first glance, this may appear to be an erosional feature, but the regularity of the surface, the gradation from the ridges, and the absence of smooth areas elsewhere on the shell seem to negate this hypothesis. It is suggested that this factor may be the result of a drastic change of environmental conditions causing the gastropod to change its micro-architectural pattern in order to survive in the new environment.

A very common species present in the well-cuttings from Hendry (Well 617:90-100 ft), Flagler (Well 5039:73-80 ft), Volusia (Well 3472:91-145 ft), and Orange (Well 6474:100-115 ft) counties was *C. regulare* Carpenter (Fig. 1), based on the description and illustration by Moore (1972). In Well 6474 in Orange County, a species (Fig. 2) was found which appears similar to *C. gurgulio* Folin, both in size and that the circular ridges are flat-topped without any striae between these ridges. But, it differs by having eight sharp-topped circular ridges at the posterior end.

From Well 4065:82-103 ft in Flagler County, a specimen of *Caecum* was found having very broad flat circular ridges (Fig. 11) which may be an ancestor of the living species, *C. textile* Folin, since its microarchitectural pattern is similar to the specimen illustrated by Mitchell-Tapping (1977).

Two specimens from the canal sample (Fig. 7 and 10) have longitudinal and circular ridges with a varix similar to *C. imbricatum* Carpenter and have microarchitectural patterns similar to specimens illustrated both by Moore (1970) and Mitchell-Tapping (1977). The specimen (Fig. 9) found in Well 4065:82-103 ft has twelve longitudinal, but no circular, ridges with a smooth round aperture. There is no similar species illustrated in the literature and it may be a new species.

All specimens are deposited with the Bureau of Geology, Florida Department of Natural Resources, Tallahassee, Florida.

ACKNOWLEDGMENTS—I thank personnel at the Bureau of Geology in Tallahassee, Florida, for their help. Dr. S. W. Wise, Department of Geology at the Florida State University, Tallahassee, and Mr. S. Windham, Bureau of Geology, Department of Natural Resources, Tallahassee, are thanked for their helpful criticism of the manuscript. Support in part was provided by NSF Grant 121-323-210.

LITERATURE CITED

BARTSCH, P. 1920. The *Caecidae* and other marine mollusks from the northwest coast of America. J. Wash. Acad. Sci. 10:566-568.

DALL, W. H. 1892. Contributions to the Tertiary fauna of Florida. Trans. Wagner free Inst. Sci. Philad. 3(2):201-473.

GRANT, U. S., AND H. R. GALE. 1931. Pliocene and Pleistocene *Mollusca* of California. Mem. San Diego Soc. Nat. Hist. 1:779-780.

MITCHELL-TAPPING, H. J. 1977. The distribution of *Caecidae* in the marine sediment around Water Island, U. S. Virgin Islands.

MOORE, D. R. 1972. Ecological and systematic notes on *Caecidae* from St. Croix, U. S. Virgin Islands. Bull. Mar. Sci. 22:881-899.

———. 1970. A new *Caecum* from Puerto Rico and the Virgin Islands. Bull. Mar. Sci. 20:368-373.
OLSSON, A., A. HARBISON, E. FARGO AND D. PILSBRY. 1953. Pliocene *Mollusca* of southern Florida. Acad. Nat. Sci. Phila. Monogr. 8:316-320.

Florida Sci. 41(1):20-24. 1978.

THREE ADDITIONS TO THE FLORA OF FLORIDA—*John Popenoe and Daniel B. Ward,* Fairchild Tropical Garden, Miami, Florida 33156; Herbarium, University of Florida, Gainesville, Florida 32611

ABSTRACT: *Three species,* Chenopodium glaucum *L.,* Erucastrum gallicum *(Willd.) O. E. Schulz and* Potentilla reptans *L., not previously known from Florida have been found in Dade County.*

THREE SPECIES not previously known from Florida have been collected in Dade County by the staff at Fairchild Tropical Garden. All are adventive from the Old World.

Chenopodium glaucum L. (Chenopodiaceae) was collected in April 1977 in a damp swale in a potato field east of Homestead Air Force Base (*D. S. Correll 48326,* with John Popenoe). "Seed" potatoes used in the field had been obtained from North Dakota and from Maine, both states in which the species is known to be established; the immediate source of the introduction may have been one of these two areas. Additional plants were present along the margins of other nearby fields, indicating the species is now also established in Florida.

Erucastrum gallicum (Willd.) O. E. Schulz (Brassicaceae) has been collected several times, the first near Thompson Park 15 miles northwest of Miami, in February 1974 (*D. S. Correll 41561,* with H. B. Correll & John Popenoe). It is most abundant at Bird Drive Park, southeast of Miami and some 10 miles from the first collection, and it occurs also at the Montgomery Foundation in Coral Gables, 5 miles farther east. The Bird Drive Park station is near the Seaboard Coast Line Railroad track, which may have served in the initial introduction of this plant into the state.

Potentilla reptans L. (Rosaceae) is a European species that has been established in the northeastern United States for many years. In April 1977 it was collected along Tennessee Road near Florida City (*D. S. Correll 48340,* with John Popenoe). It occurs for several miles along the shoulder of this road and in nearby natural areas. The location is adjacent to potato fields, again suggesting a possible mode of introduction.

Although these three species are not significant weeds where they occur elsewhere in the United States and are not at present troublesome in Dade County, their biological vigor and negative economic potential in Florida cannot yet be assessed. Documenting specimens have been placed in the herbarium of the Fairchild Tropical Garden, with duplicates at the University of Florida, the University of North Carolina, and the New York Botanical Garden.

Florida Sci. 41(1):24. 1978.

Environmental Sciences

THE EFFECTS OF FIRE ON SPECIES COMPOSITION IN CYPRESS DOME ECOSYSTEMS[1]

KATHERINE CARTER EWEL(1) AND WILLIAM J. MITSCH(2)[2]

Center for Wetlands and School of Forest Resources and Conservation (1),
and Center for Wetlands and Department of Environmental Engineering Sciences (2),
University of Florida, Gainesville, Florida 32611

ABSTRACT: *Cypress trees were more successful than pines and hardwoods in surviving a fire which destroyed 42% of the trees in two cypress dome ecosystems. Cypress trees had comprised nearly half the trees in the domes, which had been drained for several years. After the fires, an average of 89% of the trees were cypress, 9% were hardwoods, and 2% were pines. Greatest mortality was in the center of the dome, where organic matter was deepest.*[°]

BALDCYPRESS (*Taxodium distichum* (L.) Rich.) and pondcypress (*Taxodium distichum* var. *nutans* (Ait.) Sweet) are commonly found in swamps throughout the southeast and as far north as southern Illinois and southern New Jersey. In Florida, small, circular swamps (usually less than 5 ha) are frequently called domes, because the trees are taller in the middle than at the edges, giving the swamps a dome-shaped profile. Cypress ecosystems normally have standing water at least part of the year; many are dry from late fall through late spring. It has long been recognized (e.g. Harper, 1927; Garren, 1943) that cypress swamps are often burned during the dry season, yet there is little documentation of the effects of fire on the ecosystems.

Beaven and Oosting (1939) mentioned that a fire that burned for 6 months in the cypress-dominated Pocomoke Swamp in Maryland destroyed the trees as well as most of the peat that had accumulated. Cypert (1961) described the damage done by fires in the Okefenokee Swamp in 1932 and in 1954 and 1955. All but the largest pondcypress trees were killed in two areas, although more trees survived on the site where peat deposits were shallower. In both areas, most of the regrowth was by coppicing. Kurz and Wagner (1953) postulated that the characteristic shape of cypress domes is due to the greater likelihood of fire around the outside of the swamp, where the ground may be dry for a greater part of a year.

Researchers at the University of Florida are currently investigating the feasibility of utilizing cypress swamps for the disposal of secondarily treated sewage. Part of the field work for the project is being carried out at a site near Gainesville,

---

[1]This paper is University of Florida Agricultural Experiment Station Journal Series No. 911.

[2]WJM at Pritzker Department of Environmental Engineering, Illinois Institute of Technology, Chicago, Illinois 60616.

[°]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

Florida, where several small cypress domes are located in a slash pine plantation (*Pinus elliottii* Engelm.) Following an unusually dry fall, a forest fire swept the site in December 1973; the location of the domes and the extent of the fire are shown in Fig. 1. Two of the severely burned domes have been studied intensively since then.

When the project began in June 1973, pondcypress, black gum (*Nyssa biflora* Walt.), sweet gum (*Liquidambar styraciflua* L.), and sweet bay (*Magnolia virginiana* L.) were the most common trees in the domes. Since the area had been drained by a series of ditches for many years, several slash pines grew in the domes as well. The understory was very dense, but had not been characterized prior to the fire.

The floor of the two burned domes smoldered for several weeks after the fire, but did not burn extensively enough to expose the mineral soil. After the fire, no standing water was present in the domes until March 1974, when secondarily treated sewage effluent was pumped into one and groundwater into the other. Pumping rates varied initially from 0 to 14 cm/wk, but have been constant at 2.5 cm/wk since April 1975.

Many trees in the two badly burned domes perished in the fire. The differential rates of mortality among the three kinds of trees (cypress, pines, and hardwoods) were of interest because of their implications for long-term survival of cypress ecosystems in areas where invasion by other species follows drainage.

METHODS—After the fire, maps were made of the two badly burned domes. Both live and dead trees were recorded for Dome 1, but only live trees were mapped in Dome 2. Heights and diameters of all live and dead trees in both domes were recorded. Another survey was conducted the following year to determine delayed tree mortality. In both surveys, dead hardwoods were grouped together because they could not be positively identified to species.

RESULTS—The numbers of live and dead trees before and one yr after the fire are shown in Table 1. In both domes, the majority of pine trees and hardwoods

TABLE 1. Effects of fire on numbers and biomass of cypress trees in cypress domes.

Dome	Kind of Tree	% of Trees Before Fire	% Decrease	% of Living Trees
1	Cypress	51.9	18.0	96.2
	Pines	27.2	95.7	2.6
	Hardwoods	20.9	97.6	1.1
	TOTAL	(599 trees)	55.7	(265 trees)
2	Cypress	43.6	22.5	81.6
	Pines	14.2	95.8	1.4
	Hardwoods	42.2	83.3	17.0
	TOTAL	(1334 trees)	58.5	(553 trees)

were killed, while only a small percentage of the cypress were killed. Cypress comprised about half the trees in the dome before the fire, and 80 to 90% after the fire. Cypress in Dome 2 suffered heavier mortality than in Dome 1, but a

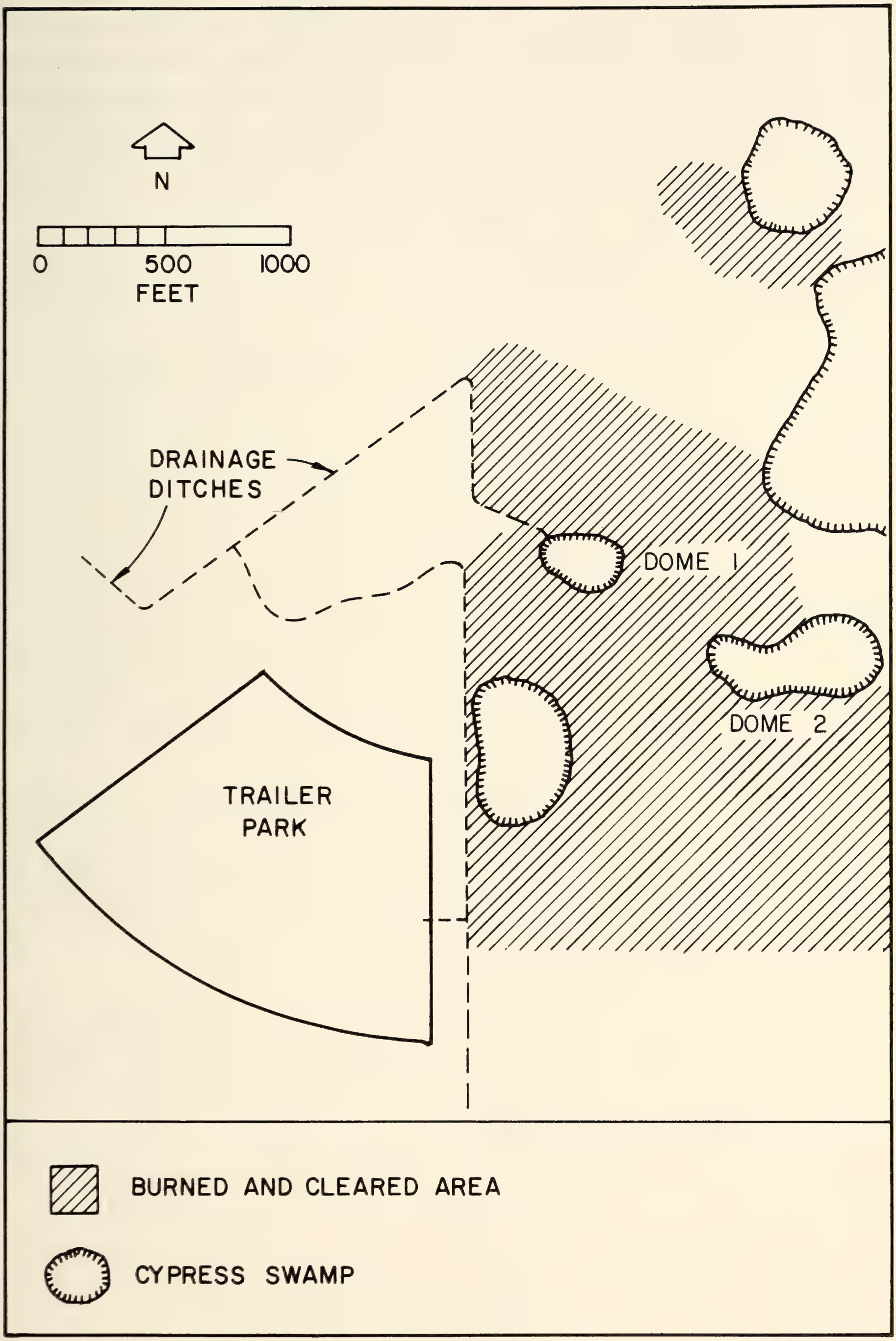


FIG. 1. Location of burned cypress domes at the experimental site of the cypress wetlands project near Gainesville, Florida.

larger proportion of the hardwoods, which had equalled cypress in number before the fire, survived. Dome 2 is the larger of the two (0.69 ha and 0.57 ha) and had a higher density of trees both before and after the fire. It had not been so severely drained originally, and had a considerably lower percentage of pine trees than did Dome 1. Table 2 shows the differences in size between live and dead trees in the domes. With the exception of pine trees in Dome 2, the surviving trees tended to be larger than the trees killed.

TABLE 2. Mean heights and diameters of three classes of trees in two burned cypress domes. Mortality was determined one year after the fire.

	Dome 1		Dome 2	
Class	Mean Height (m)	Mean DBH (cm)	Mean Height (m)	Mean DBH (cm)
Cypress:				
Live	17.3	24.0	17.7	21.6
	°°	°°	°°	°°
Dead	10.5	12.3	11.3	12.0
Pine:				
Live	14.2	17.9	9.6	10.6
				°°
Dead	13.9	16.3	12.8	14.7
Hardwood:				
Live	10.1	17.7	8.6	10.4
			°°	°°
Dead	8.3	10.7	6.8	7.2

°°Significant difference at 1% level.

Distribution of surviving cypress trees in Dome 1 after the fire is outlined in Table 3. Density of the trees varied from $0.17/m^2$ in the center to $0.09/m^2$ at 30-40 m. The highest mortality occurred in the $315\text{-}m^2$ central area where there were 55 trees before the fire: 29 cypress, 19 hardwood, and 7 pine. Only 10 trees survived, all cypress. Average height and DBH of the trees that died were close to the averages given for dead trees in Table 2.

DISCUSSION—Hare (1965) analyzed fire resistance in 14 southern trees, finding that, for trees of equal bark thickness, longleaf pine (*Pinus palustris*, Mill.) and slash pine are the most resistant to cambial damage, followed by loblolly

TABLE 3. Pattern of survival of trees in Dome 1. Areas are given for concentric rings in the dome at specified distances from the center.

Distance from center (m)	Area (m^2)	Survivors (%)
0-10	315	18
10-20	942	54
20-30	1571	48
30-40	1363	33
40-50	405	59
50-60	216	50

pine (*Pinus taeda* L.) and baldcypress, then by several hardwoods, of which the least resistant are sweetgum, black cherry (*Prunus serotina* Ehrh.), and American holly (*Ilex opaca* Ait.). For a given tree, fire resistance generally increases with tree diameter, since thicker bark and a higher crown prevent damage to either cambium or crown. Both cypress and pine might therefore be expected to survive burning better than hardwoods. However, the cypress trees at the experimental site were larger than either the pines or the hardwoods.

Since crown damage is usually more likely to kill a slash pine than is bole damage (Cooper and Altobellis, 1969), slash pine less than 1.5 m tall are easily killed in a light fire. Control burning is therefore inadvisable before the trees are 3.5 m tall (Cooper, 1965). The pine trees in the plantation surrounding the experimental site averaged 4.5 m tall, so they probably could have withstood a light fire. Nevertheless, all these trees were destroyed.

Hardwoods, on the other hand, are seldom completely destroyed by a fire, particularly in the winter when rootstocks are healthiest (Cooper, 1961). The fact that many of the hardwoods in the cypress domes were killed attests to the intense heat that must have built up in the organic matter on the floor of the cypress dome. Komarek (1972) observed that the bark of the cypress is fairly thick and fire-resistant, and that the formation of adventitious buds even after severe damage assists recovery. The majority of the cypress trees burned at the experimental site did put out adventitious branches, and some of the more severely damaged trees survived by coppicing.

In this case, the fire had a "cleansing" effect on the cypress dome, destroying most of the pines which were growing in the dome. Many of the hardwoods were also destroyed, but cypress trees are clearly capable of surviving a very damaging fire. Cypert (1961) observed that greater mortality of cypress on one burned site at the Okefenokee Swamp may have been due to greater depth of organic matter, since a smaller proportion of the roots would have extended into the mineral soil where they might have been more protected from fire. In a study of 15 cypress domes in north-central Florida, Monk and Brown (1965) found more organic matter (25-33 cm) in the soil beneath the central pool than at the edges (5-10 cm). Accordingly, Coultas and Calhoun (1975) had found that the organic and A1 horizons were 43 cm deep in the center of Dome 1 and 13 cm deep halfway to the edge. The Ap horizon was 15 cm deep at the edge. No measurements had been made in the other dome. The unusually low proportion of cypress trees that survived in the center of Dome 1 therefore supports Cypert's conclusion, and suggests that a fire which is hot enough to burn into the peat may have more serious consequences in the center than around the edges.

In a cypress dome with a normal hydroperiod, the existence of an open central pool may be attributed to both the effects of an occasional fire during a dry spell as demonstrated in this study, and the prevention of germination by the presence of standing water during normally wet years as shown by Demaree (1932). Pine trees invade cypress domes which remain dry for several years. Other work at the cypress dome experimental site indicates that decomposition of cypress needles occurs more slowly in dry areas than in wet areas (Deghi, 1976). Moreover, net productivity appears to be greater in drained domes than in undisturbed ones (Carter et al., 1973; Mitsch, 1975), so litter will accumulate fairly rapidly on the surface of a dry dome. Fires which burn through cypress domes after longer and longer drying periods will therefore do progressively greater damage, since the organic layers on the floor of the domes will have built up to a greater extent.

Cases have been documented in which cypress have been eliminated entirely from a burned site. Wells (1928) described shrub-choked bogs which developed after North Carolina swamp forests (characterized by *Nyssa, Taxodium,* and *Chamaecyparis*) had been damaged by fire. When wet conditions prevailed in such bogs, titi (*Cyrilla racemiflora* L.) predominated. Cypert (1961) showed that fires in 1954 and 1955 caused the formation of prairies in the Okefenokee Swamp by burning into the peat bed and killing the trees. No other fires since 1844 had had such a severe impact on the swamp.

Periodic fires will have little effect on the species composition of a cypress dome under normally wet conditions, and cypress will continue to be dominant in a drained cypress dome that is swept by periodic fires. Lack of fire in drained or dry cypress domes will allow a mixed stand of cypress and pine to develop. A fire which occurs after a long drying period in either case will do its greatest damage in the center of a dome, and may eliminate cypress altogether if sufficient organic matter has accumulated around the edges.

Acknowledgments—This work was supported by the National Science Foundation's program of Research Applied to National Needs, Grant AEN 73-07823 A01 (formerly G1-38721), and by The Rockefeller Foundation, Grant RF-73029 (H. T. Odum and K. C. Ewel, principal investigators).

LITERATURE CITED

Beaven, G. F. and H. H. Oosting. 1939. Pocomoke Swamp: A study of a cypress swamp on the eastern shore of Maryland. Bull. Torrey Bot. Club 66:367-389.

Carter, M. R., L. A. Burns, T. R. Cavinder, K. R. Dugger, P. L. Fore, D. B. Hicks, H. L. Revells, and T. W. Schmidt. 1973. Ecosystem analysis of the Big Cypress swamp and estuaries. U.S. E.P.A. Region IV. Atlanta.

Cooper, R. W. 1961. Effects of prescribed fire on understory stems in pine-hardwoods stands of Texas. J. Forest. 59:356-359.

__________. 1965. Prescribed burning and control of fire. In Guide to loblolly and slash pine plantation management in southeastern U.S.A. Ga. Forest Res. Counc. Rept. 14:131-137.

__________, and A. T. Altobellis. 1969. Fire kill in young loblolly pine. USDA For. Serv. Fire Contr. Notes 30 (4):14-15.

Coultas, C. L. and F. G. Calhoun. 1975. A toposequence of soils in and adjoining a cypress dome in North Florida. Soil Crop Sci. Soc. Florida 35:186-191.

Cypert, E. 1961. The effects of fires in the Okefenokee Swamp in 1954 and 1955. Amer. Midl. Nat. 66:485-503.

Deghi, G. 1976. Litterfall and litter decomposition in four cypress domes. Pp. 197-231. In Odum, H. T. et al. (eds) Cypress Wetlands for Water Management, Recycling and Conservation. Third Annual Report to National Science Foundation and The Rockefeller Foundation.

Demaree, D. 1932. Submerging experiments with *Taxodium.* Ecology 13:258-262.

Garren, K. H. 1943. Effects of fire on vegetation of the southeastern United States. Bot. Rev. 9:617-654.

Hare, R. C. 1965. Contribution of bark to fire resistance of southern trees. J. Forest. 63:248-251.

Harper, R. M. 1927. Natural resources of south Florida. Florida Geol. Surv., 18th Ann. Rept.:27-192.

Komarek, E. V., Sr. 1972. Ancient fires. Pp. 219-240. In Proc. Ann. Tall Timbers Fire Ecol. Conf. No. 12. Tall Timbers Res. Sta. Tallahassee.

Kurz, H., and K. A. Wagner. 1953. Factors in cypress dome development. Ecology 34:157-164.

Mitsch, W. J. 1975. Systems Analysis of Nutrient Disposal in Cypress Wetlands and Lake Ecosystems in Florida. Ph.D. Dissert. Univ. Florida. Gainesville.

Monk, C. D. and T. W. Brown. 1965. Ecological considerations of cypress heads in north-central Florida. Amer. Midl. Natl. 74:126-140.

Wells, B. W. 1928. Plant communities of the coastal plain of North Carolina and their successional relations. Ecology 9:230-242.

Florida Sci. 41(1):25-31. 1978.

Earth Sciences

THE TAMIAMI FORMATION—HAWTHORN FORMATION CONTACT IN SOUTHWEST FLORIDA

Thomas M. Missimer

Missimer and Assoc., Inc., 2500 Del Prado Blvd., Suite B, Cape Coral, Florida 33904

Abstract: *Stratigraphic placement of the Tamiami Formation—Hawthorn Formation contact has been arbitrary in subsurface investigations in southwest Florida. This contact is properly positioned beneath a dark colored carbonate mud unit, which contains large concentrations of detrital phosphorite, quartz sand, and various clay minerals. The mud unit, known informally as the Fort Myers clay member of the Tamiami Formation, covers the Hawthorn Formation in nearly all of southwest Florida. The formational contact is distinctive in western Lee and Charlotte Counties, where it is a stratigraphic disconformity, and becomes less distinctive to the south and east, where deposition has been continuous and no break in the stratigraphic record is evident.*[*]

Proper delineation of the contact between the Tamiami Formation and the underlying Hawthorn Formation in stratigraphic and hydro-geologic investigations has been a recurring problem in south Florida. Both units are lithologically complex and contain numerous differing sediment facies. Although these formations are separated in part by an unconformity, the lower-most Tamiami sediments sometimes have a similar composition to the uppermost Hawthorn sediments. Different contact placements have been made on the same stratigraphic sequence with early investigators placing the contact high in the sequence (Cooke, 1945; Klein, Schroeder and Lichtler, 1964; Puri and Vernon, 1964) and later investigators placing the contact at a lower stratigraphic position (Sproul, Boggess and Woodard, 1972; Boggess and Missimer, 1975; Missimer, 1975; Peck, Missimer and Wise, 1976; Peck, 1976).

The increased emphasis being placed on groundwater investigations in southwest Florida necessitates the need for detailed, accurate, stratigraphic control in order to properly delineate regional hydraulically connected aquifers. New paleontologic data and better stratigraphic control have now permitted the es-

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

tablishment of some diagnostic control on the Hawthorn—Tamiami contact (Peck, 1976; Peck, Missimer and Wise, 1976; Boggess and Missimer, 1975). Some criteria that can be used to facilitate an accurate placement of the contact in boreholes, cores, and water wells in southwest Florida (Fig. 1) are presented along with discussion of the geologic significance of the contact.

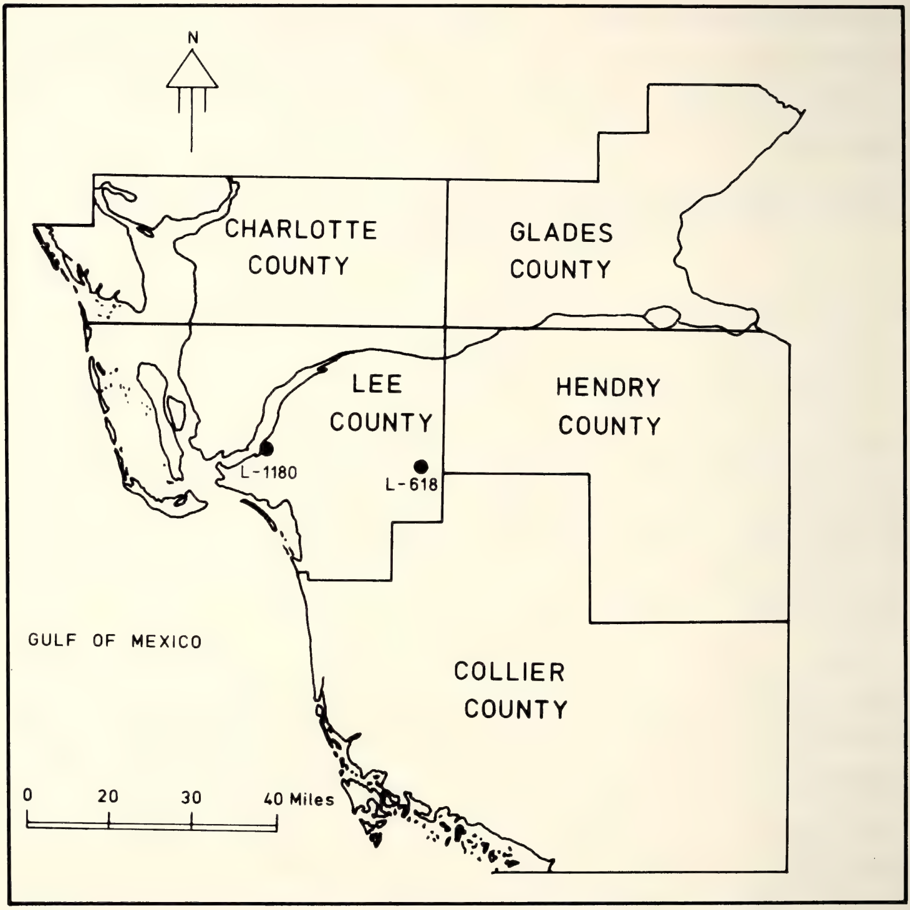


FIG. 1. Map of southwest Florida showing the area of investigation and U. S. Geological Survey test holes L-1180 and L-618.

HAWTHORN FORMATION—The Hawthorn Formation is part of a middle Miocene complex of phosphatic carbonate sediments, which occur over much of the eastern Atlantic and Gulf coastal plains. The formation was originally defined by Dall (1892) and the accepted type sections are located at Devil's Millhopper and Brooks Sink in northern peninsular Florida (Puri and Vernon, 1964).

A large diversity of lithologies, ranging from fresh-water and marine mixed carbonates and clastics to phosphatic marine limestones, are present in the Hawthorn Formation in central to south Florida. Hawthorn sediments in Florida, particularly south of Desoto and Highlands Counties, are predominantly marine carbonates with varying amounts of quartz sand, phosphorite nodules, and detrital and authigenic clays.

The higher-standing parts of the upper surface of the formation were eroded to a variable degree near the end of middle Miocene and/or beginning of late Miocene time over some of southwest Florida. The Hawthorn upper surface is therefore a regional disconformity over a large part of the area.

There is both regional and local relief at the surface of the Hawthorn Formation. The local relief appears to have been caused by differential erosion and tectonic distortion of bedding caused by uneven structural subsidence (Missimer and Gardner, 1976). Local relief on the Hawthorn surface ranges up to 60 ft in western Lee County to more than 300 ft in southern Lee and western Collier Counties. The surface has an avg regional dip of about 7 ft per mile toward the southeast from the Gulf coast in Lee County. A considerably steeper dip to the west is seen in coastal Collier County. This slope is probably caused by structural warping related to the south Florida embayment. The contact of the Hawthorn with the overlying Tamiami Formation has a regional pattern with superimposed local erosional and structural distortions. Therefore, the position of the upper formational contact of the Hawthorn Formation has considerable variation in southwest Florida and its position cannot be easily predicted without detailed geologic data at any given point.

There is a discernible regional litho-facies pattern at the top of the Hawthorn (Fig. 2). The formation is a lithified, white and light gray, phosphatic limestone in most of western Lee and Charlotte Counties. The limestone grades laterally into a partially lithified, gray to white, phosphatic, carbonate mud or marl to the south and east. There are localized areas in eastern Lee and Collier Counties and parts of Hendry County, where the upper Hawthorn is a limestone. These areas are areally narrow zones, which trend north and south and correspond to locally high areas (probably structural), such as observed at LaBelle in Hendry County (Fig. 2). East of the mixed carbonate mud—limestone area, the surface of the Hawthorn grades laterally into a phosphatic gray carbonate mud and further to the east into a sandy, phosphatic, dark green carbonate mud.

Tamiami Formation—Most of Florida south of the peninsular highlands is underlain by a complex sequence of Plio-Miocene shallow marine carbonates and mixed clastics. This sediment sequence was named the Tamiami limestone by Mansfield (1939) for a series of limestone exposures located along the Tamiami Trail in Collier and Monroe Counties. Mansfield originally assigned these sediments a Pliocene age. Parker and others (1955) added a sequence of carbonate muds and associated clastics to the unit and redefined the Tamiami Formation to include all upper Miocene sediments in south Florida. Recent investigations by Hunter (1968, 1970), Puri and Vanstrum (1970) and Peck (1976) show that the Tamiami Formation includes sediments ranging from Pliocene to upper Miocene in age. The top of the sediment sequence is no longer considered to be the Pliocene-Miocene boundary.

There are numerous lithostratigraphic units present in the Tamiami Formation (Hunter, 1968; Sproul, Boggess and Woodard, 1972; Boggess and Missimer,

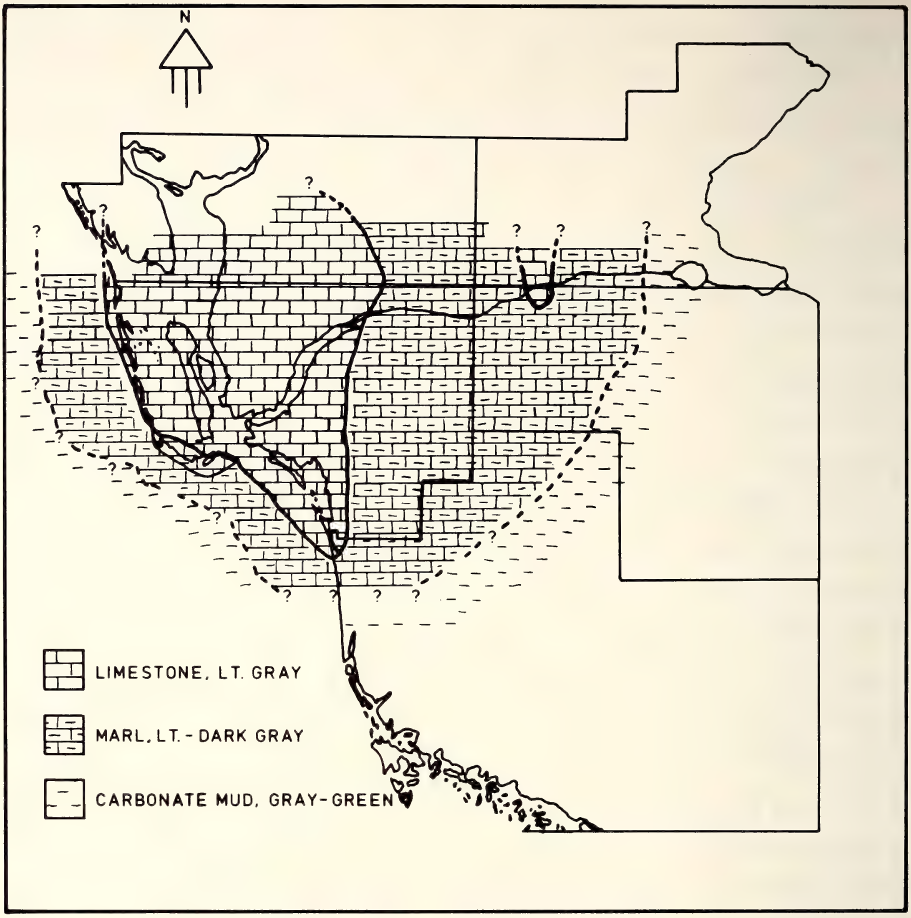


FIG. 2. General lithofacies map of the top of the Hawthorn Formation in southwest Florida.

1975; Peck, 1976). However, the most significant Tamiami unit for delineation of the Hawthorn contact is the lowest member. Since the upper boundary of the Hawthorn is in part, an erosion surface, a quantity of non-carbonate material derived from weathering and erosion of the Hawthorn Formation is present in the lowest Tamiami member. This member is between 10 and 50 ft thick over most of southwest Florida. Because of the mixed nature of its lithology, the unit has been termed the "rubble zone" by Missimer and Gardner (1976). For discussion purposes, this unit is hereby informally termed the Fort Myers clay member of the Tamiami Formation, for the area where it is best exemplified (Fig. 3).

The Fort Myers clay is a mixture of phosphorite nodules, quartz sand, carbonate mud, and detrital attapulgite, montmorillonite, and dolomite. This unit is usually dark gray to dark gray-green in color and contains a variable thickness of dense clayey carbonate mud, which is very cohesive and often inhibits rotary drilling by clogging roller bits. The overall nature and composition of the Fort

Myers clay is similar to that of the Bone Valley Formation in central Florida (Cooke, 1945; Altschuler et al., 1964; Puri and Vernon, 1964).

The heavy concentration of black phosphorite nodules is a particularly diagnostic feature of the Fort Myers clay. Phosphorite nodules are composed of a mixture of carbonate minerals and fluorapatite. The nodules have a characteristically high trace content of radioactive uranium. Gamma ray logs of wells and test holes show very high radioactivity in this zone as is illustrated in log of well L-1180. The gamma ray activity of the Fort Myers clay is often much greater than

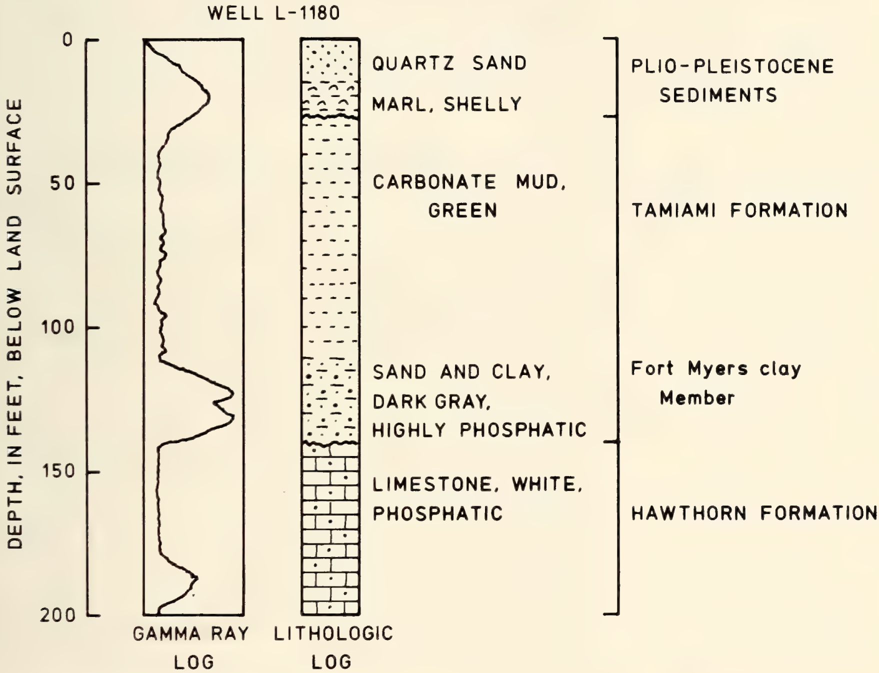


Fig. 3. Lithologic and gamma ray logs and formational contacts in U. S. Geological Survey test hole L-1180.

that measured in the overlying sediments and the underlying Hawthorn Formation. This difference in gamma ray activity is a very diagnostic indicator of the stratigraphic position of the Fort Myers clay and is indicative of the upper Hawthorn contact (Fig. 3).

Peck (1976) defined the Fort Myers clay as Tamiami Formation unit zone 8. He found that the unit was characterized by the occurrence of the benthic forminiferal species *Lenticulina americana.* The occurrence of *Valvulineria floridana* seems to indicate the upper boundary of the Fort Myers clay (or zone 8).

The Fort Myers clay is an easily mapped stratigraphic unit in all of western Charlotte and Lee Counties and it can be defined with less resolution in eastern Charlotte and Lee Counties and most of Collier and Hendry Counties. Lesser contents of phosphorite nodules and quartz sand in the unit occurs where the clay is positioned more than 250-300 ft below mean sea level.

The decrease in phosphorite content and a change in color and general texture cause difficulty in delineating the Tamiami—Hawthorn contact in the eastern parts of the study area. This fact is illustrated in the logs of well L-618 (Fig. 4).

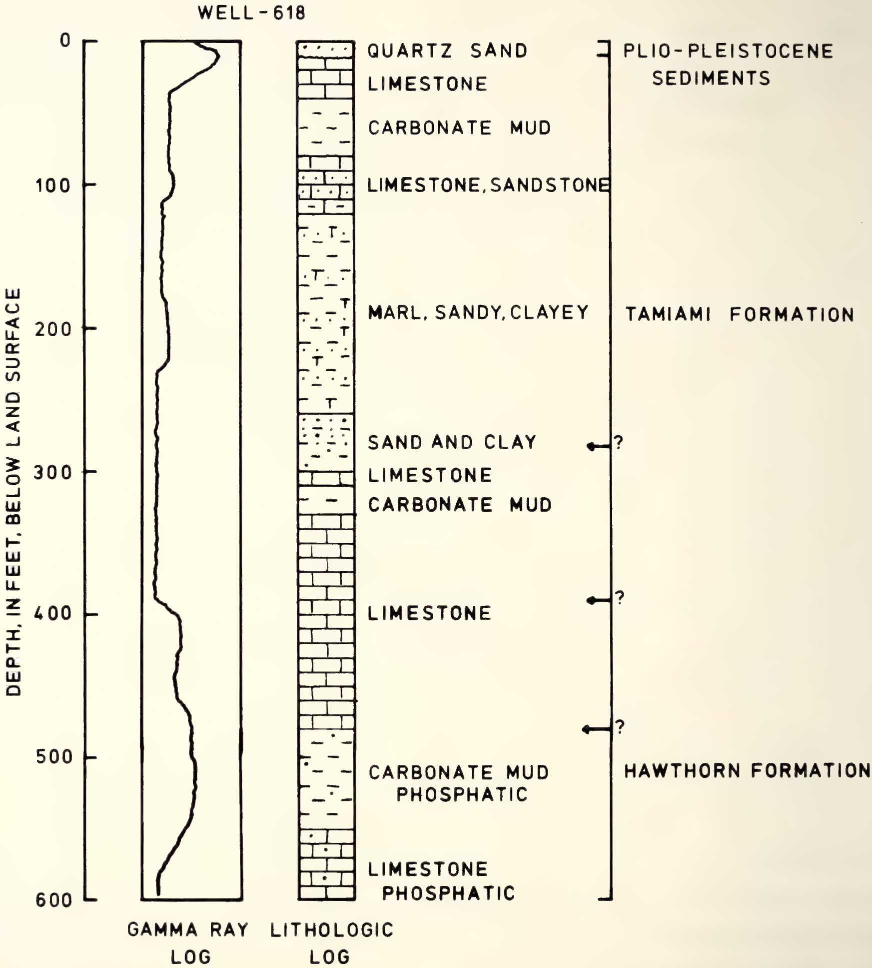


FIG. 4. Lithologic and gamma ray logs and formational contacts in U. S. Geological Survey test hole L-618.

The Fort Myers clay is apparently not a traceable unit outside of the southwest Florida area and therefore, cannot be used as an indicator of the top of the Hawthorn Formation throughout all of south Florida.

CONTACT PLACEMENT—The Hawthorn Formation—Tamiami Formation contact can be delineated with minimal difficulty in western Lee and Collier Counties. There is a distinct break in lithology between the overlying Fort Myers clay and the limestone facies of the Hawthorn. The clay contains abundant nodular phosphorite and has a characteristic dark gray to dark green color. The underlying limestone is white to light gray in color, is well lithified, and contains some black phosphorite nodules. Gamma ray intensity is very high in the Fort Myers clay and it decreases significantly at the Hawthorn contact (Fig. 3). The stratigraphic break between the two formations is distinctive only in the areas denoted by the upper Hawthorn limestone facies shown in Fig. 2.

Placement of the formational contact is less distinctive with distance away from the areas where the uppermost part of the Hawthorn Formation is limestone (Fig. 2). The Fort Myers clay is present east and southeast of coastal Lee County. However, the clay contains a smaller percentage of detrital phosphorite sand and gravel. There is lesser gamma ray activity in the clay, and the contact can not be accurately defined in wells by use of a gamma ray log. The color of the clay is usually dark gray to green in these areas and has a greasy texture. Drilling through clay is often difficult and it has a tendency to stick to the drill rods and drill bit.

Where the upper part of the Hawthorn is a phosphatic marl or mud with a light gray to gray color, (marl area in Fig. 2), the contact between the units can be accurately placed by utilizing a good set of drill cuttings, by direct on-site observations, or from a combination of a set of drill cuttings, electric logs, and a gamma ray log. The gamma ray log shows a slight increase in activity within the Fort Myers clay and a lower activity in the underlying Hawthorn marl or clay. The combined resistivity and spontaneous potential logs shows that the Fort Myers clay is denser than the underlying Hawthorn clay or marl. There are some areas where the contact cannot be delineated by use of physical data and microfossil occurrence must be used (e.g. well L-618, Fig. 4).

The Tamiami—Hawthorn contact cannot be defined accurately by physical criteria outside of southwest Florida. The Fort Myers clay and the uppermost Hawthorn clay are the same lithology in many areas. The only possible means of accurate contact delineation is by the abundant occurrence of *Lenticulina america*, but this species is also found in Hawthorn-aged sediments (Peck, 1976). More comprehensive data are needed to provide a viable method to determine the position of the Tamiami Formation—Hawthorn Formation in other parts of south Florida.

Geological Significance—The contact between the middle Miocene Hawthorn Formation and the Plio-Miocene Tamiami Formation is a distinctive disconformity in parts of southwest Florida (Fig. 6). This disconformity is not continuous over all of south Florida and can only be delineated where the top of the Hawthorn Formation is stratigraphically high. Moving away from the "high" Hawthorn areas, the disconformity fades into a continuous sediment sequence, in which there is no discernible break in sediment deposition from the Hawthorn into the Tamiami. A "pseudo-disconformity" occurs between the formations in a wide belt that is adjacent to the "high" Hawthorn areas. The "pseudo-disconformity" is the result of the influx of shedded sediment from topographically high areas into marginal shallow marine depositional areas by fluvial processes.

The nature of the Tamiami—Hawthorn contact suggests that a low stand of glacio-eustatic sea level occurred during a very late part of middle Miocene time and/or a very early part of late Miocene time. High standing parts of the Hawthorn Formation in Lee, Charlotte and Hendry Counties were subjected to a relatively short period of subaerial exposure. The duration of land surface emergence was sufficient to permit parts of the formation to undergo apparent fresh-water diagenesis and to permit some subaerial weathering and erosion of the phosphatic carbonates. The emergence was not long enough to permit the development of mature karst topography nor to permit deep incising of fluvial channels. Maximum relief between land surface and mean sea level during the minimum sea level stand was probably between 50 and 100 ft. Sea level apparently rose rapidly in early late Miocene time as the result of glacio-eustatic change and/or by rapid structural subsidence of the land mass.

Detailed subsurface stratigraphic data show that there is presently up to 300 ft of relief on the top of the Hawthorn Formation in Lee County. This relief is not only the result of a low sea level stand and the subsequent rise, but also is structural. Several sediment filled "basins", which are narrow and elongate north and south, occur in the Tamiami Formation in Lee and Collier Counties. The Hawthorn contact is severely depressed within the axial part of the "basins" and the structures resemble small synclines (Missimer, 1974). Seismic reflection data reported by Missimer and Gardner (1976) show concentric-like folds caused by uneven subsidence in the Hawthorn and Tamiami. The relief on the Tamiami—Hawthorn contact is therefore a product of subaerial exposure, deposition, and uneven structural subsidence.

Acknowledgments—The following persons provided information, helpful comments, and review of this paper: Durward H. Boggess, Thomas H. O'Donnell, Sherwood Wise, F. Stearns MacNeil and Thomas M. Scott.

LITERATURE CITED

Altschuler, Z. S., J. B. Cathcart, and E. J. Young. 1964. Geology and geochemistry of the Bone Valley Formation and its phosphate deposits, west central Florida. Geol. Soc. Amer., Guidebook for Field Trip No. 6, Annual Meeting, 68 p.

Boggess, D. H., and T. M. Missimer. 1975. A reconnaissance of hydrogeologic conditions in Lehigh Acres and adjacent areas of Lee County, Florida. U. S. Geol. Surv. Open-file Rept. 75-55:88 p.

Cooke, C. W. 1945. Geology of Florida. Florida Geol. Surv. Bull. 29:1-339.

Dall, W. H., and G. D. Harris. 1892. Correlation papers, Neogene. U. S. Geol. Surv. Bull. 84:1-349.

Hunter, M. E. 1968. Molluscan guide fossils in late Miocene sediments of southern Florida. Gulf Coast Assoc. Geol. Soc. Trans. 18:439-450.

Klein, H., M. C. Schroeder and W. F. Lichtler. 1964. Geology and ground water resources of Glades and Hendry Counties, Florida. Florida Geol. Surv. Rept. Investig. 37:1-132.

Mansfield, W. C. 1939. Notes on the upper Tertiary and Pleistocene mollusks of peninsular Florida. Florida Geol. Surv. Bull. 18:1-75.

Missimer, T. M. 1974. Structural control of late Tertiary sedimentation in southwest Florida (abstr.). Geol. Soc. Amer., Abstr. Progr. 6(7):872.

__________, and R. A. Gardner. 1976. High resolution seismic reflection for mapping shallow aquifers in Lee County, Florida. U. S. Geol. Surv. Water Resources Investig. WRI 76-45:1-30.

Parker, G. G., G. E. Ferguson and S. K. Love. 1955. Water resources of southeastern Florida. U. S. Geol. Surv. Water-Supply Pap. 1255:1-965.

Peck, D. M. 1976. Stratigraphy and paleoecology of the Tamiami Formation in Lee County, Florida. M. S. Thesis. Florida State Univ. Tallahassee.

———, T. M. Missimer, S. W. Wise and R. C. Wright. 1977. Late Miocene (Messinian) glacia-eustatic lowering of sea level: Evidence from the Tamiami Formation of south Florida (abstr.). Florida Sci. 40(Suppl. 1):22-23.

Puri, H. S., and V. V. Vanstrum. 1970. Stratigraphy and paleoecology of the late Cenozoic sediments of southern Florida. Paleoecologie Ostracodes, 1970:433-448.

———, and R. O. Vernon. 1964. Summary of the geology of Florida and a guidebook to the classic exposures. Florida Geol. Surv. Spec. Publ. 5:1-312.

Sproul, C. R., D. H. Boggess and H. J. Woodard. 1972. Saline-water intrusion from deep artesian sources in the McGregor Isles area of Lee County, Florida. Florida Dept. Nat. Res. Bur. Geol. Inf. Circ. 75:1-30.

Florida Sci. 41(1):31-39. 1978.

SHELL-CEMENTED PELECYPODS—*David Nicol*, Department of Geology, University of Florida, Gainesville, Florida 32611

Abstract: *The oldest known shell-cemented pelecypods are Mississippian in age. Shell cementation has never been a common adaptation by pelecypods, and only about 1.0% of all living species of pelecypods are shell cemented.*

Shell-cemented or shell-attached pelecypods are those bivalves that are attached to the substrate by secretions of calcium carbonate in the form of calcite or aragonite. Shell cementation appears to be a rather late adaptation acquired by the pelecypods. The first shell-cemented species of pelecypods appeared in the Mississippian and they became more common in the Permian. The pectinacean families that had shell-cemented species were the Aviculopectinidae (late Devonian to Jurassic), Pseudomonotidae (Mississippian to Permian), and Terquemiidae (Permian to Jurassic). For an excellent review of these early shell-cemented pelecypods, see Newell and Boyd (1970). All extant families which have shell-cemented species appeared during the Triassic or later time. The Plicatulidae, Ostreidae, and Gryphaeidae appeared during the Triassic, and shell cementation became a more common adaptation than at any time during the Paleozoic. The shell-cemented Pectinidae, Dimyidae, and Spondylidae made their appearance during the Jurassic, and shell cementation was common during the Jurassic and Cretaceous. There were many species of ostreids and gryphaeids living during the Jurassic and Cretaceous, and the shell-cemented rudists arose during the late Jurassic and were prolific in warm shallow seas during the Cretaceous. Shell-cemented pelecypods probably reached the peak of their diversity during the Cretaceous. Chamids may have originated during the late Cretaceous, but they did not become common until the Eocene. The other three families of pelecypods with shell-cemented species are all small and are late arrivals—the myochamids and cleidothaerids during the Miocene and the fresh-water etheriids not until the Pliocene. However, Yonge (1962) noted that the habitat in which the shell-attached etheriids live is not a good one for fossil preservation and that the etheriids may be a much older group than is indicated by the fossil record. To a certain extent this is true of the other families of shell-cemented pelecypods; even though they generally live in a shallow-water marine environment, they are epifaunal animals and are less likely to be preserved in the fossil record than infaunal pelecypods.

Of the approximately 100 extant families listed in the *Treatise on Invertebrate Paleontology* (1969, 1971), 10 have species that are attached to the substrate by shell cementation during part of their life cycle. Of these 10 families, seven (Plicatulidae, Spondylidae, Gryphaeidae, Ostreidae, Chamidae, Cleidothaeridae, Dimyidae) have all species shell cemented. Shell cementation is very rare in the Pectinidae, common in the small fresh-water family Etheriidae, and uncommon in the Myochamidae. There are approximately 750 extant genera of pelecypods, but only 22 or about 3.0% are shell cemented. There are an estimated 12,000 living species of pelecypods, but probably no more than 150 of them are shell cemented. This means that slightly more than 1.0% of all living species of pelecypods are attached to the substrate by shell cementation. Of the 150 shell-cemented species of extant pelecypods, probably two-thirds of them are ostreids and chamids. The Plicatulidae, Spondylidae, Dimyidae, and Gryphaeidae comprise most of the remaining species. There are no more than 3 species of shell-cemented Etheriidae, and about a like number in each of the families Cleidothaeridae, Myochamidae, and Pectinidae. Except for the Pectinidae, none of the most diverse families of marine pelecypods has shell-attached species. For example, the Tellinidae, the Veneridae, and the Nuculanidae, which appear to be the three largest extant families of pelecypods, are all uncemented.

There are almost no consistent physical characteristics of shell-cemented pelecypods, although there are some trends in physical characters. In most shell-cemented pelecypods, the shell is commonly thick and camerate (i.e., having macroscopic spaces or voids that are completely enclosed by shell material). Many species of ostreids, chamids, and spondylids have these characteristics, which are an indication of rapid secretion of shell material in warm water. However, *Myochama* and the Dimyidae do not have thick shells. In most families and genera, the lower or attached valve is larger and deeper than the upper or free valve, but this is not true of *Myochama*. The anterior adductor muscle is generally reduced in size or absent, but the adductor muscles are of approximately equal size in the Chamidae and *Myochama*. The hinge teeth tend to be absent or few in number, and the Chamidae probably have the best-developed hinge teeth. The ligament tends to be internal, but the ligament of the chamids is basically external. In the Ostreidae and Gryphaeidae the attached valve is consistently the left, but in the Plicatulidae, Dimyidae, Spondylidae, Myochamidae, Cleidothaeridae, and Pectinidae the right valve is cemented to the substrate. Amongst the Etheriidae and Chamidae, either the right valve or the left valve may be the shell-cemented one, and in some species of chamids the individuals may attach themselves by either the right valve or the left valve (Yonge, 1967).

It becomes obvious from this brief and general review of shell-cemented pelecypods that there is a wide array of physical characteristics, and it is evident that a fair number of basic stocks (families and superfamilies) have been able to use shell cementation; but when one examines the number of extant genera and particularly extant species, one is struck by the comparatively few genera and species of pelecypods that have adopted the shell-cemented habit. The question then arises, why have not more genera and species of pelecypods adopted shell cementation? There are at least four answers to this question. 1) It would be impossible for shell-cemented pelecypods to be deposit feeders because these animals must be able to move around in or on the bottom in search of nutriment. Furthermore, deposit-feeding pelecypods live on a soft bottom, which is unsuitable for shell-cemented pelecypods. Consequently, the Protobranchia, the Tellinidae, and the Semelidae, all of which are deposit feeders, cannot be shell-cemented. Because shell-cemented pelecypods are sessile and benthic, they are generally limited to suspension feeding. 2) The temperature of the water is another important factor. Shell-cemented pelecypods thrive in warm water and are absent from the Arctic, Antarctic, and deep-sea (2,000 m or greater depth) faunas (Nicol, 1967). Even the Ostreidae, which can live in colder water than can the other shell-cemented groups, do not invade areas where the sea water is less than 10° C during the warmest month of the year. The 3 species of freshwater shell-cemented pelecypods are tropical. 3) Yonge (1967) pointed out that the inhalent and exhalent currents must be widely separated in shell-cemented pelecypods because they commonly live in turbulent water, and this physical factor would help to prevent waste material from entering the inhalent opening. 4) Probably the most important factor is that many pelecypods are attached by a byssus, and there is no compelling necessity for them to become shell cemented. The byssally attached pelecypod species, including the Anomiidae which are attached by a calcified byssus, considerably outnumber the shell-cemented species in living faunas, and they appear to have done so in the past. Certainly these four limiting factors can explain why the pelecypods have not used shell cementation more commonly as an adaptation to a sessile mode of life.

LITERATURE CITED

Moore, R. C. (ed.). 1969, 1971. Treatise on Invertebrate Paleontology. Part N, Mollusca 6, Bivalvia, Vols. 1-2, 1969, Vol. 3, 1971. Geol. Soc. Amer. Boulder, Colorado.

Newell, N. D., and D. W. Boyd. 1970. Oyster-like Permian Bivalvia. Bull. Amer. Mus. Nat. Hist. 143(4):219-281.

Nicol, D. 1967. Some characteristics of cold-water marine pelecypods. J. Paleont. 41:1330-1340.

Yonge, C. M. 1962. On *Etheria elliptica* Lam. and the course of evolution, including assumption of monomyarianism in the family Etheriidae (Bivalvia: Unionacea). Phil. Trans. Roy. Soc. London, Ser. B., Biol. Sci., No. 715, 244:423-458.

———. 1967. Form, habit and evolution in the Chamidae (Bivalvia) with reference to conditions in the rudists (Hippuritacea). Phil. Trans. Roy. Soc. London, Ser. B., Biol. Sci., No. 775, 252:49-105.

Florida Sci. 41(1):39-41. 1978.

A NEW RECORD OF *ACETABULARIA CALYCULUS* FROM FLORIDA[1]

—*N. J. Eiseman, M. C. Benz, and D. E. Serbousek,* Harbor Branch Foundation, RFD 1, Box 196, Ft. Pierce, Florida 33450

ABSTRACT: Acetabularia calyculus *is reported from lagoons on the Florida East Coast.*°

FIVE SPECIES of the genus *Acetabularia* Lamouroux have been previously reported from Florida, *A. crenulata* Lamouroux, *A. (Chalmasia) antillana* (Solms-Laubach) Egerod, *A. pusilla* (Howe) Collins, *A. (Acicularia) shenkii* Mobius, and *A. farlowii* Solms-Laubach (Taylor 1928, 1960). *Acetabularia calyculus* Quoy & Gaimard was collected by the senior author January 7, 1971 in Jupiter Sound (26°57.2′N, 80°04.4′W) and by the junior authors on April 5, 1976 in the Indian River north of Ft. Pierce Inlet (27°31.8′N, 80°20.25′W). Both sites are part of the coastal lagoon system of the Florida East Coast. In both cases the plants were growing on rocks and loose shells near the low water mark. Some plants in both collections were in reproductive condition.

Acetabularia calyculus is readily distinguished from the other Florida species by the deeply cup-shaped cap (Fig. 1) and by the ends of the rays which are broadly notched (Fig. 2). The caps of the other species are flat, irregular, or only slightly concave with rays that are rounded or apiculate. The caps in our specimens are 4.0-4.5 mm in diameter, 2.0-2.5 mm deep, and have 21-30 rays. Calcification of the cap is very light. The stalks are 2.0-3.5 cm tall, 250 μm in diameter and more heavily calcified. The gametangial cysts are 100-125 μm in diameter. The corona superior in our specimens has two hair scars in a radial line from the axis of the plant (Fig. 3). The lobes of the corona inferior are broadly rounded (Fig. 4).

Acetabularia calyculus has been described in detail from Australia, the type locality (Solms-Laubach 1895), the Virgin Islands (Bϕrgesen 1913), and Jamaica (Collins 1909). They report that cap diameter may reach 7 mm. They also report that there may be three hair scars on the corona superior in a triangular or irregular arrangement, or rarely four hair scars. As mentioned above, our specimens have only two hair scars. The caps are also slightly smaller than other reported specimens but are otherwise typical of the species.

[1]Contribution No. 92, Harbor Branch Foundation, Inc.

°The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

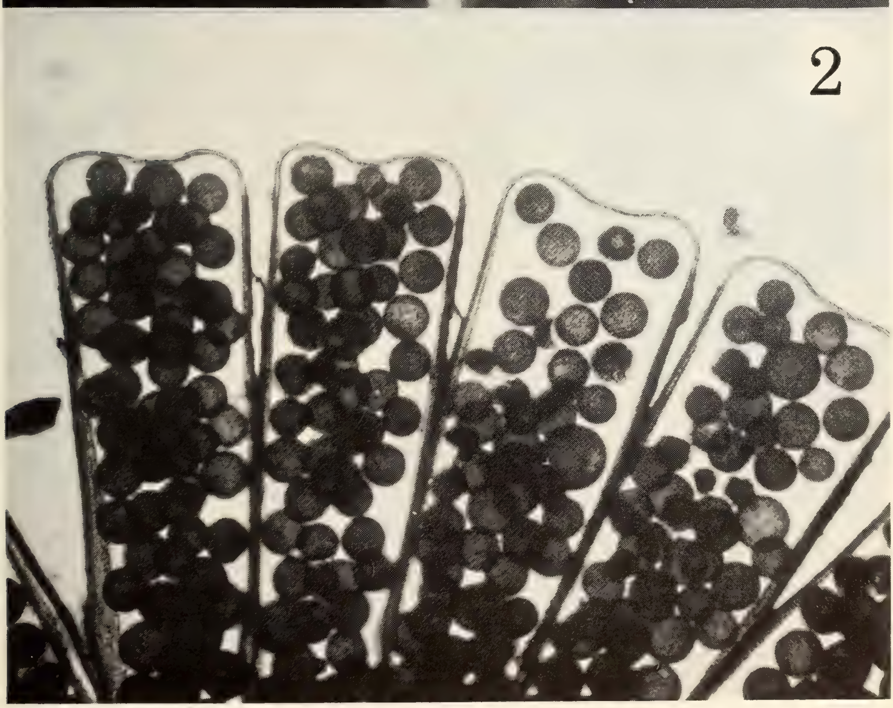
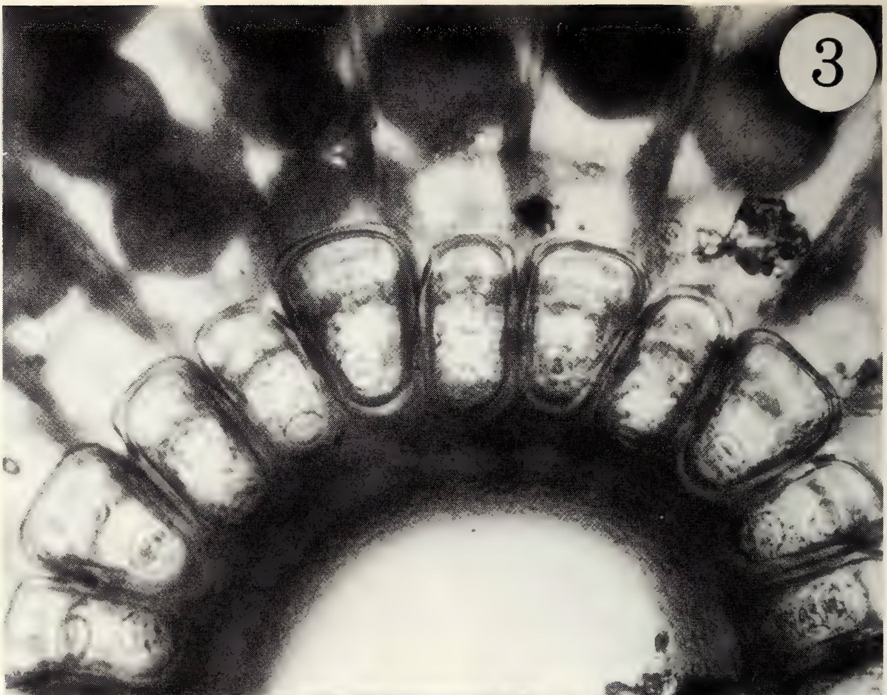


FIG. 1. Habit of a cap with the coronal hairs attached.
FIG. 2. Detail of the rays showing broadly notched ends and gametangial cysts.



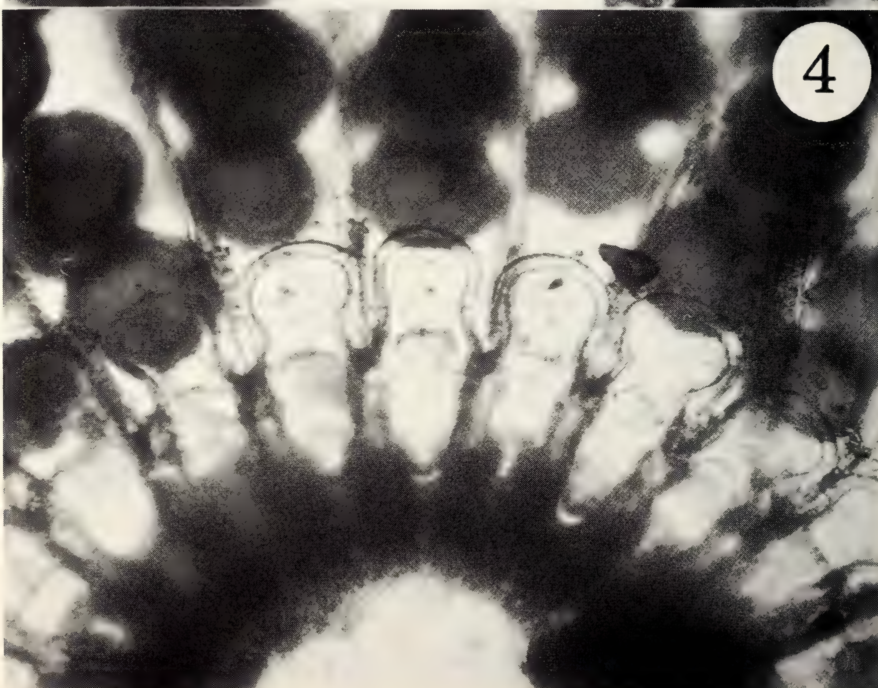


FIG. 3. Detail of the corona superior showing the lobes with two hair scars.
FIG. 4. Detail of the corona inferior showing the broadly rounded lobes.

LITERATURE CITED

Børgesen, F. 1913. Marine algae of the Danish West Indies. I. Chlorophyceae. Dansk Bot. Arkiv 1(4):1-158.

Collins, F. S. 1909. The green algae of North America. Tufts Coll. Stud. 2:69-480, pls. 1-18.

Solms-Laubach, H. 1895. Monograph of the Acetabularieae. Trans. Linn. Soc. London, Bot. Ser 2, 5:1-39, pls. 1-4.

Taylor, W. R. 1928. Marine algae of Florida with special reference to the Dry Tortugas. Carnegie Inst. Wash. 25(Publ. No. 379):1-219, pls. 1-37.

__________. 1960. Marine Algae of the Eastern Tropical and Subtropical Coasts of the Americas. Univ. Mich. Press. Ann Arbor.

Florida Sci. 41(1):42-45. 1978.

Biological Sciences

ULTRASTRUCTURAL STUDY OF GRANULOCYTES OF *BUFO MARINUS*

Albina Y. Surbis

Department of Anatomy, University of Miami School of Medicine, Miami, Florida 33152

Abstract: *An ultrastructural study was conducted of the granulocytes of the toad* Bufo marinus. *As in higher forms, three kinds of cells were observed: neutrophils, eosinophils and basophils. The granules and other subcellular components compare somewhat to mammals but further studies of this locally abundant animal are required.*[*]

The toad *Bufo marinus* is commonly known as the "giant marine toad" or as the "poisonous toad" because of the venom-secreting glands at the sides of the head. Although it is abundant in southern Florida, little research has been performed with this animal. The present study suggests that this local toad is a potentially useful animal for hematological investigation.

A search of the literature disclosed only one hematological study of *Bufo marinus*. This was the work of Alabamian investigators Kent, Evans and Attleberger (1964) and dealt with the lymphoid part of the blood system. They demonstrated the presence of a lymphoid network in the upper thorax, neck and axilla. Furthermore, they reported that cells of this system were capable both of phagocytizing India ink and producing antibodies. Previous to their findings, lymph nodes were considered to be restricted to mammals and certain birds. They concluded that the anatomical and functional characteristics of the lymphatic tissue of *Bufo marinus* were comparable to lymph nodes of mammals.

I was unable to find any reports concerning the granulocytes of the blood of *Bufo marinus*. However, a related species, *Bufo bufo*, has received a greater

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

amount of hematological attention. The German investigator Fey demonstrated cytochemically the presence of peroxidase, alkaline phosphatase, esterase and PAS reactions in blood cells of this species. His findings led him to conclude that the granulocytes (1967a) and the monocytes, plasmacytes and lymphocytes (1967b) of *Bufo bufo* are homologous to the corresponding cell forms of mammals. A group of Russian investigators studied the peripheral blood of *Bufo bufo* with the electron microscope (Khamidov et al., 1971). They noted the presence of such granulocytes as neutrophils, eosinophils and basophils; and such agranulocytes as lymphocytes, monocytes and plasma cells. I have made an ultrastructural study of the granulocytes in the blood sinusoids of the adrenal gland of *Bufo marinus*.

Methods—Observations were made from adrenal glands of 11 *Bufo marinus* females. The adrenal gland served a dual purpose in that another ultrastructural study is being made of the secretory cells of the gland. Females were used because they are larger than the males. Most specimens weighed over 400 gm. Each animal was sacrificed by pithing at approximately the same time in the morning. The adrenals were removed and, with the aid of a dissecting microscope, cut into blocks measuring 1 mm cubed. During the cutting, the tissue was kept immersed in the fixative, buffered 4% glutaraldehyde. After cutting, the tissue was kept in fixative to make 2 hr fixation. Fixation was carried out at room temperature. Tissue specimens were post-fixed with 1% osmic acid, dehydrated and embedded in Epon 812 or araldite. Thick and thin sections were cut with a Porter Blum Ultramicrotome MTII. Thick sections were stained with Richardson's stain. If thick sections showed sinusoids with satisfactory blood cells, thin sections were cut and stained with uranyl acetate and lead citrate. Electron micrographs were taken with an AEI 6B or a Philips 300.

Observations—Three kinds of granulocytes were observed in the sinusoids of the adrenal gland; neutrophils, basophils and eosinophils. The neutrophil with its small granules was easily identifiable (Fig. 1). This particular cell was approximately 10μm long making it comparable in size to human neutrophils. Two types of granules could be distinguished. Both appeared round, oval or elongate. The larger, azurophilic granule was more electron dense than the smaller, specific granule. Granules ranged from 130 to 420 nanometers (nm) long. These dimensions are less than those encountered in neutrophils of some higher forms (Bainton and Farquhar, 1968). However, as in human blood, the nucleus of *Bufo marinus* is multilobular and most of the densely stained heterochromatin of the nucleus is distributed against the nuclear envelope. A nucleolus is not apparent. Beneath the larger lobe of the nucleus may be seen an elongate mitochondrion. The cytoplasm also contains a few profiles of rough endoplasmic reticulum. The finer particles in the cytoplasm are mostly free ribosomes. Numerous small vacuoles are also dispersed throughout the cytoplasm. If the cell were actively engaged in phagocytosis, such vacuoles would be larger and contain ingested particles. Occasionally a poorly developed Golgi complex was observed. Morphologically, neutrophils of *Bufo marinus* are similar to those of higher forms.

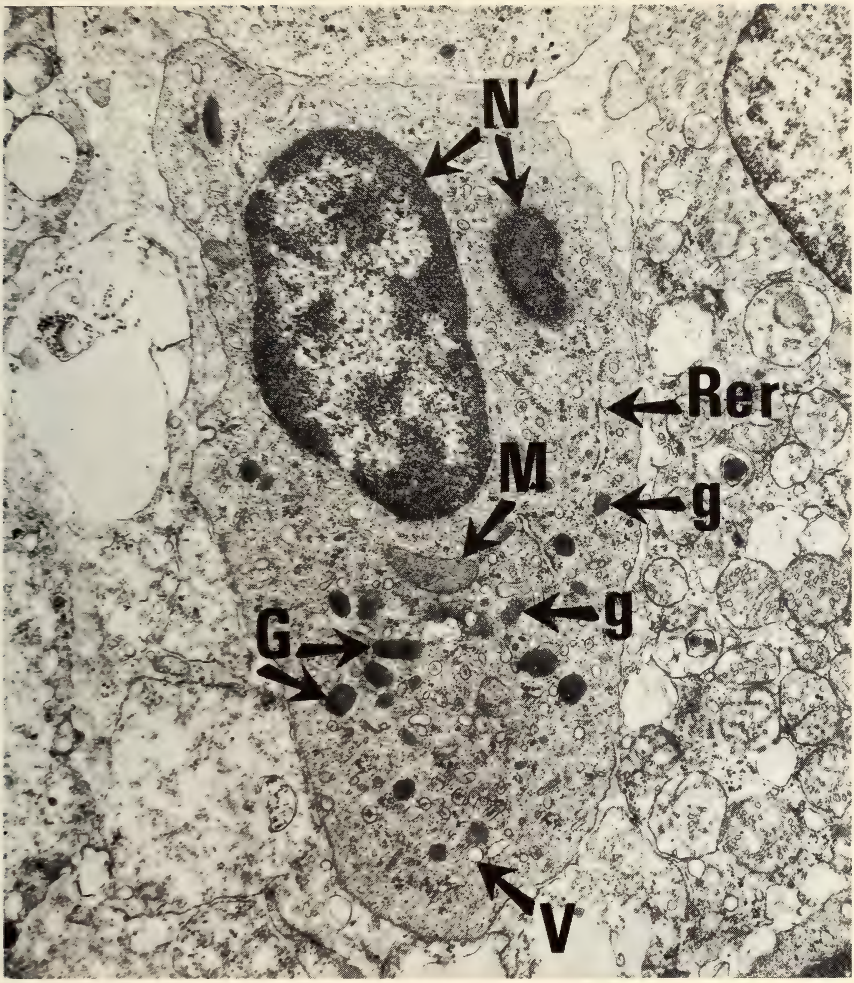


FIG. 1. Neutrophil. G. Azurophilic (primary) granule. g. Specific (secondary) granule. M. Mitochondrion. N. Nucleus. Rer. Rough endoplasmic reticulum. V. Vacuole. ×11,500.

While basophils are not numerous in human blood, they appeared to be relatively numerous in adrenal sinusoids of *Bufo marinus*. In Fig. 2 this granulocyte may be seen with its prominent, spherical granules. These granules avg about 550 nm wide, with the largest measuring about 800 nm. Human granules range from 200 to 1,200 nm (Zucker-Franklin, 1967). The granules appear to be uniformly stained. Occasional lighter areas are to be noted within the granule. When contrasting light and dark areas occur, they do not have any distinct pattern or arrangement. Mitochondria may be seen interspersed with the granules. A few short profiles of rough endoplasmic reticulum are present. Fine particles of ribosomes are dispersed throughout the cytoplasm. A Golgi complex was often not apparent. A limited number of vacuoles are present. The presence of such vacuoles suggests that the cell is capable of phagocytosis. The nucleus of this amphibian cell is not indented but is most frequently oval. In human blood, the nucleus is most often irregularly shaped, giving it a lobed appearance. The cell in Fig. 2 is approximately 8μm long. Human basophils vary from 8 to 10μm (Rhodin, 1974).

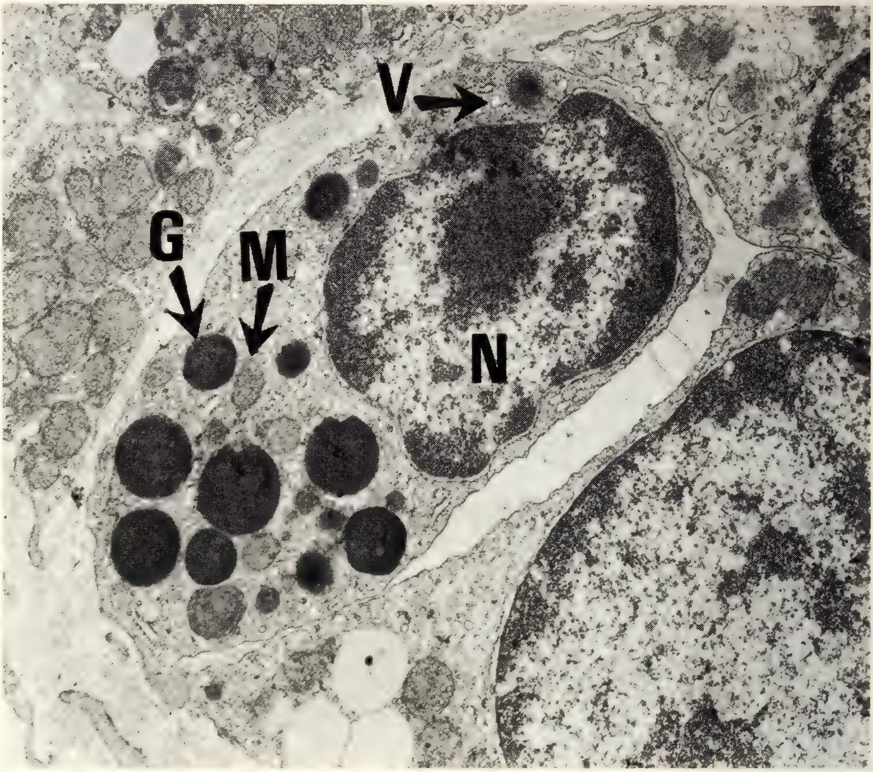


FIG. 2. Basophil. G. Granule with unit membrane. M. Mitochondrion. N. Nucleus. Rer. Rough endoplasmic reticulum. V. Vacuole. $\times$12,000.

In Fig. 3 may be seen a granulocyte which is probably an eosinophil. The cytoplasm contains spherical granules. A bounding unit membrane may be seen in some of the granules. The largest granule has a diameter of about 625 nm; the smallest, 400 nm. This is within the range of human granules which measure from 500 to 1500 nm long and 300 to 1000 nm wide (Zucker-Franklin, 1968). The granules of the blood cell in Fig. 3 contain a single, more deeply stained internal structure which is usually spherical and which varies in size. Such internal structures have been called an assortment of names, such as crystalloid, crystalline core, central core and internum. Eosinophil granules have crystalloids which vary in size and shape from species to species. A Golgi complex is not evident in the cell in Fig. 3. Mitochondria are present and like human blood, are more numerous than in the neutrophil. A few small profiles of endoplasmic reticulum may be seen. Ribosomes are scattered throughout the cytoplasm. A few small vacuoles may also be seen.

DISCUSSION—Although a vast amount of information regarding the functions of the various cells of the blood has accumulated, much still is not known or is controversial. A few areas in which further studies with *Bufo marinus* blood might be of value in seeking new knowledge are presented.

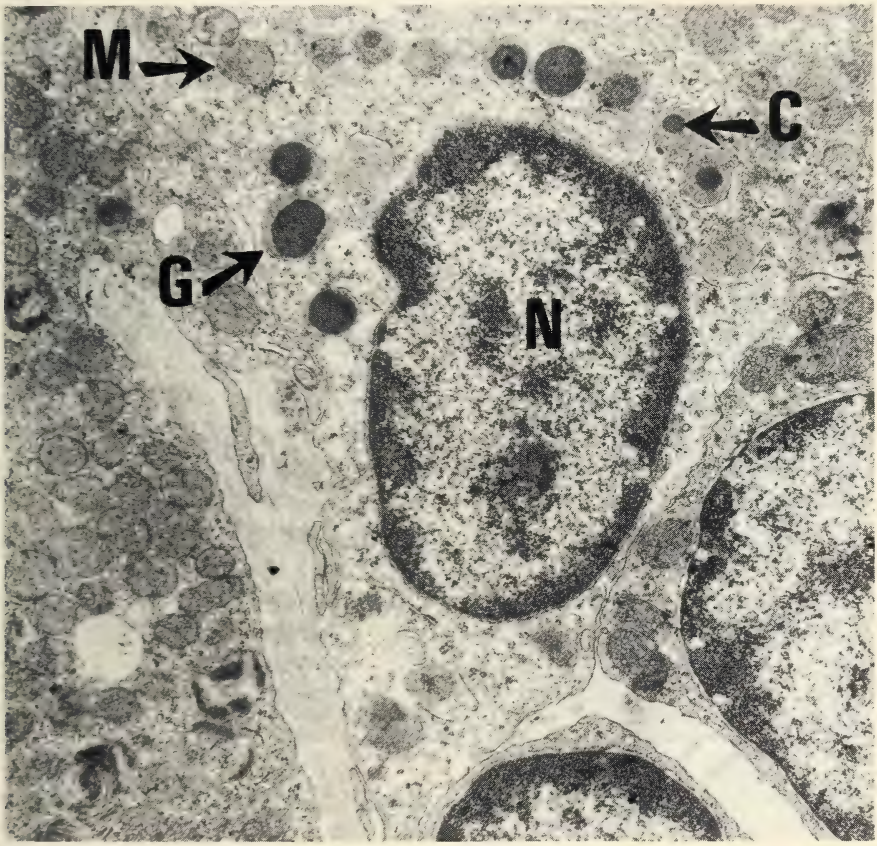


FIG. 3. Eosinophil. C. Crystalloid of granule. G. Membrane bound granule. M. Mitochondrion. N. Nucleus. ×14,000.

In this investigation, neutrophils were observed which morphologically resemble neutrophils of higher forms. This blood cell was about the same size, had a similar nucleus and contained similar subcellular structures in the cytoplasm, including small granules of various shapes and sizes. Controversy exists regarding the number of granule types that are present in these cells. Some believe there are two types of granules in the cytoplasm (Bainton and Farquhar, 1966 and 1968; Bainton et al., 1971); others believe there are three types (Wetzel et al., 1967; Spicer and Hardin, 1969; Scott and Horn, 1970). The two granules noted in the present study appear to be similar to the two types observed by Bainton and co-workers. The larger more deeply stained granule is probably similar to what they call an azurophilic granule while the smaller and less electron dense granule is probably similar to their specific granule. Those who support the three granule theory, refer to the granules as being primary, secondary and tertiary granules. Bainton and co-workers state that the third type noted by these latter investigators, may represent a "subpopulation" of one or of both of the two main types. Further studies of neutrophils of *Bufo marinus* may help to clarify this and other controversies that exist regarding this cell.

In circulating human blood, the basophil is the rarest blood cell since it constitutes only about 0.5% of all the leukocytes. In some mammals, for example, cat, rat and mouse, the cell is normally absent (Bloom and Fawcett, 1975). In the adrenal sinusoids of *Bufo marinus,* this cell was not rare; this possible abundance of basophils, should make this animal an excellent choice for the study of this granulocyte.

After leaving human bone marrow, basophils circulate 12-15 days and their "ultimate fate is not known" (Rhodin, 1974). For many years, it has been speculated whether the basophil leaves the peripheral circulation and becomes a tissue mast cell. When viewed with the light microscope, some morphological differences may be noted between the two cells. In the mast cell, the cytoplasm is filled more completely with granules than it is in the basophil. Also in comparison, the granules of the mast cell are smaller and are more uniform in size than in the basophil. In mast cells, the Golgi complex is well developed and mitochondria are relatively few. As was noted in Fig. 2, in the typical basophil a Golgi complex was not observed while mitochondria were well represented.

Furthermore, some chemical differences may exist between the two cells. Archer noted that basophils lack some chemicals (hydrolytic enzymes and 5 hydroxytryptamine) that are found in mast cells of some species (personal communication cited by Terry et al., 1969). However, there are some biochemical similarities between the two cells. Mast cells and basophils are similar in that the granules of both cells stain metachromatically. Also, both cells are known to contain heparin and histamine and both contain the immunoglobin IgE on their cell surfaces (Ishizaka and Ishizaka, 1975).

To date, electron microscopic studies have not provided any strong evidence in support of the theory that basophils may become tissue mast cells. A variety of morphological observations have been made of both basophils and of mast cells. Zucker-Franklin (1967) observed two kinds of human basophils. One type had granules that were usually filled with particles of fairly uniform size thereby conferring a homogeneous texture to the granule. A second type of granule contained concentric membranes which resembled myelin figures. While Watanabe, Donahue and Heggatt (1967) also observed these two types of human basophil granules, they noted additional granules that contained a single central oval crystalline inclusion or had crystalline inclusions that were arranged in strands. Some interesting differences have been noted in other species. Most striking was the honeycomb or hexagonal array of bands observed by a number of investigators in the basophil granules of guinea pigs (Federke and Hirsch, 1965; Terry et al., 1969).

Morphological observations of mast cells have presented a similar amount of variability. In 1956, Stoeckenius noted that human mast cells had granules which contained lamellar structures. In 1960, Hibbs and coworkers noted two kinds of mast cells, one with granules having a homogeneous texture and another type with granules containing a lamellar component mostly in the form of 'scrolls'. In 1965, Federke and Hirsch noted parallel bands, reticular formations and scroll-like structures within the granules of human mast cells.

Some of the morphological variability observed in human basophils and mast cells in the above studies, may be of a pathological nature. The myelin figures, lamellae, scrolls and other configurations may represent toxic effects. Basophils of *Bufo marinus* did not have such a variety of subcellular structures within the granules. Possibly, the human basophil having uniform particles within the granules represented the normal appearance of these cells. In the present investigation, there was little variety in the morphology of the basophil granule; and due to this homogeneity, the basophils of *Bufo marinus* may be excellent material for further studies of these cells.

The crystalloid noted in eosinophils of *Bufo marinus* in the present investigation, does not resemble crystalloids that have been studied in other species. Of all subcellular structures of blood cells, the crystalloids of eosinophils show the greatest variation between species. In *Bufo marinus* blood, the eosinophil granule has a single, spherical crystalloid which varies in size. In human eosinophils, the crystalloid appears in a great assortment of shapes. It can be bar-shaped, rectangular, square, multangular and a host of other configurations (Miller, et al., 1966). Also within a granule, there may be one or more crystalloids. The morphology of the crystalloid varies in rodents. In rabbit blood, the eosinophil granule contains numerous long, narrow, filamentous crystalloids (Wetzel et al., 1967). In rat eosinophil granules, the crystalloid material appears as a square lattice or as a series of parallel bands (Miller et al., 1966). In the guinea pig granule, the crystalloid is a bar-shaped structure. In the dog, the crystalloid has been described as being rod-shaped (Hudson, 1970). Considerable variation was noted in a study of eosinophils of domestic birds (Maxwell and Siller, 1972). Crystalloids could be present or absent. When present (duck and goose), the cores formed either a linear or a lattice-type structure.

Although the eosinophil granule of *Bufo marinus* does not resemble the granule of higher forms morphologically, the amphibian cell may have some similar functions. Further research would be necessary to establish this. The roles of this cell in human blood appear to be widespread. Many clinical conditions are associated with an increase in the number of eosinophils both in the tissues and in the peripheral circulation (Kay, 1976). Eosinophils increase in bronchial asthma, allergic rhinitis, certain parasitic infections and in disorders which involve antigen-antibody complexes. The last group includes such diseases as polyarteritis nodosa, pulmonary aspergillosis and rheumatoid arthritis. The functional role of eosinophil in these numerous conditions is still not entirely clear. Much research remains to be done. In the present report, a limited aspect of the morphology of *Bufo marinus* is presented, namely the granulocytes of peripheral blood. It is hoped that the presentation of these hematological findings will lead to a greater variety of studies using this animal.

ACKNOWLEDGMENTS—I thank Dr. Ronald G. Clark, Dr. Wilfred M. Copenhaver and Dr. David S. Smith for reading and making suggestions for improving the manuscript. I am also greatly indebted to Dr. David S. Smith for the use of his facilities. Thanks are extended to Ms. Ulla Jarlfors for her instruction and assistance. This study was supported by National Institute of Health Biomedical Research Support Grant H9693R.

LITERATURE CITED

ATWAL, O. S. 1976. Ultrastructural features of eosinophil leucocytes of the goat. J. Comp. Path. 86:183-190.

BAINTON, D. F., AND M. G. FARQUHAR. 1966. Origin of granules in polymorphonuclear leukocytes. Two types derived from opposite faces of the Golgi complex in developing granulocytes. J. Cell Biology 28:277-301.

———, AND ———. 1968. Differences in enzyme content of azurophil and specific granules of polymorphonuclear leukocytes. II. Cytochemistry and electron microscopy of bone marrow cells. J. Cell Biology 39:299-317.

BAINTON, D. F., J. L. ULLYOT AND M. G. FARQUHAR. 1971. The development of neutrophilic polymorphonuclear leukocytes in human bone marrow. J. Exp. Med. 134:907-934.

BLOOM, W., AND D. W. FAWCETT. 1975. A Textbook of Histology. W. B. Saunders Co. Philadelphia.

FEDORKO, M. E., AND J. G. HIRSCH. 1965. Crystalloid structure of guinea pig basophils and human mast cells. J. Cell Biol. 26:973-976.

FEY, F. 1967a. Vergleichende Hämozytologie nieder Vertebraten. III Granulozyten. Folia Haematol. 86:1-20.

———. 1967b. Vergleichende Hämozytologie nieder Vertebraten. IV. Monozyten, Plasmozyten & Lymphozyten. Folia Haematol. 86:133-147.

HIBBS, R., G. E. BURCH AND J. H. PHILLIPS. 1960. Electron microscopic observations on the human mast cell. Amer. Heart J. 60:121-127.

HUDSON, G. 1970. Ultrastructure of eosinophil leukocyte granules in the dog. Acta Anat. 77:62-66.

ISHIZAKA, T., AND K. ISHIZAKA. 1975. Cell surface IgE on human basophil granulocytes. Ann. N.Y. Acad. Sci. 254:462-475.

KAY, A. B. 1976. Functions of the eosinophil leucocyte. Brit. J. Hematol. 33:313-318.

KENT, S. B., E. E. EVANS AND M. H. ATTLEBERGER. 1964. Comparative immunology lymph nodes in the amphibia *Bufo marinus*. Proc. Soc. Exp. Biol. & Med. 116:456-459.

KHAMIDOV, D. K., A. A. TURDYEV, K. N. NISHANBAEV, A. T. AKILOV AND M. A. NISHANBAEVA. 1971. Submicroscopic characteristics of peripheral blood elements. Arkh. Anat. Gistol. Embriol. 60:47-52.

MAXWELL, M. H., AND W. G. SILLER. 1972. The ultrastructural characteristics of the eosinophil granules in six species of domestic bird. J. Anat. 112:289-303.

MILLER, F., E. DE HARVEN AND G. E. PALADE. 1966. The structure of eosinophil leukocyte granules in rodents and man. J. Cell Biol. 31:349-362.

RHODIN, J. A. G. 1974. Histology. A Text and Atlas. Oxford Univ. Press. New York.

SCOTT, R. E., AND R. G. HORN. 1970. Ultrastructural aspects of neutrophil granulocyte development in humans. Lab Invest. 23:202-215.

SPICER, S. S., AND J. H. HARDIN. 1969. Ultrastructure, cytochemistry and function of neutrophil leukocyte granule. Lab. Invest. 20:488-497.

STOECKENIUS, W. 1956. Zur Feinstruktur der Granule menschlicher Gewebsmastzellen. Exp. Cell Res. 11:656-658.

TERRY, R. W., D. F. BAINTON AND M. G. FARQUHAR. 1969. Formation and structure of specific granules in basophilic leukocytes of the guinea pig. Lab. Invest. 21:65-76.

WATANABE, I., S. DONAHUE AND X. HOGGATT. 1967. Method for electron microscopic studies of circulating human leukocytes and observations on their fine structure. J. Ultrastruct. Res. 20:366-382.

WETZEL, B. K., R. G. HORN AND S. S. SPICER. 1967. Fine structural studies on the development of heterophil, eosinophil and basophil granulocytes in rabbits. Lab. Invest. 16:349-382.

ZUCKER-FRANKLIN, D. 1968. Electron microscopic studies of human granulocytes: structural variations related to function. Seminars in Hemat. 5:109-133.

———. 1967. Electron microscopic study of human basophils. Blood 29:878-890.

Florida Sci. 41(1):45-52. 1978.

BEHAVIOUR OF SOME CORAL REEF FISHES IN A TIDAL ENVIRONMENT—*Judith S. Weis* (1) AND *Peddrick Weis* (2),Department of Zoology and Physiology, Rutgers, the State University, Newark, New Jersey 07102, and (2) Department of Anatomy, New Jersey Medical School, Newark, New Jersey 07103

ABSTRACT: *A community of coral reef fishes in the Boca Raton Inlet was found to be stable despite changes in temperature, salinity and turbidity due to tidal flux. Exceptions were the parrotfishes* (Sparisoma *spp.) which migrated in with the ocean water and left when the tide ebbed, and the surgeon fishes (*Acanthurus bahianus) *which became inactive and hid during the outflow of intracoastal water. An intertidal wall was found to house many dusky damselfish (*Eupomacentrus fuscus) *which defended their temporary territories with vigor.**

CORAL REEF fish communities have been shown to be rich in species and stable (Smith and Tyler, 1975). The environment of such a reef is typically warm and clear water. Within a reef community fish have diurnal activity patterns with certain species being active during the daylight hours and other species active at night. Some species undergo predictable diurnal migrations from shelter sites to feeding areas (Hobson, 1973; Collette and Talbot, 1972).

The Boca Raton Inlet connects the Intracoastal Waterway to the Atlantic Ocean in a southeastern direction. Along the north side of the inlet is a sea wall, built in 1926 of cast iron and rock. This wall, along with the many rocks at its base, forms an environment in which many typical coral reef fishes are found. This community, however, is subject to strong tidal flux of 6-8 knots, and when the tide is outgoing, the quality of the water appears strikingly changed. The outflow from the Intracoastal Waterway is highly turbid, brownish in color, and lower in salinity than the clear, blue-green ocean water that flows into the inlet. This provides an opportunity to study the behavior of coral reef fishes when alternately exposed to water of this quality and to normal clear ocean water.

MATERIALS AND METHODS—At one point the sea wall undergoes a right-angle bend toward the shore, providing an area for beaching boats. At this location, the top of the wall is dry (about 0.1 m above the water level) at low tide, and covered with about 1 m of water at high tide. In the inlet itself at the base of the wall there is less than 2 m of water at low tide, and about 3 m at high tide. Observations were generally made by snorkeling or SCUBA diving in the water. We confined our observations to an area of about 12m^2 of rocks extending out from the base of the wall at this corner (Fig. 1, A), an area equivalent to some patch reefs. This site is about 300 m from the ocean. The inner intertidal wall (B) was also observed. Observations were made during all phases of the tidal cycle, and at various times between 900 and 1800 hr. Observations were made on 18 separate occasions, for 1-2 hr each time, from late April to early June. Certain physical characteristics of incoming and outgoing water were also measured.

RESULTS—The most abundant residents of the study area were the French grunt, *Haemulon flavolineatum*, the Sargeant major, *Abudefduf saxatilis*, and

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

the dusky damselfish, *Eupomacentrus fuscus.* These species were always seen in large numbers at all phases of the tidal cycle. The dusky damselfish were aggressively territorial, and chased away any invaders of their territories. Other species seen regularly were the cocoa damselfish, *E. variabilis*; the bicolor damselfish,

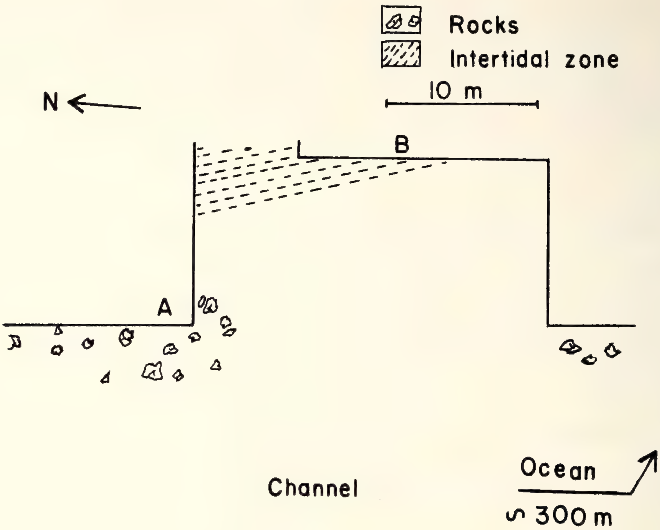


FIG. 1. The study site in the Boca Raton inlet on the east Florida coast at 26° N latitude. A is the outer sea wall; B is the intertidal wall.

E. partitus; the bluestripe grunt, *H. sciurus*; the porgy, *Diplodus holbrooki*; the mojarra, *Gerres cinereus*; the wrasses *Thalassoma bifasciatum, Halichoeres bivattatus, H. radiatus* and *H. poeyi*; the parrotfishes *Sparisoma rubripinne, S. chrysopterum* and *S. viride*; and the surgeonfish, *Acanthurus bahianus.* Juvenile grunts, parrotfishes and Sargeant majors were especially abundant. Large schools of mullet and silversides were present at all times near the surface of the water.

During the first week of observations, a juvenile French angelfish, *Pomacanthus paru,* had a cleaning station at a particular rock, and was often observed cleaning *S. rubripinne* and *H. flavolineatum.* Cleaning activity was observed only during incoming and high tides. After the first week of study the cleaner was no longer there. Since we frequently observed collectors in the area, we suspect that it fell victim to a slurp gun. Two weeks later, however, a young gray angelfish, *P. arcuatus,* had set up a new cleaning station at a nearby rock.

Although most of the resident species of fishes remained during all phases of the tidal cycle, a population of yellowtail parrotfish (*S. rubripinne)* was consistently present during incoming and high tides, but was generally absent during outgoing and low tides. On several occasions the fish were observed to arrive with the incoming ocean water, about an hr after low tide. They seemed to "ride in" with a surge of ocean water and then to settle out and feed at our study site. Other parrotfishes continued past our site, presumably heading for locations further upstream. During the hr or so between low tide and the arrival of the parrotfish the water had cleared up considerably, ocean water appearing first at the bottom and later at the surface. At low tide, a Secchi disc was visible only to 1.5 m, whereas the incoming ocean water had a visibility greater than 7 m. When the water began to ebb after high tide, the parrotfish generally left the area after about 1 hr, heading toward the ocean. After the Intracoastal water swept through, surgeon fish were no longer seen foraging but were found in crevices or under rocks.

The intertidal wall (Fig. 1, B) was found to be temporary home to 12-14 dusky damselfish (*E. fuscus*), each occupying and defending a crevice in the rock wall. Their territories were necessarily dependent on the height of the water, and had to be abandoned when the tide receded.

During this study, the temperature fluctuated from 24° C (ocean water) to 27° C (Intracoastal water) in early May, and 26° C to 28° C in late May. The salinity change in early May was from 38.1‰ incoming to 36.0‰ outgoing. At the end of May, however, after a considerable amount of rain, the salinity of the incoming water was 37.3‰ and that of outgoing water was reduced to 29.8‰, a result of inland floodgates having been opened.

When samples of water were filtered through a 0.45μm millipore filter, incoming water contained $3.3 - 0.5$ mg/l suspended material, whereas outgoing water contained 4.8 ± 0.17 mg/l showing a significant difference in weight of suspended material. Furthermore, suspended matter in outgoing water was mainly detritus, while that of incoming water was planktonic.

DISCUSSION—The most conspicuous changes in a coral reef environment are the day/night changes, and reef fish have been shown to have activity patterns corresponding to the diurnal cycle. Many species, including parrotfishes have predictable migrations associated with the day/night cycle (Randall and Randall, 1963; Collette and Talbot, 1972; Hobson, 1973). A reef is not generally subjected to turbidity in a cyclic fashion, but is so subjected occasionally due to storms, after which the increased turbidity of the water is associated with a delay in the morning appearance of most diurnally active species (Collette and Talbot, 1972).

Of the species observed at our study site only the parrotfish left the area. We cannot be sure where they go, but there are sabellariid worm reefs offshore and we suspect that they have alternative home sites on these reefs. Other migrations of *S. rubripinne* have been reported for spawning purposes (Randall and Randall, 1963). In general, however, *Sparisoma* tend to be relatively sedentary, to stay near the bottom and feed steadily, whereas species of *Scarus* tend to rove over larger areas in groups (Barlow, 1975). Yellowtail parrotfish are often associated with shallower water than other parrotfishes (Randall, 1968).

Pomacentrids have been described as highly territorial (Bardach, 1959; Smith and Tyler, 1972, 1975). In our study site, *E. fuscus* was the most abundant and aggressive defender of territory, and those individuals on the outer wall remained so throughout the tidal cycle. It was surprising, therefore, to find other members of this species defending territories by the intertidal wall, areas which must be abandoned as the tide recedes. This may be a reflection of an insufficient number of permanently subtidal territories to support the population of damselfish. These individuals may have been unsuccessful in securing a preferred territory, and have therefore had to resort to these suboptimal intertidal areas.

The community was found to be quite stable over the period of study, despite tidal fluxes, salinity changes, and pressure from collectors. Stability is a feature of coral reef fish communities (Smith and Tyler, 1975) as well as other intertidal fish communities which have been studied on a long-term basis (Thompson and Lehner, 1976).

ACKNOWLEDGMENTS—We express appreciation to the Department of Biological Sciences of Florida Atlantic University, especially the following people who were most helpful and hospitable during our stay: Drs. S. Dobkin, W. Courtenay, B. Ache, D. Austin, and G. A. Marsh. We also thank Dr. C. L. Smith for reviewing the manuscript.

LITERATURE CITED

BARDACH, J. E. 1958. On the movements of certain Bermuda reef fishes. Ecology 39:139-146.

__________. 1959. The summer standing crop of fish of a shallow Bermuda reef. Limnol. Oceanogr. 4:77-85.

BARLOW, G. W. 1975. On the sociobiology of four Puerto Rican parrotfishes (Scaridae). Mar. Biol. 33:281-294.

COLLETTE, B. B., AND F. H. TALBOT. 1972. Activity patterns of coral reef fishes with emphasis on nocturnal-diurnal changes. In B. B. Collette and S. Earle (eds.) Results of the Tektite Program: Ecology of Coral Reef Fishes. Natl. Hist. Mus. Los Angeles County Sci. Bull. 14:98-124.

HOBSON, E. S. 1973. Diel feeding migrations of tropical reef fishes. Helgolander Wiss. Meeresunters. 24:361-370.

RANDALL, J. E. 1968. Caribbean Reef Fishes. TFH Publ. Neptune City, N.J.

__________, AND H. A. RANDALL. 1963. The spawning and early development of the Atlantic parrotfish *Sparisoma rubripinne*, with notes on other scarid and labrid fishes. Zoologica 48:49-60.

SMITH, C. L., AND J. C. TYLER. 1972. Space resource sharing in a coral reef fish community. In B. B. Collette and S. Earle (eds.) Results of the Tektite Program: Ecology of Coral Reef Fishes. Natl. Hist. Mus. Los Angeles County Sci. Bull. 14:125-178.

__________, AND __________. 1973a. Direct observations of resource sharing in coral reef fish. Helgolander Wiss. Meeresunters. 24:264-275.

__________, AND __________. 1973b. Population ecology of a Bahamian suprabenthic shore fish assemblage. Amer. Mus. Novitates 2528:1-38.

__________, AND __________. 1975. Succession and stability in fish communities of dome-shaped patch reefs in the West Indies. Amer. Mus. Novitates 2572:1-18.

STEVENSON, R. A. 1972. Regulation of feeding behavior of the bicolor damselfish (*E. partitus* Poey) by environmental factors. Pp. 278-302. In H. Winn and B. Olla (eds.) Behavior of Marine Animals. Vol. 2: Vertebrates. Plenum Press. New York.

THOMPSON, D., AND C. LEHNER. 1976. Resilience of a rocky intertidal fish community in a physically unstable environment. J. Exper. Mar. Biol. Ecol. 22:1-29.

Florida Sci. 41(1):53-56. 1978.

A SECOND OCCURRENCE OF THE BRAZILIAN FRESHWATER SHRIMP, *POTIMIRIM POTIMIRIM*, ALONG THE CENTRAL EASTERN FLORIDA COAST[1]—*Robert H. Gore* (1), *George R. Kulczycki* (2) *and Philip A. Hastings* (2), Smithsonian Institution, Ft. Pierce Bureau, Ft. Pierce, Florida 33450 (1); Harbor Branch Foundation, Inc., Link Port, Ft. Pierce, Florida 33450 (2)

ABSTRACT: *Ovigerous females with viable eggs which hatched occurred in South Relief Canal, Indian River County, but the population may have been eliminated by the January 1977 cold period.*

THE atyid freshwater shrimp *Potimirim potimirim* is primarily a South American species known from Rio Itajai, Itajai, Estado do Santa Catarina, and Rio Gurjau, Recife, Estado do Pernambuco, Brazil (Villalobos, 1960). Abele (1972) first reported the apparent continental introduction of the species into eastern Florida in drainage canals of the Loxahatchee River system in Palm Beach County. We report here a second occurrence of *P. potimirim*, now from the central eastern Florida coast, in a freshwater drainage canal in Indian River County.

Rostral carapace length (RCL) was measured from the tip of the rostrum to the posterior median margin of the carapace; total length (TL) extended from the rostral tip to the posterior median margin of the telson.

MATERIAL EXAMINED—1 male, RCL 4.3, TL 12.9 mm; 6 females, ovigerous, RCL 8.2-10.5, TL 23.0-28.6 mm; Florida, Indian River County, Vero Beach, South Relief Canal, S. R. 605 (Old Dixie Highway), clinging to aquatic vegetation along banks; 10 ft seine net; 18.5° C, 0 ‰; 7 January 1977; G. R. Kulczycki and P. A. Hastings, collectors.

REMARKS—We noted three different color patterns in our living specimens:

Pattern 1): Carapace and abdomen overall, van-dyke brown, former speckled with numerous, red, "snowflake" chromatophores, those on latter white to pale green; dorsally a longitudinal, median, irregular, clear stripe from rostrum to anterior third of telson, stripe outlined with pale green chromatophores, otherwise speckled with gold, copper, or red; carapace laterally with irregular, whitish to translucent longitudinal streaks. Rostral spine, antennular segments and flagella, clear, former two with distinct, copper-colored chromatophores. Scaphocerite clear translucent blue, with red chromatophores; antennal flagella clear to reddish brown. Eyestalks translucent, outlined in dark brown, with red and gold chromatophores interspersed. Posterior two-thirds of telson and distal half of uropods dark bluish-brown; outer margin of exopod, and posterior margin of exopod and endopod clear, speckled with red and pale green; setae on same pale golden yellow. Walking legs translucent with numerous red chromatophores, later becoming brownish on pereiopod 5. This pattern is similar to that illustrated by Abele (1972), although differing slightly in color; it was seen in quiescent ovigerous females isolated in specimen bowls.

[1]Studies on Decapod Crustacea from the Indian River Region of Florida. VIII.

[2]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

Pattern 2): Carapace and abdomen overall cerulean blue; translucent lateral maculations and median dorsal stripe present, with chromatophores as in brown phase above; stripe more noticeable due to light blue coloration, appearing in refracted light under the dissecting microscope as if dusted with myriad tiny scintillating motes of copper, gold and pale green. This pattern, also noted by Abele (1972), was exhibited by agitated ovigerous females upon capture, and during laboratory observation and handling; it undoubtedly is a "fright pattern".

Pattern 3): Pattern similar to above, but overall hue pale yellow-brown, with many more pale green to yellow–green spider-like chromatophores. This pattern was exhibited by the male, and one ovigerous female which subsequently died.

Our specimens agreed well with the description provided by Villalobos (1960) but we noted some variation in characters used in the diagnosis by that author. For example, the diametrical index (i) of the *appendix masculina* (Fig. 1) in our male specimen was 50.77; Villalobos gave 50.46 in his species diagnosis for *Potimirim potimirim*, so our specimen agrees well in that respect. However, we did not see, nor apparently did Abele (1972, fig. 3, D) in his specimens, the long seta next to the *appendix interna* on this appendage. We also noted in our same male specimen that the carpus of pereiopod 4 lacked a distal spine, and the merus of pereiopod 5 had three distal spines (instead of the diagnostic 2); both of these spinal features are diagnostically indicative of *Potimirim mexicana* (Saussure, 1857 *fide* Villalobos, 1960). All ovigerous females had the distal carpal spine on pereiopod 4, but 2 specimens had 3 (instead of 2) distal meral spines on pereiopod 5, again showing similarity to *P. mexicana* (Fig. 1). The latter species differs in several meristical features from *P. potimirim*, including the *appendix masculina* (i = 58.75), although both species are otherwise morphologically quite similar.

Discussion.—The South Relief Canal, the Indian River County collection site for our specimens of *Potimirim potimirim*, is approximately 100 km (60 miles) north of Abele's (1972) collection site. This small, freshwater canal is about 20 m wide and usually is less than 0.5 m deep. The channel is artificial, possesses floodgates at several points along its 8 km (5 mile) length, and drains farmland and citrus groves in the western interior of Indian River County directly into the estuarine waters of the Indian River lagoon. While in no sense pristine, the waters of the canal are not heavily polluted. Freshwaters from the St. Johns River Valley marshland, citrus and agricultural artesian well water from the deep Floridan Aquifer, and suburban and agricultural shallow wellfield water from the Pleistocene Aquifer (primarily rainfall—renewed), make up the majority of the effluent. Rainwater runoff and isolated point-source sewage form the minor component. Seasonally heavy rainfall raises inland water levels and the canal floodgates are opened aperiodically to afford relief. Water flow and current are dependent on whether the canal is actively (floodgates open) or passively (gates closed) draining.

Like many other drainage canals in the Indian River area, South Relief Canal is heavily vegetated along either bank, and large populations of the palaemonid

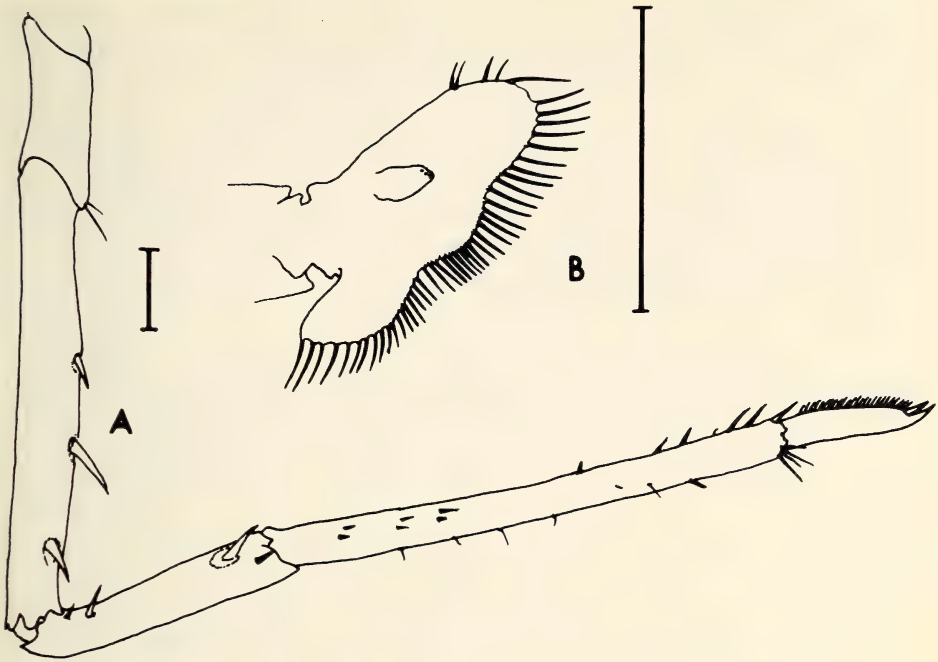


FIG. 1. *Potimirim potimirim* (Müller, 1881). A. Left pereiopod 4, male. B. Right appendix masculina, medial view. Scale lines equal 1.0 mm.

shrimp *Macrobrachium acanthurus* (Wiegmann) and *M. carcinus* (L.) find refuge here along with *P. potimirim*. The bordering vegetation overhangs the water, often becomes densely foliated, and consequently is removed either by mechanical dragline, the application of phytotoxins, or a combination of both. The population of *Potimirim potimirim* in the South Relief Canal is thus subjected to both pesticide (citrus and agricultural) and herbicide (canal vegetational maintenance) stress.

Based on ovigerous females in his collections from Palm Beach County, Abele (1972) suggested that *Potimirim potimirim* may have established a Floridan population; he thought its presence "highly probable" in other canals, both manmade and natural, of the interconnected Florida drainage system. Our findings show Abele may be right in his supposition. The Indian River locality approximately 100 km (60 miles) north of Abele's collection site, is interconnected with other canals along the central eastern Florida coast, and undoubtedly with the Florida Flood Control system. The latter, in turn, receives inflow from the numerous naturally-occurring lakes, rivers and streams in the area. It is thus entirely possible that the Indian River County population of *Potimirim* is simply an element of that noted by Abele (1972) from farther south in Palm Beach County.

On the other hand, at least eight tropical fish farms are operative in Indian River County, and several are known to culture species of Brazilian fishes. The possibility cannot be ruled out, therefore, that the Indian River population of *Potimirim* came from stowaway specimens either in tropical fish or limnetic plant shipments brought in from South America (but see below).

A third possibility is that the species arrived in Florida by rafting. Villalobos (1960) noted that *Potimirim potimirim* has been encountered out at sea, presumably carried there in the masses of fluviatile vegetation swept loose by river currents. If such rafts are not destroyed by wave action the species could conceivably be carried long distances. This supposes, of course, that osmoregulatory mechanisms in this primarily freshwater shrimp are capable of adjusting to marine salinities. Villalobos noted that the closely related *Potimirim mexicana* has been collected in localities with a salinity as high as 29.45‰.

Larvae were obtained from three females and reared at 0, 10, 16, 23‰, and 2 through 20‰. *Potimirim potimirim* hatched as a prezoea and, depending on salinity regimen, remained as stage I zoea, or molted to stage II, III, possibly stage IV, and stage III zoeae, respectively. Maximum survival was seen in constant 23‰ culture trays. These results will be further developed elsewhere. We consider it highly unlikely, but not, of course, impossible that *P. potimirim* larvae could withstand an extended sojourn in the plankton from South America and thus colonize the fresh waters of the eastern Florida seaboard. An extensive barrier island system, with estuarine or marine lagoonal waters interposed behind, extends for nearly the entire length of the eastern Florida coast. The numerous rivers, canals, and streams which occur along the western shores of this system would provide ample opportunity for colonization should the proper environmental conditions occur.

The fact that all 6 females we collected were ovigerous indicates that the Indian River specimens came from a breeding population, but not necessarily one that was firmly established. Following the severe cold period of 18-20 January 1977, in which air temperatures fell to about –3° C and fresh water temperatures dropped to 5-8° C, a second collection of *P. potimirim* was attempted. No specimens were obtained, and monthly collections at the same site through April 1977 have produced no further atyid shrimp, suggesting that the Indian River population of *Potimirim potimirim* was extremely localized, and vulnerable to extreme cold. The shrimp has not been obtained in any other freshwater collections from the Indian River region, from Cape Canaveral to Jupiter Inlet.

Specimens from this study are deposited in the National Museum of Natural History, Washington, D. C. (2 females, ovigerous; USNM 169231) and the Harbor Branch Foundation, Inc., Museum at Link Port, Fla. (1 male, 4 females, ovigerous; SIFP 89:3181).

Acknowledgments—We thank Misses Nina Blum and Kim Wilson for aid during the laboratory culture of the larvae. This is Scientific Contribution No. 89 from the Smithsonian Institution-Harbor Branch Foundation, Inc., Scientific Consortium, Link Port, Ft. Pierce, Florida 33450.

LITERATURE CITED

Abele, L. G. 1972. Introductions of two freshwater decapod crustaceans (Hymenosomatidae and Atyidae) into Central and North America. Crustaceana 23:209-218.

Müller, F. 1881. Atyoida *Potimirim*, eine schlammfressende Susswassergarneele. Kosmos 9:117-124.

Saussure, H. de. 1857. Diagnoses de quelques Crustacés nouveaux de l'Amérique tropicale. Rev. Mag. Zool. Pure Appliquée ser. 2, 9:501-505.

Villalobos, A. 1960. Contribucion al conocimiento de los Atyidae de Mexico. II. (Crustacea, Decapoda). Estudio de algunas especies del genero *Potimirim* (= *Ortmannia*), con descripcion de una especie nueva en Brasil. An. Inst. Biol. Mexico 30:269-330.

Florida Sci. 41(1):57-61. 1978.

SUITABILITY AMONG NATIVE OR NATURALIZED PLANT SPECIES OF SOUTHERN FLORIDA FOR CITRUS BLACKFLY DEVELOPMENT—

Bryan Steinberg, Robert V. Dowell, George E. Fitzpatrick and Forrest W. Howard, University of Florida Agricultural Research Center, 3205 S.W. 70th Avenue, Ft. Lauderdale, Florida 33314

Abstract: Myrsine guianensis *(Aubl.) Kuntz (Myrsine) and* Ardisia escallonioides *Schlecht and Cham. (Marlberry) support development of* Aleurocanthus woglumi *Ashby to the adult stage and are native to southern Florida.* Ardisia solanacea *Roxb.,* Schinus terebinthifolius *Raddi (Brazilian Pepper Tree) and* Eugenia uniflora *L. (Surinam Cherry) are naturalized plants which also support complete* A. woglumi *development.* Citrus *spp. and these native or naturalized plants, which support complete development are considered as potential refugia of* A. woglumi *and can affect the chances of its eradication.*°

Citrus blackfly, *Aleurocanthus woglumi* Ashby (Homoptera: Aleyrodidae), is a major pest of citrus. Native to southern Asia, *A. woglumi* was first discovered in the Western Hemisphere in Jamaica by Ashby in 1913. Since then it has become established in Mexico, the Caribbean (Dietz and Zetek, 1920), and the United States (Howard and Neel, 1977). Recently *A. woglumi* has been reported from Broward, Dade and Palm Beach Counties primarily in dooryard citrus and in nursery plant material. It is the subject of an eradication program by the Division of Plant Industries (Florida Department of Agriculture and Consumer Services) and the Animal and Plant Health Inspection Service (United States Department of Agriculture). The eradication effort includes a quarantine on the movement of citrus and other plants which act as hosts for *A. woglumi*. Since an eradication program requires a thorough knowledge of all acceptable hosts of the target species, studies were initiated at the Agricultural Research Center, Ft. Lauderdale, to determine those native, naturalized, and imported plants that support *A. woglumi* development. Here we report the results of our tests with native and naturalized plants; a previous study of species wild and cultivated in Florida (Howard and Neel, 1977) is reported elsewhere.

Materials and Methods—Potted plants of 10 species (Table 1) approximately 0.3 m tall were infested with *A. woglumi* by placing the plants within a meter of infested citrus trees for 12-15 days. These plants were then returned to the Agricultural Research Center, Ft. Lauderdale for observations of *A. woglumi* development. Potted citrus plants were used as an oviposition check. Development on *Myrsine guianensis* (Aubl.) Kuntze and *Ardisia solanacea* Roxb. is based on field observations in John D. Easterlin County Park, Ft. Lauderdale, and a swamp at U.S. Geological Survey quadrant T.49S., R.42E., Sec. 10, northeast portion respectively. We also observed *A. escallonioides* Schlecht. & Cham.,

---

[1]Florida Agricultural Experiment Station Journal Series No. 683.

°The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

TABLE 1. A list of the highest developmental stage of *A. woglumi* observed on native or naturalized plants in either lab. (°) or field conditions (+).

Plant Species	Common Name	Highest Stage of *A. Woglumi* Devel.
+ *Myrsine guianensis* (Aubl.) Kuntze	Myrsine	Adult
° + *Ardisia escallonioides* Schlecht. & Cham.	Marlberry	Adult
+ *Ardisia solanacea* Roxb.		Adult
° + *Schinus terebinthifolius* Raddi	Brazilian Pepper Tree	Adult
° + *Eugenia uniflora* L.	Surinam Cherry	Adult
° *Baccharis halimifolia* L.	Groundsel	Fourth instar
+ *Persea borbonia* (L.) Spreng.	Red Bay	Fourth instar
° *Psychotria nervosa* Sw.	Wild Coffee	Fourth instar
° *Salix caroliniana* Michx.	Coastal-Plain Willow	Fourth instar
° *Coccoloba uvifera* (L.) L.	Sea Grape	First instar
° *Sambucus simpsonii* Rehder	Southern Elderberry	First instar
° *Peltandra virginica* (L.) Schott & Endl.	Peltandra	First instar
° *Ipomoea alba* L.	Moon Flowers	No oviposition

Eugenia uniflora L., *Schinus terebinthifolius* Raddi and *Persea borbonia* (L.) Spreng. in the field for *A. woglumi* presence. Determination of plants as native or naturalized species is based on information from local floristic studies (Long and Lakela, 1971; Steinberg 1976).

RESULTS AND DISCUSSION—Five of the 13 plants observed were able to sustain complete development of *A. woglumi* (Table 1).

A primary purpose of the current quarantine is to prevent the movement of *A. woglumi* into the major citrus growing regions of the state. Based on our results, it seems unlikely that native or naturalized plant species in southern Florida could serve as such a transfer medium. Of those plants tested upon which *A. woglumi* completed its development, only *Schinus terebinthifolius* (a common plant in disturbed habitats) is widespread enough to be considered as a potential route to the citrus groves. However, this plant supports much lower numbers of *A. woglumi* than citrus species. Tests indicate that less than one adult per plant emerged from *S. terebinthifolius* compared with 41.8 per plant from *Citrus sinensis* (L.) Osbeck when potted plants of similar size were compared. (Howard and Neel, 1977).

One problem facing any eradication program is the discovery and elimination of small isolated populations (refugia) of the target organism. Native or naturalized plants suitable for complete development of *A. woglumi* can form such refugia. *Myrsine guianensis* and *Ardisia escallonioides* are native plants which support complete *A. woglumi* development. *Myrsine guianensis* is common in swamps and wetter sites of Pine Flatwoods vegetation. *Ardisia escallonioides* commonly occurs in Low Hammock and Tropical Hammock vegetation. These species are supporting populations of *A. woglumi* in several locations in the Ft. Lauderdale area. *Ardisia solanacea, Schinus terebinthifolius* and *Eugenia uniflora* are naturalized species in southern Florida on which field populations of *A. woglumi* have been observed. These plants also support complete *A. woglumi* development. *A. solanacea* occurs occasionally in disturbed portions of swamps and hammocks and other disturbed sites. *Schinus terebinthifolius* is a species that has a high potential as a refugia, as it is among the most common wild plants in southern Florida. *Eugenia uniflora* is a common cultivar in southern Florida which is naturalized in some hammock vegetation, such as Snyder Park in Ft. Lauderdale (Steinberg, 1976).

Citrus spp., the preferred hosts of *A. woglumi* are also present among the native vegetation in southern Florida. *Citrus aurantiifolia* (Christm.) Swingle (Key Lime), *C. sinensis* (L.) Osbeck (Sweet Orange), *C. limon* (L.) Burm. f. (Lemon), *C. medica* L. (Citron) and *C. aurantium* L. (Sour Orange) are naturalized in some hammocks in southern Florida (Long and Lakela, 1971) and can reinfest adjacent vegetation.

Even with the most rigorous eradication and quarantine programs in residential sections, *A. woglumi* may be able to sustain itself in suitable native or naturalized vegetation. If eradication of *A. woglumi* from southern Florida is to succeed, all sources of reinfestation must be identified and eliminated.

LITERATURE CITED

Dietz, H. F., and J. Zetek. 1920. The blackfly of citrus and other sub-tropical plants. U.S.D.A. Bull. No. 885:1-55.

Howard, F. W., and P. L. Neel. 1977. Host plant preferences of citrus blackfly (*Aleurocanthus woglumi* Ashby (Homoptera: Aleyrodidae) in Florida. Proc. 1977 International Citrus Congress, Orlando, Florida (in press).

Long, R. W., and O. Lakela. 1971. Flora of Tropical Florida. Univ. Miami Press. Coral Gables.

Steinberg, B. 1976. Vegetation analysis of the atlantic coastal ridge of Broward County, Florida. M.S. thesis. Florida Atlantic Univ. Boca Raton.

Florida Sci. 41(1):61-63. 1978.

MASS MORTALITY OF *LUIDIA SENEGALENSIS* (LAMARCK, 1816) ON CAPTIVA ISLAND, FLORIDA, WITH A NOTE ON ITS OCCURRENCE IN FLORIDA GULF COASTAL WATERS—*William J. Tiffany III*, Mote Marine Laboratory, Sarasota, Florida 33581

Abstract: *A mass mortality of* Luidia senegalensis *occurred February 18, 1977 on Captiva Island, Florida. The occurrence of the nine armed sea star in Florida Gulf coastal waters is well documented.*

Reports of mass mortalities of benthic invertebrates after they have been beached are important in that these reports establish the existence of populations of particular invertebrates in areas from which they have been previously unreported or from areas where inconclusive sampling has not established their existence. The occurrence of a mass mortality of *Luidia senegalensis* on Captiva Island, Florida is an example in point. This is the first report of any mass mortality of *L. senegalensis* in Florida.

Mrs. Evelyn Hill of Palmetto, Florida, Mrs. Posey Wood of Longboat Key, Florida, and Dr. Amy Pathe of Cincinnati, Ohio (personal communication) observed "several hundred" nine-armed sea stars on the afternoon of February 18, 1977, approximately 100 m south of the South Sea Plantation on Captiva Island. The location was a sandy beach on the Gulf of Mexico side of the north end of Captiva Island. Prior to the beaching, there were no reports of unusually rough seas or storms. The observers collected several specimens and submitted them for identification. Identification of the nine-armed sea star revealed it to be *Luidia senegalensis*. A specimen was sent to Dr. John Lawrence at the University of South Florida for verification.

Occurrence of *Luidia senegalensis* along the Gulf coast of Florida is well established; however, there are some conflicting reports regarding its exact range. Clark (1933) reported specimens collected from the Caribbean and from the vicinity of Sanibel Island. Halpern (1970) reported its occurrence as far north as Bradenton on the west coast of Florida and from a small area on the east coast near Fort Pierce, as well as the tropical western Atlantic regions. Godcharles and Jaap (1973) collected *L. senegalensis* from several locations in the eastern Gulf of Mexico including the Sanibel Island area southward to the Ten Thousand Islands. Downey (1973) reported that specimens of *L. senegalensis* have been collected from the northeast coast of South America, the Antilles, and Florida. Zeiller (1974) reported that *L. senegalensis* has not been found in Florida waters. Voss (1976) stated that *L. senegalensis* occurs in Florida and the West Indies as well as the west coast of Africa. Downey (personal communication) said that *L. senegalensis* was originally reported from the west coast of Africa (hence the name *L. senegalensis*); however, these reports are now known to be inaccurate.

Although there are some differing reports as to the exact range of *Luidia senegalensis*, the majority of the literature as well as documented sightings have established the occurrence of the nine-armed sea star on the west coast of Florida up to at least the Bradenton area.

Acknowledgments—Thanks are expressed to the following people for providing their time, information, and interest: John Lawrence, University of South Florida; Maureen Downey, Smithsonian Institution; Bill Lyons, Florida Department of Natural Resources; Lowell Thomas, Rosenstiel School of Marine and Atmospheric Sciences; Warren Zeiller, Miami Seaquarium.

LITERATURE CITED

Clark, H. L. 1933. A handbook of the littoral echinoderms of Porto Rico and the other West Indian Islands. Sci. Surv. Porto Rico and the Virgin Islands 16:1-147.

Downey, M. E. 1973. Starfishes from the Caribbean and the Gulf of Mexico. Smithsonian Contr. Zool. 126:1-158.

Godcharles, M. F., and W. C. Jaap. 1973. Fauna and flora in hydraulic clam dredge collections from Florida west and southeast coast. Florida Dept. Natur. Resources Spec. Sci. Rept. 40:1-89.

Halpern, J. A. 1970. Growth rate of the tropical sea star *Luidia senegalensis* (Lamarck). Bull. Marine Sci. 20:626-633.

Voss, G. L. 1976. Seashore Life of Florida and the Caribbean. E. A. Seemann Publishing, Inc. Miami.

Zeiller, W. 1974. Tropical Marine Invertebrates of Southern Florida and the Bahama Islands. John Wiley & Sons. New York.

Florida Sci. 41(1):63-64. 1978.

INSTRUCTIONS TO AUTHORS

Rapid, efficient, and economical transmission of knowledge by means of the printed word requires full cooperation between author and editor. Revise copy before submission to insure logical order, conciseness, and clarity.

MANUSCRIPTS should be typed double-space throughout, on one side of numbered sheets 8½ by 11 inch, smooth, bond paper.

A CARBON COPY will facilitate review by referees.

MARGINS should be 1½ inches all around.

FOOTNOTES should be avoided. Give ACKNOWLEDGMENTS in the text.

ADDRESS should be given following the author's name.

ABSTRACTS should be typed double-spaced immediately following the address.

LITERATURE CITED follows the text. Double-space every line and follow the form in the current volume.

TABLES are charged to authors at $25.00 per page or fraction. Titles must be short, but explanatory matter may be given. Type each table on a separate sheet, double-space, unruled, to fit normal width of page, and place after Literature Cited.

LEGENDS for illustrations should be grouped on a sheet, double-spaced, in the form used in the current volume, and placed after Tables. Titles must be short but may be followed by explanatory matter.

ILLUSTRATIONS are charged to authors ($20.00 per page or fraction). Drawings should be in India ink, on good board or drafting paper, and lettered by lettering guide or equivalent. Plan linework and lettering for reduction, so that final width is 4 5/8 inches, and final length does not exceed 7 inches. Do not submit illustrations needing reduction by more than one-half. Photographs should be of good contrast, on glossy paper. Do not write heavily on the backs of photographs.

PROOF must be returned promptly. Leave a forwarding address in case of extended absence.

REPRINTS may be ordered when the author returns corrected proof.

FLORIDA ACADEMY OF SCIENCES

INSTITUTIONAL MEMBERS FOR 1976

Archbold Expeditions
Barry College
Eckerd College
Edison Community College
Florida Atlantic University
Florida Institute of Technology
Florida Southern College
Florida State University
Florida Technological University
Gulf Breeze Laboratory
Jacksonville University
John Young Museum
and Planetarium
Manatee Junior College
Miami-Dade Community College
Stetson University
University of Florida
University of Miami
University of South Florida
University of Tampa
University of West Florida

Membership applications, subscriptions, renewals, changes of address, and orders for back numbers should be addressed to the Executive Secretary, Florida Academy of Sciences, 810 East Rollins Street, Orlando, Florida 32803.

ISSN: 0098-4590

Florida Scientist

Volume 41 Spring, 1978 No. 2

CONTENTS

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

FLORIDA SCIENTIST

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

The FLORIDA SCIENTIST is published quarterly by the Florida Academy of Sciences, Inc., a non-profit scientific and educational association. Membership is open to individuals or institutions interested in supporting science in its broadest sense. Applications may be obtained from the Executive Secretary. Both individual and institutional members receive a subscription to the FLORIDA SCIENTIST. Direct subscription is available at $13.00 per calendar year.

Original articles containing new knowledge, or new interpretation of knowledge, are welcomed in any field of Science as represented by the sections of the Academy, viz., Biological Sciences, Conservation, Earth and Planetary Sciences, Medical Sciences, Physical Sciences, Science Teaching, and Social Sciences. Also, contributions will be considered which present new applications of scientific knowledge to practical problems within fields of interest to the Academy. Articles must not duplicate in any substantial way material that is published elsewhere. Contributions are accepted only from members of the Academy and so papers submitted by non-members will be accepted only after the authors join the Academy. Instructions for preparation of manuscripts are inside the back cover.

Published by the Florida Academy of Sciences, Inc.
810 East Rollins Street
Orlando, Florida 32803

Printed by the Storter Printing Company
Gainesville, Florida

Florida Scientist

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Walter K. Taylor, *Editor* Henry O. Whittier, *Editor*

Volume 41 Spring, 1978 No. 2

Biological Sciences

STATUS, WINTER HABITAT, AND MANAGEMENT OF THE ENDANGERED INDIANA BAT, *MYOTIS SODALIS*

STEPHEN R. HUMPHREY

Florida State Museum, University of Florida, Gainesville, Florida 32611

ABSTRACT: *The known number of living Indiana bats (*Myotis sodalis*) has declined 28% in the last 15 yr. Winter populations represent two large breeding units, Kentucky and Missouri, and other smaller units not delimited by existing data. Kentucky populations have declined 73%; an apparent 8% decline in Missouri reflects weather influence at one exposed roost, and Missouri populations are judged to be stable. Suitable winter habitat consists of caves and mines that have cool and stable temperatures all winter long. Typically these roosts have temperatures of 4 - 8°C, enabling the bats to maintain such a low metabolism that their fat will last until spring. Causes of the decline are natural catastrophes (flooding and freezing in caves), disturbance by biologists and caving enthusiasts, and destruction of winter and summer habitat. Loss of 60,000 bats at one cave is attributable mainly to disturbance. About half of the total decline has resulted from habitat alteration—structures built at cave entrances interfere with cave thermodynamic processes and make roosts too warm for bat survival. This habitat can be restored, and the decline may be reversible. Proper management should enable the species to increase its numbers to at least 615,000 individuals.**

THE INDIANA BAT (*Myotis sodalis*) is a small, migratory insectivore (weight 6 - 9 g, forearm length 39 mm) well known for hibernating in caves in the eastern United States. The species is most common in the midwest, uncommon in the Atlantic and Northeastern states, and rare in the Southeast. The Indiana bat is listed as endangered by the United States Department of the Interior (Office of Endangered Species and International Activities, 1973) and the International Union for Conservation of Nature and Natural Resources (1968). Legal protection is afforded by the Endangered Species Act of 1973 (Public Law 93-205) and laws of several states. Endangered status was first applied by Interior in 1966, in recognition that 97% of the estimated population of 412,400 (Hall, 1962) hibernated in only four caves during winter. This degree of aggregation makes the species extraordinarily vulnerable to natural catastrophes and losses caused by humans. This study presents new information on status, population trends, and winter habitat of the Indiana bat and makes management recommendations.

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

METHODS—Hibernacula used by *M. sodalis* were identified by correspondence with bat biologists throughout the range of the species. Caves and mines and the internal sites occupied by bats were located with the help of biologists experienced with each population. To reduce error attributable to individual bias in making estimates, I made all 1975 size estimates of the major populations (except No. 376, Indiana), so only my bias applies. My method was to count all individuals in small groups; for large groups I estimated size as a function of cluster surface area after counting a portion of the cluster to evaluate the degree of packing. Previous estimates and a few 1975 estimates of minor populations were from several biologists using similar techniques; no control over individual bias among these values was possible.

I have taken several liberties with census data (Table 1) in order to evaluate trends. Estimates labelled "1960" cluster about that date, but a few are as early as winter 1953-54 or as late as 1965-66. Most "1975" estimates are from winter 1974-75, though two are from 1973-74. Additionally, populations newly discovered by other people in winter 1975-76 are included. To arrive at total figures where values are missing, I have assumed that the population size is unchanged. The effect of this assumption is greatest in Missouri, where large, newly discovered populations actually might have declined since 1960. At Pilot Knob Mine, Missouri, I was unable to find the mine section that formerly housed 100,000 *M. sodalis*. In view of minimal disturbance due to extremely dangerous conditions in the mine, I have assumed that this population remains unchanged, though it is possible that rockfall has closed off the hibernating site. Though more radical interpretations are possible, my conservative treatment is in accord with my impression that Missouri populations have not begun a significant decline.

Winter sex ratios were cumulative values taken from 1953 to 1973 by J. B. Cope at several caves in Indiana and Kentucky. The main sites were Wind Cave, Kentucky, and Wyandotte Cave, Ray's Cave, Grotto Cave, and Buckner's Cave, Indiana.

Microtemperatures were measured with utility, banjo, shielded air, and rectal thermistor probes and a three-probe, battery-powered temperature indicator (Atkins Technical Inc., 3401 S.W. 40th Blvd., Gainesville, Florida 32608). Microhumidity was measured with an Atkins psychrometer pistol.

RESULTS—*Status*. The new survey (Table 1) indicates that approximately 640,000 *M. sodalis* were living in 1960, more than were known when Hall (1962) estimated 412,400 to exist. Though this report shows the species occupying 53 caves, compared to 19 caves in Hall's study, most new finds have been of small populations. Major exceptions are the population of 100,000 in Indiana and the large populations totalling 118,750 in and near the Meramec River valley of eastern Missouri. This survey encompasses all major *M. sodalis* populations known to biologists and caving enthusiasts, but it is possible that significant populations remain to be discovered.

As of 1975, approximately 460,000 *M. sodalis* are known to exist. The species has declined in numbers by 28% in 15 yr. The focal point of the decline is Kentucky, where populations have dropped 73% over 15 yr, from about 209,800

Table 1. Winter population estimates throughout the range of *Myotis sodalis*.

Location	Population size in 1960	Population size in 1975	Trend
Missouri			
Pilot Knob Mine	100,000	-	
No. 047[a]	71,800	46,000	
No. 029	-	81,800	
No. 021	-	12,850	
No. 009	-	21,000	
No. 017	-	3,100	
No. 031	-	5,483	
Ryden Cave	5,600	6,000	
Tunnel Cave	4,000	-	
Inca Cave	2,000	-	
Onyx Cave	600	-	
Piquet Cave	600	-	
Bruce Cave	500	-	
Carroll Cave	600	-	
No. 023	800	-	
Mary Lawson Cave	600	-	
Coffin Cave	250	-	
No. 053	150	-	
Total	311,433	285,983	-8.2%
Kentucky			
Bat Cave	100,000	40,000	
Coach Cave	100,000	4,500	
Dixon Cave	2,500	3,600	
Long's Cave	1,840	7,600	
Colossal Cave	1,800	14	
Wilson Cave	550	0	
James Cave	100	0	
Bat Cave	6	68	
Wind Cave	3,000	0	
Total	209,796	55,782	-73.4%
Tennessee			
White Oak Blowhole Cave	-	6,050	
Little Mammoth Cave	4,000	1,250	
Pearson's Cave	-	10	
Bellamy Cave	94	-	
Blue Spring Cave	4	-	
Coleman Cave	1	-	
Tobacco Port Cave	145	-	
Total	-	7,554	
Arkansas			
Denney Cave	-	1,000	
Several caves in Sylamore Forestry District, total	-	700	
Total	-	1,700	

Location	Population size in 1960	Population size in 1975	Trend
Indiana			
No. 376	-	100,000	
Wyandotte Cave	1,944	1,460	
Saltpeter Cave	-	95	
Ray's Cave	512	2,700	
Coon's Cave	9	24	
Grotto Cave	200	200	
Buckner's Cave	63	345	
Total	102,823	104,824	+1.9%
Illinois			
Blackball Mine	337	192	
Cave Spring Cave	2	0	
Total	339	194	-42.8%
Virginia			
Rocky Hollow Cave	-	550	
Star Chapel Cave	-	30	
Total	-	580	
West Virginia			
Hellhole Cave	-	1,500	
Big Springs Cave	-	150	
Cave Hollow Cave	150	23	
Martha's Cave	-	80	
Cass Cave	-	4	
Total	-	1,757	
Pennsylvania			
Cement Mine	1,000	-	
Aitkin Cave	2	-	
Total	1,002	-	
New York			
Watertown Cave	-	500	
Vermont			
Aeolus Cave, very few, not censused.			
GRAND TOTALS	640,361	459,876	-28.2%

[a] Numbers refer to a cave location registry of sites under study by the U.S. Fish and Wildlife Service.

to 55,800. The small decrease in Missouri is attributable to yearly variation in winter weather at a single hibernaculum (Fig. 3) and does not represent a regional trend. Changes in other states contribute little to the overall picture because of the small number of animals involved.

The species remains highly clumped in winter distribution. The seven largest populations account for 87% of the *M. sodalis* known to be alive. This degree of aggregation contributes importantly to the endangerment of the species.

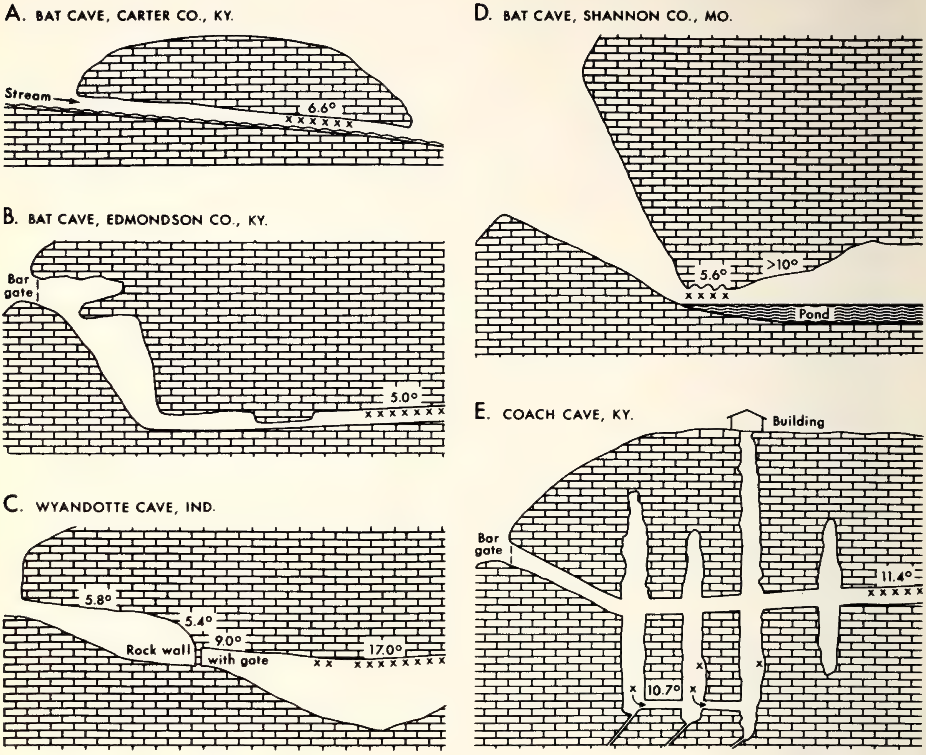


Fig. 1. Schematic side views of caves occupied by *M. sodalis*. Temperatures are those recorded in the winter 1974-75 survey. Hibernation sites are indicated by X.

Winter Habitat: Winter habitat consists of caves and mines. Suitable sites are those with cool and stable temperatures all winter long. To achieve a metabolic rate low enough to ensure that finite fat reserves will outlast the foodless winter period, this species selects sites that are both as cool as possible yet warm enough that freezing will not occur. Freezing would cause either death or energetically costly arousal and movement. Hibernation sites proven by the test of survival are used by *M. sodalis* every year, repeatedly by the same individuals, as if the locations were learned and incorporated into the annual cycle as a matter of tradition. The most favored hibernation sites have a rock temperature (the factor by which bat body temperature is determined, McNab, 1974) of 4 - 8°C (Fig. 1 A-E; Hall, 1962; Myers, 1964). The full range of roost temperatures at which the species has been found is -1.6°C (air temperature, Barbour and Davis, 1969) to 17.0°C. These include sites to which bats have moved after disturbance; presumably this range exceeds tolerable temperatures, with extreme conditions

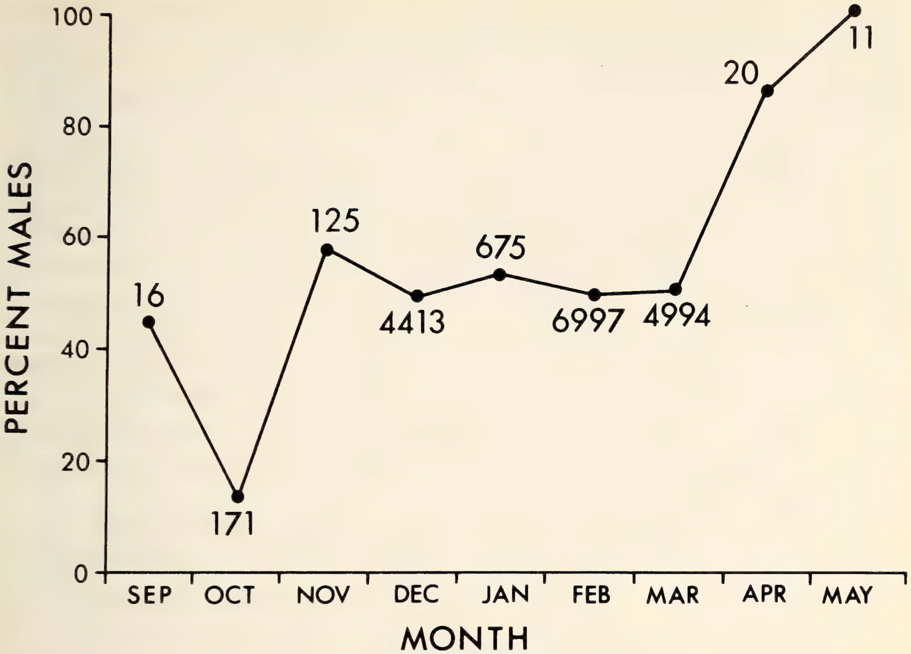


FIG. 2. Sex ratio of *M. sodalis* hibernating in Indiana and Kentucky caves. Numbers indicate sample size.

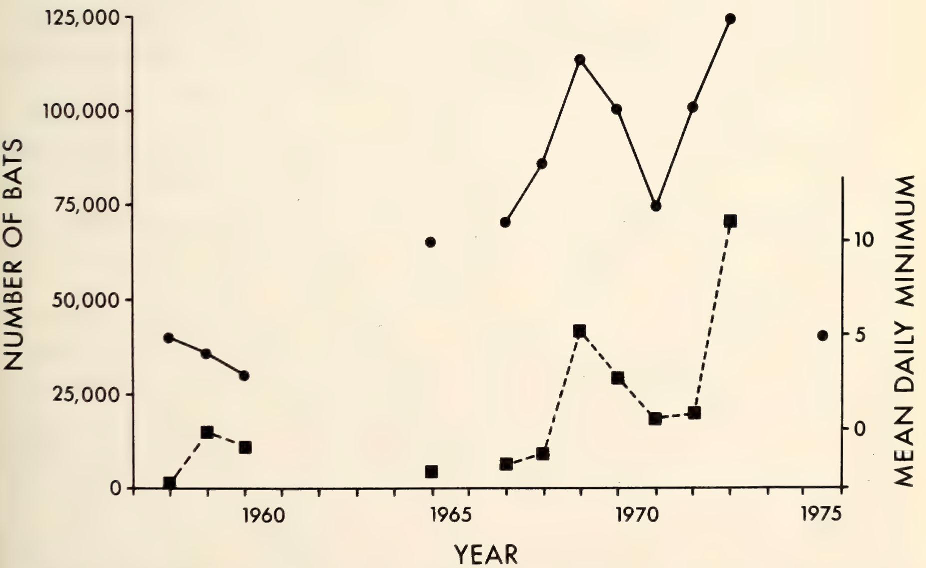


FIG. 3. Winter population size of *M. sodalis* in Bat Cave, Shannon Co., Missouri. Estimates were made by R. F. Myers. Mean minimum daily temperatures reflect the severity of winter at nearby Houston, Missouri, from 1 October to the date each estimate was made.

being lethal for winter-long occupancy. Temperatures in the preferred range occurred in caves housing major populations that have not declined (except some that have declined for reasons other than temperature change). Microhumidities in this study ranged 75-100%, and no preferences were evident within this range.

Cave temperatures become lower than regional mean annual temperature during winter only if cold air is trapped in cave passages that lie below entrances. Air enters by displacement as cold weather fronts pass and by "breathing" caused by diel changes in barometric pressure. Achievement of low temperatures depends on strong air circulation and the occurrence of voluminous passages situated below and near entrances. Once cold, cave air remains so until heated by the surrounding rock. Thus the unique shape of each cave and the climate outside determine whether the cave's microclimate is beneficial to overwintering *M. sodalis*. Figure 1 illustrates the topography of some of the most satisfactory known *M. sodalis* hibernacula (C and E and have been thermally modified by recent human activities.)

Knowledge that *M. sodalis* uses cool caves as winter habitat does not require qualification, as it does for some species of bats in which individuals use different roosts at different periods of winter and exhibit corresponding changes of behavior (e.g., Humphrey and Cope, 1976; Humphrey and Kunz, 1976). The simplicity of *M. sodalis* winter habitat use is indicated by sex ratios (Fig. 2), which are essentially stable from November through March. This uninterrupted occupation emphasizes the necessity of having suitable cave habitat. The high proportion of females in October shows that females have entered hibernation after migratory arrival, fat storage, and mating; large numbers of sperm-laden males remain active outside the caves until November, when most females have ceased aboveground activity. The high proportion of males in caves in April and May shows that all females depart for summer habitat during April. A few males occupy these caves through the summer.

Declines Caused by Natural Catastrophes: Though natural disasters have been discounted as important in bat mortality by Gillette and Kimbrough (1970), this is an unrealistic view. Both freezing and flooding are significant causes of mortality in *M. sodalis* during winter, and both have produced population declines or extirpation.

Numerous dead bats have been found under their roost in Bat Cave, Shannon Co., Missouri, during or after unusually long, cold winter storms (R. F. Myers, personal communication). The peculiar shape of this cave (Fig. 1D) affords no satisfactory thermal alternatives if the roost becomes too cold, whereas in mild winters the roost is one of the coolest and therefore best available in the southern part of the species' range. At this cave (Fig. 3), population estimates are significantly correlated ($r = 0.735$, $P < .05$) with the intensity of winter cold. When winters are severe at such sites, bats die, or remain but use large amounts of energy to maintain body temperature above ambient, or move to other caves. Either of the latter courses makes the bats less likely to survive late winter or to migrate successfully in spring.

Several floods in *M. sodalis* hibernacula have been documented. The most spectacular caused extirpation of the largest recorded population, estimated at 300,000 *M. sodalis*, at Bat Cave, Edmondson Co., Kentucky (Hall, 1962). Water from a flood of the adjacent Green River, probably during 1937, quietly flowed up through rock joints and filled the cave. The formerly enormous size of this population is understandable because Bat Cave has a flat-ceilinged passage about 1 km long with a very gentle thermal gradient and ideal winter temperatures. Until a recent disturbance, repopulation here appeared to be underway, for numbers had increased steadily from 6 in 1960 to 250 in 1970. Death of about 3,200 *M. sodalis* at Wind Cave, Kentucky, from flooding in March 1963 was reported by DeBlase et al. (1965). About 500 *Myotis* survived, mostly *M. sodalis*. The following winter, 459 *M. sodalis* were present, and this remnant diminished to zero in 1972 (Fig. 4). *M. sodalis* apparently escaped a recent flood in Bat Cave, Carter Co., Kentucky, by dispersing into small clusters throughout the incompletely flooded portions of the cave (J. Tierney, personal communication). Even though floods like these occur rarely, they can have catastrophic effects on bat populations if the animals fail to arouse quickly enough to flee.

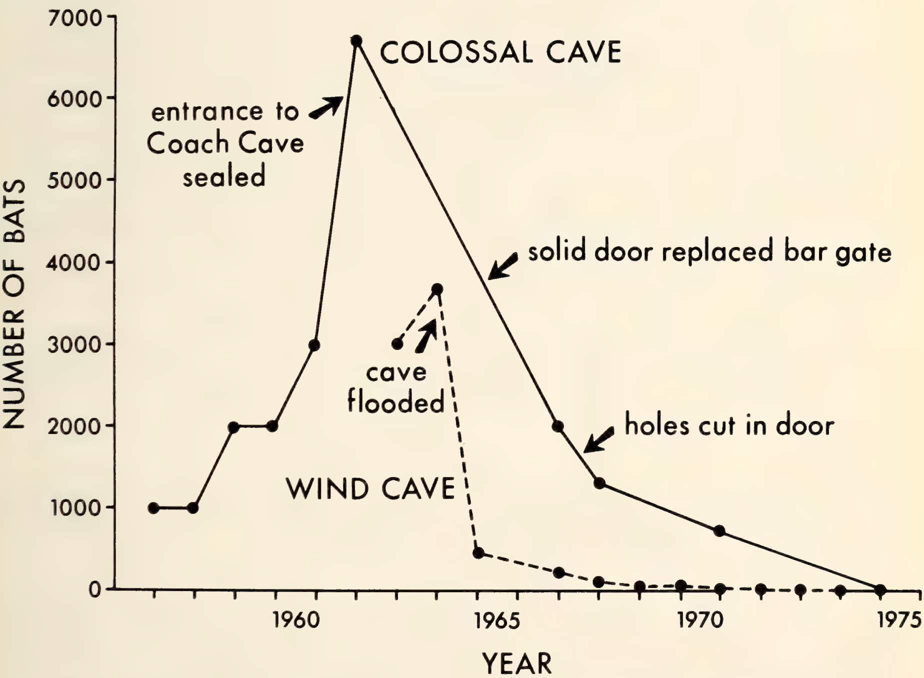


FIG. 4. Winter population size of *M. sodalis* at Colossal Cave and Wind Cave, Kentucky.

Declines Caused by Disturbance: *M. sodalis* appears to be moderately tolerant of disturbance during hibernation, in contrast to more sensitive species (e.g., *Plecotus townsendii*, Humphrey and Kunz, 1976). Even so, every human visit under a low *M. sodalis* cluster causes metabolic heat production, arousal, flight, and reclustering 30 - 60 min later, with concomitant loss of fat reserves. The mildest stimuli of sound and light from a group of passing cave enthusiasts are sufficient to produce arousal. Fat attrition is greater when biologists visit to gather data, because observation time is longer and often involves caging, handling, and other indignities. Repeated disturbances during one winter compound the effect, and by spring the bats may be in very poor condition. Death from this form of malnutrition is seldom observed in the caves, but it is reasonable to expect mortality in spring. Then emerging, emaciated bats would either attempt to migrate while metabolizing muscle and other emergency energy sources or else delay migration to feed near the hibernaculum, at a time when insects are an unpredictable food supply. As a rule, these bats do not move to an alternate cave after disturbance, which is understandable in view of the rarity of suitable caves. Even when cave habitat is rendered uninhabitable, few *M. sodalis* move to nearby caves occupied by conspecifics (Fig. 5). Instead, the affected populations become smaller with few marked individuals appearing at alternate caves. Presumably most animals that disappear have died.

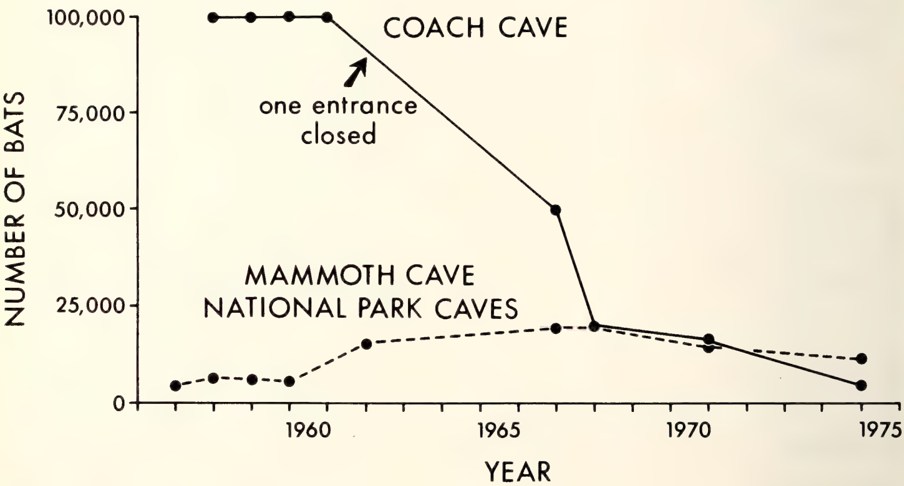


FIG. 5. Winter population size of *M. sodalis* at Coach Cave and all the occupied caves in nearby Mammoth Cave National Park, Edmonson Co., Kentucky. Wilson Cave (MCNP) is excluded; estimates there range from 0-550.

Data on disturbance effects are not extensive, but a few examples are illustrative. The steady recovery of the *M. sodalis* population at Bat Cave, Edmonson Co., Kentucky, was reversed after a biologist banded all 250 in 1971. The population was only 68 in 1975. The decline from 100,000 to 40,000 *M. sodalis* in Bat Cave, Carter Co., Kentucky, is attributable largely (I judge) to a long history of repetitious disturbance by biologists and park visitors. During recent years such visits, organized or led by Carter Caves State Park officials, have av 15 - 20 per winter.

Vandalism occurs commonly, usually as rock-throwing or burning of clustered bats with torches. In 1961 about 10,000 *M. sodalis* were killed this way in Bat Cave, Carter Co., Kentucky. The landowner found a "bushel basket full" of bats killed by vandals in Little Mammoth Cave, Tennessee, in 1970; most bats in this cave are *M. sodalis*. Several cases of vandalism against bats have occurred in Ray's Cave, Indiana, and Blackball Mine, Illinois.

Declines Caused by Habitat Destruction: Destruction of winter habitat by human activities is the cause of about half of the 15-yr decline reported here. Loss of winter habitat results from blocking or impeding air circulation, thus interfering with a cave's thermodynamic characteristics. Recorded cases are catastrophic in effect. The worst loss was at Coach Cave, Kentucky, where air circulation was almost halted. In about 1962 tourist resort owners built an observation platform and building that covered the upper entrance, which penetrates a ridge top (Fig. 1E). This event was followed by a population decline from 100,000 to 4,500, continuing to the present (Fig. 5). Before construction, bat roost rock temperature was 4–6°C (J. S. Hall, personal communication); with present temperatures of 10.7 and 11.4°C, the survival value of these sites is minimal. A synchronous increase of *M. sodalis* populations from about 6,000 to a maximum of 19,000 in nearby (3 - 15 km) protected caves in Mammoth Cave National Park indicates that some moved to alternate hibernacula.

Decline of the *M. sodalis* populations in Mammoth Cave National Park from about 19,000 to 12,000 has resulted from mismanagement of Colossal Cave (Fig. 4). Sometime between 1962 and 1966, Park personnel closed the single entrance to this cave with a solid door. In response to a biologist's recommendation, they cut three bat-sized holes in the door in 1967. This slowed the rate of decline, but it continued and only 14 *M. sodalis* remained in 1975. Roost rock temperatures increased from 4–6°C in 1960 (J. S. Hall, personal communication) to 10.7–12.3°C in 1975.

Another cause of thermal disruption is the construction of rock walls at cave entrances for the purpose of hanging rectangular gates to control visitor access. The effect of restricted air flow on microclimate at Wyandotte Cave, Wyandotte Cave State Park, Indiana (Fig. 1C), is that traditional *M. sodalis* roosts are now too warm. In 1950 this cave was occupied by about 15,000 *Myotis* (*sodalis* and *lucifugus* combined, J. B. Cope, personal communication). In 1974-75 only 1,460 *sodalis* and 2 *lucifugus* were present. The only properly designed cave gates (that is, meeting the specification that air flow be unimpeded) I encountered on this survey were at Fisher Cave, Meramec State Park, and Mushroom Cave, Meramec Lake Park, Missouri.

Discussion—Legal classification of *M. sodalis* as "endangered" certainly is justified in view of a 28% decline in 15 yr. The species is well on its way towards extirpation in Kentucky. At present rates, the species might become extinct in another 50 yr. However, that simplistic view is unrealistic because (1) the worst losses are discrete, unrelated episodes in which individual hibernacula are threatened and (2) losses of winter habitat are reversible.

In evaluating the decline, I accept the trend data in Table 1 at face value. It is possible to interpret these trends as meaningless, on the bases that possibly many existing populations are undiscovered and that possibly the "declining" populations actually are moving to unknown sites. The first possibility never can be discounted with certainty. The second has been shown to have weak supportive evidence, and it assumes that new and old roosts have equal survival value. A straightforward interpretation of trend data has the advantage of simplicity and making any errors of judgment on the side of protecting *M. sodalis* from unnecessary hardships.

An adequate management program should consider each geographically distinct breeding population. Limited definition of demes is possible from banding studies. *M. sodalis* wintering in Missouri spend the summer in Missouri and southern Iowa (Myers, 1964). Those wintering in north-central Kentucky reside in central Kentucky, Indiana, and southwestern Michigan during summer; bats hibernating in northeastern Kentucky summer in northeastern Kentucky, the western half of Ohio, and southern Michigan (Barbour and Davis, 1969). Overlap of summer distribution along the Indiana-Ohio border and a winter-to-winter movement between the two wintering areas (Hall, 1962) suggest that the two Kentucky groups may not be genetically isolated. Summer range of other winter groups is unknown. It is safe to conclude that the two largest groups of winter populations—Missouri and Kentucky—are discrete breeding units and should be treated accordingly in management recommendations.

The plight of *M. sodalis* in Kentucky heightens the importance of protecting populations elsewhere. Because of the apparent stability of Missouri populations, relatively inexpensive management practices there could assure the survival of the species. Likewise, management of small populations in other states is increasingly valuable.

Implications of the Endangered Species Act: The stiff penalties and uncompromising language of the Endangered Species Act (United States Congress, 1973) dictate prudence in dealing with *M. sodalis* and its habitat. Inducement of arousal constitutes harassment, because the loss of stored fat is a life-threatening event. Thus a winter walk under a cluster of hibernating *M. sodalis* by the most well-meaning cave enthusiast is a violation of the Act. Spelunkers would be well advised to follow the recommendations of the National Speleological Society and avoid such visits. Other common events prohibited by law include handling of *M. sodalis* by research biologists, scientific collecting, leading public tours under winter clusters by officials of private resorts and public parks, and vandalism.

The Act also directs all federal agencies to assure that their programs shall be consistent with conservation of endangered species and that these programs shall avoid destruction of critical habitat. Destruction of winter habitat of *M. sodalis* consists of closing caves or restricting entrance air flow so that internal microclimate becomes suitable. Summer habitat is protected similarly.

Management Recommendations. Though minor interference is to be expected, there is no compelling reason that the Indiana bat cannot coexist with man. The species can prosper if simply left alone. Most documented declines caused by mismanagement have resulted from ignorance, with only the loss of Coach Cave stimulated by a profit motive. The following recommendations, if implemented, should be adequate to reverse the decline in *M. sodalis* populations. These steps should enable the species to increase its numbers to at least 615,000. When that occurs the species' classification could be changed from "endangered" to "threatened."

1. *Land acquisition.* The Department of the Interior should acquire the land over and the mineral rights of the important *M. sodalis* hibernacula not now subject to federal managment. Most important to acquire are Pilot Knob Mine and Cave No. 029, Missouri, and Coach Cave, Kentucky. Once acquired, these caves should be provided protective management.

2. *Federal-state cooperation.* The Department of the Interior should seek cooperative agreements with states for conservative management of state-owned *M. sodalis* winter and summer habitat. Particularly important in this regard is Bat Cave, in Carter Caves State Park, Kentucky. Other state properties known to include winter habitat are Wyandotte Cave State Park, Indiana; Pecumsaugan Creek Nature Preserve, Illinois; and Meramec State Park, Missouri. Great numbers of state properties include summer habitat (creekside forest). Such agreements should be extended to act on requests for conservation assistance from private landowners, as in the case of Little Mammoth Cave, Tennessee.

3. *Open blocked caves.* Structures closing or constricting the entrances of *M. sodalis* caves should be removed. This should restore *M. sodalis* habitat by allowing caves to become cold in winter, and the affected populations could recover to former numbers.

4. *Restrict cave visitor access.* Access to hibernacula on state or federal property should be controlled by placing strong gates at entrances. To allow free air circulation and access by bats, use of sheet metal and solid framing (such as rock walls) must be avoided. Gates and framing should be constructed of steel bars and locks heavy enough to discourage vandalism. Visits may be unlimited during the warm months, but from 1 September to 1 May no more than one visit per yr should be permitted at each hibernaculum. In parks, all winter visitors should be accompanied by a park ranger; even some professional biologists will operate without permits, cause unnecessary disturbance, or violate understood prohibitions. So few winter entries are tolerable that the purpose of such visits should be to carry out essential management practices or to gather information needed for planning (e.g., census work).

5. *Research.* In recognition of their deleterious impact, research activities should be restricted, by use of the federal endangered species permit system, to subjects on which inadequate information is available. For example, permission might be denied to band numerous *M. sodalis* in central Kentucky caves to study migration (the basic pattern of which is known), whereas a permit to study the same matter in eastern Tennessee might be granted (to learn the distribution limits of that breeding population). Research on summer ecology might be approved in view of the scarcity of such knowledge and the small damage such activity can cause. This study and previous reports refer mainly to large *M. sodalis* populations in the heart of their range. Additional research on the biology of small populations and on populations in the periphery of the species' range would be useful. Such populations may become increasingly important in management of the species if larger populations continue to be threatened.

6. *Compliance with the Act.* Citizens and governmental agencies should comply with the purposes of the Act—to conserve threatened and endangered species and the ecosystems on which they depend. Citizens and agencies should examine their management policies towards properties inhabited by *M. sodalis* and leave the animals and the habitat alone where possible. Interior should include creekside forest in the definition of summer

habitat that is critical to the survival of the species, so other federal agencies will recognize this habitat as one to be conserved. Violators of the Act should be prosecuted and the penalties imposed should be publicized.

ACKNOWLEDGMENTS—This work was funded by the National Fish and Wildlife Laboratory, Fish and Wildlife Service, United States Department of the Interior, through a contract to World Wildlife Fund Project No. US-26. I thank Clyde Jones for encouraging me to undertake this task and Michael A. Bogan and Thomas E. Lovejoy for coordinating the program and providing administrative assistance. I am grateful to the biologists—experts on bats in their regions—who took me to populations or contributed observations: J. B. Cope, W. H. Davis, M. B. Fenton, J. S. Hall, M. J. Harvey, H. B. Hitchcock, S. D. Keefer, R. F. Myers, A. R. Richter, J. A. Simmons, D. Stevenson, M. D. Tuttle, T. Vogel, H. D. Walley, J. E. Werner, and G. Wine. Officials of the National Park Service and the Parks Departments of Missouri, Indiana, and Kentucky, Mr. G. C. Ganter of Park Mammoth Resort, and other private landowners kindly allowed me to visit their property. T. Vogel of the Fish and Wildlife Service and J. Brady of the Army Corps of Engineers helpfully took me to the future site of Meramec Park Lake and discussed the potential impact of the project on Indiana bats and other issues. The Law Enforcement Division of the Fish and Wildlife Service challenged my sense of humor by charging me $50 of Interior funds for processing my endangered species permit. Figures were drawn by N. Halliday and S. J. Scudder. J. O. Whitaker, Jr., and another person made helpful reviews of the manuscript. This work was conducted under the authority of federal endangered species permit PRT-8-83-C.

LITERATURE CITED

BARBOUR, R. W., AND W. H. DAVIS. 1969. Bats of America. Univ. Press of Kentucky. Lexington.

DEBLASE, A. F., S. R. HUMPHREY, AND K. S. DRURY. 1965. Cave flooding and mortality in bats in Wind Cave, Kentucky. J. Mamm. 46:96.

GILLETTE, D. D., AND J. D. KIMBROUGH. 1970. Chiropteran mortality. Pp. 262-283. In B. H. Slaughter and D. W. Walton, eds. About Bats. Southern Methodist Univ. Press. Dallas.

HALL, J. S. 1962. A life history and taxonomic study of the Indiana Bat, *Myotis sodalis*. Reading Publ. Mus. and Art Gallery Sci. Publ. 12:1-68.

HUMPHREY, S. R., AND J. B. COPE. 1976. Population ecology of the little brown bat, *Myotis lucifugus*, in Indiana and north-central Kentucky. Amer. Soc. Mamm. Spec. Publ. 4:1-81.

__________, AND T. H. KUNZ. 1976. Ecology of a Pleistocene relict, the western big-eared bat (*Plecotus townsendii*), in the southern Great Plains. J. Mamm. 57:470-494.

INTERNATIONAL UNION FOR CONSERVATION OF NATURE AND NATURAL RESOURCES. 1968. Red data book—Mammalia. Arts graphiques Heliographia S. A. Lausanne, Switzerland.

MCNAB, B. K. 1974. The behavior of temperate cave bats in a subtropical environment. Ecology 55:943-958.

MYERS, R. F. 1964. Ecology of three species of myotine bats in the Ozark Plateau. Ph.D. Dissert. Univ. Missouri. Columbia.

OFFICE OF ENDANGERED SPECIES AND INTERNATIONAL ACTIVITIES. 1973. Threatened Wildlife of the United States. U. S. Government Printing Office. Washington, D. C.

UNITED STATES CONGRESS. 1973. Public Law 93-205, 93rd Congress, S. 1983, December 28, 1973. U. S. Government Printing Office. Washington, D. C.

Florida Sci. 41(2):65-76. 1978.

Social Sciences

PACIFISM AND RELIGION: AN ALTERNATIVE HYPOTHESIS

ROGER HANDBERG, JR.

Department of Political Science, Florida Technological University, Orlando, Florida 32816

ABSTRACT: *In contrast to earlier studies which examined the relationships among pacifism, religious affiliation and partisanship, a pattern was found whereby partisanship, rather than religious affiliation, dominated attitudes toward pacifism. This appears explainable in terms of the political party occupying the presidency and not religious doctrine.**

PACIFISM is widely assumed to be tied closely to an individual's religious affiliation. However, for the general public, attitudes toward pacifism are better explained by an individual's partisan affiliation than by his religious affiliation. John Mueller (1973) has argued that in periods of undeclared war, foreign policy issues are so complex and confusing that the public takes its position on foreign policy from three cue sources: the position of the president, the position of the party leaders, and the content of the issue itself. Since the first two sources are the easiest to identify, most salient cues come from them, although the positions of the politicians and parties may not be entirely unambiguous.

The best example of issue ambiguity was found during the Vietnam War among Democratic Party notables. While Lyndon Johnson (Democrat) was president, they felt constrained to support his policies or at least mute their opposition. After Johnson's retirement from office the majority of the leading Democratic Party figures made public their opposition to the War in Vietnam. Once Nixon (Republican) was in office, the War was considered to be his responsibility.

Earlier evidence dealing with linkages between religiosity and attitudes toward the Vietnam War suggests an inverse relationship, that is: the higher the level of religiosity, the lower the level of opposition to the war (Granberg and Campbell, 1973). This relationship was explained as reflecting the integration of the mainstream religious groups into the society. This integration is assumed to imply acceptance of the basic societal structure and, by implication, the general policy trend of the government. The differences in level of war support found were explainable in terms of nonmainstream religious affiliation, i.e. Jew, Quaker, or nonaffiliation with organized religion as, for example, Witchcraft, Agnostic (Granberg and Campbell, 1973). An untested part of the argument presented here is that religious pronouncements on the issue of war or pacifism are of low salience to the public because the sources of such religious pronouncements are not seen as important in secular matters such as foreign policy. Re-

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

ligious pronouncements and teachings reinforced by various religious activities may provide an alternative value set but, in the area of foreign policy, the pressure to be a "realist" overrides those cues on moral preferences. Often, many of the cues coming from various authority figures within the same church are ambiguous and conflicting—especially in deciding whether or not the particular war is justified.

This lack of clarity in church position is illustrated graphically by the institution of the military chaplain whose explicit military duty is to maintain morale among the troops and, by extension, justify the activities being carried out by the military and the state. The chaplain, as a commissioned officer, is of the system and not an independent actor. For example, there are no reported cases of military chaplains (especially those on active duty) protesting or denouncing the war in Vietnam. This omission is notable given the vast media coverage devoted to other anitwar dissenters in the military. The chaplain as an intermediary for the soldier church attender may nullify the impact of statements made by other more remote religious authorities. For the individual soldier who may have been opposed to the war, the sources of information became not the chaplain but political figures who held positions of authority or visibility. The civilian clergy engaged in public protest lacked the ability to make a positive impact on the soldier, because they were perceived as "just dissidents." In this context, the political figures had more legitimacy due to their official positions (Quinley, 1970).

The argument being advanced is not an all inclusive one—we do not assume that all people use cues based only on their party's policy positions. Significant, though relatively small, groups do use their religious values as a basis for decisions about such issues. What is being presented is an expansion of the relationship between religious attitudes/affiliation and attitudes toward war to include a secular element—partisanship (Campbell, 1960).

METHOD—This study is a partial replication of two earlier studies of student pacifism. The first, done by Putney and Middleton, encompassed 16 universities and colleges in four geographic regions. The focus here is upon students at five state universities drawn from Florida, New York, Michigan, and Delaware. (A 1972-73 study by Handberg used only two schools in Florida.) In all three samples, the survey was conducted by means of anonymous self-administered questionnaires.

The pacifism scale was developed as an attempt to assess "the extent of antiwar sentiment among American college and university students" (Putney and Middleton, 1962). The students surveyed in 1972 and 1973 were decidedly more pacifist in their orientation than the 1962 group (Handberg, 1977). This shows most clearly in their responses to questions relating to unilateral disarmament and the killing of other individuals. In 1962, only 6% were willing to advocate unilateral disarmament as opposed to 36% in 1973. In 1973 55% espoused moral pacifism as regards killing compared to 17% in the earlier group. One of the axioms of American foreign policy has been the possibility of war in order to deter or defeat communism and its adherents. This policy position is now acceptable to only a minority (25%). Instead, war as an institution is now deemed a greater enemy than communism (65%).

Although the right to demonstrate in a peaceful manner is guaranteed by the first Amendment to the Constitution, politically this right has been controversial in relation to antiwar demonstrations. Nearly half of the 1962 group saw pacifist demonstrations as harmful compared to only 12% in the 1973 sample. However, in assessing pacifism in the context of reality, over one-third in 1973 felt pacifism is not a practical operating code. Pacifism may not be perceived as always practical, but is thought to be a possibility. Such a realization is important in assessing the validity of these responses. We asked hypothetical questions unsubstantiated by observable actions, along with operating at a fairly high level of abstraction (i.e. the nation state in its relations with others). The importance is that, with the exception of acts of obvious national self-defense, Vietnam may have generated an aversion to the use of force in American foreign policy. Differences between the sexes in terms of response patterns were minor with the major variation being between the two time periods (the 1962 group versus the 1973 group). The 1973 sample was consistently more pacifistic in orientation. Whereas males previously had been relative advocates of war, pacifistic sentiments were now equally attributable to males and to females.

When one examines the pattern of partisan affiliation controlling for religious affiliation, a clear pattern emerges with the Protestants being significantly more Republican than any other group (Data are obtainable from the author). This affiliation pattern is typical of the nation as a whole with the Democratic Party being most attractive to the nonprotestant minority religious churches (regardless of actual size). Because many people use their partisan affiliation as an important cue, the differences that occur in Table 1A become more clear (Campbell, 1960; Pomper, 1975).

Protestants as a group are least pacifist in their orientation. This reflects not

TABLE 1. Pacifism by religious affiliation and by partisanship.

A. RELIGION	Pacifist	Bellicose	N
Protestant	41.6%	58.4	113
Catholic	54.1%	45.9	85
Jew	65.2%	34.8	23
Other	72.2%	27.8	79
Non Christian	60.0%	40	20
	177	143	320

[1] $x^2 = 97.0$, df $= 4$, p .001

B. PARTISANSHIP[2]			
Republican	40.0%	60.0%	73
Democrat	72.0	28.0	145
Independent	72.0	28.0	102

[2] $x^2 = 25.06$, df $= 2$, p .001

that Protestantism is inherently more warlike than other religious groups but that their political party was (in 1973) responsible for the conduct of the Vietnam War. Vietnam and the possibility of nuclear war were now issues the Republicans were responsible for handling. The relationship between partisanship and nonpacifism shows up in Table 1B where the Republicans constitute the major portion of what are termed the bellicose. What occurs is that the Republicans stand out disproportionately in their support of war as a policy instrument, Table 2.

TABLE 2. Religious affiliation by pacifism controlling for party affiliation.

	Republican		Democrat		Independent	
	Pacifist	Bellicose	Pacifist	Bellicose	Pacifist	Bellicose
Protestant	48.7%	51.3	65.9%	34.1	75.0%	25.0
Catholic	53.3%	46.7	77.8%	22.2	73.3%	26.7
Jew	-0-	100	92.9%	7.1	80.0%	20.0
Agnostic	61.5%	38.5	88.6%	11.4	100%	-0-
Non-Christian	-0-	100	100%	-0-	100%	-0-
	$x^2=3.6$		$x^2=11.3$		$x^2=11.0$	
	N.S.		$p < .05$		$p < .05$	

Secular affiliations in this case appear to determine one's general orientation toward war as a policy instrument. When the party affiliation of the church members is held constant, the relationship becomes even more clear. Those individuals who are Republicans tend toward a position of accepting war as a policy alternative. Democratic partisans and Independent-oriented individuals move in the opposite direction toward pacifism regardless of religious affiliation. In effect, partisanship for this sample appears to nullify differences that might occur on the basis of religious preference. Unfortunately, our data do not allow a breakdown by specific religious affiliation which might more clearly have isolated particular sectarian beliefs. Given the ambiguity of many churches' positions on war in general, and the Vietnam War in particular (until near the end), reliance on cues other than religion is not unexpected. One must note that this partisanship cue is possibly a time-bound one since in the early 1960's, for example, the partisan differences on Cold War strategy were minimal, if not insignificant, especially in espoused policy positions.

CONCLUSION—We are not assuming that religion does not have any impact on attitudes about war; rather that the relationship between religion and pacifism is an indirect one with partisan affiliation being the intermediary variable. In fact, this particular formulation is congruent with the Granberg and Campbell study since, at the time of their study, the religious groups most antiwar in sentiment were also the most likely to be affiliated with the Democratic party.

In reference to attitudes on war, the relationship of religious and political cues may be two-fold. One situation exists where religious and political cues are congruent, and another where one set of cues (either religious or political) does not deal directly with the issue of war. For example, a number of churches did not espouse any authoritative position on the Vietnam War, but rather left it to the individual's conscience.

The relationship between religious affiliation and one's views about war is complex and multilevel. It appears that the political system, through its various mediating agents (such as political parties), is able to generate support for activities such as war. In fact, these support mechanism are able to override many objections based on religious doctrine. This is primarily because many policy statements by churches are perceived as either unrealistic or just not perceived at all. A long cultural tradition has emphasized obedience to both the state and the church except in the rarest of instances. Therefore, the acts of religiously motivated individuals who protested the Vietnam War were seen as radical attacks on the entire social/political system because these attacks on the war were part of a general critique of American society in terms of racism, poverty, and social injustice. This radicalism made their policy positions on the Vietnam War suspect to the more conventional members of society. Many clergy were uncomfortable with United States' military involvement but felt constrained about speaking out. Initially, this restraint was grounded in a general fear of controversy and an avoidance of the appearance of interfering in politics. This fear of political interference was especially potent in the early war years when such an issue was seen as distant from the immediate concerns of the congregations. This deference left the political institutions the opportunity for maximum impact on the policy attitudes of the public. Later policy pronouncements by religious leaders on the morality and justification for the Vietnam War fell on deaf ears. Religion and the values it taught were not irrelevant, rather other secular forces intervened to reduce religion's independent effects.

Acknowledgments: The author expresses his appreciation to Irene Handberg and Robert Bledsoe for their assistance in the revision process. Copies of the tables comparing the 1962 and 1973 samples are available upon request from the author.

LITERATURE CITED

Campbell, A., P. E. Converse, W. E. Miller, and D. E. Stokes. 1960. The American Voter. John Wiley & Sons. New York.

Granberg, D., and K. Campbell. 1973. Certain aspects of religiosity and orientations toward the vietnam war among Missouri undergraduates. Sociolog. Anal. 34:40-49.

Handberg, R. B., Jr. 1977. College students and pacifism: an historical note. College Stud. J. 11:204-206.

———. 1972-1973. The 'Vietnam Analogy:' student attitudes on war. Public Opinion Quart. 36:612-615.

Mueller, J. E. 1973. War, Presidents and Public Opinion. John Wiley & Sons. New York.

Pomper, G. 1975. Voter's Choice. Dodd, Mead & Company. New York.

Putney, S., and R. Middleton. 1962. Some factors associated with student acceptance or rejection of war. Amer. Sociolog. Rev. 27:655-667.

Quinley, H. 1970. The protestant clergy and the war in Vietnam. Public Opinion Quart. 34:43-52.

Florida Sci. 41(2):77-81. 1978.

Earth Sciences

SOILS OF THE INTER-TIDAL MARSHES OF DIXIE COUNTY, FLORIDA

C. L. Coultas

Department of Soil Science, Florida A & M University, Tallahassee, Florida 32307

Abstract: *Psammaquents occur in lower marsh and Haplaquods in the upper marsh sites. Sulfaquents were found at the mouth of the Suwannee River.**

Tidal marshes perform many functions that are valuable to man. They are important in the propagation and development of marine organisms (Subrahmanyam and Drake, 1975; Subrahmanyam, Kruczynski and Drake, 1976). They provide protection from erosion by the sea. They are valuable as habitat for wading birds and waterfowl and to many people they are aesthetically pleasing. Gosselink, Odum, and Pope (1973) calculated a fishery dependent on the *Spartina* marshes in Georgia to be worth $247 per ha annually. There are approximately 200,309 ha of tidal marsh in Florida (Coastal Coord. Council, 1973).

Soils of tidal marshes of the Gulf Coast are very diverse. For example, extensive areas of peats, mucks, and clays were found by Lytle and Driskell (1954) in the saline marshes of Louisiana. In a study of marshes of Wakulla County, Florida, Coultas (1969, 1970) found four great groups of soils: Haplaquods, Psammaquents, Natraqualfs and Ochraqualfs (Soil Survey Staff, 1975). In addition, Coultas and Gross (1975) and Coultas and Calhoun (1976), found Sulfaquents and Sulfihemists in Taylor and Hernando Counties. These soils were saline, predominantly sandy in texture, and shallow over limestone.

Many soils of the tidal marsh contain high levels of sulfur (Fleming and Alexander, 1961). Draining these soils produced pH values that ranged from 3 to 4, which was 2 to 3 pH units lower than under field conditions. This high acidity may be inhibitive to development of much of the potential flora and fauna of the marsh.

Tidal marshes and estuaries are attractive for many kinds of economic development. Pressure for space on which to locate homes, marinas, and industrial plants in close proximity to the land-ocean interface continues to mount. Agriculture and mariculture have also made use of the tidal marshes. The objective of this research was to provide soil information within this eco-system to permit more intelligent use of this valuable natural resource.

Factors Affecting Soil Formation—Location of the study is shown in Fig. 1. The climate is humid and temperate. Rainfall averages 139.2 cm (54.8 in) per yr and the mean annual air temperature is 21°C (69.2°F) (warmest month,

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

27.5°C, coldest month, 13.3°C) (U.S. Dept. of Commerce, 1973). The predominant vegetation of tidal marshes in Florida is *Juncus roemerianus* Scheele. *Spartina alterniflora* Loisel usually occurs at lower elevations and *Distichlis spicata* L. Green, *Batis maritima* L. with *Salicornia virginica* L. at higher elevations. Slope throughout the tidal marsh is less than 1% except for abrupt 3 to

FIG. 1. Location of Dixie County, Florida.

5% slopes at the boundaries of marsh and sea and marsh and upland. The soils were formed in sandy marine sediments of the Silver Bluff Formation (Cooke, 1945). Coultas (1969) determined that most marine sediments in the marshes of Wakulla County, Florida were deposited within the past 5,000 years. In Dixie County these sediments are usually 1 – 2 m thick and rest on Crystal River and Williston Formations (Puri and Vernon, 1964).

Elevation differs as much as 1.5 m from the lowest to the highest parts of the marsh. These tidal marshes are subject to mixed tides, usually two high and low tides per day, with 30 - 90 cm amplitudes. A dense and well developed stream system makes rapid flooding and draining of large areas of land possible. Even though water in the streams flows upstream on flood tide and downstream on ebb tide, the erosional and depositional processes that lead to stream meandering appear similar to freshwater upland streams. The streams are dynamic transport systems carrying both dissolved and suspended materials to and from the tidal marsh.

The soils of the marshes were examined along several transects in the vicinity of Rocky Creek, Horseshoe Beach, and on several islands at the mouth of the Suwannee River. Principal soils were described and sampled according to procedures outlined in the Soil Survey Manual (Soil Survey Staff, 1951). A detailed soil map for approximately 2.6 km^2 was prepared for the Rocky Creek and Horseshoe Beach area.

The following laboratory determinations were performed on all horizons: pH, particle size, electrical conductivity (ec), organic carbon (C), total nitrogen (N), cation exchange capacity (CEC) and extractable cations. Total sulfur (S) was determined on selected horizons and pH was measured with a glass electrode on 1:1 soil to water suspensions as outlined by Jackson (1958). The hydrometer method was employed to determine particle size distribution (Bouyoucos, 1962); the Walkley-Black method described by Allison (1965) was used to determine organic C; total N was determined by the modified Kjeldahl method (Bremner, 1965); saturated soil extract was used to determine electrical conductivity (U.S. Salinity Lab. Staff, 1954). Cation exchange capacities were determined and extractable cations extracted with 1 N ammonium acetate (Jackson, 1958) after first leaching the soil with 40% ethanol until all chloride ions had been removed. A Beckman model DU spectrophotometer and a model 303 Perkins Elmer atomic absorption unit were used to determine Na, K, Ca, and Mg. Total S was determined with a Leco Analyzer (model 532) employing antimony and sodium azide to eliminate interference (Tiedman and Anderson, 1971).

Marsh Soils and Their Geographic Distribution—Soils of the marsh have been subjected to considerable mixing as indicated by the variety of soil colors and the presence of krotovinas of several species of crabs. Mixing and stratification also resulted from erosion and sedimentation initiated by high tides, storms, and the rise of sea level. Evidence of these processes occurs in other counties along the Gulf Coast where recent sandy sediments cap older truncated spodic horizons and in profiles where large amounts of wood are found beneath 1 to 2 m of recent sediments (Coultas and Gross, 1975).

Psammaquents and Haplaquods occur extensively in the tidal marshes near Rocky Creek and Horseshoe Beach (Fig. 2). Psammaquents occur in the lower marsh and Haplaquods are found in an upper marsh position. These soils are similar to Psammaquents and Haplaquods of Taylor County (Coultas and Gross, 1975) except that the soils near Rocky Creek are shallower over limestone.

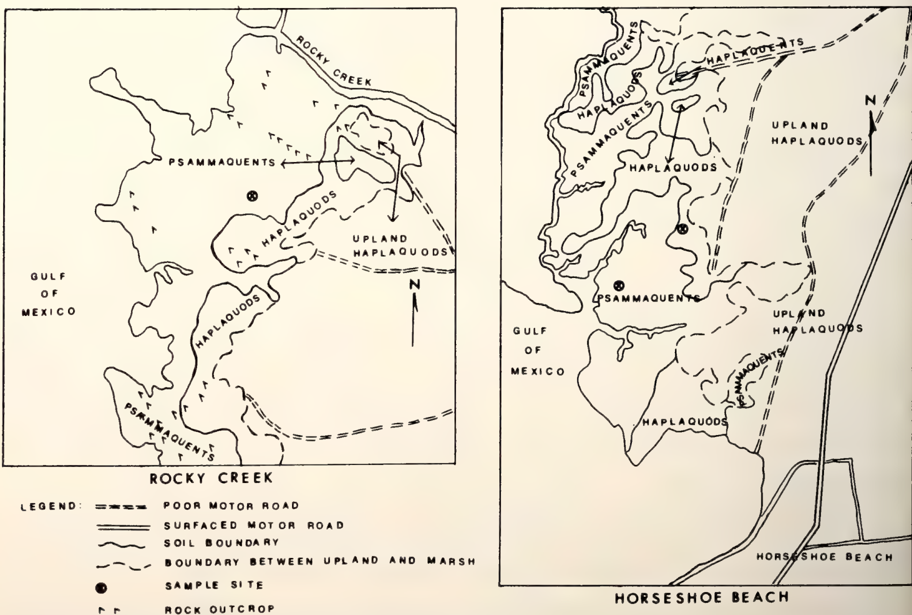


Fig. 2. Soils of the tidal marshes near Rocky Creek and Horseshoe Beach.

The Haplaquod near Horseshoe Beach is characterized as follows:

VEGETATION: *Juncus roemerianus,* dense growth with sand barrens nearby.
LOCATION: NW 1/4, Sec. 11, T12S, R10E

HORIZON	DEPTH, cm	DESCRIPTION
A1	0-12	Very dark gray (10YR 3/1) mixed with grayish-brown (10YR 5/2) loamy sand; single grain; slightly sticky; many roots and rhizomes; neutral; clear wavy boundary.
A2	12-40	Light brownish-gray (10YR 6/2) sand with distinct dark gray mottles; single grain; non-sticky; many roots; neutral; abrupt wavy boundary.
B21h	40-58	Black (5YR 2/1) sand with prominent grayish-brown mottles; massive; slightly sticky; common roots; neutral; gradual wavy boundary.
B22h	58-100	Dark brown (7.5YR 3/2) sand; single grain; non-sticky; common roots; neutral; gradual wavy boundary.
C1	100-140	Brown (10YR 5/3) sand; single grain; non-sticky; few roots; neutral; gradual wavy boundary.
C2	140-180	Pale brown (10YR 6/3) sand; single grain; non-sticky; few roots; neutral.

The Psammaquent near Horseshoe Beach is sandy textured throughout the profile as seen by the following:

VEGETATION: *Spartina alterniflora* and *Juncus roemerianus* evenly mixed.
LOCATION: NW 1/4, Sec. 11, T12S, R10E

HORIZON	DEPTH, cm	DESCRIPTION
A11	0-4	Very dark gray (10YR 3/1) loamy sand; massive; sticky; neutral; abrupt smooth boundary.
A12	4-18	Dark grayish-brown (7.5YR 4/1) and brown (7.5YR 5/2) sand; single grain; non-sticky; many roots and rhizomes; slightly acid; clear wavy boundary.
A13	18-40	Very dark gray (10YR 3/1) mixed with grayish-brown (10YR 5/2) sand; single grain; non-sticky; many roots; neutral; gradual wavy boundary.
A14	40-60	Dark gray (10YR 4/1) and grayish-brown (10YR 5/2) sand; single grain; non-sticky; many roots; medium acid; clear wavy boundary.
C1	60-84	Dark grayish-brown (10YR 4/2) sand; single grain; non-sticky; medium acid; few roots; gradual wavy boundary.
C2	84-110	Dark grayish-brown (10YR 4/2) sand; single grain; non-sticky; slightly acid; gradual wavy boundary.
C3	110-180	Brown (10YR 5/3) sand: single grain; non-sticky; neutral.

Sulfaquents are the dominant soils on the tidal islands at the mouth of the Suwannee River; description of a typical pedon follows:

VEGETATION: Needle rush (*Juncus roemerianus*) predominated, also 10% *Distichlis spicata.*
LOCATION: SE 1/4, SE 1/4, Sec. 23, T13S. R11E

Horizon	Depth, cm	Description
A11	0-2	Very dark gray (10YR 3/1) clay loam; massive; sticky; few roots; slightly acid; abrupt smooth boundary.
A12	2-30	Very dark gray (5YR 3/1) very fine sandy loam; massive; sticky; many roots and rhizomes; neutral; gradual smooth boundary.
A13	30-64	Very dark gray (10YR 3/1) very fine sandy loam; massive; sticky; common roots; slightly acid; gradual smooth boundary.
A14g	64-109	Dark olive-gray (5Y 2.5/2) sandy loam; massive; slightly sticky; common dead roots; neutral; gradual smooth boundary.
A15g	109-145	Dark olive-gray (5Y 2.5/2) sand; single grain; slightly sticky; few roots; neutral; clear smooth boundary.
C1	145-175	Dark grayish-brown (10YR 4/2) sand with faint dark gray mottles; single grain; slightly sticky; rare roots; neutral; gradual smooth boundary.
C2	175-203	Gray (10YR 5/1) sand; single grain; slightly sticky; neutral.

Some physical and chemical properties of the Haplaquod, Psammaquent, and Sulfaquent are shown in Tables 1 and 2. Soil reaction was near neutral under field conditions but dropped 0.5 - 3 units in most horizons upon drying. This was probably due to the oxidation of S and S compounds. Electrical conductivity indicates the high salt content of these soils. Calcium and Mg were the principal cations and Na was more abundant than K reflecting the composition of sea water. Cation exchange capacity was highest at the soil surface and decreased with depth except in the Haplaquod where it was highest in the spodic layer (Bh). Cation exchange capacity varied directly with organic C content. Sulfur was highest in the Sulfaquent ranging 0.23 - 1.43% in the upper 109 cm. Soil horizons containing $\geq$ 0.75% S in the upper 50 cm are classified as sulfidic (Soil Survey Staff, 1975). Haplaquod and Psammaquent do not contain sufficient S to be so classified.

Both the Haplaquod and the Psammaquent had loamy sand surfaces underlain by sand. The Sulfaquent, however, contained 5 - 39% clay in the A1 horizon and was clay loam at the surface. None of these marsh soils have a good load-bearing capacity as indicated by their high "n" values. An "n" value of ≥ 0.7 indicates poor capacity to support machinery or livestock (Soil Survey Staff, 1975). The Sulfaquent had a low bulk density ranging from 0.35 to 1.05 g/cc in the A1 horizon.

Small ares of a Haplaquent were found in the NW 1/2 Sec 11 near Horseshoe Beach. These soils were marly and are similar to those I have found near Ozello in Citrus County and in Hernando County (Coultas and Calhoun, 1976). These deposits occur in a high position in the marsh and were probably deposited during a lower sea level stand (H. K. Brooke, personal communication).

CONCLUSIONS—Soils occurring in the tidal marshes of Dixie County are diverse, but have many properties in common. The soils are saline and wet; limestone occurs within 0.5 - 2 m of the soil surface; they are near neutral in pH;

TABLE 1. Some physical and chemical properties of soils of the tidal marshes.

Horizon	Depth cm	pH (H_2O) Field Moist	pH (H_2O) Air Dried	Electrical Conductivity mmhos/cm	Extractable Cations meq/100g Ca	Mg	K	Na	CEC meq/100g	Total percentage N	Organic C	S
					Haplaquod, Horseshoe Beach							
A1	0-12	7.2	6.0	12	1.8	3.5	0.2	0.5	4.2	0.07	1.92	0.06
A2	12-40	7.2	6.2	14	1.2	1.3	0.1	0.2	1.4	0.04	0.77	0.03
B21h	40-58	7.1	6.3	12	2.4	3.2	0.1	0.5	4.9	0.06	2.07	0.04
B22h	58-100	7.1	6.2	6	1.6	2.8	0.2	0.4	3.4	0.04	0.66	0.03
C1	100-140	6.9	6.5	6	0.6	0.7	0.1	0.1	2.0	0.02	0.51	0.05
C2	140-180	6.9	6.4	8	0.6	0.9	0.1	0.1	1.5	0.01	0.24	—
					Psammaquent, Horseshoe Beach							
A11	0-4	7.2	6.8	18	10.5	23.3	0.8	4.2	27.1	0.63	7.09	0.52
A12	4-18	6.2	5.0	34	3.1	7.8	0.3	1.5	10.1	0.22	1.95	—
A13	18-40	6.6	4.5	36	1.9	5.1	0.4	0.6	7.7	0.13	1.64	0.22
A14	40-60	6.0	3.4	28	0.8	4.1	0.1	0.2	2.4	0.07	1.00	—
C1	60-84	5.9	3.8	20	0.6	0.8	0.1	0.1	2.3	0.03	0.98	—
C2	84-110	6.5	4.1	17	0.5	0.8	0.1	0.1	1.9	0.03	0.54	0.14
C3	110-180	6.6	5.2	13	0.4	1.0	0.1	0.1	1.5	0.01	0.28	—
					Sulfaquent, Suwannee River Mouth							
A11	0-2	6.1	5.8	19	12.0	21.6	1.8	8.9	58.0	1.17	8.72	0.64
A12	2-30	6.6	5.5	24	6.3	10.7	1.2	3.2	24.8	0.42	5.55	0.23
A13	30-64	6.5	3.9	28	6.3	4.9	0.5	0.3	21.5	0.33	5.17	1.43
A14g	64-109	6.6	3.2	28	9.4	4.1	0.4	0.2	33.7	0.48	9.02	1.18
A15g	109-145	6.7	3.4	19	2.2	0.7	0.1	0.2	7.1	0.09	2.44	—
C1	145-175	6.8	4.2	14	0.7	0.4	0.0	0.1	2.1	0.02	0.63	—
C2	175-203	7.1	6.1	11	0.4	0.6	0.1	0.1	1.2	0.01	0.26	—

TABLE 2. Particle size analysis and "n" value of soils of the tidal marsh.

Horizon	Depth cm	Percentages of V. Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	V. Fine Sand	Silt	Clay	Texture[a]	"n" Value
					Haplaquod, Horseshoe Beach					
A1	0-12	0.9	24.2	35.9	15.7	1.0	19.8	2.3	ls	2.1
A2	12-40	0.7	34.1	41.8	20.6	0.9	0.2	0.9	s	1.4
B21h	40-58	0.7	22.0	45.6	28.0	0.7	1.9	0.9	s	1.3
B22h	58-100	0.6	20.3	47.9	27.7	0.6	0.3	2.6	s	0.7
C1	100-140	0.6	21.0	47.6	26.9	0.5	1.0	2.3	s	0.4
C2	140-180	0.6	21.4	46.9	26.9	0.5	0.2	3.6	s	0.5
					Psammaquent, Horseshoe Beach					
A11	0-4	0.8	17.9	32.9	27.3	2.3	8.9	9.9	ls	3.7
A12	4-18	1.0	21.6	37.0	30.9	1.7	4.0	3.8	s	5.2
A13	18-40	1.0	21.8	36.3	31.6	2.7	2.7	3.9	s	3.4
A14	40-60	0.9	23.3	38.4	32.4	1.9	0.6	2.5	s	1.5
C1	60-84	0.7	26.1	35.3	33.3	1.2	0.3	3.0	s	0.5
C2	84-110	1.0	23.1	37.8	33.0	1.2	0.9	3.0	s	0.3
C3	110-180	1.1	20.2	41.1	32.6	1.1	1.3	2.4	s	0.1
					Sulfaquent, Suwannee River Mouth					
A11	0-2	0.2	1.4	4.6	11.0	17.6	26.2	39.0	cl	3.8
A12	2-30	0.0	1.5	5.0	19.3	38.7	17.3	18.2	vfsl	3.2
A13	30-64	0.0	0.4	1.7	1.8	59.1	23.9	13.1	vfsl	3.3
A14g	64-109	0.2	4.8	11.7	15.9	20.8	35.0	11.6	sl	5.4
A15g	109-145	0.6	7.1	32.6	3.0	46.1	5.6	5.0	s	2.8
C1	145-175	0.7	10.5	39.2	12.0	32.8	3.1	1.7	s	1.5
C2	175-203	1.1	11.3	38.1	15.7	30.4	1.1	2.3	s	1.5

[a] ls—loamy sand; s—sand; cl—clay loam; vfsl—very fine sand loam; sl—sandy loam.

and a high cation exchange capacity exists at or near the surface. Organic matter and clays are concentrated at the surface resulting in high CEC and in the soil's ability to remove bases from the tidal waters. Soils with the highest organic matter and clay content usually occur at the lower elevations in the marsh. These soils are highest in sulfur content and lowest in load-bearing capacity. Marsh soils at higher elevations are often related to the adjoining uplands soils, differing primarily by higher pH, organic matter content, and salt levels. These soils have been described as "drowned" upland soils (Coover, Bartelli and Lynn, 1975).

Sulfaquents contain high levels of S and have thick dark surface horizons which contain high amounts of organic matter. Upon drainage, the S will be oxidized to sulfuric acid resulting in an extremely acid, toxic environment for most organisms. Sulfaquents occur at low elevations and have a low load-bearing capacity. Psammaquents are sandy soils that occur at all elevations in the marsh. Haplaquods are soils with a subsurface accumulation of organic C (spodic horizon). These soils are sandy and occur in a relatively high position in the marsh.

Haplaquents are developed in recent thin deposits of marly material at a high position in the marsh.

These soils perform many functions that are valuable to man. They support a dense and productive vegetation principally of *Juncus roemerianus* and *Spartina alterniflora*. Vegetation stabilizes the soil, protecting it from erosion and provides a large food base for fish consumption (Kruczynski, Subrahmanyam and Drake, 1978). Marsh soils offer many hazards for engineering manipulation—high corrosion potential, low load-bearing capacity, and extreme wetness. Man should consider carefully the "free" services performed by this system before tampering seriously with it.

Acknowledgments—This research was supported in part by a grant from the Cooperative State Research Services (USDA), grant no. 416-15-15.

LITERATURE CITED

Allison, L. E. 1965. Organic carbon. Pp. 1367-1378. In C. A. Black (ed.). Methods of Soil Analysis. Part 2. Agronomy 9. Amer. Soc. Agron. Madison.

Bouyoucos, G. J. 1962. Hydrometer method improved for making particle size analysis of soils. Agron. J. 54:464-465.

Bremner, J. M. 1965. Total nitrogen. Pp. 1149-1178. In C. A. Black (ed.). Methods of Soil Analysis. Part 2. Agron. 9 Amer. Soc. Agron. Madison.

Coastal Coordinating Council. 1973. Statistical Inventory of Key Biophysical Elements in Florida's Coastal Zone. Florida Dept. Nat. Resources. Tallahassee.

Cooke, C. W. 1945. Geology of Florida. Florida Geol. Surv. Bull. 29:1-399.

Coover J. R., L. J. Bartelli and W. C. Lynn. 1975. Application of soil taxonomy in tidal areas of Southeastern United States. Soil Sci. Soc. Amer. Proc. 39:703-706.

Coultas, C. L. 1969. Some saline marsh soils in North Florida: Part 1. Soil Crop Sci. Soc. Florida Proc. 29:111-123.

__________. 1970. Some saline marsh soils in North Florida: Part 2. Soil Crop Sci. Soc. Florida Proc. 30:275-282.

__________, and F. G. Calhoun. 1976. Properties of some tidal marsh soils of Florida. Soil Sci. Soc. Amer. J. 40:72-76.

__________, and E. R. Gross. 1975. Distribution and properties of some tidal marsh soils of Apalachee, Florida. Soil Sci. Soc. Amer. Proc. 39:914-919.

FLEMING, J. F., AND L. T. ALEXANDER. 1961. Sulfur acidity in South Carolina tidal marsh soils. Soil Sci. Soc. Amer. Proc. 25:94-95.

GOSSELINK, J. G., E. P. ODUM AND W. M. POPE. 1973. The Value of the Tidal Marsh. Urban and Regional Development Center Work Paper no. 3. Gainesville.

JACKSON, M. L. 1958. Soil Chemical Analysis. Prentice-Hall. Englewood Cliffs.

KRUCZYNSKI, W. L., C. B. SUBRAHMANYAM AND S. H. DRAKE. 1978. Studies on the plant communities of a North Florida salt marsh. Part 1. Primary production. Bull. Marine Sci. 28:*in press.*

LYTLE, S. A., AND B. N. DRISCOLL. 1954. Physical and chemical characteristics of the peats, mucks, and clays of the coastal marsh area of the St. Mary Parish, Louisiana, La. State Univ. Bull. No. 484. Baton Rouge.

PURI, H. S., AND R. O. VERNON. 1964. Summary of the geology of Florida and a guide-book to the classic exposures. Florida Geol. Surv. Spec. Publ. 5:

SOIL SURVEY STAFF. 1951. Soil Survey Manual. USDA Handbook No. 18. Washington, D. C.

__________. 1975. Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Soil Conservation Service. USDA Handbook No. 436. Washington, D. C.

SUBRAHMANYAM, C. B., AND S. H. DRAKE. 1975. Studies on the animal communities in two north Florida salt marshes. Part 1. Fish communities. Bull. Marine Sci. 25:445-465.

__________, W. L. KRUCZYNSKI AND S. H. DRAKE. 1976. Studies on the animal communities in two north Florida salt marshes. Part 2. Macroinvertebrate communities. Bull. Marine Sci. 26:172-195.

TIEDMANN, A. R., AND T. D. ANDERSON. 1971. Rapid analysis of total suplhur in soils and plant material. Plant and Soils 35:197-200.

U.S. DEPT. OF COMMERCE. 1973. Monthly averages of temperature and precipitation for state climatic divisions. 1941-70. Florida. Climatography of the U.S. No. 85. Nat. Climatic Center. Asheville, N.C.

U.S. SALINITY LABORATORY STAFF. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handbook No. 60. Washington, D.C.

Florida Sci. 41(2):82-90. 1978.

Biological Sciences

SPECIES COMPOSITION AND DISTRIBUTION OF SEAGRASS BEDS IN THE INDIAN RIVER LAGOON, FLORIDA

M. JOHN THOMPSON

Remote Sensing Services Harbor Branch Foundation,
Ft. Pierce, Florida 33450

ABSTRACT: *Six species of seagrasses are found in the Indian River with* Syringodium filiforme *and* Halodule wrightii *being the most abundant.* S. filiforme *exhibits a disjunct distribution within the study area. Drift algae accumulations, difficult to distinguish from grassbeds by aerial photo-analysis alone, are extensive in some locations and apparently play an important role in the River's total ecosystem. Over the last 30 yr the Indian River has not experienced major seagrass bed losses documented in other estuaries.*[*]

ONE MAJOR recommendation of the 1973 International Seagrass Ecosystem Workshop (McRoy, 1973) was: "The productivity, standing crop, and distribution

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

of seagrasses should be studied on a regional and global scale using aerial photography and satellite imagery coupled with field measurement". Following this recommendation, the Harbor Branch Foundation has undertaken aerial monitoring of seagrass beds as part of its Indian River Coastal Zone Study. This report documents the location, aerial coverage, and species composition of major seagrass beds within the southern half of the Indian River Lagoon system.

METHODS—On 2 April 1976 an aerial photographic record was made of the Indian River from Merritt Island to St. Lucie Inlet (Fig. 1). A photomosaic

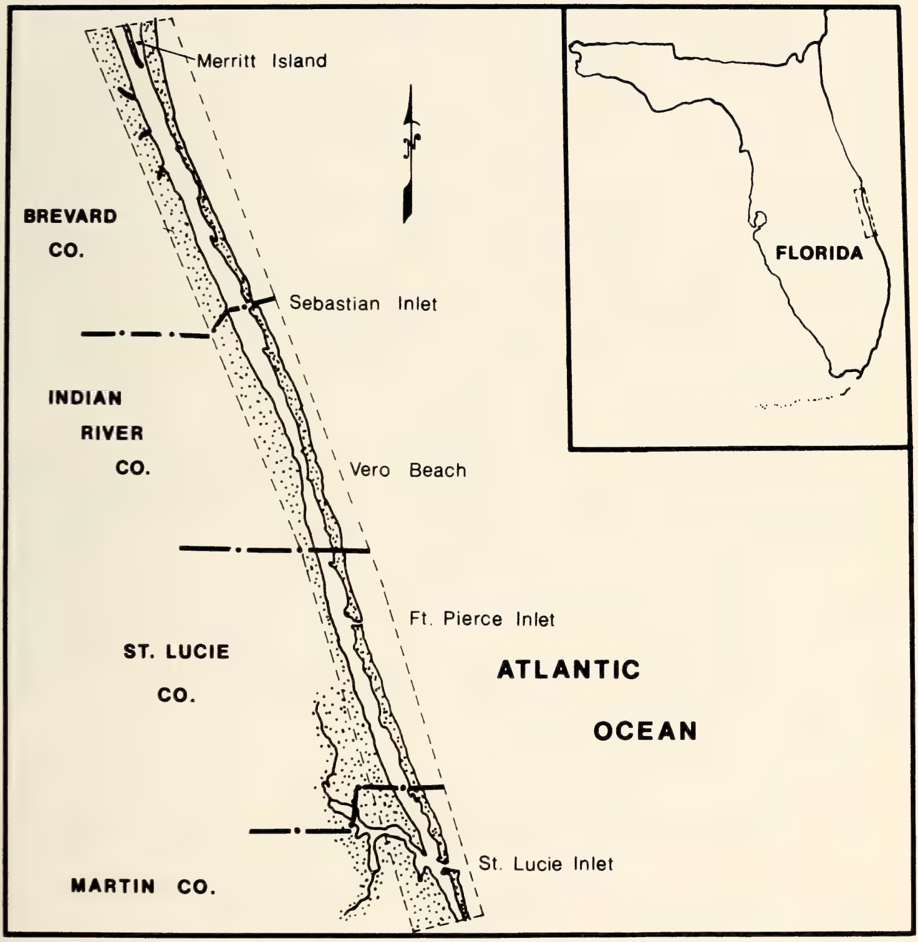


FIG. 1. The study area.

covering approximately 150,000 ha of river was constructed from the imagery. Maps of all shorelines and major seagrass beds were made from this mosaic. Aerial color transparencies and ground sampling verified map accuracy (Thompson, 1976). Scale on all imagery was 1:24000 or 1 cm = 240 m. A Wratten #3 filter was used with Kodak 2448 aerial color transparency film for the color imagery. Black and white imagery was obtained using Kodak 2405 aerial film without a filter.

In the color imagery the bottom could be resolved to 1.53 m water depth throughout most of the River, with good detail down to approximately 1.2 m. Resolution on black and white imagery exceeded 1.2 m in most locations.

Field sampling began in May and continued until mid-August of 1976. Eighty-one sites were investigated to verify submerged features seen in the photographs. Fifty-three additional stations located within mapped grassbeds were sampled. Plant species distribution and shoot abundance were measured by recording the species found at each meter mark along a 100 m transect line. Four such 100 m sampling transects, forming a square, were examined at each station yielding 400 data points per station.

Analysis of plant assemblages consisted of summing quantitative sampling records in blocks of 5 consecutive stations and applying community ordination procedures. Bray-Curtis (1957) similarity coefficients (C) were computed for each 5-station unit. Dissimilarity coefficients were computed as the difference between the similarity coefficient and a possible maximum value of one (1.00—C). In this ordination technique the x-axis length (L) is determined by the two most dissimilar assemblages. The y-axis length (L′) is determined by the assemblage showing the poorest fit on the x-axis ordination. Once this Cartesian plane has been defined, all other assemblages receive Cartesian coordinates based on their dissimilarity values (Beals, 1960). The result is a 2 dimensional plot illustrating the relationship among assemblages.

Results—Six species of seagrasses are reported from the Indian River Lagoon system: *Thalassia testudinum* Banks ex König and Sims, *Halodule wrightii* Ascherson, *Syringodium filiforme* Kützing, *Ruppia maritima* Linnaeus, *Halophila engelmanni* Ascherson, and one undescribed species of *Halophila* (Eiseman, 1975). The most common species are *Syringodium filiforme* and *Halodule wrightii*. *Thalassia testudinum* appeared in patches around St. Lucie Inlet and from Ft. Pierce Inlet to Vero Beach. All large concentrations of *Halophila* were near Ft. Pierce Inlet. *Ruppia maritima* was found only near Sebastian Inlet. Total floral coverage within the study area is 2,776 ha, or 2% of the River bottom (Table 1).

Between the Ft. Pierce Inlet and the southern tip of Merritt Island (Sta.

Table 1. Percent species composition and hectares of coverage of Indian River seagrasses.

Species	Percent composition	Hectare coverage
Thalassia testudinum	2.7	74.87
Halodule wrightii	46.2	1282.49
Syringodium filiforme	47.1	1307.18
Ruppia maritima	0.2	5.67
Halophila (all species)	3.0	83.37
Substrate attached algae[1]	0.8	22.26

[1]Drift and epiphytic algal populations were not quantified.

#21-50), *Syringodium filiforme* declined markedly from concentrations seen in other areas. From the southern tip of Merritt Island northward (Sta. #51-53), *S. filiforme* appeared again as numerically dominant in terms of numbers of erect shoots recorded (Fig. 2).

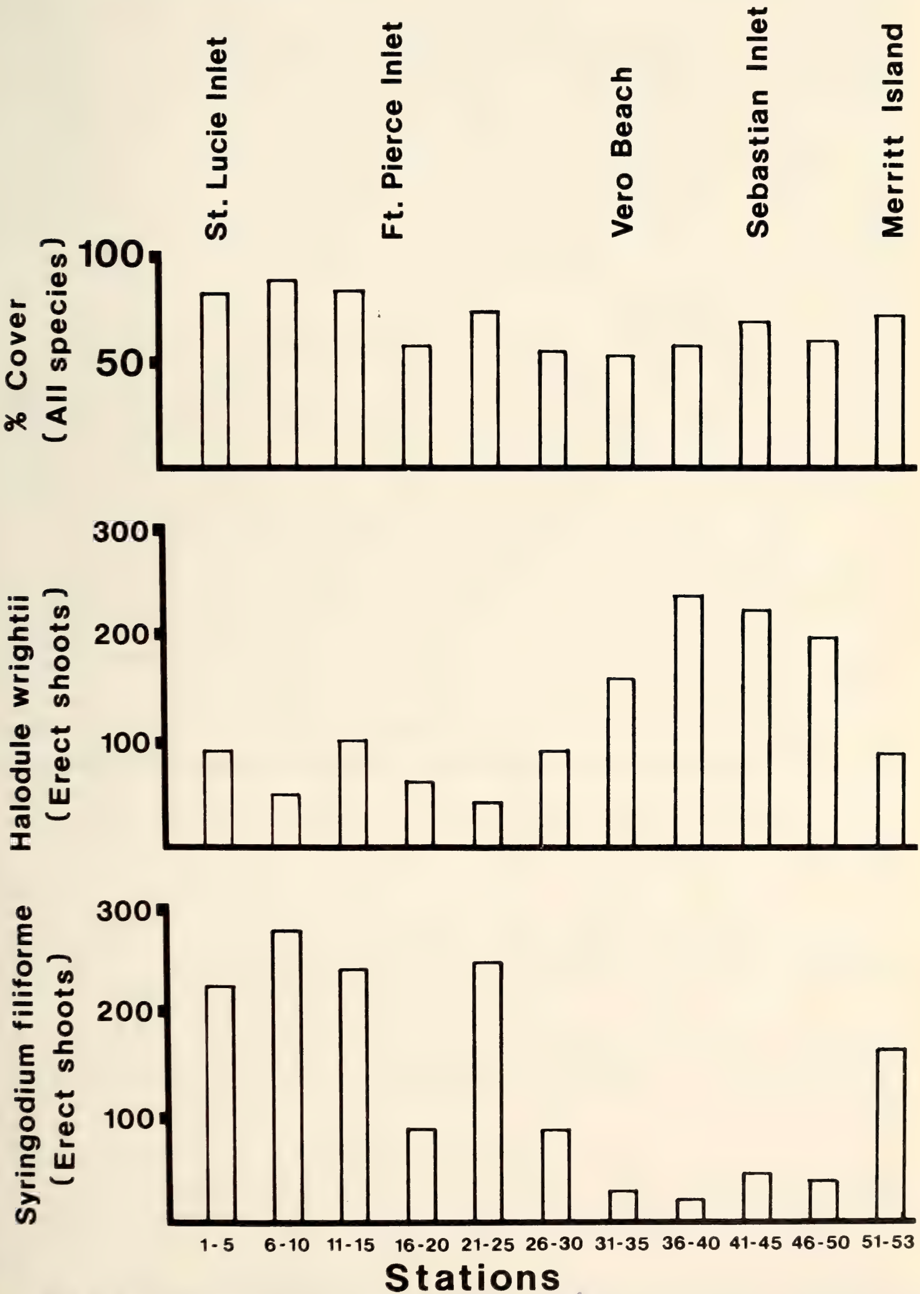


FIG. 2. Vegetative cover and the average number of erect shoots of *Syringodium filiforme* and *Halodule wrightii* per station related to station location within the Indian River.

Community ordination (Fig. 3) indicates a similarity between the seagrass beds around Merritt Island and those around St. Lucie. This similarity, as well as the numerical dominance of *Syringodium filiforme* at opposite ends of the

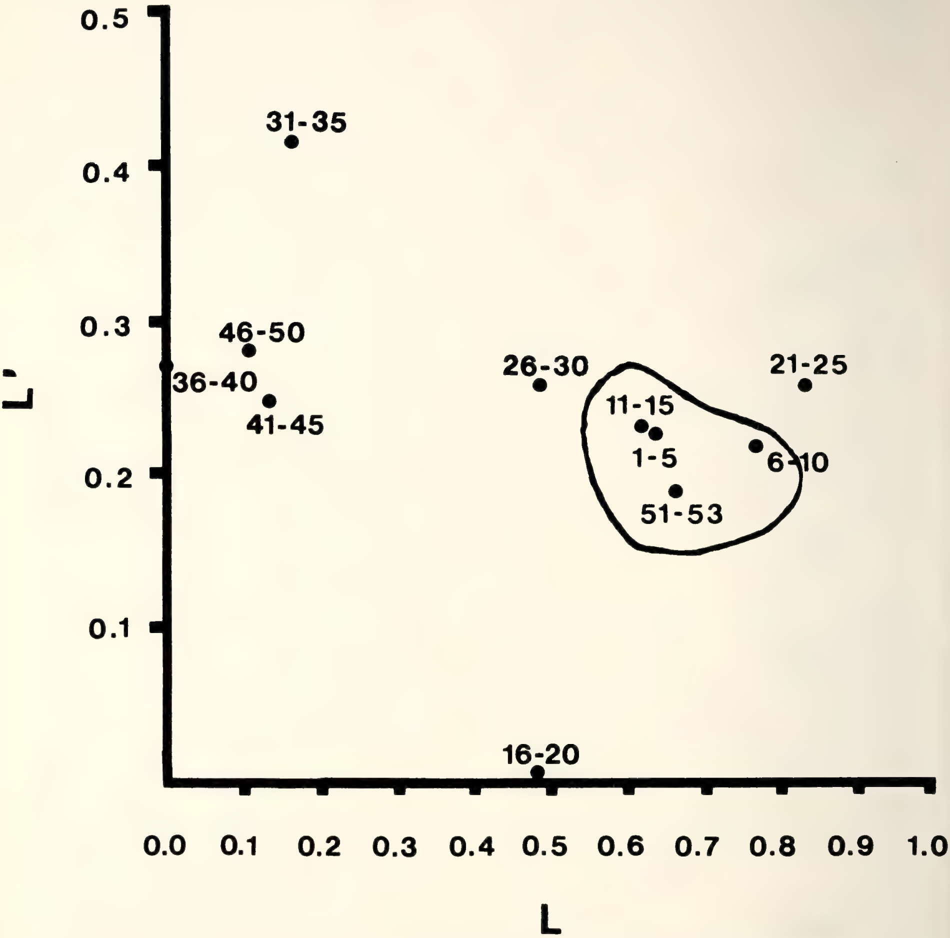


FIG. 3. Ordination plot of seagrass assemblages within the Indian River. Circled assemblages are dominated by *Syringodium filiforme*. Stations: 1-5, 6-10, 11-15 St. Lucie Inlet; 16-20, 26-30 Ft. Pierce Inlet; 31-35, 36-40 Vero Beach; 41-45, 46-50 Sebastian Inlet; 51-53 Merritt Island.

study area (Fig. 2), suggests that factors other than annual temperature regimes are responsible for the reduced abundance of *S. filiforme* between Ft. Pierce Inlet and Merritt Island.

South of Sebastian Inlet, aerial photo interpretation was complicated by large aggregations of drift algae. Selected areas south of Sebastian Inlet were re-photographed quarterly throughout 1976 to determine if measurable changes occurred in either the location or photographic appearance of these algal aggregations. Photographs and observations from these overflights confirmed that specific areas accumulate large quantities of drift algae, apparently as a result of water circulation patterns and bottom topography. There appeared to be little change in either location, outline, or photographic appearance of these algal accumulations during subsequent overflights through November 1976. A winter survey flight (27 January 1977), however, showed considerable reduction in the quantity of drift algae.

DISCUSSION—Aerial photographs of the River dating back to 1945 were reviewed to determine trends in seagrass coverage. Although periodic dredging for landfill and to maintain the Intracoastal Waterway has altered bottom topography in localized areas of the Indian River, no major grassbed losses could be detected when we compared the 1945 and 1954 aerial photos to our 1976 series. Over the past 30 yr, the Indian River apparently has not experienced major seagrass bed destruction such as occurred in the Chesapeake Bay (Orth and Gordon, 1975), the North Atlantic (Rasmussen, 1973), or Biscayne Bay (Wanless, 1976).

Depth or light level related seagrass zonation at the southern and northern ends of the study area corresponds with descriptions of seagrass zonation by Phillips (1960) for Florida west coast estuaries. *Halodule wrightii* dominates the intertidal or littoral zone. *Syringodium filiforme* and *Thalassia testudinum* (when present) occur in the sublittoral zone, and occasionally *H. wrightii* appears again in the deep sublittoral (Eiseman, 1974). This pattern is not seen in middle sections of the study area because of the absence of *S. filiforme*.

Changes in ambient salinities and turbidities are reported to shift seagrass bed species composition ratios in relatively short periods of time (Zimmerman, et al., 1971). Between Ft. Pierce Inlet and Merritt Island several major drainage canals, creeks, and rivers drain fresh water from both the St. John's drainage basin and irrigated agricultural land into the lagoon. *Syringodium filiforme* grows successfully in salinities of less than 25°/₀₀ (McMillan and Moseley, 1967), but reduced light levels caused by tannins in the freshwater runoff may be responsible for the decline of *S. filiforme* in this area.

Submerged features are seen in 1945 and 1954 photographs in or near areas of present day drift algal accumulation. Assuming these features to be drift algal accumulation would indicate that drift algae has been a significant feature in the estuary for at least the last 30 yr. The extent and persistence of large drift algal accumulations documented by aerial photographs in the study supports the suggestion that the drift algal community is an important part of the total ecosystem in the Indian River (Eiseman and Benz, 1975; Gilmore, 1976).

ACKNOWLEDGMENTS—I wish to express my appreciation to Drs. R. S. Jones, D. K. Young, R. Gore, and N. Eiseman for their editorial comments on this manuscript, and particularly to Mr. Tim Wolcott who supervised all ground truthing operations during this study. Contribution No. 095; Harbor Branch Foundation, Inc.

LITERATURE CITED

BEALS, E. 1960. Forest bird communities in the Apostle Islands of Wisconsin. Wilson Bull. 72:156-181.

BRAY, J. R., AND J. T. CURTIS. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27:325-349.

EISEMAN, N. J. 1974. Studies on the benthic and shoreline plants of the Indian River region. Pp. 256-292. *In*: Indian River Study Annual Report 1973-1974. Harbor Branch Found., Inc., Fort Pierce, Florida.

———. 1975. Studies on the benthic plants of the Indian River region. Pp. 89-103. *In*: Indian River Coastal Zone Study Second Annual Report 1974-1975. D. K. Young (ed). Harbor Branch Found., Inc., Fort Pierce, Florida.

———, AND M. C. BENZ. 1975. Marine algae of the Indian River. I. Species of the algal drift community collected from April 1974–April 1975. Tech. Rept. No. 1. Harbor Branch Found., Inc., Fort Pierce, Florida.

GILMORE, R. G. 1976. Studies of fishes of the Indian River lagoon and vicinity. Pp. 133-147. *In*: Indian River Coastal Zone Study Third Annual Report 1975-1976. D. K. Young (ed). Harbor Branch Found., Inc., Fort Pierce, Florida.

MCMILLAN, C., AND F. N. MOSELEY. 1967. Salinity tolerances of five marine spermatophytes of Redfish Bay, Texas. Ecology. 48:503-506.

MCROY, C. P. 1973. Seagrass ecosystem: Research recommendations of the international seagrass workshop, 22-26 October 1973. International Decade of Ocean Exploration, Natl. Sci. Found., Washington, D.C.

ORTH, R. J., AND H. GORDON. 1975. Remote sensing of submerged aquatic vegetation in the lower Chesapeake Bay. Final Report to NASA Langley Research Center, Contract NAS1-10720, p. 62.

PHILLIPS, R. C. 1960. Observations on the ecology and distribution of Florida seagrasses. Fl. St. Bd. Conserv. Mar. Lab. Prof. Pap. Ser. No. 2:1-72.

RASMUSSEN, E. 1973. Systematics and ecology of the Isefjord marine fauna (Denmark). Ophelia. 11:1-50.

THOMPSON, M. J. 1976. Photomapping and species composition of the seagrass beds in Florida's Indian River estuary. Tech. Rept. No. 10. Harbor Branch Found., Inc., Fort Pierce, Florida.

WANLESS, H. R. 1976. Man's impact on sedimentary environments and processes. Pp. 287-300. *In*: Biscayne Bay: Past/Present/Future. A Thorhaug (ed.). Univ. Miami, Sea Grant Program, Coral Gables, Florida.

ZIMMERMAN, R., J. FEIGL, D. BALLANTINE, AND H. J. HUMM. 1971. Seagrass zonation in Anclote anchorage. Pp. 89-93. *In*: Anclote Environmental Project Report 1971. Mar. Sci. Inst., Univ. South Florida, St. Petersburg, Florida.

Florida Sci. 41(2):90-96. 1978.

NEW INTERPRETATIONS OF FISH DISPERSAL VIA THE LOWER MISSISSIPPI RIVER—*Vincent Guillory*, Florida Game and Fresh Water Fish Commission, Eustis, Florida 32757

ABSTRACT: *Expatriates from upland streams found in the lower Mississippi River main channel may have illustrated the process of "tributary hopping" (ie., a stepwise movement from one habitable tributary to the next via the main channels of large rivers). Two types of tributary hopping exist: an active method, stimulated by behavioral mechanisms, entailing a brief migration; and a passive method, involving "waif immigrants" or floodborne transients. An analysis of Mississippi Embayment geology suggests that a large scale dispersal took place in the lower Mississippi River during Pleistocene glacial periods whereas tributary hopping by passive (waif dispersal) and active mechanisms occurred during the middle and late Pleistocene interglacial periods.*

THE lower Mississippi River main channel, along with the alluvial floodplain, presently forms a barrier to most small stream fishes. Consequently, the lower Mississippi River is of importance when considering the zoogeography of small stream species inhabiting the Gulf Coast region. The movement of these species down or across the lower Mississippi River valley presumably took place during the Pleistocene, although the exact manner and time of dispersal has not been resolved.

Avenues of dispersal by fishes between river systems include headwater transfer by stream piracy or diversions due to glacial blockage, swampy connections across drainages, low salinity bridges formed by flooding of estuarine complexes, confluence of coastal plain rivers caused by eustatic changes in sea level, and artificial introductions. Other means of dispersal via large rivers involve processes variously termed by different authors. Bailey and Taylor (1950) used the term "waif immigrants", or floodborne stragglers, in discussing a method of passive dispersal in the lower Mississippi River. Bailey and Allum (1952) described active dispersal of small stream fishes from one habitable tributary of Missouri River to the next in a stepwise manner. Subsequently, Metcalf (1966) coined the term "tributary hopping" for the latter method of dispersal. Later studies have referred to "tributary hopping" (Branson et al., 1969; Jenkins et al., 1972; Pflieger, 1971; Thomerson, 1969), or to the annual occurrence of small stream fishes in riverine habitats (Snelson, 1972). However, no one has made a distinction between active and passive main channel dispersal.

Literature discussing lower Mississippi River Pleistocene ichthyo-dispersal related either to the origin of the relict fauna (i.e., *Notropis camurus, Pimephales notatus, Ericymba buccata, Chrosomus erythrogaster, Fundulus catenatus, Etheostoma caeruleum,* and *E. rubrum*) of eastern tributaries of the lower Mississippi River or to the dispersal of upland species across or down the lower Mississippi River (Bailey and Taylor, 1950; Gilbert, 1964; Pflieger, 1971; Swift, 1970; Thomerson, 1969; Viosca, 1944; Wallace, 1973; Zorach, 1972). Opinions, however, differ as to whether these dispersals occurred during glacial or interglacial periods or involved active or passive mechanisms. A contrasting method of dispersal in the eastern lower Mississippi Valley was presented by Tsai and Raney (1974); they indicated *Etheostoma zonale lynceum* probably dispersed by stream capture rather than through the hostile lower Mississippi River.

I will discuss possible modes of dispersal of tributary species via the main channel of the Mississippi River to help clarify certain aspects of the Pleistocene ichthyo-geography of that region. My arguments are based on geologic data presented by Cook (1966) and Fisk (1944) and new records in the Mississippi River main channel of certain small stream species by Guillory (1974).

Results and Discussion—*Notropis longirostris*, a characteristic small stream species in eastern Gulf of Mexico drainages, occurred sporadically in Mississippi River main channel seine collections during three successive winters from 1972 to 1974 (Guillory, 1974). This species was absent in other seasons, except during the spring flood of 1973. Its annual occurrence in the Mississippi River independent of flood displacement (see following paragraphs) may illustrate a deliberate mechanism by which this small stream species migrates via the inhospitable, muddy, main channel from one habitable tributary to the next. This process may be termed "active tributary hopping", as envisioned by Bailey and Allum (1962).

During the record spring flood of 1973, 5 species (excluding *Notropis longirostris*) characteristic of small upland tributaries were collected by seine in the Mississippi River: *Notropis camurus, Pimephales notatus, Etheostoma parvipinne,* *E. whipplei*, and *Percina ouachitae* (Guillory, 1974). These would be termed "waif immigrants" (Bailey and Taylor, 1950) or floodborne stragglers. Although the above species were encountered in only one or two seine collections, their presence is important because it suggests that many species normally restricted to upland tributaries of the Mississippi River may be susceptible to waif dispersal, or "passive tributary hopping", during excessive flooding.

When discharge exceeded 19,820 m per sec in the Mississippi River during the spring flood of 1973, *Notropis logirostris* appeared regularly in seine collections, comprising 2.6% of the total catch during the period of flooding. The appearance of this species in main channel collections during this vernal flood was correlated with "waif immigration", rather than an active behavioral mechanism as previously described. In addition to being the only species observed to actively make regular winter excursions out of the tributaries, *N. longirostris* was the most abundant floodborne straggler in the river. Hence, those tributary species that are most capable of active annual excursions into riverine habitats, may in many cases be most susceptible to flood dispersal.

An additional 15 species common to Mississippi River floodplain habitats were also collected in the main channel during and immediately after the 1973 flood. These fishes included *Esox americanus, Notropis fumeus, N. maculatus, Aphredoderus sayanus, Fundulus notti, F. chrysotus, Poecilia latipinna, Centrachus macropterus, Lepomis marginatus, L. microlophus, L. punctatus, Elassoma zonatum, Etheostoma chlorosomum*, and *E. proeliare* (Guillory, 1974). Their occurrence in the main channel collections does not have the implications as do the more restricted upland species; however, they illustrate the disruption of normal distributional patterns by floods of sufficient magnitude.

The presence of floodborne transients and the active dispersal mechanism exhibited by *Notropis longirostris* suggest that main channel conveyance is more important than stream capture as a method of dispersal of upland species inhabiting immediate tributaries of the lower Mississippi River. Indeed, any upland species in that region may be susceptible to dispersal from one habitable tributary to another via the main channel. Walters (1955) indicated that a fish tends to expand its range into all suitable localities provided they lie within the radius of dispersal (ie., the distance across unfavorable territory that may be traversed) from localities where the species occurs. The unfavorable territory in this case would be the lower Mississippi River main channel and adjacent floodplain. It should be cautioned however, that possible faunal saturation and later specific competition are factors to consider in the dispersal of fishes to previously unoccupied but suitable habitats.

Implications derived from Guillory's (1974) data and from Pleistocene geology (Cook, 1966; Fisk, 1944) also invite speculation on lower Mississippi valley ichthyo-geography—more specifically, the Pleistocene dispersal of small stream fishes down or across the Mississippi River. The manner and sequence of dispersal of these fishes can be correlated with environmental conditions associated with the inundation of the Mississippi Embayment by the Gulf of Mexico during early Pleistocene interglacial periods, "aluvial drowning" during later interglacial periods, and "rejuvenation" of the Mississippi valley during glacial periods.

Periodic inundations of the Mississippi Embayment by the Gulf of Mexico during Pleistocene interglacial periods as late as the Wicomico and Penholoway extended up the present Mississippi valley as far north as Tennessee (Cook, 1966). Obviously, these salt water inundations decimated populations of freshwater fishes. Between these catastrophic events freshwater fishes were able to expand to some extent into the newly available areas. However, unfavorable ecological conditions for upland species also existed in the lower Mississippi main channel and floodplain during interglacial periods after the Wicomico and Penholoway inundations. At such times the Mississippi River and its tributaries filled their valleys with alluvium, the main channel became deeper and muddier, and had a greater volume of flow (Fisk, 1944). These conditions are similar to those existing today; thus, as in recent times, small stream fishes could have been dispersed during Pleistocene interglacial periods after the Wicomico and Penholoway by waif immigration and, to some extent, by active tributary hopping.

During lowest base level of each Pleistocene glacial period the environmental conditions in both the alluvial floodplain and main channel may not have been inimical to upland-dwelling fishes. Fisk (1944) indicated that lowered sea levels during Pleistocene glacial periods rejuvenated the Mississippi River and its floodplain tributaries. Subsequently, the valley became deeply incised within the coastal plain sediments; thus, the river and its floodplain tributaries were steeper, clearer, smaller, and had coarser sediments. These factors would encourage the migration of upland species into the floodplain. In the absence of barriers, a large scale dispersal from various pre-glacial drainages probably took place during glacial periods via the lower Mississippi River, as well as a reciprocal exchange of tributary faunas.

In summary, data on expatriates from upland tributaries in the lower Mississippi River main channel illustrate the process of "tributary hopping", or stepwise movement from one habitable tributary to the next via the main channels of large rivers. Two types of main channel dispersal are evident: an active method, represented by *Notropis longirostris*, which entails a brief migration from tributary to main channel habitats, perhaps stimulated by behavioral mechanisms; and a passive method, exemplified by numerous examples involving waif immigrants or floodborne transients.

So far as dispersal of small stream fishes across the lower Mississippi River is concerned the following sequence is believed to have taken place. A large scale phase of dispersal down or across the river took place during Pleistocene glacial periods, and tributary hopping by waif dispersal and active mechanisms was utilized during the middle and late Pleistocene interglacial periods (as well as recent times) following the Wicomico and Penholoway interglacial periods.

ACKNOWLEDGMENTS—Special thanks are extended to Dr. Fred Byran and John V. Conner of Louisiana State University for critically reviewing my thesis and the data substantiating major points in this paper; appreciation is also extended to Gray Bass and Neil Eicholz for reviewing this paper.

LITERATURE CITED

BAILEY, R., AND M. ALLUM. 1962. Fishes of South Dakota. Misc. Publ. Mus. Nat. Hist. Univ. Michigan 119:1-131.

———, AND W. TAYLOR. 1950 *Schilbeodes hilderbrandi,* a new ameiurid catfish from Mississippi. Copeia 1950:31-38.

BRANSON, J., J. TRIPLETT, AND R. HARTMAN. 1969. A partial biological survey of the Spring River drainage in Kansas, Oklahoma, and Missouri. II. The Fishes. Trans. Kansas Acad. Sci. 72:429-472.

COOK, C. 1966. Emerged Quarternary shorelines in the Mississippi Embayment. Smithsonian Misc. Coll. 149(10):1-41.

FISK, H. 1944. Geological investigation of the alluvial valley of the lower Mississippi River. Mississippi River Comm. Rept. 78 pp.

GILBERT, C. 1964. The American cyprinid fishes of the subgenus Luxilus (genus *Notropis*). Bull. Florida State Mus. Biol. Sci. 8:95-194.

GUILLORY, V. 1974. Distribution and Abundance of Fishes in Thompson Creek and Lower Mississippi River, Louisiana. M.S. thesis. Louisiana State Univ. Baton Rouge.

JENKINS, R., E. LACHNER, AND F. SCHWARTZ. 1972. Fishes of the central Appalachian drainages: Their distribution and dispersal. Virginia Poly. Inst. State Univ. Res. Div. Monogr. 4:43-168.

METCALF, A. 1966. Fishes of the Kansas River system in relation to zoogeography of the Great Plains. Univ. Kansas Publ. Mus. Nat. Hist. 20(3):255-570.

PFLIEGER, W. 1971. A distributional study of Missouri fishes. Univ. Kansas Publ. Mus. Nat. Hist.

SNELSON, F. 1972. Systematics of the subgenus *Lythrurus*, genus *Notropis* (Pisces: Cyprinidae). Bull. Florida St. Mus. Biol. Sci. 17:1-93.

SWIFT, C. 1970. A Review of the Eastern North American Cyprinid Fishes of the *Notropis texanus* Species Group (subgenus *Alburnops*), with a Definition of the Subgenus *Hydrophlox,* and Materials for a Revision of the Subgenus *Alburnops*. Ph.D. Dissert. Florida State Univ. Tallahassee.

THOMERSON, J. 1969. Variation and relationships of the studfishes *Fundulus catenatus* and *F. stellifer.* Tulane Stud. Zool. Bot. 16:1-21.

TSAI, C. AND E. RANEY. 1974. Systematics of the banded darter, *Etheostoma zonale* (Pisces: Percidae). Copeia 1974:1-24.

VIOSCA, P. 1944. Distribution of certain cold blooded animals in Louisiana in relation to the geology and physiography of the state. Proc. Louisiana Acad. Sci. 1944:46-42.

WALLACE, D. 1973. The distribution and dispersal of the silverjaw minnow, *Ericymba buccata.* Amer. Midl. Nat. 89:145-155.

WALTERS, V. 1955. Fishes of western Arctic America and eastern Arctic Siberia. Taxonomy and zoogeography. Bull. Amer. Mus. Nat. Hist. 106(5):255-368.

ZORACH, T. 1972. Systematics of the percid fishes *Etheostoma camurum* and *E. chlorobranchium* new species, with a discussion of the subgenus *Nothonotus*. Copeia 1972:427-447.

Florida Sci. 41(2):96-100. 1978.

Environmental Sciences

EFFECTS OF GRASS CARP INTRODUCTION ON MACROPHYTIC VEGETATION AND CHLOROPHYLL CONTENT OF PHYTOPLANKTON IN FOUR FLORIDA LAKES

ROBERT D. GASAWAY AND T. F. DRDA

State of Florida, Game and Freshwater Fish Commission, Lake Wales, Florida 33853

ABSTRACT: *Aquatic macrophytic vegetation and chlorophyll content of phytoplankton were studied in two natural ponds, a natural lake and a borrow pit to determine effects of grass carp (*Ctenopharyngodon idella *Val.) introduction. Macrophytes were reduced in all study areas after grass carp introduction and several native species were eliminated although they remained where protected from grass carp. Chlorophyll* a, b, *and* c *content increased although generic richness of phytoplankton declined after introduction.*[*]

INCREASED water use in Florida coupled with rapid land development and urbanization creates serious water management problems in the State. Along with these trends are introductions of exotic organisms with their concomitant hazards. Exotic aquatic weed growth interferes with some forms of resource utilization. Many homeowners on urbanized lakes regard aquatic plants as unsightly. Some water managers and agriculturalists claim these weeds restrict water usage (Holm et al., 1969). In many instances, present control methods for these plants seem economically or technically restricted. Accordingly, some aquatic plant managers propose grass carp (*Ctenopharyngodon idella* Val.) introduction to control submerged aquatic plants. Effects of grass carp introduction on water quality in natural situations are not well researched. Some authors (Prowse, 1966; Bailey and Boyd, 1970; Cagni et al., 1971) stated that grass carp will lessen the rate of eutrophication; however, grass carp are reported to cause algal blooms and organically stained water (Stroganov, 1963; Avault et al., 1968; Opuszynski, 1972; Chittum, 1974). Major changes in water quality have been reported (Michewicz et al., 1972; Stanley, 1974) as a result of grass carp feeding in laboratory environments. We sought to determine if grass carp introduction would change aquatic macrophytic vegetation and chlorophyll *a, b,* and *c* derived from phytoplankton of four Florida lakes.

STUDY AREAS—Three ponds and a lake were chosen for study (Fig. 1). The northernmost two sites, Suwannee Lake and Madison Pond, were natural lakes somewhat similar in their water quality characteristics and climatic settings. Suwannee Lake, located on the University of Florida Agricultural Experiment Station, had a drainage area of 65 ha comprised of a mixture of upper coastal plain flatwoods and agricultural land. It was the largest body of water studied, having a surface area of 12.2 ha. Madison Pond is smaller, 3.4 ha with a larger

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

drainage area of 185 ha which is agricultural and upper coastal plain hardwoods. Pasco Pond in west central Florida is a 2.63 ha natural marsh pond, draining 1.6 ha of pine flatwoods. This pond has a low pH (4.5 - 5.5) and was surrounded by a cypress tree (*Taxodium* spp.) fringe. Seasonal temperature changes are less extreme in this region of the state. Broward Pond was formed by the Florida

FIG. 1. Location of the four study sites in Florida.

Department of Transportation to obtain fill material for highway construction. Its morphometry was atypical, with box-cut sides, 6.1 m deep and a rectangular 2.0 ha surface area. This site was subtropical with a yr-round growing season. It has a small urbanized drainage area of 2 ha.

METHODS—In 1972, the Florida Game and Fresh Water Fish Commission and the Florida Department of Natural Resources jointly began a 3 yr sampling program with one control year (without grass carp) and 2 treatment yr (with grass carp). We stocked approximately 67 kg per ha of grass carp in October, 1973 into each pond or lake. Suwannee Lake had approximately 298 fish per ha; Madison Pond had 51 per ha; Pasco Pond had 185 per ha and Broward Pond had 119 per ha.

Aquatic vegetation was sampled quarterly using modified line transects (Fig. 2). A small area in each pond was screened to prevent grass carp feeding to serve as a second control. Permanent markers were established and a pole was lowered through the water at each 1.5 m interval and plant species which touched the pole were recorded. A frame 1 m square was placed in the water at 9.1 m intervals, and coverage of each plant species within the frame was recorded. Frequency of occurrence (percent composition) and percent relative cover were calculated.

Fixed stations were established (Fig. 2); 2 shallow water (less than 3 m) and 2 deep water (greater than 3 m) stations were established in Madison, Pasco and Broward Ponds; 6 stations, 3 each in deep and shallow water, were established in Suwannee Lake. These stations were sampled at the surface and bottom for phytoplankton using a two 1 Kemmerer water sampler. Deep water stations were also sampled at mid-depth unless water levels dropped below 3 m. Phytoplankton identification and counts were conducted monthly from a 100 ml aliquot of a two 1 sample taken at each station and depth. Identification to genus and numerical counts were made using a 1-ml Sedgewick-Rafter counting cell. Chlorophylls *a*, *b* and *c* were determined monthly from four 1 samples collected from surface and mid-depth at Station 3 at each site using a two 1 Kemmerer water sampler. Samples were placed on ice and transferred to the laboratory for analysis. These were analyzed by the spectrophotometric method described

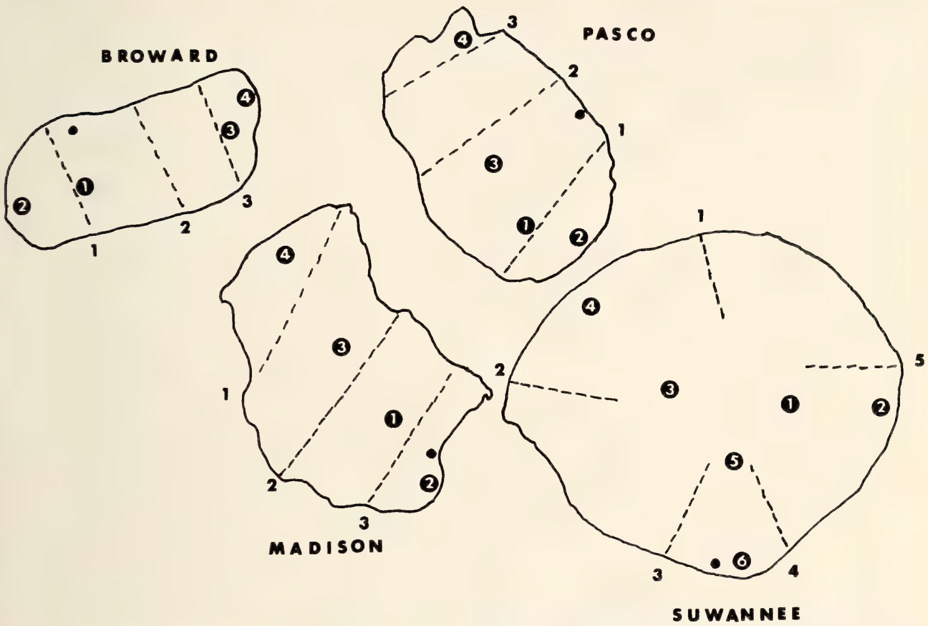


FIG. 2. Location of sampling stations (circled numbers), vegetation transects (dotted lines), and vegetation enclosures in each of the four study sites.

by Richards and Thomson (1952) and Parsons and Strickland (1963). Data were handled using an IBM 370-165 computer. Computer programs were written using SAS program language (Barr and Goodnight, 1972).

RESULTS—Changes in cover and frequency of occurrence of vegetation in each of the four study sites are shown in Fig. 3. Suwannee Lake was only moderately vegetated but supported a diverse flora. The lake margin was vegetated with *Panicum hemitomon*. Several floating pad communities present were composed of *Nymphoides aquaticum*, *Nuphar macrophylla*, *Brasenia schreberi*, and *Nymphaea odorata*. *Eleocharis acicularis* was the most frequently encountered plant, forming a mat on the bottom and extending a considerable distance lakeward from shore. Twenty-three aquatic plant species were encountered in control yr transects. One yr after introduction, *E. acicularis* was reduced to 0.4% cover from 40.16%; *P. hemitomon* and *Fuirena scirpoidea* also showed marked decreases after stocking grass carp. Some plant species were eliminated from transects by the end of the third study yr, but additional shoreline plants were encountered during that yr and some of those previously detected increased due to a rise in water level. Submerged rooted vegetation accessible to carp was totally eliminated from the transects by the end of the study.

The most abundant plants in Madison Pond were *Alternanthera philoxeroides*, *P. hemitomon*, *Cabomba caroliniana*, and *Utricularia gibba-fibrosa*. The community was characterized by a densely matted periphery dominated by *P.*

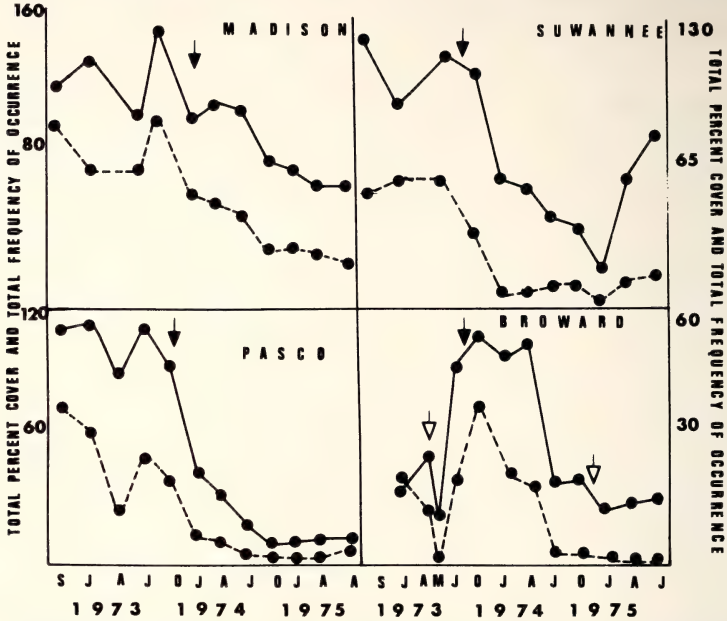


Fig. 3. Total percent frequency of occurrence (solid line) and total percent cover (broken line) for the vegetation community for the study period. Figures often exceed 100% since all vegetation stories (emergent, floating and submerged) are added together.

hemitomon and *A. philoxeroides*, extending 9 to 21 m from shore. The pond middle was densely vegetated with *C. caroliniana* interspersed with *U. gibba-fibrosa*. Eighteen species were encountered in transects during the first yr transects. This pond supported massive aquatic plant growth. *A. Hernanthera philoxeroides* and *P. hemitomon* remained essentially unchanged during the second yr and *C. caroliniana* and *U. gibba-fibrosa* were reduced by about 72% and 84% respectively. The third yr *A. philoxeroides* was reduced 37% in cover as opposed to only slight change the second yr. The screened area was well vegetated while adjacent unprotected areas were free of plants. At the end of the study, this pond was still heavily vegetated.

Dominant aquatic plants in Pasco Pond were *E. acicularis*, several other species including *B. schreberi*, *N. odorata*, and *N. macrophylla*, and *U. purpurea*; 16 species were encountered the first yr. Vegetational changes were very pronounced during the second yr of the study; *B. schreberi, E. acicularis* and *U. purpurea* were totally eliminated except in the screened enclosure. By the beginning of the third yr, *N. macrophylla* and *N. odorata* had also declined. Submerged vegetation was totally eliminated from transects by the end of the third yr.

Broward Pond was specifically selected because an exotic plant, *Hydrilla verticillata*, was present and proliferating. Water hyacinths (*Eichhornia cras-*

sipes) comprised a major portion of aquatic vegetation found the first yr, but were mechanically removed to encourage hydrilla growth. The pond was relatively new compared to the other three and several plant species had invaded. By the end of the first yr, *Hydrilla* occupied an 24.4 m fringe around the pond. *Najas guadalupensis* and *Typha angustifolia* were also present. Fourteen taxa were encountered in first yr transects. By the end of the second yr, *Hydrilla verticillata* was completely eliminated outside the screened area. *N. guadalupensis*, detected only once prior to grass carp introduction, was also not detected after introduction although *T. angustifolia* increased.

Chlorophyll concentrations for the 4 sites are shown in Fig. 4. In all sites, chlorophyll content of phytoplankton seemed stable before the introduction of grass carp. Afterwards, chlorophyll concentrations increased when compared to baseline data for Suwannee Lake, Pasco Pond and Broward Pond and by the middle of the third year in Madison Pond chlorophyll *a* concentrations doubled. Chlorophyll *b* concentrations increased after introduction in Suwannee, Pasco and Broward but were inconsistent in Madison; changes in chlorophyll *c* concentrations paralleled chlorophyll *a*.

Analysis of variance between control and treatment years revealed significant change in chlorophyll *a, b* and *c* (Table 1). Chlorophyll *a* and *b* were significantly different when location in the water column interacted with the above comparison. Chlorophyll *c* was significantly different in the control year vs treatment yr comparison, but not in the water column comparison. Phytoplankton diversity illustrated using pooled samples declined after introduction; however, some decline seemed evident even in the control yr (Fig. 5).

Discussion—From the standpoint of succession, based on characteristics illustrated by Welch (1952), Broward Pond is in an early successional stage with a consolidated bottom and recently established emergent vegetation. Pasco Pond possessed a heavy detritus-muck bottom, considerable emergent vegetation in the form of floating islands and generally low dissolved oxygen concentrations as in late successional stages. Madison Pond and Suwannee Lake are successionally intermediate.

Madison Pond was heavily vegetated and had considerable submerged vegetation remaining at the end of the study. Suwannee, Pasco and Broward had less aquatic vegetation initially and lacked submerged vegetation at the end of the study, except in enclosed areas.

Increases in chlorophyll occurred when aquatic vegetation was removed indicating increased phytoplankton quantity and eutrophication (Edmondson, 1969; Putnam et al., 1972). Ferens and Byers (1972) used chlorophyll indicators to show that stressed aquatic systems increased in primary productivity after controls decline. Environmental conditions which are more stressed usually permit more development of nanoplankton in relation to net plankton (Stewart and Rohlich, 1967). Nanoplankton are more active biologically (Pavoni, 1963) than net plankton. No increase in phytoplankton numbers was detected in Suwannee Lake or Madison Pond based on counts. Although chlorophyll levels

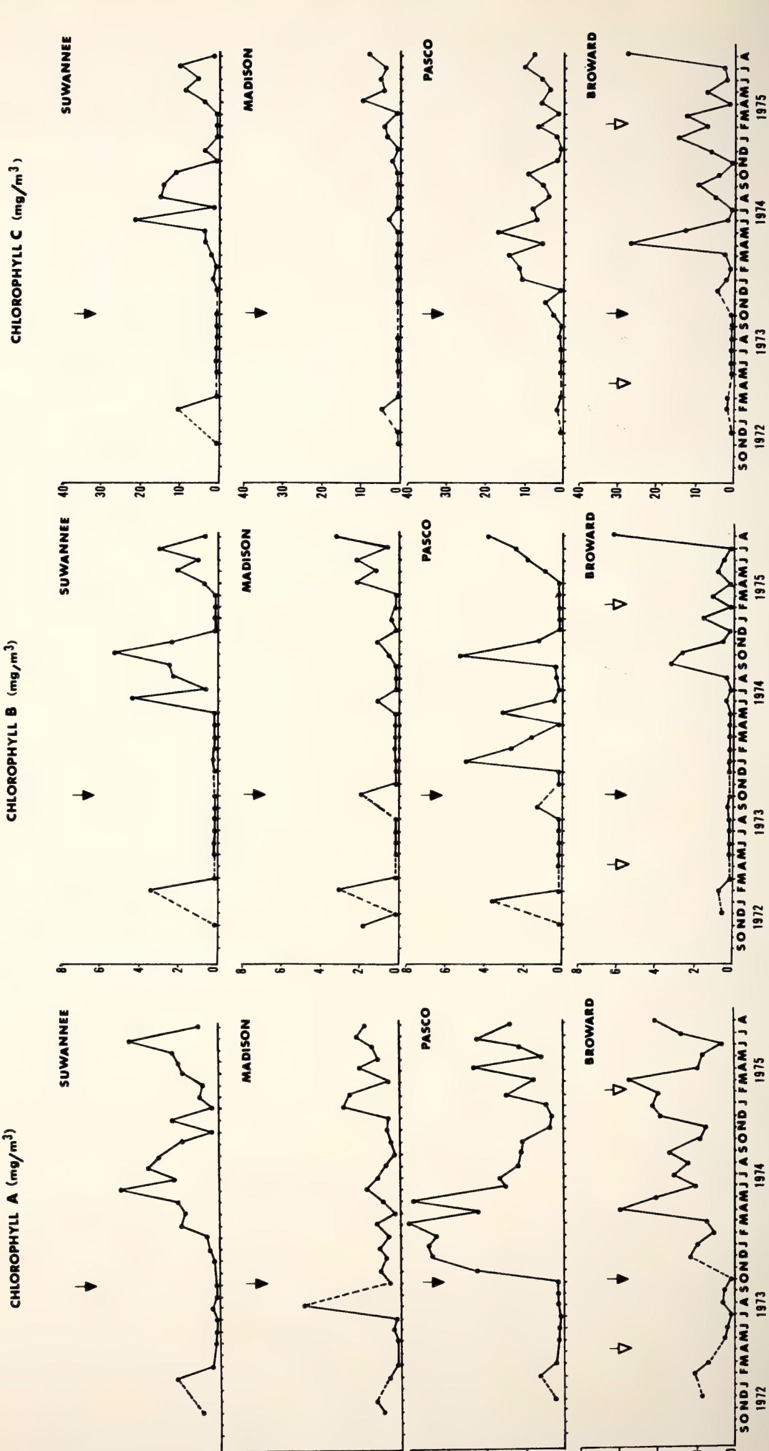


FIG. 4. Mean chlorophyll *a*, chlorophyll *b*, and chlorophyll *c* content in phytoplankton for each of the four sites through the study period. The solid arrows indicate where grass carp were stocked. The open arrows indicate where mechanical alteration of the environment occurred in Broward Pond.

TABLE 1. Analysis of variance for chlorophyll *a*, chlorophyll *b*, and chlorophyll *c* content in phytoplankton. Asterisks denote significance at $P < .05$ (*) or $P < 0.01$ (**); unmarked values represent non-significant differences.

Source of variation	Degrees of Freedom	Chlorophyll *a* Mean Square	Chlorophyll *a* F	Chlorophyll *b* Mean Square	Chlorophyll *b* F	Chlorophyll *c* Mean Square	Chlorophyll *c* F
Ponds (Madison, Suwannee, Pasco)	2	801.97327	1.17535	2.99810	1.70554	136.14402	2.12399
Madison vs. Suwannee and Pasco	1	779.77815	1.14282	4.93014	2.80464	254.79475	3.92034
Suwannee vs. Pasco	1	824.16840	1.20788	1.06606	0.60645	17.49331	.27291
Years (control, treatment year 1, treatment year 2)	2	951.32792	1.39424	9.11393	5.18470	287.82031	4.49031
Control vs. treatment years	1	1421.10940	2.08275	8.03058	4.56841	563.13850	8.78557*
Treatment year 1 vs. treatment year 2	1	481.54645	.70574	10.19737	5.80105	12.50212	.19505
Ponds across years	4	682.32322	*Error*	1.75785	*Error*	64.09810	*Error*
Location in the water column	1	212.67291	3544548.5**	.08167	43.67396	91.13005	32.00173
Location interaction with control vs. treatment years	1	9.01622	150270.33**	6.06341	3242.4652*	.77436	.27193
Location interaction with treatment year 1 vs. treatment year 2	1	.00006	*Error*	.00187	*Error*	2.84766	*Error*
Season (months)	11	45.89881	0.42454	4.89781	0.64801	35.68126	7.32093
Season interaction with control vs. treatment years	1	71.43518	0.66075	83.14053	11.00000	53.61260	11.00001
Season interaction with treatment year 1 vs. treatment year 2	1	108.11223	*Error*	7.55823	*Error*	4.87387	*Error*

after grass carp introduction compared to levels in eutrophic lakes in central Florida as reported by Putnam et al. (1972), they were not exceptionally high. Edmondson (1966) reported an increase in chlorophyll values with enrichment in Lake Washington.

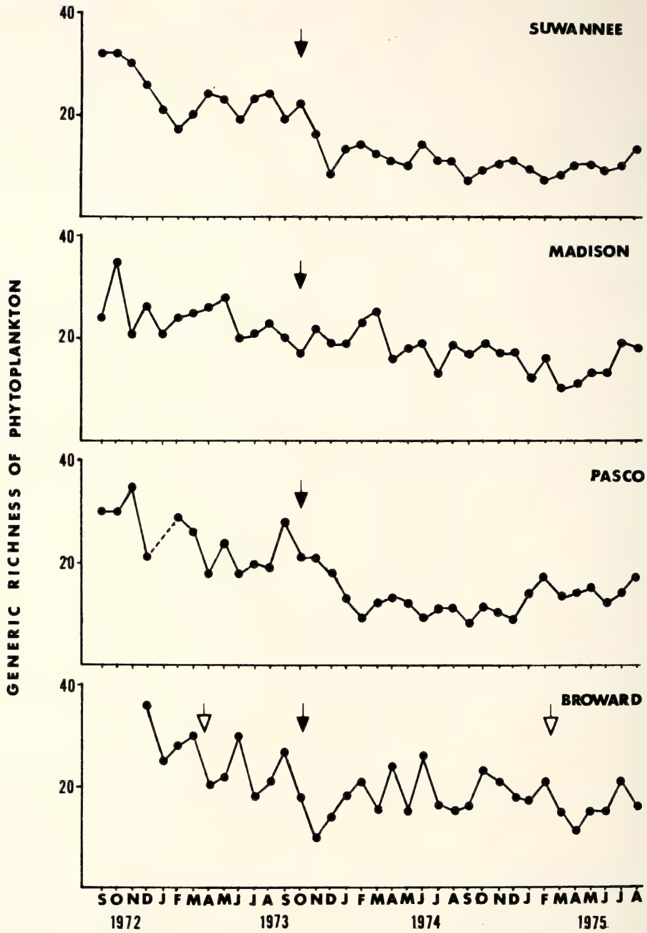


FIG. 5. Phytoplankton diversity for each of the four sites studied. The solid arrows indicate where grass carp were stocked. The open arrows indicate where mechanical alteration of the environment occurred in Broward Pond.

Lund (1965) reported that as an algal population becomes more productive, distribution is limited to uppermost layers of water. In clear unnutrified water bodies, production in any one unit volume may be small but the total volume in which phytosynthesis is possible may be greater than in a hypereutrophic lake with a high production in a small volume. Chlorophylls *a* and *b* were found to vary significantly in their location in the water column when the control and treatment years were compared.

The reduction of aquatic macrophytes, increase in chlorophyll content of phytoplankton and the decrease in phytoplankton diversity indicate a change from a macrophyte based community to a phytoplankton based community. Increased phytoplankton activity will probably occur when amounts of aquatic plants similar to those found in this study are removed using grass carp.

ACKNOWLEDGMENTS—The authors gratefully acknowledge the help of members of the Florida Game and Fresh Water Fish Commission and the Department of Natural Resources staffs. Mr. Mondell Beach of the Florida Department of Natural Resources should have been a co-author; however, he and his Department differ with our interpretation of the data. Dr. Paul Geissler of the Southeastern Cooperative Statistics Unit at North Carolina State University provided technical assistance. The staff of Rollins College in Winter Park, Florida analyzed chlorophyll samples and identified phytoplankton. The facilities of the Northeast Regional Data Center in Gainesville, Florida were used for data analysis.

LITERATURE CITED

AVAULT, J. W., R. O. SMITHERMAN AND E. W. SHELL. 1968. Evaluation of eight species of fish for aquatic weed control. FAO Fisheries Report 44, VII-E-3:109-122.

BAILEY, W. M., AND R. L. BOYD. 1970. A preliminary report on spawning and rearing of grass carp (*Ctenopharyngodon idella*) in Arkansas. Proc. 24th Ann. Conf. S. E. Assoc. Game Fish Comm. 560-569.

BARR, A. J., AND J. H. GOODNIGHT. 1972. Statistical Analysis System. North Carolina State Univ. Raleigh.

CAGNI, J. E., D. L. SUTTON AND R. D. BLACKBURN. 1971. A review of the amur. Aquatic Plant Control Research Planning Conference. Interagency Res. Advis. Comm. Aquat. Plant Contr. Office of Chief of Eng., Dept. of Army.

CHITTUM, R. 1974. Some observations of white amur at the Newtown Fish Farm. Ohio Dept. Nat. Res. Wildl. In-Service Note 239:1-5.

EDMONDSON, W. T. 1966. Changes in the oxygen deficit of Lake Washington. Proc. Int. Soc. Theor. Applied Limn. 16:153-158.

———. 1969. Eutrophication in North America. Pp. 124-149. *In* Eutrophication: Causes, Consequences and Correctives. Natl. Acad. Sci., Washington, D.C.

FERENS, M. C., AND R. J. BEYERS. 1972. Studies of a simple laboratory microecosystem: Effects of stress. Ecology 53:709-713.

HOLM, L. G., L. W. WELDON AND R. D. BLACKBURN. 1969. Aquatic weeds. Science 166:699-708.

LUND, J. W. 1965. The ecology of the freshwater phytoplankton. Cambridge Phil. Soc. Bio. Rev. 40:231-293.

MICHEWICZ, J. D., D. L. SUTTON AND R. D. BLACKBURN. 1972. Water quality of small enclosures stocked with white amur. Hyacinth Contr. J. 10:22-25.

OPUSZYNSKI, K. 1972. Use of phytophagous fish to control aquatic plants. Wiadomosci Ekol. 18:111-125.

PARSONS, T. E., AND J. D. H. STRICKLAND. 1963. Discussion of marine-plant pigments, with revised equations for ascertaining chlorophylls and carotenoids. J. Mar. Res. 21:155-163.

PAVONI, M. 1963. Die Bedeutung des nannoplankton in Vergleich zum netzplankton. Schweiz. Z. Hydrol. 25:219-341.

PROWSE, G. A. 1966. Some aspects of tropical fish culture. Verh. Int. Ver. Limnol. 16:1405-1407.

PUTNAM, H. D., P. L. BREZONIK AND E. E. SHANNON. 1972. Eutrophication Factors in North Central Florida Lakes. U.S. Environmental Protection Agency. Washington, D.C.

RICHARDS, F. A., AND T. G. THOMSON. 1952. The estimation and characterization of plankton populations by pigment analysis; II a spectrophotometric method for the estimation of plankton pigments. J. Mar. Res. 11:156-172.

STANLEY, J. G. 1974. Energy balance of white amur fed *Egeria*. Hyacinth Contr. J. 12:62-66.

STEWART, K. M., AND G. A. ROHLICH. 1967. Eutrophication—A review. California Water Qual. Contr. Bd.

STROGANOV, N. S. 1963. The food selectivity of the amur fishes. Akad. Nauk. Turkmensk. SSR. Ashkhabad. Pp. 181-191. From Ref. Zh. Biol., 1964, No. 3132 (Transl. from Russian).

WELCH, P. S. 1952. Limnology. McGraw-Hill. New York.

Florida Sci. 41(2):101-109. 1978.

Environmental Sciences

USE OF THE MULTIPLE-PLATE SAMPLER IN BIOLOGICAL MONITORING OF THE AQUATIC ENVIRONMENT

PHILIP T. P. TSUI(1) AND BENJIMAN W. BREEDLOVE(2)

Aquatic Environments Limited, Calgary, Alberta(1) Breedlove and Associates, Industrial Environmental Studies, Gainesville, Florida(2) 32611

ABSTRACT: *Field studies indicate that the diversity of macroinvertebrates collected by the multiple-plate sampler is time dependent. Pilot studies to determine optimum exposure period are recommended. Comparisons of samples of macroinvertebrates collected by the multiple-plate sampler and the petite Ponar grab from both lentic and lotic environments indicate significant differences.**

ARTIFICIAL substrate samplers are widely used for routine biological monitoring of aquatic environments because samplers effectively collect benthic invertebrates, periphyton, and attached marine organisms (Beak et al., 1973). Among the various samplers used, the multiple-plate sampler (Hester and Dendy, 1962) is popular because it is light, small, and inexpensive to construct (Fullner, 1971). In spite of its wide application, published data on the performance of the sampler are limited (Weber, 1973). We have reviewed: 1) relationship between exposure time and diversity of the macroinvertebrates collected, and 2) macroinvertebrate populations collected by the multiple-plate sampler compared to those taken by the Ponar grab from lentic and lotic waters.

METHODS—Construction of the multiple-plate sampler and its usage were based on recommendations in Weber (1973). Essentially, the sampler was made of alternately spaced large (7.5 cm dia) and small (2.5 cm dia) circular masonite plates held together by a nylon rope passed through a hole drilled in the middle of each plate. The sampler had 14 large plates and a total effective surface of 0.13 m^2.

Benthic macroinvertebrate samples collected by both the multiple-plate sampler and the Ponar grab were washed in a sieve (U.S. Standard No. 30) and spread in a Petri dish. Organisms were removed and examined with a stereoscopic dissecting microscope.

EXPOSURE PERIOD AND MACROINVERTEBRATES COLLECTED—At present, 6 wk exposure is provisionally recommended by EPA biologists (Weber, 1973) for colonization by macroinvertebrates, although data on optimum exposure time for different habitats are lacking. The relationship between exposure time and the diversity of macroinvertebrates collected was determined by multiple-plate samplers retrieved after 30, 60, and 90 da of emplacement in the Caloosahatchee River, Florida. Of the 36 samplers emplaced, 12 were retrieved after 30 da, 10 after 60 da, and 3 after 90 da. Macroinvertebrates collected from each sampler were counted and identified. Subsequently, the diversity of the macroinvertebrates from each sampler was determined by the Shannon-Weaver index of

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

general diversity, $\bar{H}$ (Shannon and Weaver, 1949), where:

$$\bar{H} = -\Sigma \frac{(ni)}{N} \ln \frac{(ni)}{N}$$

N = total number of individuals
ni = number of individuals of the ith species.

Our results are in Tables 1, 2, and Fig. 1. We followed Dickson and Cairns (1972) in presenting our data in Table 1: new species had not been previously recorded and recurring species were those that were eliminated but subsequently became reestablished. At the end of a particular exposure, the number of species eliminated was determined by combining the new species and the recurring species to the total number of species present at the previous exposure and then subtracting the current total number of species.

TABLE 1. Total number of macroinvertebrate species collected, number of new species, recurring species, species eliminated, colonization rate, and extinction rate at the end of each exposure period.

Days Exposed	No. of Samplers Counted	Total Species Collected	New Species	Recurring Species	Species Eliminated	Colonization rate (sp/day)	Extinction rate (sp/day)
30	12	27	27	0	0	0.90	0.00
60	10	19	2	0	10	0.48	0.16
90	3	12	1	1	9	0.34	0.21

TABLE 2. Percentage composition of major macroinvertebrate taxa collected by the multiple-plate samplers after three different exposure periods.

	Exposure period (days)		
Taxa	30	60	90
Amphipoda	43.28	39.55	25.63
Isopoda	36.05	41.75	65.36
Diptera	15.81	9.25	8.45
Mollusca	2.31	3.05	0.42
Ephemeroptera	0.68	0.00	0.14
Rhyncobdellida	1.15	5.89	0.00
Trichoptera	0.46	0.22	0.00
Coleoptera	0.13	0.22	0.00
Odonata	0.13	0.07	0.00

The results indicate that about 90% of the total number of macroinvertebrate species was collected during the first 30 da (Table 1). The species colonization rate decreased with increasing exposure time and the species extinction rate increased with exposure time. Table 2 illustrates the changes in the composition of the major macroinvertebrate taxa collected after 3 different exposures. With

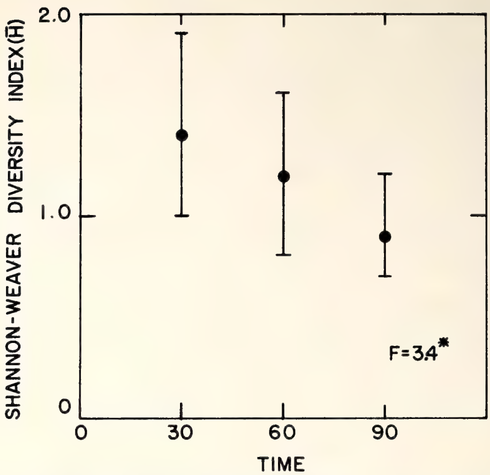


FIG. 1. Range of $\bar{H}$ in relation to time in days of exposure. *F value calculated with 2,22 df, significant at 0.05 probability point. 0 = avg. for population.

increased exposure time, there was a decrease in both the number of taxa collected and in the $\bar{H}$ values of the samples (Fig. 1). $\bar{H}$ values for the 3 exposure times were significantly different ($F = 3.4$; 2,22 df) at the 5% probability level.

Because interpretation of water quality often depends upon the diversity of the biological community, it seems appropriate that pilot studies be performed when biological monitoring programs use artificial substrate samplers. For a year-round biological monitoring program, pilot studies should be done seasonally, to account for differences in breeding cycles and specific colonization rates of various species in the community. This would determine the optimum exposure time when the maximum diversity of organisms can be collected in the shortest time period. Furthermore, since $\bar{H}$ is time dependent, data comparison should be based on samples with similar exposure periods.

LENTIC CONDITIONS—The multiple-plate sampler is used often for macroinvertebrates in streams and rivers, and was initially designed to be used in running (lotic) waters (Hester and Dendy, 1962). The Ponar grab is conventionally used to sample benthos of lakes, impoundments, and other lentic waters. We evaluated the applicability of the multiple-plate sampler to collect macroinvertebrates from standing (lentic) waters, and compared its performance with that of the Ponar grab in a similar environment. In three 30-da periods, a total of 9 multiple-plate samplers (3 samplers/period) was suspended 1 m below the surface in the center of a man-made lake in south Florida. Concurrently, 4 Ponar grab samples were taken 60 da after the initiation of the study and another 4 at its conclusion. All grab samples were taken near the suspended multiple-plate samplers at a depth of about 8 m; each grab sampled an area of 0.05 m^2. The multiple-plate sampler can be adequately used to collect benthic macroinvertebrates in a lentic environment, and its efficiency compares favorably with that of the Ponar grab (Table 3). However, it is apparent that the organisms collected by the two methods differed significantly. Of the 32 macroinvertebrate species collected, only 6 were commonly collected by both samplers. The dominant species collected by one method were often absent or poorly represented in samples taken by the other (e.g., the chironomids). Most organisms collected by the multiple-plate samplers were those associated with the littoral

TABLE 3. A comparison of the macroinvertebrates collected by the multiple-plate sampler and Ponar grab from a lentic aquatic environment.

Taxa	Multiple-plate Sampler	Ponar grab
Bryozoa	+	–
Oligochaeta Sp. A	–	3
Sp. B	41	–
Ostracoda	5	–
Amphipoda		
Gammarus sp.		
Isopoda		
Cassidinidae lunifrons	3	–
Ephemeroptera		
Caenis diminuta	330	38
Callibaetis floridanus	14	–
Odonata		
Amphiagrion sp.	14	–
Agrion sp.	8	–
Trichoptera		
Athripsodes sp.	–	2
Oecetis sp.	1	–
Coleoptera		
Berosus sp.	1	–
Diptera		
Tribelos sp.	69	1
Parachironomus sp.	57	8
Tanytarsus sp.	44	16
Pedionomus beckae	26	2
Ablabesmyia sp.	21	–
Chironomus sp.	13	–
Dicrotendipes sp.	12	1
Glyptotendipes sp.	9	–
Endochironomus sp.	4	–
Anatopynia sp.	3	–
Arctopelopia sp.	1	–
Tanypus sp.	–	107
Procladius sp.	–	38
Coelotanypus sp.	–	27
Bezzia group sp.	–	12
Harnischia sp.	–	4
Chaoborus sp.	–	2
Cricotopus sp.	–	1
Mollusca		
Physa sp.	3	–
Total Number of Individuals	680	262
Total Number of Taxa	23	15
Shannon-Weaver Diversity Index	1.96[1]	1.87

[1] Bryozoans not included.

zone of lakes (e.g., bryozoans, *Callibaetis* nymphs and *Physa*), whereas the Ponar grab collected mainly substrate-associated organisms (e.g., *Tanypus* and *Procladius*).

Lotic Condition—To compare the performance of the multiple-plate sampler with that of the Ponar grab in collecting macroinvertebrates from lotic habitats, a total of 25 multiple-plate samplers was placed 1 m below the surface in the Caloosahatchee River, Florida. Twelve samplers were retrieved after 30 da of exposure, 10 after 60 da, and 3 after 90 da. Concurrently, 23 Ponar grab samples were taken at a depth of 2 m near the multiple-plate samplers. The results are in Table 4. The data indicate that the multiple-plate sampler collected

Table 4. A comparison of the macroinvertebrates collected by the multiple-plate sampler and Ponar grab from a lotic aquatic environment.

Taxa	Multiple-plate Sampler	Ponar grab
Bryozoa	+	–
Oligochaeta		
Branchiura sp.	–	28
Lumbriculid sp.	–	17
Tubificid sp. A	–	498
Tubificid sp. B	–	219
Amphipoda		
Gammarus sp.	1335	7
Isopoda		
Asellus sp.	25	–
Cassidinidae lunifrons	1525	6
Cyathura sp.	15	–
Aegids	1	–
Valviferids	1	–
Rhyncobdellida		
Helobdella sp.	90	6
Ephermeroptera		
Caenis diminuta	8	–
Callibaetis floridanus	1	–
Choroterpes hubelli	1	–
Stenonema sp.	1	–
Odonata		
Aphylla sp.	–	1
Enallagma sp.	3	–
Trichoptera		
Cyrnellus sp.	5	–
Hydropsyche sp.	2	–
Oecetis sp.	2	–
Coleoptera		
Microcylloepus sp.	3	–
Stenelmis sp.	2	–
Diptera		
Glyptotendipes sp.	70	2
Psectrocladius sp.	73	1
Dicrotendipes sp.	242	1
Parachironomus sp.	8	–
Ablabesmyia sp.	12	–
Polypedilum sp.	6	6
Tribelos sp.	3	1

Pedionomus beckae	1	–
Chironomus sp.	2	–
Coelotanypus sp.	–	15
Bezzia group sp.	–	2
Tanytarsus sp.	–	2
Einfeldia sp.	1	–
Procladius sp.	–	2
Cryptochironomus sp.	–	1
Mollusca		
Amnicola sp.	53	–
Corbicula sp.	–	2273
Goniobasis sp.	–	38
Helisoma sp.	1	–
Helisoma duryi	2	–
Laevipex sp.	19	–
Physa sp.	2	–
Pleurocera sp.	–	17
Total Number of Individuals	3515	3137
Total Number of Taxa	32	21
Shannon-Weaver Diversity Index	[1]1.44	0.97

[1] Bryozoans not included.

a fauna of macroinvertebrates that was qualitatively different from that collected by the Ponar grab. Of the 45 species collected, only 8 were common to both samplers. The multiple-plate sampler collected more amphipods, isopods, mayfly nymphs, dragonfly nymphs, caddisfly and coleopterous larvae, while the Ponar grab collected mainly substrate-associated organisms (e.g., oligochaetes, clams, and some chironomid larvae). Obviously, the invertebrates collected by the two samplers are different. When evaluation of water quality is based on saprobic (Sladecek, 1973) and indicator organisms (Beck, 1955), precautions should be taken that comparable collecting techniques have been employed. In surveillance programs that involve monitoring of benthos, both the multiple-plate sampler and a bottom grab should be used.

Summary—1. The diversity of macroinvertebrates collected by the multiple-plate sampler is time dependent. Pilot studies to determine the optimum exposure period for a particular environment are desirable when using the multiple-plate sampler.

2. The efficiency of the multiple-plate sampler in collecting benthos from lentic waters compares favorably with that of a petite Ponar grab. However, the organisms collected by the two samplers are significanly different.

3. In lotic waters, the multiple-plate sampler collects a benthos that is significantly different from that collected by the petite Ponar grab. Data collected by the two samplers cannot be meaningfully compared.

LITERATURE CITED

Beak, T. W., Griffing, T. C. and A. G. Appleby. 1973. Use of artificial substrate samplers to assess water pollution. *In* Biological Methods for the Assessment of Water Quality. Amer. Soc. Testing Mat. ASTM STP 528:227-241.

Beck, W. M. Jr. 1955. Suggested methods for reporting biotic data. Sew. and Industr. Wastes. 27:1193-1197.

Dickson, K. L., and J. Cairns Jr. 1972. The relationship of freshwater macroinvertebrate communities collected by floating artificial substrates to the MacArthur-Wilson equilibrium model. Amer. Mid. Nat. 88:68-75.

Fullner, R. W. 1971. A comparison of macroinvertebrates collected by basket and modified multiple-plate samplers. J. Water Poll. Contr. Fed. 43:494-499.

Hester, F. E., and J. S. Dendy. 1962. A multiple-plate sampler for aquatic macroinvertebrates. Trans. Amer. Fish. Soc. 91:420-421.

Shannon, C. E., and W. Weaver. 1949. The Mathematical Theory of Communication. Univ. Illinois Press, Urbana.

Sladecek, V. 1973. System of water quality from the biological point of view. Ergenbisse der Limnologie. 7:1-218.

Weber, C. I. (ed.). 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. EPA-670/4-73-001. Analytical Quality Control Laboratory Cincinnati, Ohio.

Florida Sci. 41(2):110-116. 1978.

Earth and Planetary Sciences

SUNSPOT SHAPE, MOTION AND GROWTH

Fred Van Swearingen (1) and Ray N. Moses (2)

15549 Bedford Circle East, Clearwater, Florida 33516 (1), and Department of Physics, Furman University, Greenville, South Carolina 29613 (2)

Abstract: *The behavior of sunspots follows patterns of shape, motion, growth and decay which differ for leader and follower spots; some empirical rules are deduced and reported.**

Extensive data on solar activity, including daily spot drawings, can be found in *Solar Geophysical Data Bulletins*. We used the bulletins for the yr 1967 through 1974 for this study. Sunspot growth and decay were studied as functions of spot shape, rate of spot separation from magnetic neutral lines, and spot group age.

Sunspot Shapes:—Sunspots usually begin as elongated features, assume a more circular form, and then become more elongated during the latter stages of their decay. Large leader spots often have a long-lived circular phase (30 da or more) and then decay slowly. Follower spots, on the other hand, seldom have a long-lived circular phase.

Figure 1 shows how ellipticity versus change in area with respect to time differs for spots in different size groups. Figure 2 demonstrates how ellipticity changes from one day to the next. Overall, about 55% of the sunspots become more circular, 32.6% become more elliptical, and 12.4% did not change appreciably between successive days.

In the elliptical stage, there are differences between leader and follower spots. As seen in Fig. 3, leader spots are more elongated in an E-W direction with

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

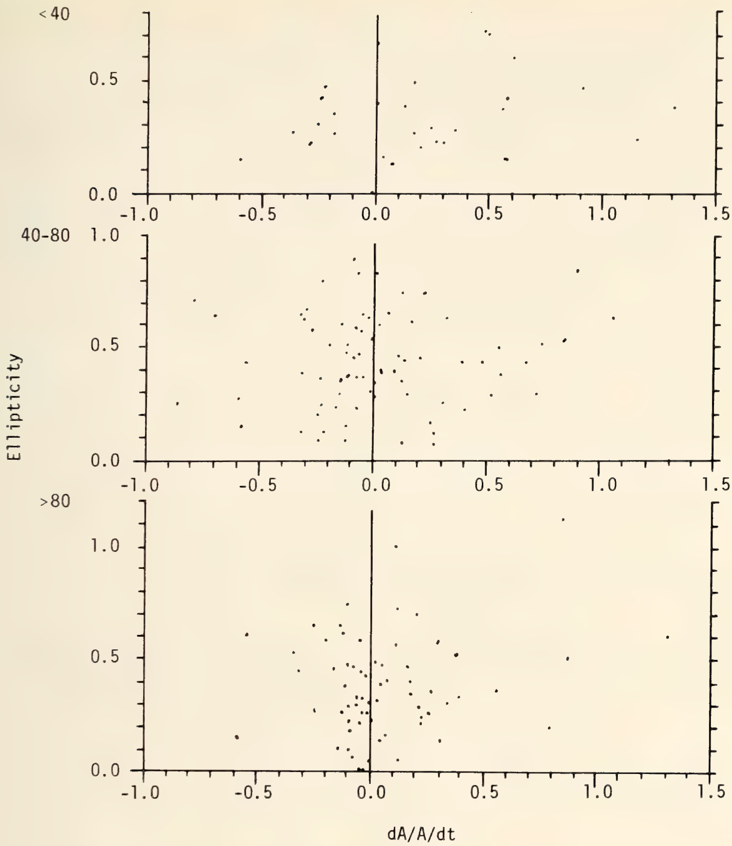


FIG. 1. Fractional change in spot area per day. Spot size in 10^{-6} of a solar hemisphere.

respect to the solar rotation axis, while follower spots are often elongated in a N-S direction.

SUNSPOT MOTION:—Early in the lifetime of a spot group, the spots are often rapidly separating, usually on the order of 0.15 km/sec or about 1°/da. Generally speaking, leader spots move away from the magnetic neutral line at a faster rate than do follower spots (see Fig. 4 and 5).

SUNSPOT GROWTH AND DECAY:—Sunspot growth and decay are related to spot elongation and rate of motion with respect to the photosphere. During the early stages of the evolution of an active region, the rapidly separating spots are usually also rapidly growing (see Fig. 6). These spots are usually elongated. As spots approach their maximum size, their rate of separation slows. The spots then become more round.

New regions do not appear at random on the solar disk. Pairs of regions occur at greater than random frequency. This can be shown by constructing Poisson distributions for spot groups of a given A_{max} range. We compared the number of days where spots of a certain size appear with a normal Poisson distribution

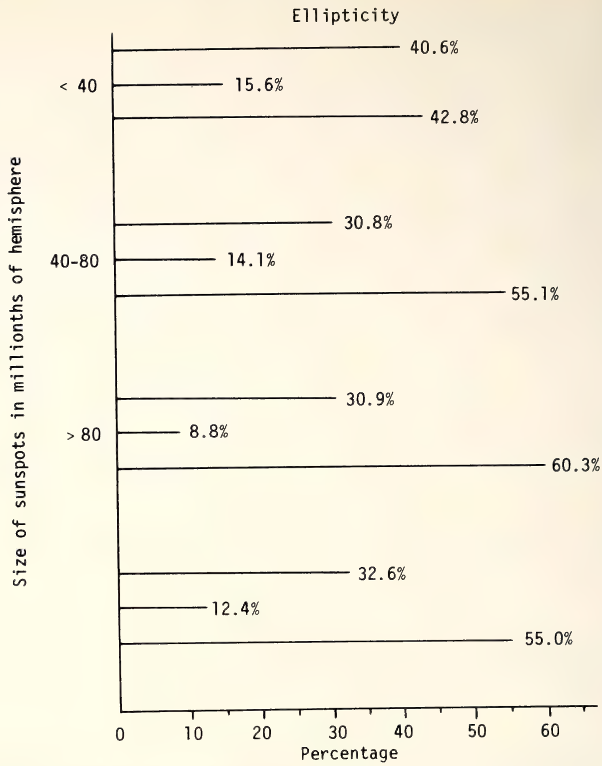


FIG. 2. Sunspot growth in ellipticity. (Top line - more elliptical; middle - no change; bottom - more circular).

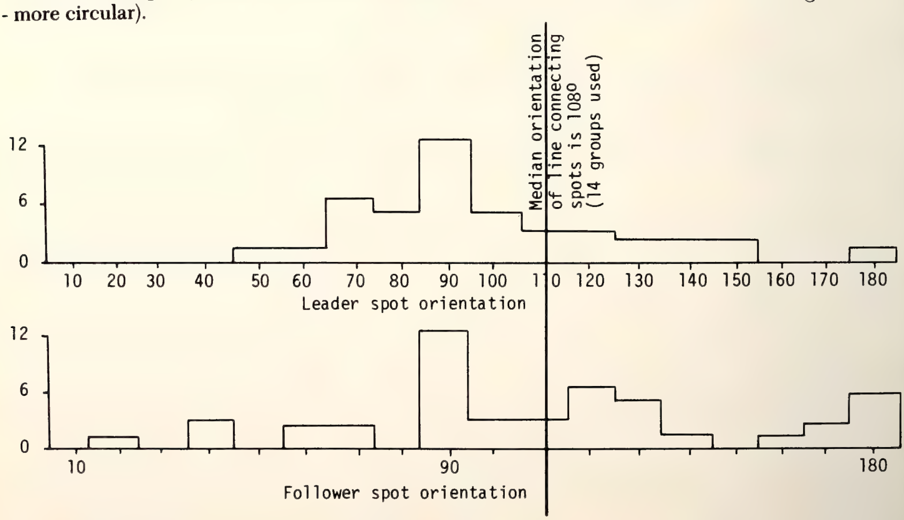


FIG. 3. Spot Orientation. (The vertical line represents the line connecting follower and leader spots and this line is well offset from the peaks of the spot orientation histograms, apparently due to the eastward motion of the spots with respect to the photosphere. Sample of North Hemisphere spots: 1967, 1968, 1969. Spots $> 40 \times 10^{-6}$ solar hemisphere in area. Source: *Solar Geophysical Data.* Orientation measure - clockwise from north.

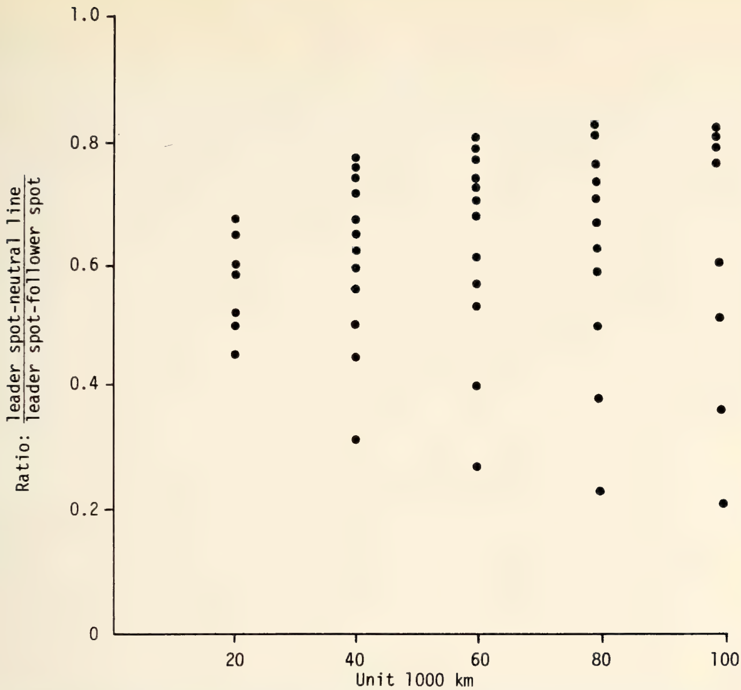


FIG. 4. Ratios of distances of leaders spots from neutral line to leader-follower distance. Leader spots are usually farther from neutral lines than are follower spots. Distance between major follower and leaders spots rounded off to the nearest 20,000 km.

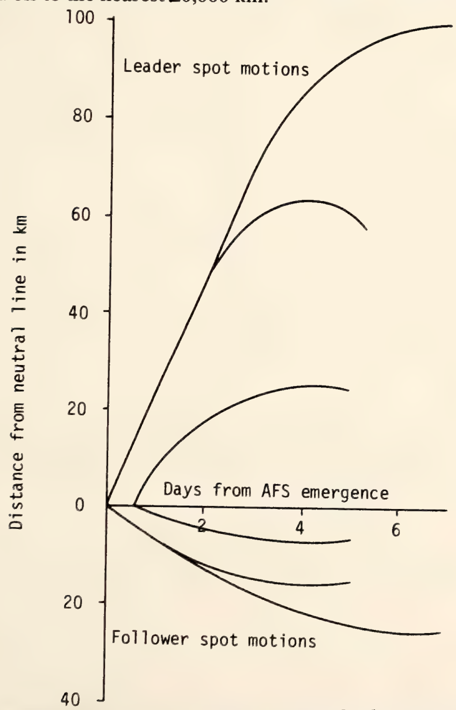


FIG. 5. Spot separation during the development phase. The lines represent spot locations as a function of time for three spot groups. This pattern is typical of long-lived spot groups which are isolated by 5° heliocentric or greater from nearby groups. AFS refers to arch filament system.

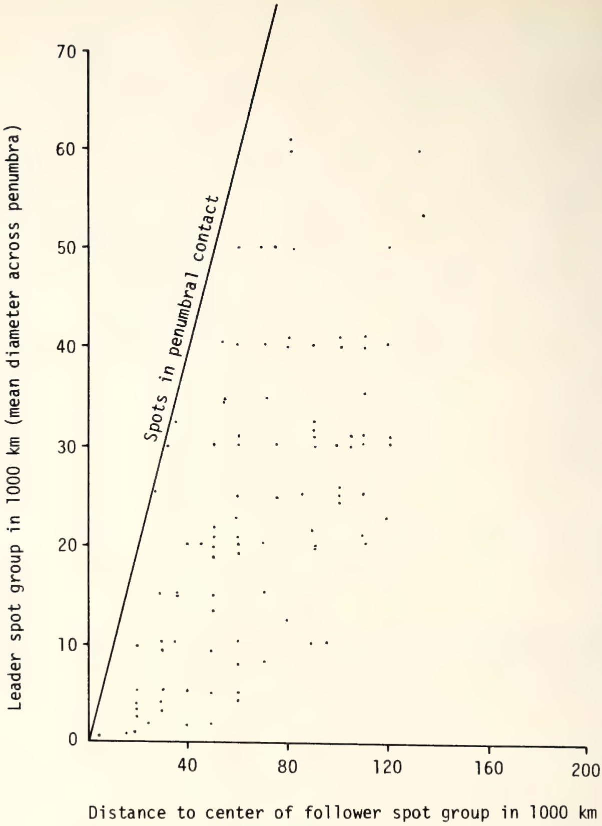


FIG. 6. Leader spot diameter and mean distance to follower spots.

(Fig. 7). The top triangle of each square contains the number of days of group appearance if spot groups appeared at random. The bottom triangle contains the actual number of days of appearance. As seen by the third column, pairs occur at a greater rate than predicted, especially in the smallest size range. This appears to coincide with a similar decrease in the rate of appearance for single spot groups.

Most sunspots gain or lose only a small percentage of their area from one day to the next (Fig. 8). Approximately 54.5% of spots gain or lose less than 20% of their area between consecutive days, while 78.6% gain or lose less than 40% of their area in a similar time period.

Growth and decay also depend on the age of the spot group. Bray and Loughhead (1964) give Waldmeier's "rule-of-thumb" for the lifetimes of sunspot groups as

$$T = 0.1\ A_{max}$$

where A_{max} is in millionths of a solar hemisphere.

For short-lived spots ($T \leq 13$ da), the rate of growth (area) versus time is shown in Fig. 9. This same curve appears to hold for both leader and follower spots.

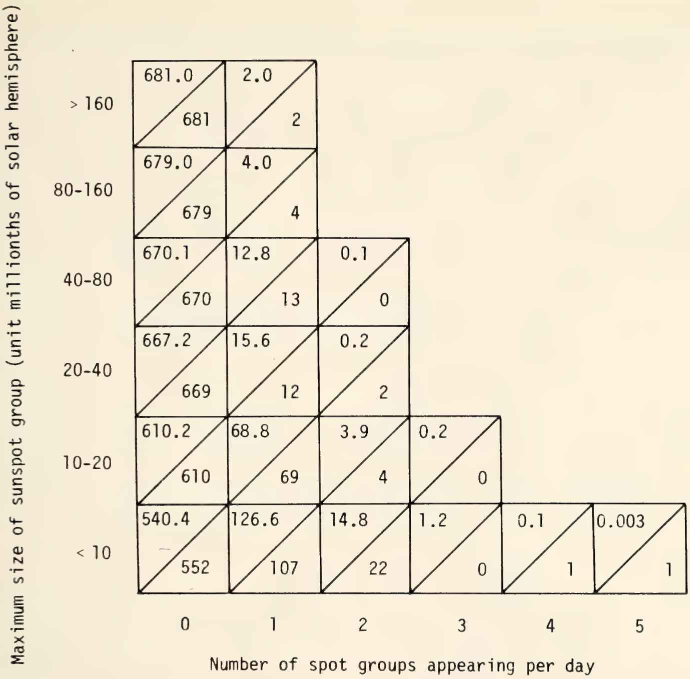


FIG. 7. Comparison of actual number of spot groups appearing per day with expected number from a series of Poisson distribution. The upper triangle shows the Poisson number while the lower gives the actual count. The total is 683 da.

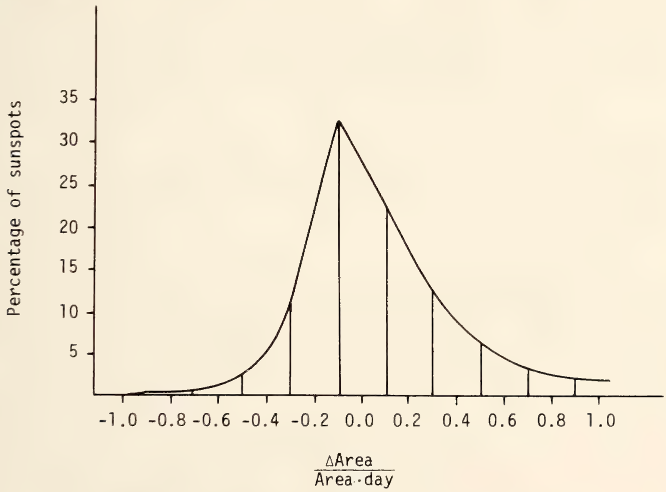


FIG. 8. Histogram of relative area changes in sunspots.

For a spot that lasts approximately 13 da, the peak of the curve appears at about the 5-6 da mark. As mentioned before, longer-lived spots generally spend more time in a circular shape. Thus, the peak of their curve tends to flatten out.

CONCLUSION—The area of a sunspot clearly depends on many factors. Those we have investigated are spot shape, motion, age of spot group, and whether the

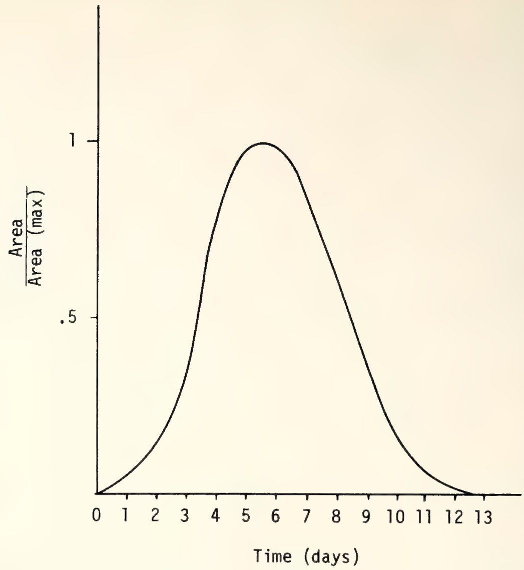


FIG. 9. Growth and decay of a typical short-lived sunspot.

spot is a leader or follower. However, other factors may alter this simplified picture. For example, the addition of new flux into the spot or the presence of spots from nearby groups may influence the area of the sunspot to a great extent. Thus, complete explanation of the behavior of sunspots may require taking these effects into consideration.

LITERATURE CITED

BRAY, R. J., AND R. E. LOUGHEAD. 1965. Sunspots. John Wiley and Sons, New York.

Florida Sci. 41(2):116-122. 1978.

Agricultural Sciences

EFFECT OF ENVIRONMENTAL pH ON THE ATTACHMENT AND INFECTIVITY OF CURLY-TOP VIRUS IN PEPPER, CAPSICUM ANNUUM L.[1]

ALEXANDER A. CSIZINSZKY

Agricultural Research & Education Center, 5007-60th Street East, Bradenton, Florida 33505

ABSTRACT: *Movement and attachment of labeled curly-top virus (CTV) in resistant and susceptible pepper seedlings were investigated by macro and micro autoradiography. The ^{35}S label remained localized in the tissues where the insect vector was feeding and the cytidine-5-^{3}H label indicated*

[1]Florida Agricultural Experiment Stations Journal Series No. 438.

virus transport in the phloem and 2 hr after inoculation appears to be attached to the nuclei of phloem parenchyma in both resistant and susceptible peppers. pH in plant tissues and body fluid and saliva of the insect vector is the major factor regulating stability of nucleocapsids and infectious and non-infectious forms of CTV.[*]

CURLY-TOP VIRUS (CTV) causes an important disease of a wide array of plants, belonging to 18 families, 48 genera and 300 species, in the warm, arid and semi-arid areas of the western United States and in other parts of the world. A similar disease called pseudo curly-top, occurs in tomatoes in Florida (Bennett, 1971). The causative agent of the disease is a systemic, non-propagative, tissue and vector specific virus. On electron micrographs the virus appears as an isometric particle, 18-22 nm in diameter. It looks very much like the Nepoviruses which have a single stranded RNA (Mink and Thomas, 1947; Mumford, 1974). In the USA it has only one known vector, the beet leafhopper, *Circulifer tenellus* (Baker) (Bennett and Wallace, 1938). Leafhoppers feed in the phloem tissue, specifically in a single sieve element, to which they may be guided by a pH gradient existing in the plant tissues (Fife and Frampton, 1936). The CTV particles probably are transmitted to the phloem cells during the feeding process. For 40 yr it was thought that the CTV was restricted to the phloem (Esau, 1968). All experimental evidence tended to support this hypothesis. Researchers, however, found evidence for the existence of virus in the parenchyma and apical parenchyma of sugarbeets (Artschwager and Starrett, 1936; Bennett and Esau, 1936) in meristematic tissues of root tips in beans and sugarbeets and in cambium of young tobacco plants (Lackey, 1946). In 1973, Esau and Hoefert reported that by electron microscopic (EM) studies they could detect CTV particles in infected sugarbeet seedlings only in the nuclei of phloem parenchyma cells. The absence of nucleocapsids in the sieve elements suggested to Esau and Hoefert (1973) that the virus is transported as viral nucleic acid and not as a complete particle. In view of the often contradictory reports regarding the attachment of viruses in plants, and because we were unable to explain some results obtained in field and greenhouse experiments during the CTV research program at Washington State University, it was decided to investigate the plant-virus relationship *in vivo* (Csizinszky, 1976a). The insect vector was utilized to transmit the *in vivo* labeled CTV in a relatively purified form (Braun and Maramorosch, 1951) from its host plant, the sugarbeet, to susceptible 'California Wonder 300' and resistant 'Jerusalem' pepper seedlings. The movement and location of the labeled CTV were followed by autoradiography during the first few hours after inoculation.

METHODS AND MATERIALS—Two tracers, ^{35}S for labeling the protein coat of the virus and cytidine-5-^{3}H (Sp. Act. 20 mci/mmole) for labeling both the protein coat and the viral RNA, were used (Herrmann and Abel, 1972). The ^{35}S was followed by whole plant and light microscopic autoradiography and the ^{3}H by light microscopic autoradiography. The ^{35}S, at a concentration of 2.5 mci/1.9 l, was applied in the 1/2 strength Hoagland solution in which viruliferous sugar-

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "advertisement" solely to indicate this fact.

beet was grown (Hoagland and Arnon, 1938). A second viruliferous sugarbeet was labeled with the ^{3}H tracer by immersing its leaves in 500 ml of aerated deionized H_2O containing 1 mci of cytidine-5-^{3}H. For controls, radioactively labeled healthy and non-labeled healthy beets were used.

Non-viruliferous leafhoppers were used to transmit the presumably labeled CTV from sugarbeets to 2-4 true leaf stage pepper seedlings. The leafhoppers were allowed to feed on the beets for 72 hr, then transferred into clip type leaf cages (Csizinszky, 1976b). The cages were attached to one of the oldest leaves on the peppers for exactly 1 hr. Five, 10 or 20 leafhoppers were used to inoculate the seedlings. Samples of the inoculated seedlings for whole plant autoradiography were taken at the end of the 1 hr transmission feeding time then at plus 2 hr and at plus 5 hr. Six plants plus 3 controls were autoradiographed at each of the 3 time intervals for each of the 3 levels of leafhoppers, using Kodak no-screen X-ray film. Plants at the end of sampling time were frozen at –40°C and exposed for 6 months at –17°C (Gahan, 1972). For light microscopic autoradiography the same transmission feeding and sampling times were used with 10 leafhoppers. At the 3 time intervals samples 2-3 mm long were cut from the leaf on which the leafhoppers fed, from the petiole of this leaf, from the stem, from the root just below the transition region and from the apex. Plant samples were prepared for Epon 812 embedding (Hayat, 1972) and 5μm thick sections were cut on a Reichert Model OMU2 ultramicrotome. The glass slides with the sections were covered with Kodak NTB 2 emulsion and exposed for 12 wk at 4°C (Bogoroch, 1972). Slides were developed at 15°C and evaluated by bright field and phase contrast microscopy (Ramon Lastra and Schlegel, 1975; Schlegel and de Zoeten, 1967).

RESULTS—^{35}S tracer on both whole plant and microautoradiographs appeared to be localized in all 3 sampling times and the different levels of leafhoppers where the insects fed during the 1 hr transmission feeding (Figs. 1 and 2). In the microautoradiographs the label appears to be localized in the phloem and phloem parenchyma cells of the leaves (Figs. 3, 4).

The ^{3}H tracer at the end of the 1 hr transmission feeding could be detected in the phloem of the leaf, the petiole and the stem, but not in the apical region and in the roots. Two hr after the end of the transmission feeding time the label is attached to the nuclei of the phloem parenchyma cells even in the apical region (Figs. 5-6). Five hr after inoculation there is further evidence for the association of label with the nuclei of the phloem parenchyma cells in all plant parts investigated with the exception of roots (Figs. 7-8). No differences in the movement and attachment of virus were detected in the susceptible 'California Wonder 300' and resistant 'Jerusalem' peppers.

DISCUSSION—The immobility of the ^{35}S tracer observed on the whole plant and light microscopic autoradiographs may be explained in that the separation of protein capsids from the viral nucleic acid occurs in the leaves, and only the infectious viral RNA is translocated with the organic solutes in the phloem. However, Esau and Hoefert (1973) could not detect CTV in the nucleocapsid form in the sieve elements, yet Bennett (1934) demonstrated that the leafhoppers feed

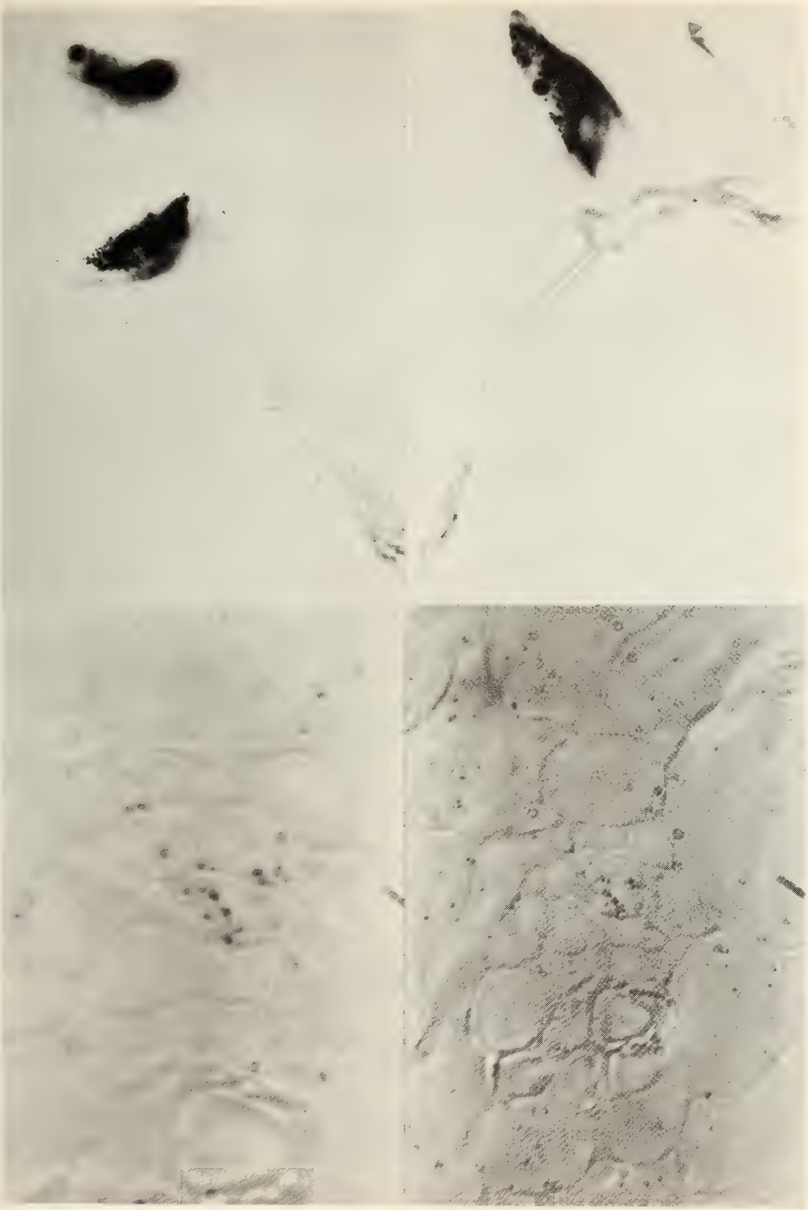


FIG. 1. Jerusalem plant inoculated by 20 leafhoppers fed on ^{35}S labeled plant, sample taken 2 hr after transmission feeding. (upper left).

FIG. 2. Jerusalem plant inoculated by 10 leafhoppers fed on ^{35}S labeled CTV infected plant, sample taken 5 hr after transmission feeding. (upper right).

FIG. 3. Transverse cut of the main vein of a Jerusalem leaf, plant inoculated by 10 leafhoppers fed on ^{35}S labeled plant, sample taken 5 hr after transmission feeding, 1500X. (lower left).

FIG. 4. Transverse cut of the main vein of a California Wonder 300 leaf, plant inoculated by 10 leafhoppers fed on a ^{35}S labeled CTV infected plant, sample taken 2 hr after transmission feeding, 1000X. Tracer located in the sieve elements and in the parenchyma cells. (lower right).

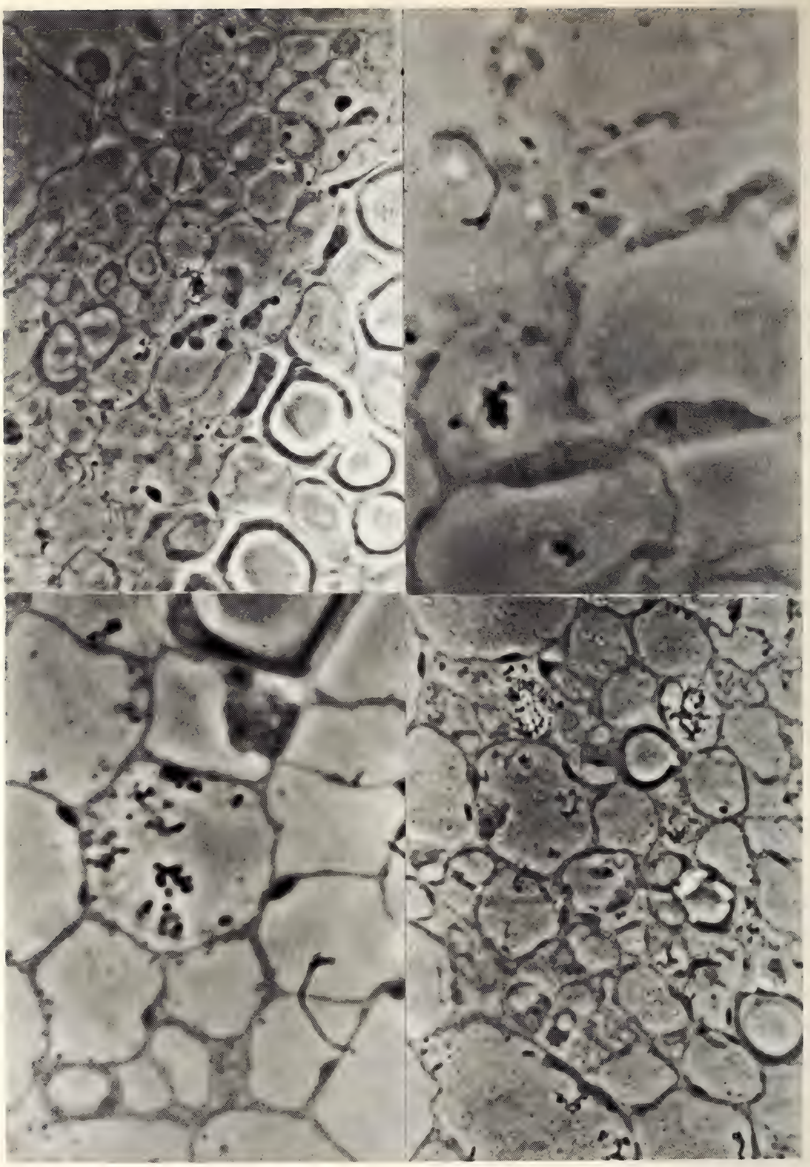


FIG. 5. Transverse cut of the main vein of a Jerusalem leaf, plant inoculated by 10 leafhoppers fed on ^{3}H-cytidine labeled CTV infected plant, sample taken 2 hr after transmission feeding, 1000X. Tracer located in the sieve cell and in the phloem parenchyma cell. (upper left).

FIG. 6. Transverse cut of the apical region of a Jerusalem plant inoculated by 10 leafhoppers fed on ^{3}H-cytidine labeled CTV infected plant, sample taken 2 hr after transmission feeding, 2000X. Tracer in the nuclei of parenchyma cells adjacent to provascular tissues. (upper right).

FIG. 7. Transverse cut of the main vein of a Jerusalem leaf, plant inoculated by 10 leafhoppers fed on ^{3}H-cytidine labeled CTV infected plant, sample taken 5 hr after transmission feeding, 2000X. Tracer located in the phloem parenchyma. (lower left).

FIG. 8. Transverse cut of the stem apical region of a Jerusalem plant inoculated by 10 leafhoppers fed on ^{3}H-cytidine labeled CTV infected plant, sample taken 5 hr after transmission feeding, 1500X. Tracer located in parenchyma cells surrounding provascular tissue. (lower right).

on a single sieve element. It is therefore possible that leafhoppers acquire and transmit CTV only in the form of infectious nucleic acid, presumably RNA.

The viral RNA is attached then to the nuclei of the phloem parenchyma cells adjacent to the sieve elements. In the nuclei it establishes a template for its replication and the formation of coat proteins. Fully assembled virus particles therefore appear in the nuclei of the phloem parenchyma cells as observed on electron micrographs.

It is proposed that the reason why the CTV's viral RNA is attached to the nuclei of the phloem parenchyma cells in the early stages of infection, and for the two different forms of CTV in the plants, is specific hydrogen ion concentrations in the different tissues. Fife and Frampton (1936) found that a pH gradient exists from the epidermal and parenchyma cells to the bundle sheath and phloem of sugarbeet petioles. The phloem parenchyma cells where the nucleocapsids are formed have a pH of 6.6, and the phloem cells where the leafhoppers feed a pH of 7.4. In small spherical plant viruses the stabilizing forces between the capsids of the protein coat and between the protein coat and viral RNA are weakened with increasing pH's, and completely eliminated at alkaline pH's (Kaper, 1972). In turnip yellow mosaic virus (TYMV) at pH 6.6 only 15% of the RNA is released, and at pH 7.4, 87% is freed from the protein capsid (Lyttleton and Matthews, 1958). This pH influenced rescue of viral nucleic acid from infected cells is not limited to plant viruses. The simian virus 40 (SV 40) at pH 8.4 has a titer 4 logs higher than at pH 6.4 (Calothy et al., 1973). The attachment of viral RNA and its replication has to take place where there is no interference by nucleases. This nuclease-free location in the cell is in the nucleus (Strobel and Mathre, 1970). In the phloem, where the pH of 7.4 is higher than the optimum for the action of RN-ase I, RN-ase II and nuclease I (Wilson, 1975), the viral RNA can exist and be transported to new infection sites relatively free from the attack of these enzymes.

The cell specificity of CTV is not unique among plant viruses. The wound tumor virus (WTV) is able to initiate tumor growth in sweet clover roots, *Melilotus alba* Desr., only in the parenchyma cells of the pericycle opposite to the primary phloem and immediately adjacent to the endodermis (Braun and Stonier, 1958; Kelly and Black, 1949). The second symptom is the abnormal differentiation of phloem tissue and then the xylem elements. When the cellular structure breaks down, metastasis takes place and the disease symptoms appear elsewhere in the plant.

In the body fluids of the leafhopper the pH is > 8 and the saliva has a pH of 10.6 or higher (Fife, 1940). Both pH's are unfavorable for the existence of nucleocapsids and plant nucleases. In the saliva the phosphodiester bonds of the viral RNA are subject to alkaline hydrolysis (Kaper, 1972), and upon prolonged fasting, the leafhoppers temporarily lose their infectivity (Fife, 1940).

LITERATURE CITED

Artschwager, E., and R. C. Starrett. 1936. Histological and cytological changes in sugarbeet seedlings affected with curly top. J. Agric. Res. 53:637-657.

Bennett, C. W. 1934. Plant-tissue relations of the sugarbeet curly-top virus. J. Agric. Res. 48:665.

_________. 1971. The curly top disease of sugarbeet and other plants. Amer. Phytopath. Soc. Monogr. 7:1-81.

_________, and K. Esau. 1936. Further studies on the relation of the curly top virus to plant tissues. J. Agric. Res. 53:595-620.

_________, and H. E. Wallace. 1938. Relation of the curly top virus to the vector *Eutettix tenellus.* J. Agric. Res. 56:31-51.

Bogoroch, R. 1972. Liquid emulsion autoradiography. Pp. 66-94. In P. B. Gahan (ed.) Autoradiography for Biologists. Academic Press. London.

Braun, A. C., and K. Maramorosch. 1951. A method for obtaining saliva from certain leafhoppers. Phytopathol. 41:1126-1128.

_________, and T. Stonier. 1958. Morphology and physiology of plant tumors. Protoplasmatologia 10(5a) 1-93. Springer-Verlag. Wien.

Calothy, G., C. M. Croce, V. Defendi, H. Koprowski and H. Eagle. 1973. Effect of environmental pH on rescue of Simian virus 40. Proc. Nat. Acad. Sci. USA 70:366-368.

Csizinszky, A. A. 1976a. Radioactive tracer studies with labeled curly-top virus in peppers *Capsicum annum* L. Ph.D. Dissert. Washington State Univ. Pullman.

_________. 1976b. Greenhouse breeding of leafhoppers for curly-top virus research. Washington State Univ. Coll. Agric. Res. Ctr. Circ. 592:

Esau, K. 1968. Viruses in plant hosts. Form, distribution and pathological effects. Univ. Wisconsin Press. Madison.

_________, and L. L. Hoefert. 1973. Particles and associated inclusions in sugarbeet infected with the curly-top virus. Virology 56:454-464.

Fife, J. M. 1940. Hydroxil-ion concentration of the saliva of partially desiccated beef leafhoppers. Phytopathol. 30:433-437.

_________, and J. L. Frampton. 1936. The pH gradient extending from the phloem into the parenchyma of sugarbeet and its relation to the feeding behavior of *Eutettix tenellus.* J. Agric. Res. 53:581-593.

Gahan, P. B. 1972. Macro-autoradiography. Pp. 19-31. In P. B. Gahan (ed.) Autoradiography for Biologists. Academic Press. London.

Hayat, M. A. 1972. Basic Electron Microscopy Techniques. Van Nostrand Reinhold Co. New York.

Herrmann, R. G., and W. O. Abel. 1972. Microautoradiography of organic compounds insoluble in a wide range of polar and non-polar solvents. Pp. 123-165 In U. Lüttge (ed.) Microautoradiography and Electron Probe Analysis. Springer-Verlag. New York.

Hoagland, D. R., and D. I. Arnon. 1938. The water culture method for growing plants without soil. Univ. Calif. Agric. Exp. Sta. Circ. 347:1-32.

Kaper, J. M. 1972. Experimental analysis of the stabilizing interactions of simple RNA viruses: a systematic approach. Pp. 19-41. In H. Bloemendahl, E. M. Jaspars, A. van Kammen, and R. J. Planta. (organizers) RNA Viruses: Replication and Structure. Federation of European Biochemical Societies, Eighth Meeting, Amsterdam, 1972. North Holland Publishing Co. Amsterdam.

Kelly, S. M., and L. M. Black. 1949. The origin, development and cell structure of a virus tumor in plants. Amer. J. Bot. 36:65-73.

Lackey, C. F. 1946. Occurrence of curly-top virus in meristematic tissue. Phytopathol. 36:462-468.

Lyttleton, J. W., and R. E. F. Matthews. 1958. Release of nucleic acid from turnip yellow mosaic virus under mild conditions. Virology 6:460-471.

Mink, G. L., and P. E. Thomas. 1974. Purification of curly-top virus. Phytopathol. 64:140-142.

Mumford, D. L. 1974. Purification of curly-top virus. Phytopathol. 64:136-139.

Ramón Lastra, J., and D. E. Schlegel. 1975. Viral protein synthesis in plants infected with broadbean mottle virus. Virology 65:16-20.

Schlegel, D. E., and G. A. de Zoeten. 1967. Improved resolution in light microscope radioautography. J. Cell. Biol. 33:728-731.

Strobel, G. A., and D. E. Mathre. 1970. Outlines of Plant Pathology. Van Nostrand Reinhold Co. New York.

Wilson, C. M. 1975. Plant nucleases. Ann. Rev. Plant Physiol. 26:187-208.

Florida Sci. 41(2):122-128. 1978.

INSTRUCTIONS TO AUTHORS

Individuals who publish in the *Florida Scientist* must be active members in the Florida Academy of Sciences.

Submit a typewritten original and one copy of the text, illustrations, and tables. All typewritten material—including the abstract, literature citations, footnotes, tables, and figure legends—shall be double-spaced. Use one side of 8 1/2 × 11 inch (21 1/2 cm × 28 cm) good quality bond paper for the original; the copy may be xeroxed. Margins should be at least 3 cm all around. Number the pages through the Literature Cited section. Avoid footnotes and do not use mimeo, slick, erasable, or ruled paper. Use metric units for all measurements. Assistance with production costs will be negotiated directly with authors of papers which exceed 10 printed pages of text.

Address follows the author's name.

Abstract—All manuscripts shall have a short, concise, single-paragraphed abstract. The abstract follows immediately the author's address.

Acknowledgments are given in the body of the text preceding immediately the Literature Cited section.

Literature cited section follows the text. Double-space every line and follow the format in the current issue.

Manuscripts of 5 or less, double-spaced typewritten pages should conform to the short article protocol. See recent issue for proper format of both long and short articles.

Tables shall be typed on separate sheets of paper, double-spaced throughout. Each table shall contain a short heading. Do not use vertical rulings. Maximum character width, including spaces, of tables is 98.0. This includes a minimum space of 5 characters between columns. Tables are charged to authors at $25.00 per page or fraction.

Illustrations—All drawings shall be done in good quality India ink, on good board or drafting paper. Letter by using a lettering guide or equivalent. Typewritten letters on illustrations are unacceptable. Drawings and photographs should be large enough to allow 1/3 to 1/2 reduction in size. Photographs shall be glossy prints of good contrast. Whenever possible, mount photographs in lots size.

The author's name and figure number should be penciled lightly on the back of each figure. Figure legends must be listed on a separate page and *not* on the drawing or photograph. The legend must be double-spaced. Illustrations are charged to authors at $20.00 per page or fraction.

Proof must be returned promptly. Notification of address change and proofreading are the author's responsibility. Alterations after the type has been set will be charged to the author.

Reprints may be ordered from the printer on forms provided when the corrected proofs are returned to the Editor.

FLORIDA ACADEMY OF SCIENCES

Institutional Members for 1976

Archbold Expeditions
Barry College
Eckerd College
Edison Community College
Florida Atlantic University
Florida Institute of Technology
Florida Southern College
Florida State University
Florida Technological University
Gulf Breeze Laboratory
Jacksonville University
John Young Museum and Planetarium
Manatee Junior College
Miami-Dade Community College
Stetson University
University of Florida
University of Miami
University of South Florida
University of Tampa
University of West Florida

Membership applications, subscriptions, renewals, changes of address, and orders for back numbers should be addressed to the Executive Secretary, Florida Academy of Sciences, 810 East Rollins Street, Orlando, Florida 32803.

PUBLICATIONS FOR SALE

by the *Florida Academy of Sciences*

Complete sets. Broken sets. Individual numbers. Immediate delivery. A few numbers reprinted by photo-offset. All prices strictly net. No discounts. Prices quoted include postage.

PROCEEDINGS OF THE FLORIDA ACADEMY OF SCIENCES (1936-1944)
Volumes 1-7—$10.00 per volume; single numbers $3.50
QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES (1945-1972)
Volumes 8-35—$10.00 per volume; single numbers $3.50
FLORIDA SCIENTIST (1973-1975)
Volumes 36-38—$10.00 per volume; single issues $3.50
except for symposium numbers priced separately.
Volumes 39 onward—$13.00 per volume; single numbers $4.25 except for symposium numbers priced separately.
Florida's Estuaries—Management or Mismanagement?—Academy Symposium
FLORIDA SCIENTIST 37(4)—$5.00
Land Spreading of Secondary Effluent—Academy Symposium
FLORIDA SCIENTIST 38(4)—$5.00
Solar Energy—Academy Symposium
FLORIDA SCIENTIST 39(3)—$5.00 (includes do-it-yourself instructions)

Individual orders should be sent with payment. A statement will be sent in response to a bona fide purchase order over $10.00 from a recognized institution. Address all orders to:

The Florida Academy of Sciences, Inc.
The John Young Museum
810 East Rollins Street
Orlando, Florida 32803

PLAN NOW TO ATTEND THE ANNUAL MEETING
AT FLORIDA INTERNATIONAL UNIVERSITY, MIAMI
MARCH, 1979

Do your friends a favor—invite them to join the Florida Academy of Sciences.

ISSN: 0098-4590

Florida Scientist

Volume 41 Summer, 1978 No. 3

CONTENTS

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

FLORIDA SCIENTIST
QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

The FLORIDA SCIENTIST is published quarterly by the Florida Academy of Sciences, Inc., a non-profit scientific and educational association. Membership is open to individuals or institutions interested in supporting science in its broadest sense. Applications may be obtained from the Executive Secretary. Both individual and institutional members receive a subscription to the FLORIDA SCIENTIST. Direct subscription is available at $13.00 per calendar year.

Original articles containing new knowledge, or new interpretation of knowledge, are welcomed in any field of Science as represented by the sections of the Academy, viz., Biological Sciences, Conservation, Earth and Planetary Sciences, Medical Sciences, Physical Sciences, Science Teaching, and Social Sciences. Also, contributions will be considered which present new applications of scientific knowledge to practical problems within fields of interest to the Academy. Articles must not duplicate in any substantial way material that is published elsewhere. Contributions are accepted only from members of the Academy and so papers submitted by non-members will be accepted only after the authors join the Academy. Instructions for preparation of manuscripts are inside the back cover.

Published by the Florida Academy of Sciences, Inc.
810 East Rollins Street
Orlando, Florida 32803

Printed by the Storter Printing Company
Gainesville, Florida

Florida Scientist

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Walter K. Taylor, *Editor* Henry O. Whittier, *Editor*

Volume 41 Summer, 1978 No. 3

Astronomy

INTERPRETING LIGHT CURVES OF EE PEGASI AND CM LACERTAE ON THE RUSSELL MODEL[1,2]

JOHN E. MERRILL

Department of Physics and Astronomy, University of Florida, Gainesville, Florida 32611

ABSTRACT: *Procedures for analysis of light curves of eclipsing binaries appropriate to the Russell Model and employing, at most, very modest computer formulations, are applied to a series of observations of EE Pegasi and to a series for CM Lacertae. Attention is called to: (1) a suggested improvement in the process for determination of the reflection coefficient; (2) the importance of estimating the reasonableness of the ellipticity coefficient as derived from the Fourier approximation representing the between-eclipses portion of the light curve; (3) the usefulness of a very simple, quasi-least squares method of refining tabularly the Russell-type parameters obtained directly from the Princeton Nomographs; (4) the numerical measure of interdependence of parameters which may be provided by plots of the proportioning factors κ, γ, σ, ε; (5) the need to recognize that, probably because of the plethora of parameters involved explicitly or implicitly, "refinements" of not greatly different preliminary sets may not always converge to a single final set, whatever the particular method used.*[*]

THE ORGANIZING COMMITTEE for this colloquium asked Dr. Albert P. Linnell and me to choose light curves of two eclipsing binaries showing fairly small interaction effects, and to set forth in some detail procedures appropriate for interpretation of those light curves on the Russell Model. As I understand the charge by the Committee, I was to develop "preliminary", "intermediary", and perhaps "definitive" parameters, in the Russell-Merrill (1952) parlance, using a desk-calculator approach and at most modest electronic-computer formulations, while Dr. Linnell was to start from "intermediary" sets of parameters and move forward with his excellent computerized approach to whatever levels of precision he felt justified by the data. One system chosen was to have complete eclipses and the other eclipses partial at minimum. Dr. Linnell and I finally de-

[1]An invited paper presented at the International Astronomical Union Colloquium No. 16, "Analytical Procedures for Eclipsing Binary Light Curves", held at the University of Pennsylvania, Philadelphia, 8-11 September 1971.

[2]Rosemary Hill Observatory Contribution No. 77.

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

cided to use Ebbighausen's (1971) observations of EE Pegasi in the blue, for the total-annular case, and the observations of CM Lacertae by Barnes, Hall, and Hardie (1968) for the partial-partial case. Since both these observational series show need for "rectification" and for some sort of adjustment for "complications" it was not practicable for us to pursue the "Spherical Model" portions of the solutions from completely identical modified series, at least after the very first round. I shall treat EE Pegasi first, in considerable detail, and then omit from my treatment of CM Lacertae such explanations as follow along lines already set forth in the case of EE Pegasi.

EE PEGASI BACKGROUND—Dr. Ebbighausen kindly supplied his data on EE Peg as a card deck of 1620 individual observations in the blue, Δm(v-c) corrected for differential extinction versus J.D. heliocentric, and with a Calcomp plot of these individual observations in phase on his own elements. That original plot not only shows clearly that secondary eclipse is total and primary is annular, and that secondary is effectively at mid-period and equal in width to primary, but (at its scale of 1 inch = $0^{m}\!.1$ and 1 inch = 0.02 period) yields at sight the curve characteristics listed in Table 1 and as immediate consequences the set of approximate orbital and other parameters also listed there. We should take particular note of three facts about the system demonstrated by that original plot Δm versus phase: (1) there is no evidence of significant eccentricity of orbit although Wellmann (1953) and Bakos (1965) both find an e of a few hundredths as best fitting their radial velocity material; (2) there is clear evidence between

TABLE 1. Prediction of characteristics of EE Peg.

Secondary Eclipse

At shoulders $\Delta m = +0.031$, at bottom $\Delta m = +0.122$
so $\ell_0^{\,Sec} \cong 0.920$ "rectified"
$L_g \cong 0.920 \qquad L_s \cong 0.080$
$\phi_e \cong 0.0435 \qquad \phi_i \cong 0.0115$

Primary Eclipse

At shoulders $\Delta m = +0.030$, at bottom $\Delta m = +0.631$
so $\ell_0^{\,prim} \cong 0.575$ "rectified"
$\phi_e \cong 0.0455$
At $\phi = 0.0120$, $\Delta m = +0.573$, $\ell_1^{\,prim} \cong 0.606$ "rectified"

$\alpha_0^{oc} = 1 \qquad \alpha_0^{tr} = \dfrac{0.425}{0.394} \cong 1.08$

If eclipses central $r_g \cong 0.174$, $r_s \cong 0.102$, k $\cong 0.60$
$86° \ll i \leq 90°$
Then by Contribution 23 Auxiliary Tables p. 371 $x_g \cong 0.6$
$J_h / J_c = 0.425 / 0.080 \cong 5.3$
At $\phi = 0.25$ and 0.75, $\Delta m = +0.020$
$\Delta m\ (A_0) = +0.025 \qquad A_0 = 0.977$
$\Delta m\ (-2A_2) = +0.0105 \qquad A_2 = -0.005$
$\Delta m\ (2A_1) = +0.001 \qquad A_1 = +0.0005$

the eclipses, of interaction effects between the components, although Catalano and Rodonò (1970) decided that their observations needed no rectification; and (3) that the shoulders of primary eclipse are higher, not lower, than those of secondary, contrary to all simple theories for differential "reflection" effect.

One remark should be made here about preliminary values for the radii of the components in cases of complete eclipses. It seems not to be generally known that for *given* ϕ_e and ϕ_i the r_g derived on the assumption of $i = 90°$ is the minimum possible while the r_s derived is the maximum possible. Obviously neither component can differ much from the size determined for edgewise orientation of the orbit; the smaller changes even more slowly than the larger, per unit change in the inclination.

We had, then, 1620 individual observations. A plot of the (O-C)'s for the minima listed in Table 2 but on Ebbighausen's light elements, seemed to call for some decrease in the period but retention of Ebbighausen's epoch, as a reasonable compromise between the long-term linear run and his short-term elements derived solely from the two excellent epochs of primary he achieved in the two

TABLE 2. Observed epochs of primary minimum for EE Peg and residuals from the adopted elements.

$$\text{Prim.Min.} = \text{J.D.(helioc.) } 2440286.4329 + 2\overset{d}{.}6282154n$$

Observer	*J.D.*	*n*	*O-C*
	2,400,000 +		
Gomi (1940),vis	29176.986	−4227	+0$\overset{d}{.}$020
Wellmann (1953),vis	33889.394	−2434	+0.037
	33910.400	−2426	+0.018
	33923.537	−2421	+0.014
	33931.417	−2418	+0.009
	33939.297	−2415	+0.004
	33947.176	−2412	−0.001
	33960.316	−2407	−0.002
Bakos (1965),pe	34606.863	−2161	+0.004
	34622.633	−2155	+0.004
	34635.770	−2150	+0.000
	34643.656	−2147	+0.002
Marks (1962),vis	37204.358	−1173	+0.822
Dueball, Lehmann (1965),vis	37569.440	−1034	+0.582
Virkhristijuk (1964),vis	38281.309	− 763	+0.204
Catalano, Rodonò (1970),pe	38299.508	− 756	+0.006
	39324.509	− 366	+0.003
	40462.526	+ 67	+0.003
Ebbighausen (1971),pe	40099.8286	− 71	−0.0010
	40417.8445	+ 50	+0.0008

successive summers covered by his observations. That compromise was made simply by laying a "thread" through Ebbighausen's mean epoch and the lower part of Bakos' group of (O-C)'s; the resulting linear light elements and the corresponding residuals from them, are listed in Table 2. All except three clearly aberrant ones are plotted in Fig. 1. I have not investigated why the difference of $0^{d}.003$ exists between the apparently-equally-good determinations of epoch by Catalano and Ebbighausen on contemporaneous observational data.

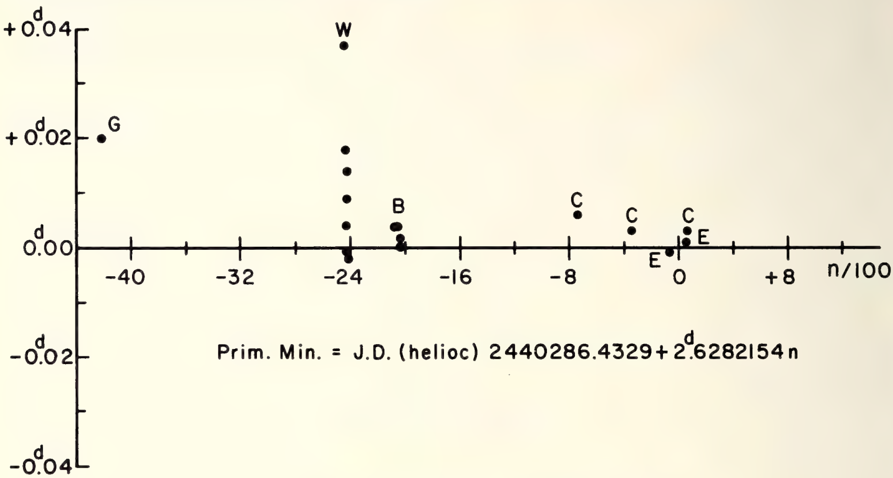


FIGURE 1. EE Peg (O-C)'s from the adopted elements.

Having computed phases (in ϕ) for the 1620 individual observations on these new elements, I took straight means of 5, strictly in order of phase, averaging the phases and averaging the Δm(v-c)'s, then added $1^{m}.2750$ to the Δm's to get a zero point of the scale close to but very slightly brighter than the brightest observation. A plot of these 5-normals on a Calcomp plot of the individuals indicated that 7 individual observations should in reason (in view of the high degree of accordance of the rest of the data) be eliminated. (In point of fact, Ebbighausen had omitted 3 of these 7.) The 7 affected normals were re-evaluated for phase and Δm, and the entire set of 324 normals converted to ℓ versus phase ϕ. This set forms the basis for all my further study of EE Peg; the 5-normals within the eclipses are listed in Appendix A along with the running means of the 5-normals for the two regions between eclipses.

Finally, besides the spectroscopic work of Wellmann and of Bakos, already mentioned, and Dr. Roman's (1956) classification of the spectrum as A3, Dr. Abt studied the spectrum of EE Peg at Dr. Ebbighausen's request. The spectral type of the hotter, brighter component is classified by Abt as A2 to A5 depending on which lines are used, as is often the case with metallic-line stars. Since even at the bottom of primary (see Table 2) the cooler, fainter component contributes only one-sixth as much light as the hotter, brighter one, the spectrum of that fainter component probably cannot be classified directly, nor its radial velocity measured, with any certainty by present means; Popper (1970) mentions "double lines but of poor quality" for some spectra.

RECTIFICATION AND ADJUSTMENT—The process conventionally called rectification has of necessity become more complex as the apparent precision of light curves has improved, and at the same time this improved precision has shown us ever more cases of clear, though small, divergences between Model and Nature. When such a divergence is demonstrably systematic and significant, it can and should be incorporated into the Model; this was the case, for example, with the "photometric ellipticity". When, however, such "complications" as small "sine terms", not even of the same algebraic sign in all systems, are found in the observational data, the mathematical-physical situation is entirely different; it may well seem to the investigator of a given light curve that, rather than either just throwing up his hands in despair, or spending months or years in perhaps premature attempts at model-building, he will contribute most by removing the intruder in some *specified* fashion, *noting the removal,* and getting ahead with the immediate job of solution at hand. It is reasonable to hope that after many such cases (well-authenticated) have accumulated someone may find it possible to correlate at least some of them into a further improvement of the model.

Now the process called rectification (proper) involves three steps, fundamentally: (1) an analysis of the between–eclipse portions of the light curve for variations we have *a priori* reason to believe might show themselves there; (2) an act of faith-and-reason in extending those variations across the regions of eclipse and compensating appropriately for them in those regions; (3) a test, explicitly or otherwise, of the probable essential validity of the foregoing procedure by examination of the final overall solution in various respects.

At the first of the three steps named, problems arise in many (if not most) precisely-observed, carefully-studied light curves, in these days of epochal curves in limited wave length regions: effects which we would *a priori* expect to be present, are, but in significantly different degree, or effects not embraced by our Model (or perhaps any present model) are uncovered by that analysis, and in the absence of basic theory to account for the observed conditions, we are without theory governing compensation for them. It is well known that "complications" are both common and frequently of considerable size in W Ursae Majoris-type systems; it is very evident by now that they are common in the between-eclipse regions of light curves of well-separated systems also, though (hopefully) of sizes commensurate with the smaller interaction effects to be expected there. Our first task, then, is to identify as well as may be the effects showing themselves in the tops of our light curves and thereby to decide how best to adapt the second stage of the rectification process to the realities of Nature.

The first stage, analysis of the tops, calls for both graphical and computational Fourier analysis through the fourth harmonics, in my opinion, to provide as firm ground as possible for the second stage. The results of these analyses, for Ebbighausen's EE Peg blue, are given in Table 3. The computational one (made for me on the Florida 360/65 by our departmental programmer, Joseph Whalen) is purely formal and requires only one special comment: contrary to what many investigators seem to suppose, the probable errors of the derived coefficients clearly do not increase sharply with the number of harmonics included in case of well separated pairs; they will all of course be larger for closer pairs, but the gain in real knowledge resulting from including harmonics through the fourth is likely to more than offset the decrease in the separate weights of determination even in close pairs.

TABLE 3. Analysis of EE Peg tops.

Coefficient	Computer	Graphical	Mean(*O-C*)'s for computer curve	
			Phases	Mean (*O-C*)
A_0	+0.97664 ±12	+0.97682		
A_1	+0.00019 ±18	+0.00034	0.05 to 0.25	+0.00007
A_2	-0.00576 +20	-0.00598	0.25 to 0.45	-0.00021
A_3	-0.00120 ±18	-0.00113	0.55 to 0.75	+0.00027
A_4	-0.00009 +17	-0.00066	0.75 to 0.95	-0.00018
B_1	+0.00034 ±14	+0.00050		
B_2	-0.00065 +13	-0.00029		
B_3	-0.00009 ±14	-0.00044		
B_4	-0.00007 ±14	+0.00006		

Now graphical analysis of the tops has a special value for the investigator. The "*abcd*" form (Merrill 1970) giving (in its simplest mode of employ) equal weights to the four "branches" rather than to the individual observations, helps the investigator to decide whether the coefficients arrived at in both processes, represent fairly continuous trends in the light variation in the tops or are strongly influenced by discernible groups. This is illustrated in Figure 2.

The curvature in the C_1 extends all the way from quadrature to the (obvious) eclipse shoulder. This pretty well guarantees that it represents a real trend; there is a significant cos 3ϕ term or something simulating one, spread through the tops, and we cannot possibly escape the conclusion that $A_1 > 0$. The curvature in the C_2 is not a little localized affair; there is a persistent trend throughout the tops, representing (or simulating) a small cos 4ϕ term. The continuous divergence of the S_2 from the zero axis speaks for the persistence and therefore the "reality" of a sin 2ϕ term while the absence of any spread anywhere in the re-entrant loop

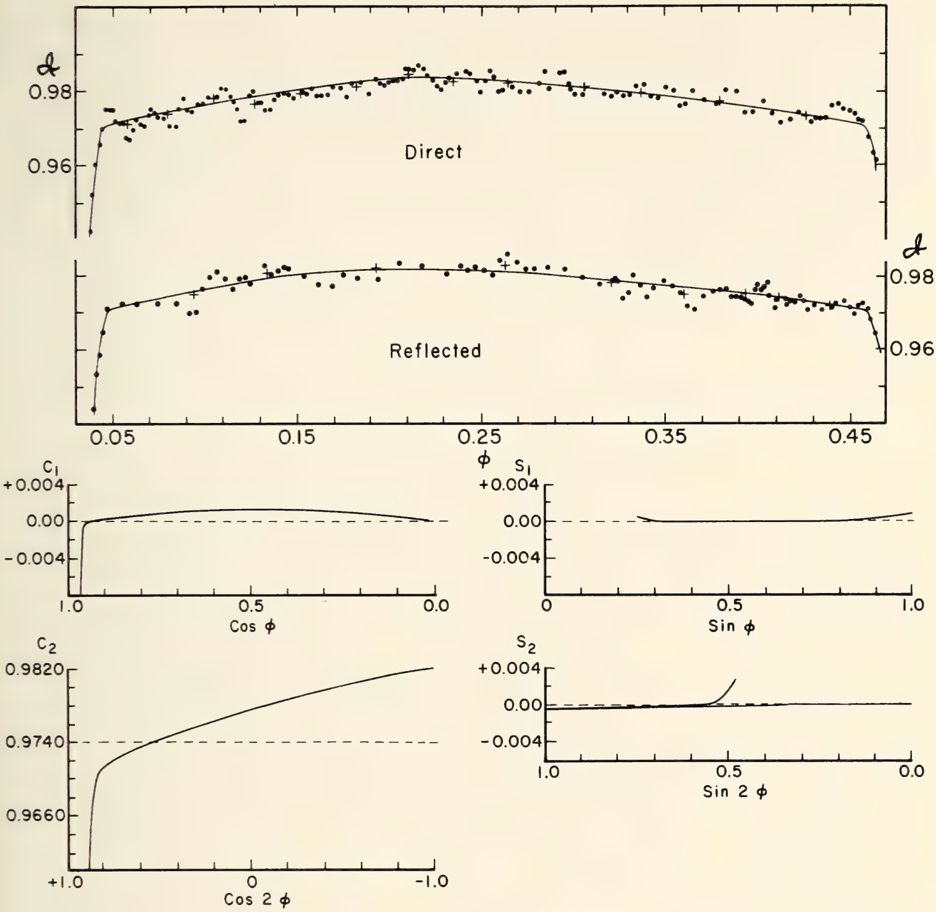


FIGURE 2. EE Peg tops and graphical analysis.

of S_2 gives assurance that the absence of a significant sin 4ϕ term is no localized matter. On the other hand the sin ϕ and sin 3ϕ terms suggested in the S_1 chart seem to arise partly from patches of higher data rather close to the quadratures.

There in the Fourier coefficients are our observations on Nature; now for our expectations as to the sizes of the reflection and ellipticity parameters on the basis of the Russell Model. In the first place, neither that Model nor any other well-studied model in existence, calls for any asymmetry terms whatever in the case of circular orbit. Second, there is not usually any good reason to doubt the validity of the A_0 that one gets by any sensible kind of analysis of the tops, or its applicability to the eclipse regions as well as the tops.

The differential reflection effect appears, (as is well known) as a term in cos ϕ, with the higher order theoretical terms usually wholly insignificant. There are several good ways, some of them in print and some not, for obtaining the coefficient of that reflection term. I regret to have to say that use of equations (107) of

Contribution 26 just as they stand has turned out to be a very *bad* way because it has become painfully evident that the A_1 of the Fourier analysis of tops cannot be simply equated to the a_1 of reflection theory as we all assumed 20 yr ago that it could; equations (107) are correct for the Model if we write the a_1 of reflection theory in them, but not necessarily correct when we write in them the observed Fourier coefficient.

Probably the simplest and safest way to arrive at the C's is by use of equation (108) of Contribution 26, in the form

$$G_c + G_h = [(G_c / G_h)^{1/2} + (G_h / G_c)^{1/2}](I_cI_h)^{1/2}(r_cr_h) \tag{1}$$

and its obvious mate (also an identity)

$$G_c - G_h = [(G_c / G_h)^{1/2} - (G_h / G_c)^{1/2}](I_cI_h)^{1/2}(r_cr_h) \tag{2}$$

with G_c / G_h obtained from the known spectral type and one's own crudely-rectified eclipse depths, and the $(I_c\ I_h)^{1/2}\ r_cr_h$ either from an "eyeball" solution of one's light curve (as in a case like EE Peg) or from someone else's solution of his light curve of the star. The resultant quantities are of course always very small, so multidigital accuracy in the data is not necessary for a preliminary solution, and after that sufficiently firm and self-consistent values for all the parameters involved in the forms suggested above are available within that preliminary solution itself. The C_0, C_1, C_2 listed in Table 4 come from the data of Table 1 with the spectral type of S_h assumed A4V, and agree closely with the set implied by the Catalano-Rodonò work on EE Peg. So much for the reflection terms expected on the basis of the Russell Model.

Now the mass-ratio for the components of EE Peg is not available through radial velocity measures. If one goes to the extreme length of trusting the mass-luminosity relation in the individual case under discussion, it appears that one may take that mass-ratio as a little less than one-half; 0.485 is what one gets from the data of Table 1. Then going through the appropriate relations for the shapes of the components, one arrives at η^2 and therefore at $z = 0.0766$; this is the geometrical z of the Russell Model. At this point it becomes necessary to convert the geometric ellipticity z to the photometric ellipticity Nz, and the investigator is facing what is probably the weakest link in our theories of rectification; although Hosokawa (1957), Kopal (1946) and others have contributed significantly on the theoretical side of the subject, much more observational study is needed of gravity darkening on spheroidal components of eclipsing binaries. The values of N(x) given in Contribution 26 are probably still about as credible as any; if one assumes $x = 0.6$, as is reasonable from Table 1 and the spectral types, and the Contribution 26 value of N corresponding, the ellipticity coefficient a_2 comes out as -0.00486 on the Russell Model.

Next, it is well known that the ratios of the theoretical Fourier coefficients for light variation due to ellipticity, are independent of the masses of the com-

TABLE 4. Reflection and ellipticity coefficients for EE Peg.

$J_h / J_c = 4.67$ from curve or solution.
$S_h = A4V \rightarrow S_c = dF7$ by Fig. II of Contributions 26.
$(G_c / G_h)^{1/2} = 1.916$ $\quad (G_h / G_c)^{1/2} = 0.507$
$(I_c I_h)^{1/2} r_c r_h = 0.00485$
$G_c + G_h = 2.480 \times 0.00485 = 0.01204$
$G_c - G_h = 1.466 \times 0.00485 = 0.00711$
$i = 88° - 90°$ $\quad \sin i \cong 0.9997$
$C_0 = 0.00361$
$C_1 = 0.00285$ $\quad a_1(\text{refl}) = -0.00285$
$C_2 = 0.00120$
$\mathfrak{m}_s / \mathfrak{m}_g = \mathfrak{m}_c / \mathfrak{m}_h \cong 0.485$ by mass-luminosity relation.

$$\eta^2 \cong \frac{3\mathfrak{m}_s}{\mathfrak{m}_g} a_g^3 \qquad 1 \leq \frac{a_g^4}{r_g^4} < 1.04$$

$\eta^2 = 0.00766$ $\quad z = \eta^2 \sin^2 i = 0.00766$
$N^2 = 0.0199$
a_2 (predicted ellipticity coefficient) $= \dfrac{N^2(A_0 - C_0)}{4 - N^2} = -0.00486$

$A_2(\text{Fourier}) = -0.00576$ $\quad$ Accept reluctantly

For $S_h: u = \frac{3}{5}, \tau = 1, \frac{a}{R} \leq \frac{1}{5}$

$$\text{So} \quad \frac{a_1}{a_2} \cong \frac{2}{55}, \quad \frac{a_3}{a_2} \cong \frac{2}{33}, \quad \frac{a_4}{a_2} \cong -\frac{1}{180}$$

For S_c halve the above. Note that these ratios are independent of $\mathfrak{m}_s / \mathfrak{m}_g$.
Conclusion: Observed A_1 and A_3 not appreciably affected by ellipticity, so contain "complications."

ponents. The approximate values for those ratios listed in Table 4 (assuming $r_g = 0.2$, $r_s = 0.1$) imply that the contributions of ellipticity to the theoretical expression for the tops, except the $\cos 2\phi$ term, should be practically negligible, especially in a preliminary solution at least.

A review of the situation is now in order: (1) the Russell Model calls for a term $-0.00285 \cos \phi$ while the observations yield $+0.00019 \cos \phi$; (2) the Model calls for a term of about $-0.00486 \cos 2\phi$ while the observations yield $-0.00576 \cos 2\phi$; (3) the Model calls for practically negligible terms in $\cos 3\phi$ and $\cos 4\phi$, while the observations yield $-0.00120 \cos 3\phi$ but negligible $\cos 4\phi$; (4) the Model provides no call for sine terms while the observations yield $+0.00034 \sin \phi$ and $-0.00065 \sin 2\phi$. These numerical specifics should be evaluated in the context of two more generalized statements: (1) extraneous sine terms of small or moderate size are nuisances in the orbital-parameter stage of the solution because they in effect increase the scatter of the observational points in an eclipse when one branch is reflected onto the other, but extraneous cosine terms are far more vicious because they both change the relative depths of the two eclipses and alter the shapes of the wings of the individual eclipse curves; (2) the basic data for EE Peg are obviously extremely accordant.

In view of these two general facts, it appears reasonable to me that the following disposition be made in the four specific situations stated: for (1), add in $C_1 \cos \phi$ to rectify for reflection, subtract out $(C_1 + A_1) \cos \phi$ to remove the $\cos \phi$ "complication"; for (2), somewhat reluctantly accept $-0.00576 \cos 2\phi$ as about the best we can do in the present state of the theory; (3) subtract out $A_3 \cos 3\phi$ and regard the $A_4 \cos 4\phi$ as negligible; (4) subtract out $B_1 \sin \phi$ and $B_2 \sin 2\phi$, and regard the other two sine terms as negligible. It has already been noted that A_0 is reasonable.

Two points should be emphasized. First, it is not intended to imply by this procedure that there is any doubt about the existence of, for example, the "extra" $0.00304 \cos \phi$ variation of light *in the system*. It is not a part of the Model being used, so specific note should be made of its removal, against that future time when someone may think out an improved model. Second, removal of these terms means the removal of possible evidence concerning eccentricity of orbit, because very small eccentricity must evidence itself principally in small apparent sine and cosine terms in ϕ and 2ϕ. Any more careful study than the simplistic one already made, of possible orbital eccentricity, through this photometric curve, requires first the restoration of the "complications" now being removed.

Table 5 shows the final form of the equation for *rectification and adjustment* in light to be applied throughout the entire curve, and the simple formula for the phase rectification, to be applied only to the eclipse data. Finally, it is important to check that the formula used for rectification of the intensities really also normalized the data, for that is a part of its function. Mean values of ℓ'' for regions in each top are listed in Table 5 to show the flatness achieved. This does *not* in any way guarantee correctness! It should also be noted that the $\sigma = 0.00222$ given there simply measures, in its way, the scatter of the rectified-and-adjusted normals in the tops about the unit adopted. Appendix A carries all the data treated as described above, in the columns ϕ'' and ℓ''.

Nomographic Solution—Figure 3 is a much-reduced copy of the Calcomp plot of the rectified-and-adjusted 5-normals of Appendix A for the eclipses, plotted ℓ'' versus ϕ'' counted from the 0.0 epoch and the 0.5 epoch for primary and secondary respectively. The individual points are properly (ϕ'', ℓ'') and on them lies a "theoretical" (and therefore smooth) curve $\mathcal{L}''$, picturing the light variation to which the instantaneous readings ℓ'' give us clues. Our purpose from now on is to construct a succession of theoretical (Russell-Model) curves $(\phi'', \mathcal{L}'')$ approximating more and more credibly to the view of Nature provided by the points (ϕ'', ℓ''). The original Calcomp plot had for its scales 1 inch = 0.04 in light, 1 inch = 0.002 in phase, giving it an appropriate size and shape for effective work on material of this quality. The plus-signs represent data points plotted "direct", the times-signs those plotted reflected across the zero epochs.

The level of the shoulders of the curves is of course already fixed by the normalization, but there is no need of trying to draw the shoulders in, in detail, at this juncture. The level of bottom of secondary was fixed by taking the straight

TABLE 5. Rectification and adjustment formulas for EE Peg.

$$\mathscr{l}' = \mathscr{l} + 0.003596 + 0.00285 \cos\phi + 0.001198 \cos 2\phi + -0.00304 \cos\phi + 0.00120 \cos 3\phi + -0.00034 \sin\phi + 0.00065 \sin 2\phi$$

$$\mathscr{l}'' = \frac{\mathscr{l}'}{0.97664 + 0.003596 + (-0.00576 + 0.001198) \cos 2\phi}$$

$$\mathscr{l}' = \mathscr{l} + 0.00360 - 0.00019 \cos\phi + 0.00120 \cos 2\phi + +0.00120 \cos 3\phi - 0.00034 \sin\phi + 0.00065 \sin 2\phi$$

$$\mathscr{l}'' = \frac{\mathscr{l}'}{0.98024 - 0.00456 \cos 2\phi}$$

Around phase	Mean $\mathscr{l}''$
0.057	0.99892
0.25	1.00008
0.435	1.00015
0.565	0.99962
0.75	1.00031
0.920	0.99953
First top	1.00005
Second top	0.99992
Both tops	1.00000

The standard deviation of a single 10-normal, over both tops, is 0.00222
Assuming $x = 0.6$, and A_0, A_2, C_0, C_2 as listed earlier

$N = 2.6$ $\quad z = 0.01137 \quad \sin^2\phi'' = \dfrac{\sin^2\phi}{1 - 0.01137 \cos^2\phi}$

mean, 0.91974, of the six 5-normals lying safely inside totality, and will henceforth be held fixed. The level of bottom of primary was set, graphically, at $\mathscr{l}_0^{pr} = 0.57856$ for the present; it is subject to slight revision when a curve of truly theoretical shape is available, and will indeed be adjusted very slightly then. The curves are free-hand, and therefore contain of course some "personal equation" but this material permits little wandering. Short bars were drawn at the levels n = 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 0.95 and the values of ϕ'' read off for those levels. While only the ϕ'' at the n = 0.5 level and that at the n = 0.8 level are used directly in calculating the χ_8's for the nomographic solution, it is highly desirable to read off all those mentioned and then to difference and smooth them. (If one has to do any amount of smoothing, then obviously one should go back and survey the curve again.) With such material as this one achieves in this way a consistent (whether or not "true") set of phases to rather better than 4 decimals. This done, tolerances for the phases were read from the 0.5 and 0.8 levels and the nomographic input data, as listed in the first few lines of Table 6, set up.

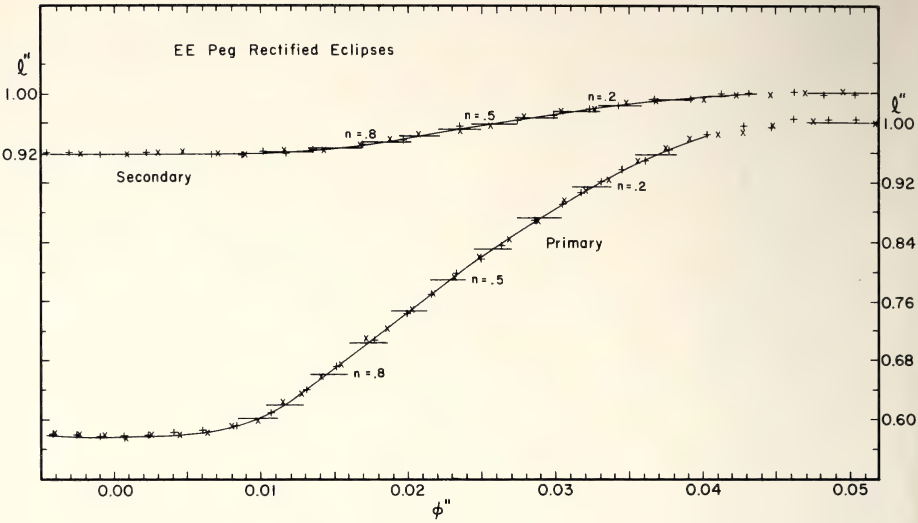


FIGURE 3. Freehand curves drawn on plots of the 5-normals for EE Peg. Levels n for readings ϕ'' are shown.

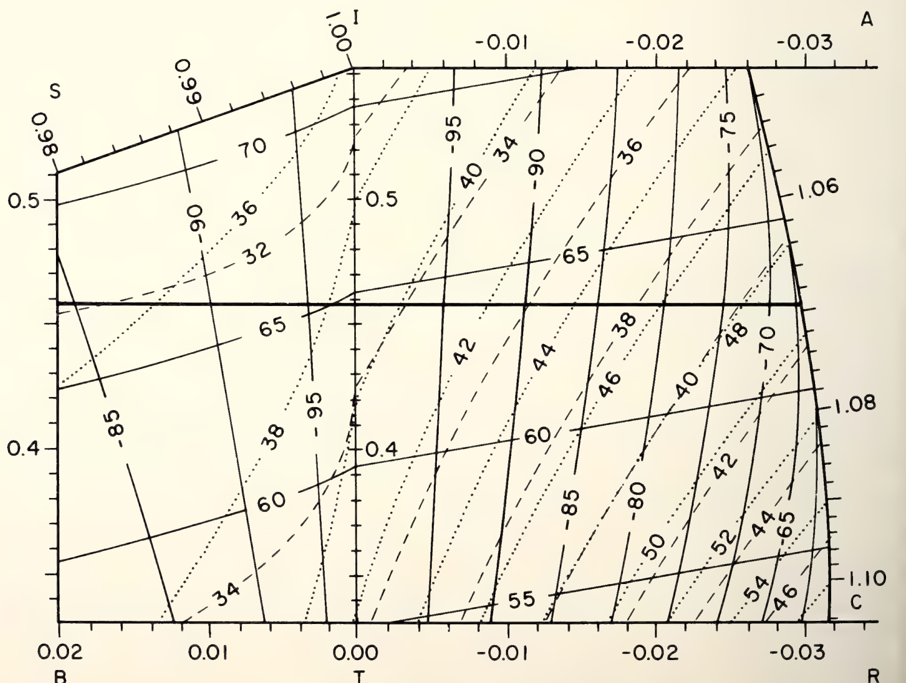


FIGURE 4. Section of the $x_g = x_s = 0.6$ Nomograph pertinent to EE Peg. Drawing follows the convention set up in Figure I of Contribution 26. The heavy horizontal line is the depth line for EE Peg.

TABLE 6. Nomographic solution for EE Peg.

Preliminary $\mathscr{L}_0^{pr} = 0.57856$, $\mathscr{L}_0^{sec} = 0.91974$

$\chi_s^{tr} = 0.405 \qquad 0.400 \leq \chi_s^{tr} \leq 0.410$

$\chi_s^{oc} = 0.502 \qquad 0.480 \leq \chi_s^{oc} \leq 0.520$

$(1 - \mathscr{L}_0^{tr}) + (1 - \mathscr{L}_0^{oc}) = 0.5017$

$$\frac{1 - \mathscr{L}_0^{tr}}{\mathscr{L}_0^{oc}} = 0.4582$$

Limits on k for fixed $\mathscr{L}_0^{pr}$ and $\mathscr{L}_0^{sec}$

$x = .4 : 0.658 \geq k \geq 0.645$ by Contr. No. 23 p. 152
$.6 : 0.647 \geq k \geq 0.626$ by Contr. No. 23 p. 216
$.8 : 0.635 \geq k \geq 0.604$ by Contr. No. 23 p. 280

With χ^{oc} tolerances, solutions exist on

$x = 0.6$ and $x = 0.8$ for $0.60 \leq k \leq 0.63$,

$1.06 \leq \alpha_0^{tr} \leq 1.08, \quad -1.51 \leq p_0 \leq -1.42$

It now appears that x_g is close to 0.6, x_s probably about 0.7

Final Nomographic solution (by measurement) is

${}^6\alpha_0^{tr} = 1.0624$, ${}^6k^{tr} = 0.6275$, ${}^6p_0^{tr} \cong -1/0.700$

Adjustment by Contr. No. 23 yields

${}^6\alpha_0^{tr} = 1.0626$ and ${}^6p_0^{tr} = -1.4067$ for ${}^6\alpha_0^{tr}\,{}^6\tau = 0.45822$
${}^6n^{ann}$ table (p. 215) yields correction of $+0.00015$ for $\mathscr{L}_0^{pr}$ and therefore $\alpha_0^{tr}\tau = 0.45805$

It is perfectly obvious in this EE Peg case that we are concerned only with complete eclipses and the depth line for the Nomographs (Merrill 1953) horizontally across TIC at the level $\alpha_0^{tr} = (1 - \mathscr{L}_0^{pr}) / \mathscr{L}_0^{sec}$. As an added convenience to users of the Tables (Merrill 1950) and Nomographs, Contribution 23 provides the limiting values of k (called there k_i and k_c) for the range of values possible for $\alpha_0^{tr}\tau$ for each darkening x_g, the values of k, in other words, where the depth line cuts IT and IC. Those for x = 0.4, 0.6 and 0.8 are listed in Table 6 and show even before going to the Nomographs, that k is severely restricted; it must lie between 0.60 and 0.65, and for any particular darkening it is limited to a range of about 0.02.

Figure 4 shows the relevant section of the Nomograph $x_g = x_s = 0.6$ with the particular depth line drawn across it. It is important to note that the statements $\alpha_0^{tr}\tau = 0.4582$, $\chi_8^{tr} = 0.405$, and $\chi_8^{oc} = 0.502$ are pure observational "facts", completely independent of any knowledge of or assumption about limb darkening; it is only when we go to the Tables and/or Nomographs dependent on the Model that degree of darkening enters the picture. (This ignores the minute effect of choice of limb darkening on the phase-rectification performed earlier.)

Time spent poring over the array of Nomographs laid out side by side, is usually time well spent. A day or so invested in trials, comparisons, rejections, even one or two tentative probings into cases such as $x_g = 0.6$, $x_s = 0.8$ and vice versa, helps significantly in achieving a good understanding of the relation of the observed system to those Model parameters involved directly on the Nomographs. This survey yields a decision that the $x_g = x_s = 0.6$ Nomograph provides the most credible results, in this case (as often) most easily read from the scales and contours with a Leverrier-type triangular scale. (As is usually the case, the deduced α_0^{tr} is to be regarded as probably more trustworthy than the p_0). The parameters as read from the Nomograph, when subjected to "fine adjustment" for consistency in the x = 0.6 Table, yield the set ${}^6k = 0.6275$, ${}^6\alpha_0^{tr} = 1.0626$, ${}^6p_0 = -1.4067$, ${}^6\tau = 0.431234$, with ${}^6\alpha_0^{tr\,6}\tau$ compromised thereby at 0.45822; the darkening index has been attached here to emphasize the fact that a selection (reasoned and reasonable, but a selection) has now been made.

Finally, this set of parameters implies ${}^6\chi_8^{tr} = 0.404$ (very close to the "preferred" value) but ${}^6\chi_8^{oc} = 0.484$, within the assigned tolerance but about as far to one side of the preferred value as an $x_s = 0.8$ solution would be on the other. There is therefore a suggestion from the Nomographs that x_s may well be about 0.7; we proceed, however, on the basis of $x_g = x_s = 0.6$ for now, in effect giving more weight (as seems appropriate) to the much deeper primary eclipse.

Intermediary Solution—The needed nomographic data, input and output, can easily be transformed into parameters for a ψ^{tr} curve, a course slightly preferable in this particular case to avoid double interpolations in the χ's near centrality; then this ψ^{tr} equation yields immediately $\sin\phi'_i = 0.060605$ and thereby enables us to enter the very useful little ${}^6n^{ann}$ table (Contribution 23,215) to calculate (O-C)'s for the 5-normals nearest to $\phi'' = 0.0$. (Of course the same result would be obtained using the ψ^{tr} equation directly, if one preferred that.) The mean (O-C) for the six normals nearest primary epoch is +0.00015, so $\mathcal{L}_0^{pr}$ is now altered to 0.57871 and will be held at that level throughout all further work. For convenience the data needed for the next steps are brought together at the beginning of Table 7.

The value of ϕ''_e yielded by the preliminary ψ^{tr} equation, 0.044904, is (fortunately!) seen to fit both eclipses well enough for our present purposes, so the middle-level parameters (the old n = 0.5 values of ϕ'') are now abandoned and $\phi''_e = 0.0450$ is used with the $\alpha_0^{tr} = 1.0622$ to define a new ψ^{tr} equation for a curve passing through $\mathcal{L}_0^{pr} = 0.57871$; this is the equation for the "base curve C for primary" given in Table 7. This equation establishes the phase of internal tangency at $\sin^2\phi''_i = 0.00366625$ and enables us to construct the ψ^{oc} equation for a curve through that point and the $\phi''_e = 0.0450$; this is the equation for the "base curve C for secondary" given in Table 7. This pair of equations, or pair of curves, C can reasonably be regarded as semi-final. The residuals $R^{tr} = \mathcal{L}'' - \mathcal{L}_C^{tr}$ and $R^{oc} = \mathcal{L}'' - \mathcal{L}_C^{oc}$ for the 5-normals in the respective eclipses, form the basis for the study of possible refinement of parameters next undertaken.

TABLE 7. Data and formulas for refining solution for EE Peg.

$1 - \mathcal{L}_0^{pr} = 0.42129$, $1 - \mathcal{L}_0^{sec} = 0.08026 = L_s$, $L_g = 0.91974$
$x_g = x_s = 0.6$

$$\frac{1 - \mathcal{L}_0^{tr}}{\mathcal{L}_0^{oc}} = \alpha_0^{tr}\tau = 0.45805$$

${}^6\tau = 0.431234$ ${}^6\alpha_0^{tr} = 1.0622$

$\phi(\alpha^{tr} = 0.53130) = 0.02289$

Then $\phi_e = 0.044904$ Abandon $\phi(\alpha^{tr} = 0.53130)$ and set $\phi_e = 0.0450$,
$\sin^2\phi_e = 0.07783598$

Then $\sin^2\phi_i = 0.00366625$; this is used with ϕ_e, for secondary Base Curves C

For the 48 points of secondary

${}^6\psi^{oc}(0.6275, \alpha^{oc}) = 81.2704 \sin^2\phi - 1.6950$
$\mathcal{L}_C^{oc} = 1 - 0.08026\,\alpha^{oc}$ $R^{oc} = \mathcal{L}'' - \mathcal{L}_C^{oc}$

For the 58 points of primary

${}^6\psi^{tr}(0.6275, \alpha^{tr}) = 93.3925 \sin^2\phi - 1.6342$
$\mathcal{L}_C^{tr} = 1 - 0.39662\,\alpha^{tr}$ $R^{tr} = \mathcal{L}'' - \mathcal{L}_C^{tr}$

Refining vectors: $K = G = S = E = 0$ at base curves C;

$K = 1$ at $k = 0.6375$; $G = 1$ at $x_g = 0.8$; $S = 1$ at $x_g = 0.8$; $E = 1$ at $\phi_e = 0.0445$,
$\sin^2\phi_e = 0.07616110$

Equations for Target Curves

K: ${}^6\psi^{oc}(0.6375, \alpha^{oc}) = 79.7614 \sin^2\phi - 1.5168$
$\mathcal{L}_K^{oc} = 1 - 0.08026\,\alpha^{oc}$ $\kappa^{oc} = \mathcal{L}_K^{oc} - \mathcal{L}_C^{oc}$
${}^6\psi^{tr}(0.6375, \alpha^{tr}) = 91.7246 \sin^2\phi - 1.4330$
$\mathcal{L}_K^{tr} = 1 - 0.40958\,\alpha^{tr}$ $\kappa^{tr} = \mathcal{L}_K^{tr} - \mathcal{L}_C^{tr}$

G: ${}^6\psi^{oc}(0.6275, \alpha^{oc}) = 78.3005 \sin^2\phi - 1.4638$
$\mathcal{L}_G^{oc} = 1 - 0.08026\alpha^{oc}$ $\gamma^{oc} = \mathcal{L}_G^{oc} - \mathcal{L}_C^{oc}$
${}^8\psi^{tr}(0.6275, \alpha^{tr}) = 95.1574 \sin^2\phi - 1.3600$
$\mathcal{L}_G^{tr} = 1 - 0.41229\,\alpha^{tr}$ $\gamma^{tr} = \mathcal{L}_G^{tr} - \mathcal{L}_C^{tr}$

S: ${}^8\psi^{oc}(0.6275, \alpha^{oc}) = 81.2704 \sin^2\phi - 1.7922$
$\mathcal{L}_S^{oc} = 1 - 0.08026\,\alpha^{oc}$ $\sigma^{oc} = \mathcal{L}_S^{oc} - \mathcal{L}_C^{oc}$
$S^{tr} = C^{tr}$ and therefore all $\sigma^{tr} = 0$

E: ${}^6\psi^{oc}(0.6275, \alpha^{oc}) = 83.0579 \sin^2\phi - 1.6950$
$\mathcal{L}_E^{oc} = 1 - 0.08026\,\alpha^{oc}$ $\varepsilon^{oc} = \mathcal{L}_E^{oc} - \mathcal{L}_C^{oc}$
${}^6\psi^{tr}(0.6275, \alpha^{tr}) = 95.4463 \sin^2\phi - 1.6342$
$\mathcal{L}_E^{tr} = 1 - 0.396623\,\alpha^{tr}$ $\varepsilon^{tr} = \mathcal{L}_E^{tr} - \mathcal{L}_C^{tr}$

Some general statements are in order. First, the situation at hand calls for refinement of four "independent" parameters. Second, while in principle this refinement can be pursued in either the ψ-functions or the α-functions (indeed in the χ-functions as far as accuracy is concerned!) this writer prefers the ψ's. Third, while in principle one has considerable choice among orbital and curve parameters to be refined, this writer slightly prefers the mixed set k, x_g, x_s, and ϕ_e'', though this preference is not so strong as that for use of the ψ's already mentioned; the first three named are involved explicitly as arguments in all the Tables, and the fourth is (more or less) directly visible on the light curve, in contrast for instance with cos i. Fourth, rather than deal with these parameters themselves directly, one finds it convenient to deal with the proportion of change in each parameter over an interval for that parameter deliberately selected so that it lies entirely within the region of reality for that parameter for that binary system. We shall call these four proportioning parameters K,G,S,E to associate them easily in mind with k,x_g,x_s, and ϕ_e'' respectively.

Fifth and finally, at this intermediary-orbit stage there are considerable advantages in adjusting the selected parameters one at a time, bit by bit, over and over, rather than all in one fell swoop. The process is, in its first round, that of least squares adjustment of single parameters, applied to the four (at most) in a succession determined by the simple criterion of stability of the first divisions involved. That is, for a given star one naturally solves for the parameters in the order of decreasing size of the denominators [$\kappa\kappa$], [$\gamma\gamma$], [$\sigma\sigma$] and [$\varepsilon\varepsilon$]. As can be seen from the "Data" in Table 8, for EE Peg that order is G,K,S,E, not the somewhat conventionalized order in which the ψ equations are listed at the end of Table 7.

Now if one were adjusting only one parameter, then the first division would of course accomplish all that can be accomplished, but re-adjusting by the second, third, fourth parameters introduces new residuals to be taken account of in a second round. These new residuals are so related to the initial data that one can set up a very simple set of recursion formulas for their evaluation. The recursion forms are in fact so simple that it is not worth the small bit of algebra involved, to leapfrog two or three rounds, or even to solve the full-dress set of least squares normal equations, to which solution the simplistic one-at-a-time round-and-round one tends in those cases where one encounters no troubles in the more sensitive four-unknown case.

What intervals should be chosen over which to extend our implicit assumption of linearity of effects? The choices will depend somewhat on the individual case. We already know that solutions for EE Peg are considerably restricted in k by $(1-\mathscr{L}_0^{pr}) / \mathscr{L}_0^{sec}$, so an interval of 0.01 in k is perhaps reasonable, and the Nomographic situation indicated that k might be *slightly* more likely to be more rather than less than 0.6275. We choose k = 0.6375 as the "target", or the working parameter K to be O at k = 0.6275 and 1 at k = 0.6375. A logical "step" for x_g is the 0.2 of the Tables and one would therefore wish to use x_g = 0.4 as the terminal for the working parameter G, but no real solution exists at x_g = 0.4, k = 0.6375, α_0^{tr} = 1.0622, so we take G as 0 at x_g = 0.6 and 1 at x_g = 0.8 where a

TABLE 8. Refining solution for EE Peg.

Algorithms

Secondary Eclipse

$$G_1 = \frac{[R\gamma]}{[\gamma\gamma]}$$

$$K_1 = \frac{[R\kappa]}{[\kappa\kappa]} - \frac{[\kappa\gamma]}{[\kappa\kappa]} G_1$$

$$S_1 = \frac{[R\sigma]}{[\sigma\sigma]} - \frac{[\gamma\sigma]G_1 + [\kappa\sigma]K_1}{[\sigma\sigma]}$$

$$E_1 = \frac{[R\varepsilon]}{[\varepsilon\varepsilon]} - \frac{[\gamma\varepsilon]G_1 + [\kappa\varepsilon]K_1 + [\sigma\varepsilon]S_1}{[\varepsilon\varepsilon]}$$

$$G_{n+1} = -\frac{[\kappa\gamma]K_n + [\gamma\sigma]S_n + [\gamma\varepsilon]E_n}{[\gamma\gamma]}$$

$$K_{n+1} = -\frac{[\kappa\sigma]S_n + [\kappa\varepsilon]E_n + [\kappa\gamma]G_{n+1}}{[\kappa\kappa]}$$

$$S_{n+1} = -\frac{[\sigma\varepsilon]E_n + [\gamma\sigma]G_{n+1} + [\kappa\sigma]K_{n+1}}{[\sigma\sigma]}$$

$$E_{n+1} = -\frac{[\gamma\varepsilon]G_{n+1} + [\kappa\varepsilon]K_{n+1} + [\sigma\varepsilon]S_{n+1}}{[\varepsilon\varepsilon]}$$

$$\Sigma R^2_{n-1} = \Sigma R^2_n - [\gamma\gamma]G^2_{n+1} - [\kappa\kappa]K^2_{n+1} - [\sigma\sigma]S^2_{n+1} - [\varepsilon\varepsilon]E^2_{n+1}$$

Primary Eclipse

For primary eclipse delete S

Data

Secondary Eclipse

$[R\gamma] = -0.00005207$	$[\gamma\gamma] = +0.00037694$	$[\sigma\sigma] = +0.00008493$
$[R\kappa] = -0.00004107$	$[\kappa\gamma] = +0.00030631$	$[\gamma\varepsilon] = +0.00005194$
$[R\sigma] = +0.00002452$	$[\kappa\kappa] = +0.00025076$	$[\kappa\varepsilon] = +0.00004454$
$[R\varepsilon] = -0.00000650$	$[\gamma\sigma] = -0.00016726$	$[\sigma\varepsilon] = -0.00002690$
$\Sigma R^2 = +0.00016356$	$[\kappa\sigma] = -0.00013959$	$[\varepsilon\varepsilon] = +0.00001580$

Primary Eclipse

$[R\gamma] = +0.00013765$	$[\gamma\gamma] = +0.01236374$	$[\gamma\varepsilon] = +0.00182073$
$[R\kappa] = +0.00007550$	$[\kappa\gamma] = +0.00592028$	$[\kappa\varepsilon] = +0.00073708$
$[R\varepsilon] = +0.00004347$	$[\kappa\kappa] = +0.00300286$	$[\varepsilon\varepsilon] = +0.00042070$
$\Sigma R^2 = +0.00039778$		

Adjustment Equations

Secondary Eclipse

$G_1 = -0.1381$
$K_1 = -0.1638 - 1.2215\,G_1$
$S_1 = +0.2887 + 1.9694\,G_1 + 1.6436\,K_1$
$E_1 = -0.4114 - 3.2873\,G_1 - 2.8190\,K_1 + 1.7025\,S_1$
$G_{n+1} = -0.8126\,K_n + 0.4437\,S_n - 0.1378\,E_n$
$K_{n+1} = +0.5567\,S_n - 0.1776\,E_n - 1.2215\,G_{n+1}$
$S_{n+1} = +0.3167\,E_n + 1.9694\,G_{n+1} + 1.6436\,K_{n+1}$
$E_{n+1} = -3.2873\,G_{n+1} - 2.8190\,K_{n+1} + 1.7025\,S_{n+1}$
$\Sigma R^2_{n+1} = \Sigma R^2_n - 0.00037694\,G^2_{n+1} - 0.00025076\,K^2_{n+1} - 0.00008493\,S^2_{n+1} - 0.00001580\,E^2_{n+1}$

Primary Eclipse

$G_1 = +0.0111$
$K_1 = +0.0251 - 1.9715\,G_1$
$E_1 = +0.1033 - 4.3279\,G_1 - 1.7520\,K_1$
$G_{n+1} = -0.4788\,K_n - 0.1473\,E_n$
$K_{n+1} = -0.2455\,E_n - 1.9715\,G_{n+1}$
$E_{n+1} = -4.3279\,G_{n+1} - 1.7520\,K_{n+1}$
$\Sigma R^2_{n+1} = \Sigma R^2_n - 0.01236374\,G^2_{n+1} - 0.00300286\,K^2_{n+1} - 0.00042070\,E^2_{n+1}$

Results of Four Rounds

Secondary Eclipse

Round	G	K	S	E	$\Delta\Sigma R^2$	ΣR^2_n
						0.00016356
1	−0.1381	+0.0050	+0.0248	+0.0710	−0.00000733	0.00015623
2	−0.0028	+0.0046	+0.0246	+0.0380	−0.00000008	0.00015615
3	+0.0019	+0.0046	+0.0233	+0.0205	−0.00000006	0.00015609
4	+0.0038	+0.0047	+0.0217	+0.0112	−0.00000005	0.00015604

Primary Eclipse

						0.00039778
1	+0.0111	+0.0032		+0.0496	−0.00000259	0.00039519
2	−0.0088	+0.0052		+0.0290	−0.00000139	0.00039380
3	−0.0068	+0.0062		+0.0184	−0.00000083	0.00039297
4	−0.0057	+0.0067		+0.0129	−0.00000060	0.00039237

Adopted Adjustments

$G = -0.020$ $\qquad$ $\Delta x_g = -0.004$
$K = +0.020$ $\qquad$ $\Delta k = +0.0002$
$S = +0.10$ $\qquad$ $\Delta x_s = +0.02$
$E = +0.120$ $\qquad$ $\Delta\phi_e = -0.00006$

For each 5-normal these constants imply

$R' = R - 0.02\,\kappa - 0.12\,\varepsilon + 0.02\,\gamma - 0.10\,\sigma$

For Comparisons

	ΣR^2	ΣR_4^2	$\Sigma R'^2$
Secondary Eclipse	*0.00016356*	*0.00015604*	*0.00016029*
Primary Eclipse	*0.00039778*	*0.00039237*	*0.00039210*
Both Eclipses	*0.00056134*	*0.00054841*	*0.00055239*

The standard deviation of a single 5-normal, over both eclipses, is 0.00228.

---

solution does exist, and thereby anticipate a small negative value of G emerging from our analysis. An alternative would have been using $x_g = 0.4$ and a target k (i.e., K = 1) at a value permitted by the Tables and therefore the Model. There is no problem about choosing $x_s = 0.8$ and therefore S = 0 at $x_s = 0.6$, S = 1 at $x_s = 0.8$. Lastly, $\phi''_e = 0.0450$ appears good but *perhaps* a little high, so we set E = 0 at 0.0450 and E = 1 at 0.0445; an advantage of ϕ''_e over some other possible choices for the fourth parameter is that it cannot possibly "blow up".

So in simple routine fashion the "Equations for Target Curves" shown on Table 7, three for each eclipse for each of the four working parameters, are set up, and our study concentrates itself on the determination of values of K,G,S, and E such that, operating on the curve differences $\kappa,\gamma,\sigma,\varepsilon$ at the given observed phases, they reduce the ΣR^2 derived from the base curves C reasonably. The recursion forms, the numerical summations, the numerical recursion equations, and a display of the progress round-by-round through four rounds, are all given in Table 8.

Now before we proceed with the interpretation of our formal results of the adjustment process, some of the interesting and important implications of Figure 5 should be considered. For secondary (above primary because that is the way the eclipses "nest" in Figures 3 and 6) there are displayed the five sets of differences R^{oc},κ^{oc},γ^{oc},σ^{oc}, and ε^{oc} defined in Table 7, and for primary the four sets R^{tr}, κ^{tr},γ^{tr},ε^{tr} (with σ^{tr} omitted because $\sigma^{tr} = 0$). On the R charts, the plus-signs are for the points on the ascending branches and the times-signs for the points on the descending branches, reflected. These two R charts show us first of all (what we already knew) that the semi-final relations C do indeed provide a good "solution" themselves.

Take any one of the other plots, say the one labelled K in primary. Each dot represents, actually, the value of κ for the particular 5-normal at that phase on the ascending branch, that is the total effect at that phase, of changing k *alone*, from 0.6275 to 0.6375; that little chart is labelled K because it is multiplication of the finally-adopted value of K into these κ's which is of later interest to us. For the present we note some other related points of importance.

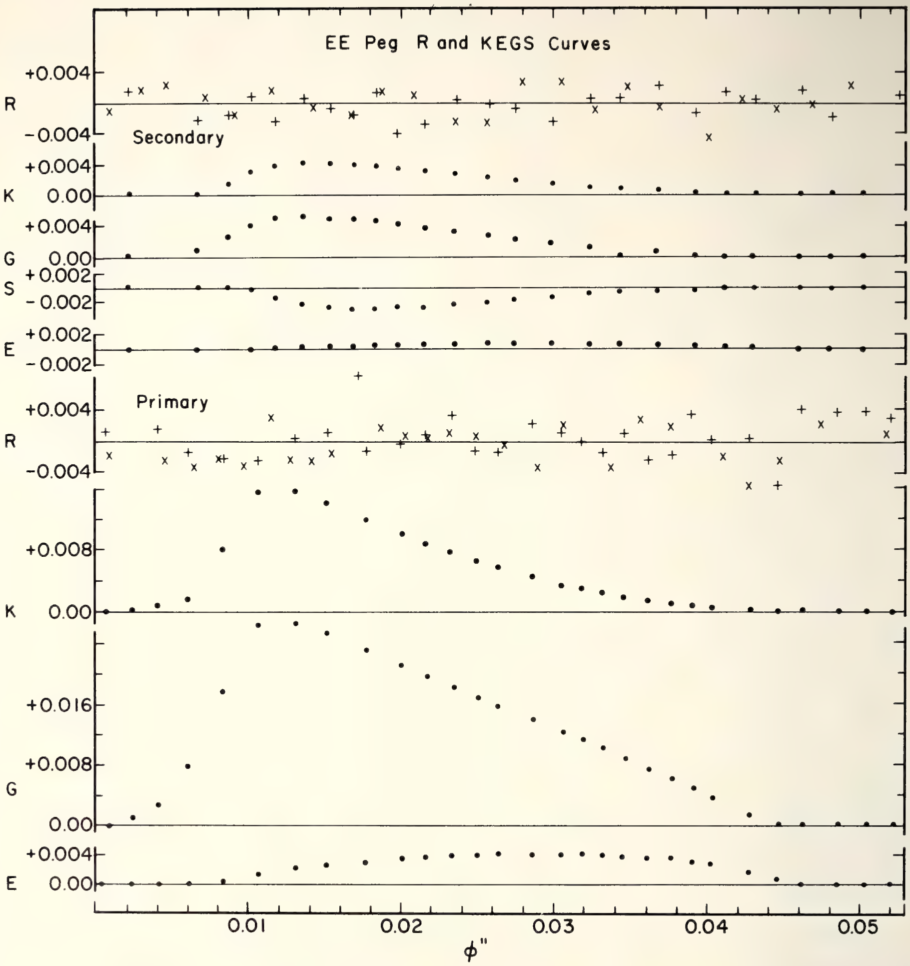


FIGURE 5. Residuals from base curves C for EE Peg, with values for κ, γ, σ, and ε. Note that all vertical scales are the same.

First, in both eclipses there is evidenced strong correlation between K and G. While we can reasonably hope that our finally-adopted values of K and G do together remove most of the (κ,γ) effect, we cannot be sure that the apportionment to ratio of radii versus darkening on the larger star, is correct. Fortunately, in this case the total amount is so small we are probably safe. Second, the G plot in secondary shows that the choice of darkening for the larger star does indeed affect the shape of the ψ curve for the occultation eclipse, for the reason stated earlier, namely that it affects the choice for the phase of internal tangency. Third, for both eclipses the relative heights of the K and G plots imply that for EE Peg at least the effect of a change of x_g by a full 0.2 corresponds fairly well to a change of k by only 0.015! No better example could be asked for, of the well-known fact that light curves are usually relatively insensitive to changes in darkening over

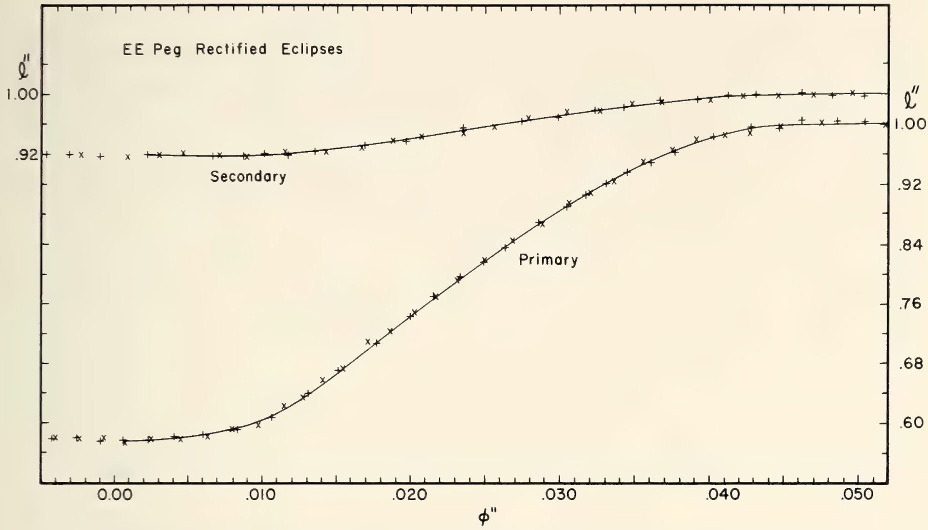


FIGURE 6. Adopted theoretical curves F drawn on plots of the 5-normals for EE Peg.

most of their length. And fourth, ϕ_e'' really is nicely independent of the other parameters.

The step-by-step and round-by-round results of the first four rounds of the intermediary solution, are exhibited in Table 8. It is obvious that no real gain in overall precision was being achieved after about the second round at most. Again, the interplay between the G and the K raises questions about the reality of the final apportionment of adjustment between these two correlated parameters.

Sometimes the process tends clearly towards essentially the same final values for a given parameter out of both eclipses; this is the case with the uncorrelated E. When this does not occur, as in the strongly correlated G and K cases, some reasonable balance needs to be struck *deliberately*, between the tendencies of the two eclipses. Obviously, in compromising on a value for G in the present case the weight for the primary eclipse should be greater than that for the secondary. Reason and not blind formalism should prevail. So having decided, from the $\Delta\Sigma R_n^2$ values listed, to cut off at four rounds, the compromises given under "Adopted Adjustments" were selected and the values of $\Sigma R'^2$ listed near the end of the table calculated.

It should be noticed that the standard deviation of a single 10-normal in the tops (Table 5) and that for a single 5-normal in the eclipses (Table 8) are practically identical whereas for random distribution of errors they should be in the ratio 0.7 to 1. There can be seen in the original data what looks like an extremely-short–period fluctuation; it was not removed in the rectification-adjustment process employed, and probably accounts at least partly for the equality of the two measures of dispersion. This says again that little further "refinement" of the eclipse parameters alone would be justified.

INTERPRETATIONS—At the beginning of Table 9 are given the values of k, x_g, x_s, and ϕ''_e derived from the intermediary solution discussed above. It is obvious that the change from the base curves C is extremely small, too small to distinguish on ordinary published plots, actually. We show in Fig. 6 the theoretical curves corresponding to the adopted parameters, plotted from the lists of $\mathscr{L}''$ - $\mathscr{L}^{oc}_F$ = R'^{oc} and $\mathscr{L}''$ - $\mathscr{L}^{tr}_F$ = R'^{tr} in Appendix A, on existing Calcomp plots of $\mathscr{L}''$ rather than by setting up new ψ equations for that purpose alone. Those lists had been derived by use of the formulas for R′ stated on Table 8.

TABLE 9. Adopted parameters for EE Peg.

Assumed $e = 0$	Derived P = 2.6282154 days		
$\mathscr{L}^{pr}_0 = 0.57871$	$\mathscr{L}^{sec}_0 = 0.08026$		
$k = 0.6277$	$x_g = 0.596$	$x_s = 0.62$	$\phi''_e = 0.04494$
$^{.596}\tau(0.6277) = 0.43120$	$^{.596}\alpha^{tr}_0 = 1.0623$	$p_0 = -1.4091$	
τ τ τ			
$a_g = 0.1716$	$b_g = 0.1708$	$c_g = 0.1703$	
$a_s = 0.1077$	$b_s = 0.1072$	$c_s = 0.1069$	
$\eta^2 = 0.00927$	$\zeta^2 = 0.01511$		
$i_r = 88°.864$	$j = 88°.869$	$i = 88°.873$	
$L_g = 0.91974$,	$L_s = 0.08026$ for facing sides		
$\bar{J}_h / \bar{J}_c = 4.515$ for facing sides			
From the above and spectrum of S_h as A4V:			
Spectrum of S_c F9V			
$G_c = 0.01372$	$G_h = 0.00181$		
$C_0 = 0.00466$	$C_1 = 0.00476$	$C_2 = 0.00155$	
$L^{\circ}_g = 0.91829$	$L^{\circ}_s = 0.06928$ for backs		
From ϕ''_e, $\phi_e = 0.04470$			
$\phi''_i = 0.009674$ and thereby $\phi_i = 0.009620$			

The material of Table 9 is arranged somewhat in order of its development out of the formal solution. No effort has been made to reduce redundancy because redundancy is an outstanding characteristic of work in this field with this Model. The three theoretically different values for the inclinations are given, partly to illustrate how very little they do actually differ. The value for $\bar{J}_h / \bar{J}_c$ comes from the now-known radii and total luminosities for the facing sides rather than from the simple depths of the rectified eclipses.

This leads us to repeat the derivation for the spectrum of S_c and the longer one for the C's. The increase in C_1 is marked, but would in no way alter the net coefficient of the $\cos\phi$ term to be removed, since the increase merely calls (on this philosophy) for a "complication" term that much larger. Since C_0 and C_2 occur in both the numerator and the denominator of the rectification expression the changes seen in them would have extremely little effect, and without more credible information on the mass ratio there is no useful change to be made in the coefficients relating to the ellipticity portion of the rectification form. One concludes therefore that that process has effectively converged.

Given the revised G_c and G_h of Table 9 one finds at once the luminosities of the backs of the two components, and may be a little surprised to see that as separate objects in the sky they would have a brightness ratio in excess of 13:1 in the blue. Finally, knowledge of i_r and $(a_g - a_s)$ yields ϕ_i'', so there are given the phase of internal tangency in the "rectified" orbit and the phases for both tangencies in the "true" orbit, the latter obtained by inverting the phase rectification equation. It is not surprising that the "eyeball" estimate for ϕ_i listed in Table 1 is not quite so close to the adopted value as the mean of the two ϕ_e's there is to that adopted quantity.

No "probable errors" have been appended to any of the deduced parameters for the system. Formal probable errors were stated for the Fourier coefficients developed in the analysis of the tops; how meaningful they are for the system parameters, in view of the "complications" present, is problematical. Probable errors for the individual parameters would be of doubtful value at this stage, considering the marked correlation of k and x_g to which attention has already been called. Standard deviations for a single normal, for the solution as a whole, have been stated above and they appear to this writer to afford the best means of estimating the overall precision of this solution.

Some frankly personal assessments may be advanced as to reliability. The adopted period of revolution is still a little too long if one believes that the system has a rigorously constant period and that the three (O-C)'s for Marks, Dueball and Lehmann, and Virkhristijuk all represent gross blunders, but it is a little too short if one takes at face value the two excellent runs through primary minimum by Ebbighausen. It is hard to see how the value derived for k can be in error by as much as 0.005 unless x_g is in error by 0.07 (in the opposite sense), and even then the geometry for central phase imposes one limit. The radii found for the two components are severely conditioned by the obviously rather long duration of totality, so the derived radii should be reliable to a few thousandths, but certainly not in the fourth decimal. For a similar reason the inclination should be valid to $0^\circ\!.05$, probably, not of course to the number of decimals listed. All this is so much a function of the reasonableness of the procedure for handling the "complications" not a part of the Russell Model that attaching formalistic measures of precision to the individual parameters developed under the Model might do more harm than good at this stage. A procedure likely to be more helpful in the long run would be to analyze the apparent differences developed here between the Model and Nature, recast the totality of differences into categories such as "improvements in first-order Model terms", "perturbations", and "probable true complications", and re-solve *ab initio* on that basis. But this was not, in my opinion, really a part of the charge from the Organizing Committee.

CM LACERTAE BACKGROUND—In the Russell Model solution for CM Lacertae most of the procedure is of course the same as in the case of EE Pegasi, but some little food for thought is provided by certain of the differences. I shall concentrate most of my discussion on these latter.

Three sets of photoelectric observations are available: Popper's (1958) 180 each in the yellow and the blue; Alexander's (1957) 354 in yellow and 225 in blue; and Barnes, Hall and Hardie's (1968) 295 each in yellow, blue and ultraviolet. Dr. Linnell and I had originally intended to consider all three colors in the latter material, but need arose unexpectedly for additions to the work and this, somewhat regrettably, prevented my going beyond the treatment of the yellow.

Alexander decided that his data were satisfactorily represented on the Russell Model with $k = 0.88$, $x_g = x_s = 0.2$ in the yellow and $x_g = x_s = 0.6$ in the blue, and primary an occultation. Barnes, Hall, and Hardie (hereinafter called BHH) decided on a solution with $k = 0.89$, $x_g = x_s = 0.6$, and primary a transit, as representing their data. Popper did not publish an orbital solution for his material; his observations in the yellow furnish very valuable information concerning the probable shape of ingress shoulder of secondary to firm up the rectification study for the BHH yellow curve without actually mixing the two sets of data.

In the BHH list, a single J.D. heliocentric is given for the three associated observations of the variable, so the time-wise accuracy for a given color is thereby limited slightly. It appeared that one should follow the BHH course and adopt Alexander's light elements.

Prim. Min. = J.D.(helioc.) $2427026.3159 + 1^{d}.6046914n$ for the reductions to phase.

Extinction corrections had already been applied to the published BHH observations. Magnitude differences $\Delta m_v = V - 8^{m}.186$ were run out, to bring the unit of light to the level of the brightest V observation, then the requisite values of ϕ and ℓ calculated. These are listed for the individual yellow observations in the first two columns of Appendix B. The 293 pairs (ϕ, ℓ) therein (2 observations were rejected at an early stage as aberrant) form the basis of this present study.

The general character of the system is evident from the plots and solutions published in 1957 and 1968; the eclipses are certainly partial and there is some need for rectification. Popper (1968) decided on $e = 0$ as satisfying his radial velocity observations, and obviously the secondary eclipse is at mid-period on the light curve. The only anomaly in the picture is the divergence between the Alexander and the BHH brightnesses and sizes for the two components and the concomitant choices for the character of the respective eclipses.

RECTIFICATION AND ADJUSTMENT—There are 42 individual observations in the first top and 63 in the second. It was obvious from the original (ϕ, Δm_v) plot that some of the observations on ingress shoulder of secondary were questionable. Neither Alexander's published diagram nor a plot of Popper's data showed any such degree of asymmetry for the shoulders. The Fourier analyses, computer

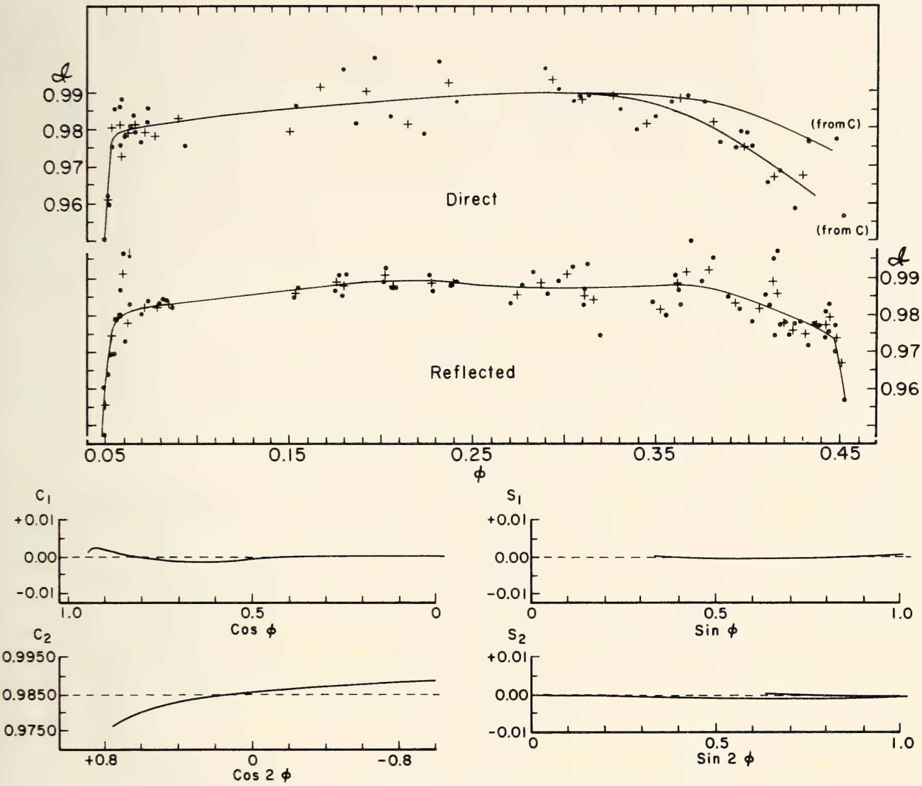


FIGURE 7. CM Lac tops and graphical analysis.

and graphical, were run through both including and excluding 6 observations on J.D. 2427224 which appeared low relative to those before and after on the same night, as seen in Fig. 7, upper. It was decided to omit those 6 from further work but to furnish the reader in Table 10 the computer-based Fourier coefficients for both cases for comparison or use. This matter of selection may seem of some special importance at a later stage.

Both the spectra of the two components and the mass ratio are available in this case from Popper's 1968 study. His radial velocity diagram puts the more massive A3 component in eclipse at primary, and the mass ratio at 0.782; he classifies the less massive component as A8, so there can be no doubt as to which component would be eclipsed at which minimum. We are therefore led without ambiguity through the derivations summarized in Table 11 to the rectification-and-adjustment form for ℓ'' and the phase-rectification formula given in Table 12. Mean values of ℓ'' in selected regions are also given there, and the effect the "low shoulder" would have had in ℓ'' is shown. The individual values of ℓ'' for all 293 observations, and the values of ϕ'' and $\sin^2\phi''$ for the individuals in the eclipses are listed in Appendix B.

NOMOGRAPHIC SOLUTIONS—The freehand curves drawn on the Calcomp plots of ℓ'' led to sets of ϕ'' readings at the conventional n levels shown on Fig. 8, which in turn (after smoothing and re-checking) provided the "preferred" values $\chi_8^{pr} = 0.2727$ and $\chi_8^{sec} = 0.2727$, and their tolerances, listed in Table 13. With $\chi_8^{pr} = \chi_8^{sec}$ one knows of course, even before going to the Nomographs, that any acceptable solution requires k very close to 1 unless the two darkenings are markedly (0.4, say) different, and there does not seem to be any particular reason, either from the light curve or from the Nomographs, to suppose that they are.

Figure 9 shows the regions of the $x_g = x_s = 0.2$ and the $x_g = x_s = 0.4$ Nomographs (the only ones on which any intersections occur even within the toler-

TABLE 10. Analysis of CM Lac tops

Coeff.	Computer: Including Shoulder	Computer: Excluding Shoulder	Graphical
A_0	+0.98224 ±49	+0.98326 ±58	+0.9834
A_1	+0.00354 ±71	+0.00164 ±92	+0.0023
A_2	−0.00863 ±79	−0.00709 ±91	−0.0067
A_3	+0.00244 ±74	+0.00152 ±79	+0.0026
A_4	−0.00154 ±92	−0.00142 ±93	−0.0021
B_1	−0.00113 ±61	−0.00058 ±64	+0.0001
B_2	+0.00048 ±57	−0.00046 ±65	−0.0005
B_3	−0.00333 ±58	−0.00192 ±73	−0.0005
B_4	+0.00152 ±55	+0.00040 ±64	+0.0003

Mean (*O-C*)'s for Computer Curves

Phases	Including Shoulder	Excluding Shoulder
0.055 to 0.25	−0.00005	0.00000
0.25 to 0.445	+0.00003	+0.00020
0.555 to 0.75	−0.00011	−0.00019
0.75 to 0.945	+0.00025	+0.00026
Both tops	$\sigma = 0.00603$	$\sigma = 0.00600$

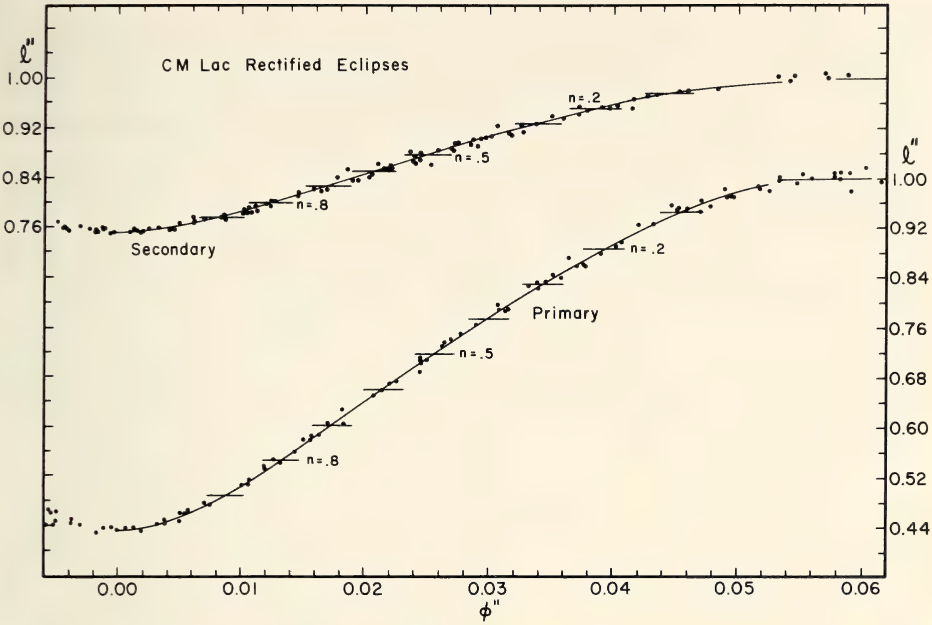


FIGURE 8. Freehand curves drawn on plots of the individual observations for CM Lac. Levels n for readings ϕ'' are shown.

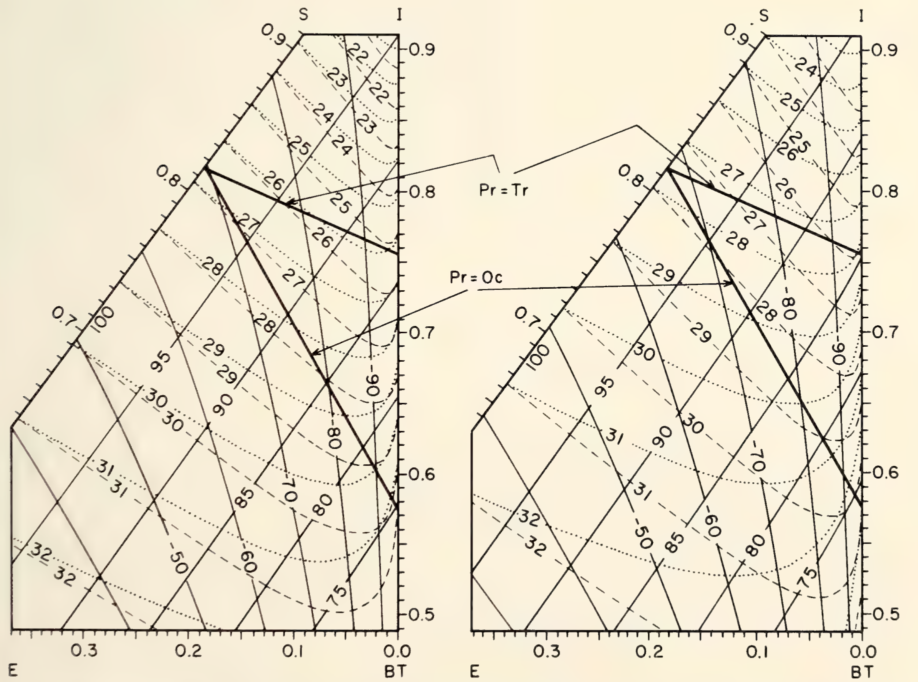


FIGURE 9. Section of the $x_g = x_s = 0.2$ Nomograph (Left) and of the $x_g = x_s = 0.4$ (Right) pertinent to CM Lac. The heavy oblique lines are the depth lines for CM Lac.

TABLE 11. Reflection and ellipticity coefficients for CM Lac.

From the observed curve $\frac{J_h}{J_c} = 2.224$

From the spectral types (A2, A8) and Figure II of Contribution No. 26

$$\left[\frac{G_c}{G_h}\right] = 3.51$$

1. Utilizing Hardie's solution of the curve

$(I_c I_h)^{1/2} r_c r_h = 0.01337$ $\quad i = 87^{\circ}.7$

$G_c + G_h = 0.0322$ $\quad G_c - G_h = 0.0179$

$C_0 = 0.00965$

$C_1 = 0.00715$ $\quad a_1$ (refl) $= -0.00715$

$C_2 = 0.00321$

2. Alternatively, utilizing the statistical approach

$G_c + G_h = 0.30 \sin^2 \phi_e$ with $\phi_e = 0.058$, $i = 86^{\circ}$

$G_c + G_h = 0.0382$, $G_c = 0.0297$, $G_h = 0.00847$

$C_0 = 0.01144$

$C_1 = 0.00848$ $\quad a_1$ (refl) $= -0.00848$

$C_2 = 0.00380$

- -

From the radial velocities $\frac{\mathfrak{M}_2}{\mathfrak{M}_1} = 0.782$

From Hardie's solution $a_g = 0.184$

With $x = 0.6$ and $\eta^2 = 3 \times 0.782\, a_g^3$

$z = 0.0146$ from the dynamics

$z = 0.0161$ from the light curve

Accept observed A_2 as ellipticity effect.
As in case of EE Peg, effect of ellipticity on observed A_1, A_3 and A_4 is negligible.

- -

Conclusion: Observed A_1, A_3, A_4 contain significant "complications."

ances) around the two possible positions of the depth lines, for prim = tr and for prim = oc. It is perfectly clear that the assumption pr = tr fits the x = 0.4 case rather well with $k \cong 0.97$ but does not fit the x = 0.2 case at all well (hardly inside the tolerances); it is just as clear that the assumption pr = oc fits the x = 0.2 case well with $k \cong 0.95$ but not at all well the x = 0.4 case (barely inside the tolerances). Two solutions differing by about 0.08 in real k and with the eclipse characters interchanged, definitely are set out for further investigation, by the (of course limited) data taken to the Nomographs.

Careful setting and resetting of the depth lines on these two Nomographs results in the sets of output parameters listed on Table 13 and the conclusion that the difference in darkening on the two components is probably, but not certainly, less than 0.2 whichever geometrical situation obtains. Special notice should be taken of the close agreement in both "solutions" of the χ_8^{sec} and χ_8^{pr} read

TABLE 12. Rectification and adjustment formulas for CM Lac.

$$\ell' = \ell + 0.00965 + 0.00715 \cos\phi - 0.00879 \cos\phi + 0.00321 \cos 2\phi + -0.00152 \cos 3\phi + 0.00142 \cos 4\phi$$

$$\ell' = \ell + 0.00965 - 0.00164 \cos\phi + 0.00321 \cos 2\phi + -0.00152 \cos 3\phi + 0.00142 \cos 4\phi$$

$$\ell'' = \frac{\ell'}{0.99291 - 0.00388 \cos 2\phi}$$

Around phase	Mean ℓ''
0.059	0.9970
0.256	1.0014
0.417	0.9897 (before excluding 6 obs. on shoulder)
0.559	1.0023
0.749	0.9979
0.940	1.0034
First top (36)	0.9992 (excluding 6 on shoulder)
Second top (63)	1.0010
Both tops (99)	1.0003 (excluding 6 on shoulder)

The standard deviation of a single rectified observation, over both tops but excluding the low shoulder, is 0.00606

For $x = 0.6$ and A_0, A_2, C_0, C_2 as listed earlier.

$N = 2.6$ $z = 0.01611$

$$\sin^2\phi'' = \frac{\sin^2\phi}{1 - 0.01611 \cos^2\phi}$$

TABLE 13. Nomographic solutions for CM Lac.

From the freehand curves for eclipses

		Primary	Secondary
ℓ_0		0.4322	0.7520
Maximum	ϕ_5	0.02571	0.02523
Preferred	ϕ_5	0.02551	0.02493
Minimum	ϕ_5	0.02531	0.02473
Maximum	ϕ_8	0.01348	0.01318
Preferred	ϕ_8	0.01328	0.01298
Minimum	ϕ_8	0.01308	0.01278
Maximum	χ_8	0.280	0.280
Preferred	χ_8	0.2727	0.2727
Minimum	χ_8	0.266	0.264

No clear indication from the χ's as to which eclipse is transit, but strong indication that k is very close to 1.

For primary as	Transit	Occultation
Depth line crosses *EI* at	0.8158	0.8158
Depth line crosses *IT* at	0.7551	0.5738
Intersection	Very satisfactory	Very satisfactory
$x_g = x_s$	0.4	0.2
χ_8^{Sec}	0.274	0.271
χ_8^{Prim}	0.272	0.273
k	0.970	0.950
α_0^{oc}	0.848	0.8416
p_0	−0.720	−0.718

No clear choice between these two solutions at this stage, perhaps a very slight preference for prim = oc.

No need evident for any $x_g \neq x_s$.

As usual, α_0^{oc} is slightly more firmly determined than p_0.

from the Nomograph compromises, with the 0.2727 for both χ's with which we entered the Nomographs. The fact that there is "perhaps a very slight preference for prim = oc" obviously does not remove the need to investigate the prim = tr possibility since the difference between the two solutions is almost certainly too great for either to converge into the other even near k = 1 where the geometrical distinction is least. The amount of work in prospect on refining solution for CM Lac has therefore doubled!

Intermediary Solutions—The parameters taken from the Nomographs (and adjusted to consistency by the Tables) were used to construct preliminary ψ equations in the manner described earlier. The equations served two purposes: (1) they provided information on ϕ_e'' and a reasonable range of adjustment for it; (2) they provided (O-C)'s for each observation near the minima, by which to adjust the levels $\mathcal{L}_0^{pr}$ and $\mathcal{L}_0^{sec}$. It seemed reasonable to set $\phi_e'' = 0.0551$ (E = 0) and E = 1 at $\phi_e'' = 0.0544$. No change seemed called for in $\mathcal{L}_0^{sec} = 0.7520$; $\mathcal{L}_0^{pr}$ was lowered slightly, to 0.4310. These two levels are hereafter held fixed. At the top of Tables 14 and 15 are listed the several parameters pertinent to the base curves and equations C for the respective solutions.

One procedural matter should be mentioned here. It is important that the two equations of a given ψ^{oc}, ψ^{tr} pair be truly matched and in practice this means that the pair α_0^{oc}, α_0^{tr} be carefully matched. Choosing these correctly is frequently one of the most irritating little jobs in the whole process; the procedure here suggested (apparently not generally known) makes things straightforward.

The depth equation as applied to the minima can be written

$$ {}_{x_g}\alpha_0{}^{tr} = \frac{1-\mathcal{L}_0{}^{tr}}{{}_{x_g}\tau(k)} \qquad \frac{{}_{x_s}\alpha_0{}^{oc}}{{}_{x_s}\alpha_0{}^{oc}-(1-\mathcal{L}_0{}^{oc})} \tag{3} $$

where $\mathcal{L}_0^{tr}$ and $\mathcal{L}_0^{oc}$ are observed quantities and ${}_{x_g}\tau(k)$ is obtainable (Contribution 23, p. 350) since k is known; equation (3) therefore becomes a simple numerical relation between α_0^{tr} and α_0^{oc}. An approximate value of p_0 is known and the gradients of $\alpha^{tr}(p)$ and $\alpha^{oc}(p)$ are always linear over a short interval of the Tables, for given k. Taking the two values p_1 and p_2 of the argument p bracketing p_o, and forming the ratio

$$ Q = (\alpha^{tr}_2 - \alpha^{tr}_1)/(\alpha_2{}^{oc} - \alpha_1{}^{oc}) \tag{4} $$

we have (2)

$$ \alpha_0^{tr} = Q\alpha_0^{oc} + (\alpha_1^{tr} - Q\alpha_1^{oc}). \tag{5} $$

Substitution of equation (5) for α_0^{tr} in equation (3) produces a quadratic in α_0^{oc}, the algebraically greater root of which is the required value of α_0^{oc}.

Tables 14 and 15 carry all the ψ equations needed for the two refining solutions, and Tables 16 and 17 the specific algorithms, the results by steps and the final adopted adjustments, with the consequent values of ΣR^2 and so forth. Figure

TABLE 14. Data and formulas for refining solution for CM Lac, Pr = Tr.

$1-\mathcal{l}_0^{tr} = 1-\mathcal{l}_0^{pr} = 0.5690,\ 1-\mathcal{l}_0^{oc} = 1-\mathcal{l}_0^{sec} = 0.2480$

Base Curves C:

$k = 0.97,\quad \chi_g = \chi_s = 0.4,\quad {}^4\tau = 0.953802$

${}^4\alpha_0^{oc} = 0.84974,\quad {}^4\alpha_0^{tr} = 0.84243,$

$\phi_e = 0.0551\qquad \sin^2\phi_e = 0.1151442$

$L_s = 0.291855\qquad L_g = 0.708145$

For the 102 points of secondary

$C^{oc}{:}{}^4\psi^{oc}(97,\quad \alpha^{oc}) = 78.2740 \sin^2\phi'' - 0.88980$

$\mathcal{l}_C^{oc} = 1 - 0.291855\,\alpha^{oc}\qquad R^{oc} = \mathcal{l}'' - \mathcal{l}_C^{tr}$

For the 86 points of primary

$C^{tr}{:}{}^4\psi^{tr}(97,\quad \alpha^{tr}) = 80.6740 \sin^2\phi'' - 0.88514$

$\mathcal{l}_C^{tr} = 1 - 0.675430\,\alpha^{tr}\qquad R^{tr} = \mathcal{l}'' - \mathcal{l}_C^{tr}$

Refining vectors: $E = G = S = K = 0$ at base curves C;

$E = 1$ at $\phi_e = 0.0544$, $\sin^2\phi_e = 0.11235167$;

$G = 1$ at $x_g = 0.6$; $S = 1$ at $x_s = 0.6$; $K = 1$ at $k = 0.96$

Equations for target curves

$E^{oc}{:}{}^4\psi^{oc}(97,\quad \alpha^{oc}) = 80.2195 \sin^2\phi'' - 0.88980$

$\mathcal{l}_E^{oc} = 1 - 0.291855\,\alpha^{oc}\qquad \varepsilon^{oc} = \mathcal{l}_E^{oc} - \mathcal{l}_C^{oc}$

$E^{tr}{:}{}^4\psi^{tr}(97, \alpha^{tr}) = 82.6791 \sin^2\phi'' - 0.88514$

$\mathcal{l}_E^{tr} = 1 - 0.675430\,\alpha^{tr}\qquad \varepsilon^{tr} = \mathcal{l}_E^{tr} - \mathcal{l}_C^{tr}$

$G^{oc}{:}{}^4\psi^{oc}(97,\quad \alpha^{oc}) = 78.1426 \sin^2\phi'' - 0.87467$

$\mathcal{l}_G^{oc} = 1 - 0.295445\,\alpha^{oc}\qquad \gamma^{oc} = \mathcal{l}_G^{oc} - \mathcal{l}_C^{oc}$

$G^{tr}{:}{}^6\psi^{tr}(97,\quad \alpha^{tr}) = 79.3073 \sin^2\phi'' - 0.87277$

$\mathcal{l}_G^{tr} = 1 - 0.677687\,\alpha^{tr}\qquad \gamma^{tr} = \mathcal{l}_G^{tr} - \mathcal{l}_C^{tr}$

$S^{oc}{:}{}^6\psi^{oc}(97,\quad \alpha^{oc}) = 76.1065 \sin^2\phi'' - 0.91322$

$\mathcal{l}_S^{oc} = 1 - 0.288788\,\alpha^{oc}\qquad \sigma^{oc} = \mathcal{l}_S^{oc} - \mathcal{l}_C^{oc}$

$S^{tr}{:}{}^4\psi^{tr}(97, \alpha^{tr}) = 80.6000 \sin^2\phi'' - 0.87662$

$\mathcal{l}_S^{tr} = 1 - 0.678355\,\alpha^{tr}\qquad \sigma^{tr} = \mathcal{l}_S^{tr} - \mathcal{l}_C^{tr}$

$K^{oc}{:}{}^4\psi^{oc}(96,\quad \alpha^{oc}) = 77.1327 \sin^2\phi'' - 0.92238$

$\mathcal{l}_K^{oc} = 1 - 0.28796\,\alpha^{oc}\qquad \kappa^{oc} = \mathcal{l}_K^{oc} - \mathcal{l}_C^{oc}$

$K^{tr}{:}{}^4\psi^{tr}(96,\quad \alpha^{tr}) = 80.0012 \sin^2\phi'' - 0.90567$

$\mathcal{l}_K^{tr} = 1 - 0.66765\,\alpha^{tr}\qquad \kappa^{tr} = \mathcal{l}_K^{tr} - \mathcal{l}_C^{tr}$

TABLE 15. Data and formulas for refining solution for CM Lac, Pr = Oc.

$1 - \mathcal{L}_0^{oc} = 1 - \mathcal{L}_0^{pr} = 0.5690, \qquad 1 - \mathcal{L}_0^{tr} = 1 - \mathcal{L}_0^{sec} = 0.2480$

Base Curves C

$k = 0.95, \quad x_g = x_s = 0.2, \quad {}^2\tau = 0.911247$

${}^2\alpha_0^{oc} = 0.84278, \qquad {}^2\alpha_0^{tr} = 0.83776$

$\phi_e = 0.0551, \qquad \sin^2 \phi_e = 0.1151442$

$L_s = 0.67514 \qquad L_g = 0.32486$

For the 102 points of secondary

C^{tr}: ${}^2\psi^{tr}(95, \alpha^{tr}) = 79.2928 \sin^2 \phi'' - 0.87411$

$\mathcal{L}_C^{tr} = 1 - 0.29603\,\alpha^{tr} \qquad R_C^{tr} = \mathcal{L}'' - \mathcal{L}_C^{tr}$

For the 86 points of primary

C^{oc}: ${}^2\psi^{oc}(95, \alpha^{oc}) = 77.6132 \sin^2 \phi'' - 0.88371$

$\mathcal{L}_C^{oc} = 1 - 0.67514\,\alpha^{oc} \qquad R_C^{oc} = \mathcal{L}'' - \mathcal{L}_C^{oc}$

Refining vectors: $E = G = S = K = 0$ at base curves C;

$E = 1$ at $\phi_e = 0.0544, \qquad \sin^2 \phi_e = 0.11235167;$

$G = 1$ at $x_g = 0.4; \qquad S = 1$ at $x_s = 0.4; \qquad K = 1$ at $k = 0.94$

Equations for target curves

E^{tr}: ${}^2\psi^{tr}(95, \alpha^{tr}) = 81.2637 \sin^2 \phi'' - 0.87411$

$\mathcal{L}_E^{tr} = 1 - 0.29603\,\alpha^{tr} \qquad \varepsilon^{tr} = \mathcal{L}_E^{tr} - \mathcal{L}_C^{tr}$

E^{oc}: ${}^2\psi^{oc}(95, \alpha^{oc}) = 79.5423 \sin^2 \phi'' - 0.88371$

$\mathcal{L}_E^{oc} = 1 - 0.67514\,\alpha^{oc} \qquad \varepsilon^{oc} = \mathcal{L}_E^{oc} - \mathcal{L}_C^{oc}$

G^{tr}: ${}^4\psi^{tr}(95, \alpha^{tr}) = 78.8158 \sin^2 \phi'' - 0.87018$

$\mathcal{L}_G^{tr} = 1 - 0.296028\,\alpha^{tr} \qquad \gamma^{tr} = \mathcal{L}_G^{tr} - \mathcal{L}_C^{tr}$

G^{oc}: ${}^2\psi^{oc}(95, \alpha^{oc}) = 77.5228 \sin^2 \phi'' - 0.87330$

$\mathcal{L}_G^{oc} = 1 - 0.67870\,\alpha^{oc} \qquad \gamma^{oc} = \mathcal{L}_G^{oc} - \mathcal{L}_C^{oc}$

S^{tr}: ${}^2\psi^{tr}(95, \alpha^{tr}) = 79.1444 \sin^2 \phi'' - 0.85702$

$\mathcal{L}_S^{tr} = 1 - 0.29857\,\alpha^{tr} \qquad \sigma^{tr} = \mathcal{L}_S^{tr} - \mathcal{L}_C^{tr}$

S^{oc}: ${}^4\psi^{oc}(95, \alpha^{oc}) = 75.4519 \sin^2 \phi'' - 0.88585$

$\mathcal{L}_S^{oc} = 1 - 0.67235\,\alpha^{oc} \qquad \sigma^{oc} = \mathcal{L}_S^{oc} - \mathcal{L}_C^{oc}$

K^{tr}: ${}^2\psi^{tr}(94, \alpha^{tr}) = 78.1330 \sin^2 \phi'' - 0.88346$

$\mathcal{L}_K^{tr} = 1 - 0.29428\,\alpha^{tr} \qquad \kappa^{tr} = \mathcal{L}_K^{tr} - \mathcal{L}_C^{tr}$

K^{oc}: ${}^2\psi^{oc}(94, \alpha^{oc}) = 76.2546 \sin^2 \phi'' - 0.89428$

$\mathcal{L}_K^{oc} = 1 - 0.67064\,\alpha^{oc} \qquad \kappa^{oc} = \mathcal{L}_K^{oc} - \mathcal{L}_C^{oc}$

10 shows the initial residuals and the $\kappa,\gamma,\sigma,\varepsilon$ values in the case pr = tr. (The corresponding Calcomp plot for pr = oc was, regrettably, not constructed.) No distinction has been made in the dots for R between ascending and descending branches of the respective curves. The plus signs on those two plots represent graphically-determined means of 8 residuals, put there to aid somewhat in visualizing the trends. Note that the tendencies to correlation between the approximating parameters are very different from those in the case of EE Peg, except that E is still pretty independent. Note also that the two orders of solution differ from each other and from that for EE Peg, to take maximum advantage of denominator sizes.

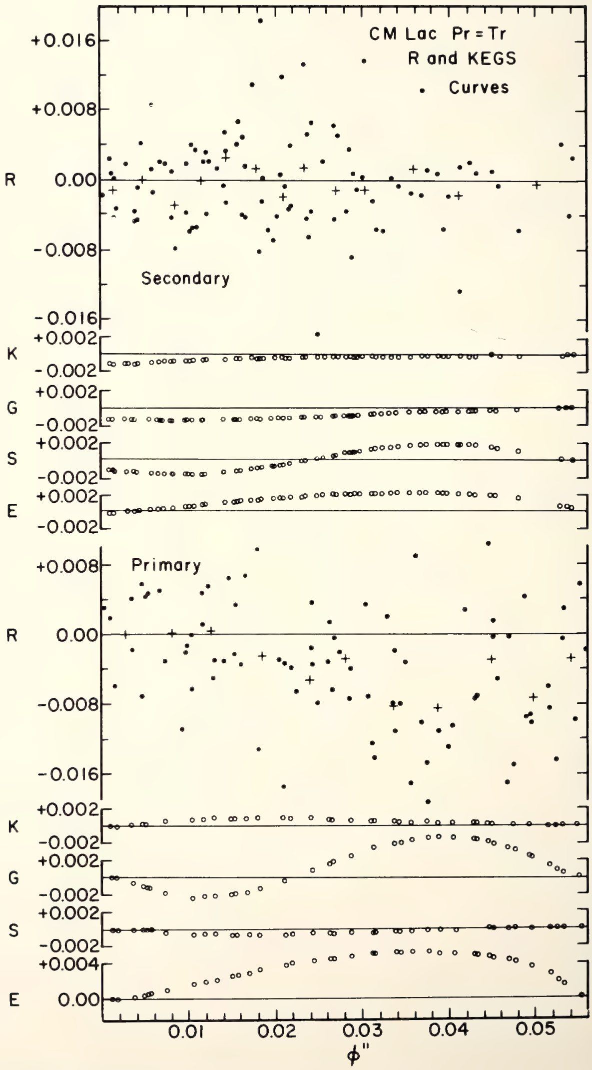


FIGURE 10. Residuals from base curves C for CM Lac Pr = Tr, with values for κ, γ, σ and ε. Note that all vertical scales are the same.

INTERPRETATIONS—The Nomographs showed two possible solutions (Table 13) to be investigated, with very, very little choice between them at that stage. So the two indicated possibilities were studied by identical procedures, with the numerical results shown in Tables 16 and 17. It had been intended to take the limits on E in opposite order on the pr = oc solution because of its preliminary ψ solution, but this was not done; it is interesting to note that the adopted value for E did come out opposite to that for the pr = tr case. At first thought this may seem to confirm the reality of that solution in a general sense, but it may instead indicate a tendency of a least squares solution on several variables to converge on a set of constants near the initial set, in some of our rather complex eclipsing binary situations of interdependent variables.

TABLE 16. Refining solution for CM Lac, Pr = Tr.

Algorithms

Formally similar to those for EE Peg Secondary Data

Secondary Eclipse

$[R\varepsilon] = +0.00000992$	$[\varepsilon\varepsilon] = +0.00023954$	$[\gamma\gamma] = +0.00012464$
$[R\sigma] = -0.00001772$	$[\sigma\varepsilon] = +0.00005103$	$[\kappa\varepsilon] = -0.00003018$
$[R\gamma] = -0.00000918$	$[\sigma\sigma] = +0.00016211$	$[\kappa\sigma] = +0.00004269$
$[R\kappa] = +0.00000832$	$[\gamma\varepsilon] = -0.00012344$	$[\kappa\gamma] = +0.00005111$
$\Sigma R^2 = +0.00299479$	$[\gamma\sigma] = +0.00006680$	$[\kappa\kappa] = +0.00002846$

Primary Eclipse

$[R\varepsilon] = -0.00151262$	$[\varepsilon\varepsilon] = +0.00118181$	$[\kappa\kappa] = +0.00003048$
$[R\gamma] = +0.00048290$	$[\gamma\varepsilon] = -0.00057708$	$[\sigma\varepsilon] = -0.00011885$
$[R\kappa] = -0.00016488$	$[\gamma\gamma] = +0.00057854$	$[\gamma\sigma] = -0.00001696$
$[R\sigma] = +0.00012522$	$[\kappa\varepsilon] = +0.00033609$	$[\kappa\sigma] = -0.00002360$
$\Sigma R^2 = +0.00592740$	$[\kappa\gamma] = +0.00002453$	$[\sigma\sigma] = +0.00001831$

Adjustment Equations

Secondary Eclipse

$E_1 = +0.0414$

$S_1 = -0.1093 - 0.3148\,E_1$

$G_1 = -0.0737 + 0.9904\,E_1 - 0.5359\,S_1$

$K_1 = +0.2923 + 1.0604\,E_1 - 1.5000\,S_1 - 1.7959\,G_1$

$E_{n+1} = -0.2130\,S_n + 0.5153\,G_n + 0.1260\,K_n$

$S_{n+1} = -0.4121\,G_n - 0.2633\,K_n - 0.3148\,E_{n+1}$

$G_{n+1} = -0.4101\,K_n + 0.9904\,E_{n+1} - 0.5359\,S_{n+1}$

$K_{n+1} = +1.0604\,E_{n+1} - 1.5000\,S_{n+1} - 1.7959\,G_{n+1}$

$\Sigma R^2_{n+1} = 0.00299479 - 0.00023954\,E^2_{n+1} - 0.00016211\,S^2_{n+1} - 0.00012464\,G^2_{n+1} - 0.00002846\,K^2_{n+1}$

Primary Eclipse

$E_1 = -1.2799$

$G_1 = +0.8347 + 0.9975\ E_1$

$K_1 = -5.4094 - 11.0266\ E_1 - 0.8048\ G_1$

$S_1 = +6.8389 + 6.4910\ E_1 + 0.9263\ G_1 + 1.2889\ K_1$

$E_{N+1} = +0.4883\ G_n - 0.2844\ K_n + 0.1006\ S_n$

$G_{n+1} = -0.0424\ K_n + 0.0293\ S_n + 0.9975\ E_{n+1}$

$K_{n+1} = +0.7743\ S_n - 11.0266\ E_{n+1} - 0.8048\ G_{n+1}$

$S_{n+1} = +6.4910\ E_{n+1} + 0.9263\ G_{n+1} + 1.2889\ K_{n+1}$

$\Sigma R^2_{n+1} = 0.00592740 - 0.00118181\ E^2_{n+1} - 0.00057854\ G^2_{n+1} - 0.00003048\ K^2_{n+1} - 0.00001831\ S^2_{n+1}$

Results of Four Rounds

Secondary Eclipse

Round	E	S	G	K	$\Delta\Sigma R^2$	ΣR^2_n
						0.0022995
1	+0.0414	+0.1223	+0.0982	+0.0236	−0.000002	0.002993
2	+0.0275	−0.0554	+0.0472	+0.0274	−0.000000	0.002993
3	+0.0396	−0.0391	+0.0489	+0.0128	−0.000000	0.002993
4	+0.0352	−0.0346	+0.0481	+0.0028	−0.000000	0.002993

Primary Eclipse

Round	E	S	G	K	$\Delta\Sigma R^2$	ΣR^2_n
						0.005927
1	−1.2799		+0.4420		−0.002049	0.003878
2	+0.2158		+0.2153		−0.000082	0.003796
3	+0.1051		+0.1049		−0.000019	0.003777
4	+0.0512		+0.0511		−0.000005	0.003772

Adopted Adjustments

$E = -0.7$	$\Delta\phi_e = +0.0005$
$S = 0$	$\Delta x_g = 0$
$G = +0.75$	$\Delta x_g = +0.15$
$K = 0$	$\Delta k = 0$

For each observation these constants imply

$$R' = R - 0.8\,\varepsilon + 0.75\,\gamma$$

For Comparisons

	ΣR^2	$\Sigma R_4{}^2$	$\Sigma R'^2$
Secondary Eclipse	0.002995	0.002993	0.003396
Primary Eclipse	0.005927	0.003773	0.005245
Both eclipses	0.008922	0.006766	0.008641

The standard deviation of a single observation, over both eclipses, is 0.00678.

TABLE 17. Refining solution for CM Lac, Pr = Oc.

Algorithms

Formally similar to those for EE Peg Secondary

Data

Secondary Eclipse

$[R\varepsilon] = +0.00022120$	$[\varepsilon\varepsilon] = +0.00023843$	$[\sigma\sigma] = +0.00002072$
$[R\gamma] = +0.00010583$	$[\gamma\varepsilon] = +0.00013201$	$[\kappa\varepsilon] = -0.00002417$
$[R\sigma] = -0.00006511$	$[\gamma\gamma] = +0.00010547$	$[\kappa\gamma] = -0.00000778$
$[R\kappa] = -0.00002641$	$[\sigma\varepsilon] = -0.00006008$	$[\kappa\sigma] = +0.00000853$
$\Sigma R^2 = +0.00318449$	$[\gamma\sigma] = -0.00002057$	$[\kappa\kappa] = +0.00000353$

Primary Eclipse

$[R\varepsilon] = -0.00004331$	$[\varepsilon\varepsilon] = +0.00121544$	$[\gamma\gamma] = +0.00002740$
$[R\sigma] = -0.00022738$	$[\sigma\varepsilon] = +0.00041064$	$[\kappa\varepsilon] = -0.00014415$
$[R\gamma] = -0.00004461$	$[\sigma\sigma] = +0.00041554$	$[\kappa\sigma] = -0.00000283$
$[R\kappa] = -0.00004221$	$[\gamma\varepsilon] = -0.00014692$	$[\kappa\gamma] = +0.00002656$
$\Sigma R^2 = +0.00417911$	$[\gamma\sigma] = -0.00000080$	$[\kappa\kappa] = +0.00002577$

Adjustment Equations

Secondary Eclipse

$E_1 = +0.9277$

$G_1 = +1.0034 - 1.2516\, E_1$

$S_1 = -3.1424 + 2.8996\, E_1 + 0.9928\, G_1$

$K_1 = -7.4816 + 6.8470\, E_1 + 2.2040\, G_1 - 2.4164\, S_1$

$E_{n+1} = -0.5537\, G_n + 0.2520\, S_n + 0.1014\, K_n$

$G_{n+1} = +0.1950\, S_n + 0.0738\, K_n - 1.2516\, E_{n+1}$

$S_{n+1} = -0.4117\, K_n + 2.8996\, E_{n+1} + 0.9928\, G_{n+1}$

$K_{n+1} = +6.8470\, E_{n+1} + 2.2040\, G_{n+1} - 2.4164\, S_{n+1}$

$\Sigma R^2_{n+1} = \Sigma R^2_n - 0.00023843\, E^2_{n+1} - 0.00010547\, G^2_{n+1} - 0.00002072\, S^2_{n+1} - 0.00000353\, K^2_{n+1}$

Primary Eclipse

$E_1 = -0.0356$

$S_1 = -0.5472 - 0.9882\, E_1$

$G_1 = -1.6281 + 5.3620\, E_1 + 0.0292\, S_1$

$K_1 = -1.6380 + 5.5937\, E_1 + 0.1098\, S_1 - 1.0307\, G_1$

$E_{n+1} = -0.3379\, S_n + 0.1209\, G_n + 0.1186\, K_n$

$S_{n+1} = +0.0019\,G_n + 0.0068\,K_n - 0.9882\,E_{n+1}$

$G_{n+1} = -0.9693\,K_n + 5.3620\,E_{n+1} + 0.0292\,S_{n+1}$

$K_{n+1} = +5.5937\,E_{n+1} + 0.1098\,S_{n+1} - 1.0307\,G_{n+1}$

$\Sigma R^2_{n+1} = \Sigma R^2_n - 0.00121544\,E^2_{n+1} - 0.00041554\,S^2_{n+1} - 0.00002740\,G^2_{n+1} - 0.00002577\,K^2_{n+1}$

Results of Four Rounds

Secondary Eclipse

Round	E	S	G	K	$\Delta\Sigma R^2$	ΣR^2_n
						0.003185
1	+0.9277		−0.1577		−0.000208	0.002977
2	+0.0873		−0.1093		−0.000003	0.002974
3	+0.0605		−0.0757		−0.000001	0.002973
4	+0.0419		−0.0524		−0.000001	0.002972

Primary Eclipse

Round	E	S	G	K	$\Delta\Sigma R^2$	ΣR^2_n
						0.004179
1	−0.0356	−0.5120			−0.000110	0.004069
2	+0.1730	−0.1710			−0.000049	0.004020
3	+0.0578	−0.0571			−0.000005	0.004015
4	+0.0193	−0.0191			−0.000001	0.004014

Adopted Adjustments

$E = +0.6$	$\Delta\phi_e = -0.0004$
$S = -0.75$	$\Delta x_s = -0.15$
$G = -0.50$	$\Delta x_g = -0.10$
$K = 0$	$\Delta k = 0$

For each observation these constants imply

$R' = R + 0.6\,\varepsilon - 0.75\,\sigma - 0.50\,\gamma$

For comparisons

	ΣR^2	ΣR^2_4	$\Sigma R'^2$
Secondary eclipse	0.003185	0.002972	0.003010
Primary eclipse	0.004179	0.004014	0.004241
Both eclipses	0.007364	0.006986	0.007251

The standard deviation of a single observation, over both eclipses, is 0.00621.

In neither refining solution did a need for altering the respective initial values of k, arise. In the pr = tr case, S appeared with a positive sign in the solution for secondary eclipse but effectively cancelled itself out in the later rounds; G was strong and consistent in both eclipses, perhaps offsetting some of the effect of K in secondary but probably not in primary. In the pr = oc case, the S is strong and unremarkable in primary while the K seemed to have to be omitted from both the eclipse rounds because of weakness of denominator, that is, low "weight" in the refinement. Altogether, both refining solutions have raised more questions of credibility and of applicability of fundamental assumptions than they have settled. They have pointed up, however, the need for thorough re-observation of CM Lac within an interval of two observing seasons at most, with a thousand observations in each color and with a distribution of data outlining sharply all four shoulders and the bottoms after firm and credible rectification-and-adjustment.

On the basis of blind choice by numbers, the $\Sigma R'^2 = 0.007251$ for the pr = oc solution versus the 0.008641 for the pr = tr or the parallel $\sigma = 0.00621$ for the former and $\sigma = 0.00678$ for the latter, the pr = oc solution would be "preferred" over the pr = tr one. The situation is far more serious (and intriguing!) than that, however, and one must ask some searching questions: (1) Are the two solutions arrived at here really separated by a significant "ridge" in the four-space of k, x_g, x_s and ϕ_e''? This writer believes the answer is "Yes." (2) Do there exist cases of true duplicity of "solution" for error-less data? Or for data as nearly error-less as modern equipment and methods can make it? The word duplicity is chosen deliberately; the question is not simply about range of ambiguity or of uncertainty in one solution. To the first half of this question this writer answers "I do not know, but I doubt it; the question can presumably be settled purely mathematically as far as this particular Model is concerned." To the second this writer answers "I think probably there do". (3) If we grant for the moment the existence of some real duplicities with modern data, how many cases have gone unnoticed for lack of warning by some such device as the Nomographs, which display a wide range of possibilities around the one most immediately obvious or possibilities arising out of small changes needed in the rectification-and-adjustment formulas as applied in a second and more definitive solution? There is no way to know except to reexamine the initial stages of "suspected" solutions, but probably some were overlooked. (4) If real duplicities exist, are they duplicities "in the nature of things" or are they duplicities heretofore concealed in the Russell Model, by far the most thoroughly investigated model in its field? This question is rather closely related to question (2) above. It is this writer's opinion that some cases of each may exist. Again the need would be for thorough "theoretical" study of any proposed model. Model-building is partly a study in postulate theory, so not an odd rainy afternoon's work.

Tables 18 and 19 exhibit the sets of parameters deduced in the two cases considered, and Fig. 11 and 12 show the curves corresponding to those adopted parameters plotted on the rectified eclipse data. Clearly the curves (especially at the published size) provide no reliable basis for choice between the two solutions, nor do the sets of parameters, of course.

It is interesting to note that the larger components and the smaller components have come out respectively practically equal in their larger dimension but of very slightly different shape and of course different total brightnesses and different surface brightnesses. The new C's are essentially identical in the two sets; they do not differ enough from the original set to warrant re-rectification and re-solution in view of the larger outstanding dilemma, but would probably warrant re-rectification were it not for that.

Obviously the pr = oc solution corresponds approximately to Alexander's, and the pr = tr to that by Barnes, Hall and Hardie. In each case there has come about an increase of k by 7% from the earlier solution with the radius of the larger component changing little. The respective total brightnesses in Alexander's solution match well those in the present pr = oc one, and similarly for the BHH solution and the present pr = tr one. It is still the relation of the dimensional geometry to the luminosities which is under question.

TABLE 18. Adopted parameters for CM Lac, Pr = Tr.

Assumed $e = 0$ and $P = 1.6046914$ days			
$\ell_0^{pr} = 0.4310$	$\ell_0^{sec} = 0.7520$		
$k = 0.970$	$x_g = 0.55$	$x_s = 0.40$	$\phi_e'' = 0.0556$
$^{55}\tau\,(0.97) = 0.95973$	$\alpha_0^{tr} = 0.84035$	$\alpha_0^{oc} = 0.84215$	
$p_o = -0.7068$			
$a_g = 0.1757$	$b_g = 0.1746$	$c_g = 0.1738$	
$a_s = 0.1705$	$b_s = 0.1694$	$c_s = 0.1686$	
$\eta^2 = 0.01260$	$\zeta^2 = 0.02218$		
$i_r = 86\overset{\circ}{.}833$	$j = 86\overset{\circ}{.}853$	$i = 86\overset{\circ}{.}868$	
$L_g = 0.70551$	$L_s = 0.29448$ for facing sides		
$\bar{J}_h / \bar{J}_c = 2.254$ for facing sides			
Spectra: $S_h = S_g$	A3	$S_c = S_s$	A8
$G_c = 0.02115$	$G_h = 0.00861$		
$C_0 = 0.00892$	$C_1 = 0.00501$	$C_2 = 0.00297$	
$L_g^* = 0.69862$	$L_s^* = 0.27756$ for backs		
From ϕ_e'' ,	$\phi_e = 0.0552$		

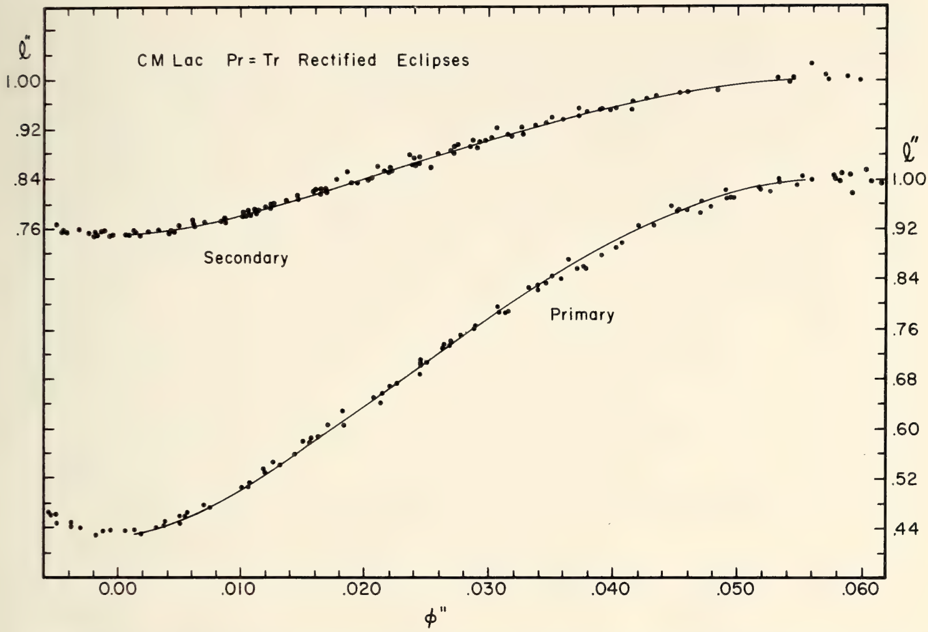


FIGURE 11. Adopted theoretical curves F, Pr = Tr, drawn on plots of the individual observations for CM Lac.

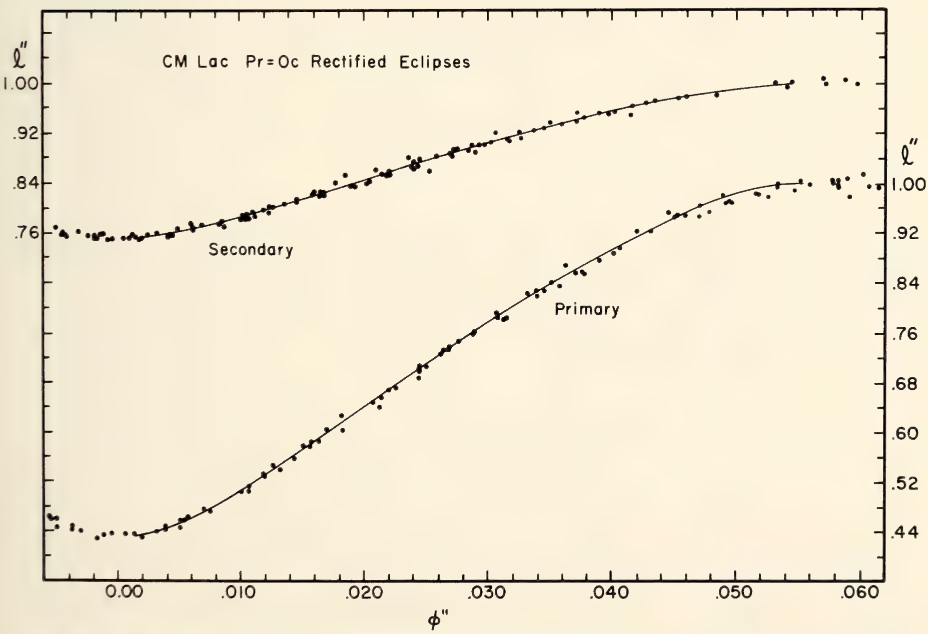


FIGURE 12. Adopted theoretical curve F, Pr = Oc, drawn on plots of the individual observations for CM Lac.

TABLE 19. Adopted parameters for CM Lac, Pr = Oc.

Assumed $e = 0$ and $P = 1.6046914$ days

$\ell_0^{pr} = 0.4310$ $\quad$ $\ell_0^{sec} = 0.7520$

$k = 0.950$ $\quad$ $x_g = 0.10$ $\quad$ $x_s = 0.05$ $\quad$ $\phi_e'' = 0.0547$

${}^{.10}\tau = 0.90672$ $\quad$ $\alpha_0^{tr} = 0.84238$ $\quad$ $\alpha_0^{oc} = 0.84258$

$p_o = -0.7288$

$a_g = 0.1747$ $\quad$ $b_g = 0.1730$ $\quad$ $c_g = 0.1719$

$a_s = 0.1660$ $\quad$ $b_s = 0.1644$ $\quad$ $c_s = 0.1633$

$\eta^2 = 0.01958$ $\quad$ $\zeta^2 = 0.03224$

$i_r = 86^\circ\!.918$ $\quad$ $j = 86^\circ\!.948$ $\quad$ $i = 86^\circ\!.968$

$L_g = 0.32469$ $\quad$ $L_s = 0.67531$ for facing sides

$\bar{J}_h / \bar{J}_c = 1.877$ for facing sides

Spectra: $\quad$ $S_h = S_s$ $\quad$ A3 $\quad$ $S_c = S_g$ $\quad$ A8

$G_0 = 0.02128$ $\quad$ $G_h = 0.00867$

$C_0 = 0.00898$ $\quad$ $C_1 = 0.00504$ $\quad$ $C_2 = 0.00299$

$L_g^* = 0.30766$ $\quad$ $L_s^* = 0.66838$ $\quad$ for backs

From ϕ'' , $\quad$ $\phi_e = 0.0543$

ACKNOWLEDGMENTS—It has been a real privilege to take part in this colloquium and to have the opportunity to set forth some of the strengths of the Russell Model and (quite unexpectedly!) some of the pitfalls attendant on the process of interpretation of light curves for an eclipsing binary system on that model or (probably) on any other. It is a pleasure also to record here my appreciation of the work of Mr. W. W. Richardson of the Department of Physics and Astronomy in preparing the several drawings included in this paper.

LITERATURE CITED

ALEXANDER, R. S. 1958. Photoelectric light curves of the eclipsing binary CM Lacertae. Astron. J. 63:106-108.

BAKOS, G. A. 1965. Spectroscopic and photometric orbits of EE Pegasi. Publ. David Dunlay Obs. 2 (15):431-440.

BARNES, R. C., D. S. HALL, AND R. H. HARDIE. 1968. Absolute dimensions of CM Lacertae. Publ. Astron. Soc. Pac. 80:69-80.

CATALANO, S., AND M. RODONÒ. 1970. Photometric and absolute elements of EE Per. Astron. Astroph. 4:173-179.

DUEBALL, J., AND P. B. LEHMANN. 1965. Beobachtungsergebnisse der Berliner Arbeitsgemeinschaft für Veränderliche Sterne e. V.(BAV) Astron. Nachr. 288:167-175.

EBBIGHAUSEN, E. G. 1971. The photometric elements of the eclipsing binary EE Pegasi. Astron. J. 76:460-464.

GOMI, K. 1940. Varänderliche mit provisorischer Bezeichnung. Beobachtungsz. Astron. Nachr. Kiel. 22:39-40; Mem. Astron. Soc. Japan 6:63.

HOSOKAWA, Y. 1957. The photometric ellipticity constant in eclipsing binary systems. Sci. Rept. Tohoku Univ. Ser. 1, XL (4):208.

KOPAL, Z. 1946. Introduction to the study of eclipsing variables. Harvard College Obs. Monogr. 6:138.

MARKS, A. 1962. Minima of eclipsing binaries. Acta Astron. 12 (2):138-139.

MERRILL, J. E. 1950, 1953. Tables for Solution of Light Curves of Eclipsing Binaries. Contrib. Princeton Univ. Obs. No. 23.

_________. 1953. Nomographs for Solution of Light Curves of Eclipsing Binaries. Contrib. Princeton Univ. Obs. No. 24.

_________. 1970. Rectification of light curves of W Ursae Majoris-type systems. In Vistas in Astronomy (ed. A. Beer) 12:43.

POPPER, D. M. 1957. Photoelectric observations of eclipsing binaries. Astrophy. J. Suppl. 3:108-140.

_________. 1968. Rediscussion of eclipsing binaries. VIII. Three systems with unequal main-sequence components. Astroph. J. 154:191-202.

_________. 1970. UCLA observatory report in Bull. A. A.S. 2:12.

ROMAN, N. G. 1956. Spectral types of some eclipsing binaries. Astroph. J. 123:246-249.

RUSSELL, H. N., AND J. E. MERRILL. 1952. The Determination of the Elements of Eclipsing Binaries. Contrib. Princeton Univ. Obs. No. 26.

VIRKHRISTIJUK, S. S. 1964. Minima of eclipsing variable stars. Perem. Zvezdy 15:219.

WELLMANN, P. 1953. Der Bedeckungsveränderliche EE Pegasi. Zeits. f Astrophys. 32:1-10.

Florida Sci. 41(3):129-181. 1978.

APPENDIX A

Normals of Ebbighausen's B Observations of EE Peg, Primary Eclipse (5-Normals).

ϕ	ℓ	ϕ''	$\sin^2 \phi''$	ℓ''	$\ell'' - \ell_F^{tr}$
0.94859	0.97293	0.94832	0.101803	1.00108	+0.00108
0.95284	0.97391	0.95258	0.086159	1.00236	+0.00236
0.95555	0.96856	0.95531	0.076801	0.99706	−0.00246
0.95754	0.96066	0.95731	0.070244	0.98909	−0.00583
0.95924	0.95686	0.95902	0.064857	0.98529	−0.00189
0.96116	0.94994	0.96095	0.059014	0.97831	+0.00291
0.96271	0.93741	0.96250	0.054485	0.96556	+0.00177
0.96461	0.92193	0.96441	0.049167	0.94981	+0.00256
0.96659	0.89660	0.96640	0.043901	0.92395	−0.00357
0.96815	0.88287	0.96797	0.039952	0.90996	−0.00042
0.96957	0.86882	0.96940	0.036513	0.89563	+0.00198
0.97131	0.84205	0.97115	0.032503	0.86828	−0.00356
0.97331	0.81875	0.97316	0.028171	0.84448	−0.00069
0.97522	0.79368	0.97508	0.024316	0.81887	+0.00054
0.97702	0.76837	0.97689	0.020936	0.79299	+0.00095
0.97837	0.74777	0.97825	0.018564	0.77193	+0.00011
0.97982	0.72674	0.97971	0.016172	0.75042	+0.00061
0.98147	0.70296	0.98137	0.013647	0.72610	+0.00163
0.98293	0.68764	0.98283	0.011590	0.71044	+0.00835
0.98460	0.65329	0.98451	0.009440	0.67528	−0.00157
0.98601	0.63698	0.98593	0.007795	0.65860	+0.00241
0.98733	0.61426	0.98726	0.006396	0.63534	−0.00247
0.98859	0.60403	0.98852	0.005190	0.62489	+0.00318
0.99034	0.58040	0.99028	0.003722	0.60070	−0.00311
0.99203	0.57253	0.99198	0.002534	0.59266	−0.00221
0.99364	0.56540	0.99360	0.001614	0.58538	−0.00332
0.99548	0.56118	0.99545	0.000816	0.58108	−0.00259
0.99748	0.56038	0.99747	0.000254	0.58028	+0.00005
0.99908	0.55721	0.99907	0.000034	0.57704	−0.00187
0.00072	0.56017	0.00072	0.000021	0.58009	+0.00125
0.00239	0.55998	0.00240	0.000228	0.57990	−0.00018
0.00406	0.56444	0.00409	0.000660	0.58448	+0.00177
0.00602	0.56634	0.00606	0.001447	0.58643	−0.00120
0.00830	0.57387	0.00835	0.002748	0.59415	−0.00223
0.01060	0.58951	0.01066	0.004478	0.61017	−0.00238
0.01301	0.62120	0.01308	0.006740	0.64263	+0.00024
0.01501	0.65008	0.01510	0.008972	0.67221	+0.00112
0.01757	0.68546	0.01767	0.012276	0.70844	−0.00130
0.01984	0.72023	0.01995	0.015631	0.74404	−0.00053
0.02145	0.74538	0.02157	0.018255	0.76979	+0.00072
0.02315	0.77281	0.02328	0.021251	0.79786	+0.00324
0.02474	0.79077	0.02488	0.024233	0.81623	−0.00149
0.02615	0.81017	0.02630	0.027060	0.83608	−0.00167
0.02839	0.84333	0.02855	0.031827	0.87000	+0.00210
0.03027	0.86540	0.03044	0.036135	0.89255	+0.00085
0.03157	0.87952	0.03175	0.039260	0.90698	−0.00018
0.03293	0.89309	0.03311	0.042657	0.92084	−0.00149
0.03430	0.90946	0.03449	0.046225	0.93756	+0.00090
0.03589	0.92109	0.03609	0.050553	0.94942	−0.00246
0.03744	0.93444	0.03764	0.054905	0.96303	−0.00194

ϕ	ℓ	ϕ''	$\sin^2 \phi''$	ℓ''	$\ell'' - \ell^{oc}_{F}$
0.03880	0.94964	0.03901	0.058898	0.97854	+0.00341
0.04002	0.95417	0.04024	0.062581	0.98313	+0.00012
0.04248	0.96626	0.04271	0.070312	0.99540	+0.00041
0.04433	0.96459	0.04457	0.076382	0.99360	−0.00573
0.04589	0.97510	0.04614	0.081702	1.00428	+0.00428
0.04823	0.97483	0.04849	0.089976	1.00388	+0.00388
0.05007	0.97521	0.05034	0.096741	1.00417	+0.00417
0.05181	0.97431	0.05209	0.103343	1.00315	+0.00315

Observations of EE Peg, First top (Running Means of 5-Normals)

ϕ	ℓ	ℓ''
0.05094	0.97476	1.00366
0.05262	0.97169	1.00042
0.05443	0.97107	0.99967
0.05634	0.97098	0.99946
0.05814	0.96733	0.99561
0.05999	0.96683	0.99498
0.06191	0.96965	0.99774
0.06401	0.97205	1.00005
0.06617	0.97122	0.99905
0.06825	0.97090	0.99857
0.07017	0.97352	1.00111
0.07196	0.97514	1.00263
0.07401	0.97391	1.00121
0.07610	0.97285	0.99996
0.07855	0.97242	0.99932
0.08204	0.97055	0.99719
0.08496	0.97010	0.99648
0.08698	0.97508	1.00134
0.08923	0.97787	1.00400
0.09157	0.97450	1.00035
0.09446	0.97441	1.00000
0.09751	0.97648	1.00184
0.09990	0.97648	1.00163
0.10219	0.97816	1.00314
0.10452	0.97784	1.00260
0.10713	0.97795	1.00247
0.10988	0.98046	1.00478
0.11243	0.98025	1.00433
0.11473	0.97841	1.00224
0.11656	0.97699	1.00062
0.11854	0.97502	0.99843
0.12063	0.97189	0.99504
0.12277	0.97205	0.99501
0.12515	0.97867	1.00154
0.12745	0.98003	1.00272
0.12972	0.97699	0.99942
0.13191	0.97670	0.99893
0.13406	0.97468	0.99668
0.13632	0.97485	0.99665
0.13862	0.97719	0.99884
0.14081	0.97854	1.00002
0.14352	0.97915	1.00042
0.14651	0.97896	0.99997
0.14885	0.97780	0.99860
0.15147	0.97961	1.00023
0.15416	0.97899	0.99939
0.15631	0.97896	0.99919
0.15865	0.98028	1.00036
0.16160	0.97854	0.99837
0.16466	0.97878	0.99840
0.16727	0.97905	0.99849
0.17046	0.98069	0.99995
0.17435	0.98082	0.99983
0.17779	0.97808	0.99683
0.18106	0.98199	1.00062
0.18521	0.98252	1.00094
0.18917	0.97917	0.99734
0.19237	0.98255	1.00062
0.19521	0.98202	0.99996
0.19785	0.98137	0.99919
0.20046	0.98223	0.99997
0.20271	0.98254	1.00021
0.20534	0.98274	1.00032
0.20790	0.98311	1.00062
0.20965	0.98569	1.00320
0.21160	0.98614	1.00360
0.21399	0.98582	1.00322
0.21649	0.98687	1.00424
0.21895	0.98614	1.00345
0.22158	0.98397	1.00121
0.22431	0.98289	1.00008
0.22653	0.98139	0.99853
0.22866	0.98041	0.99752
0.23092	0.98206	0.99919

ϕ	ℓ	ℓ''
0.23347	0.98281	0.99994
0.23763	0.98471	1.00187
0.24179	0.98515	1.00234
0.24463	0.98437	1.00158
0.24745	0.98259	0.99980
0.24990	0.97944	0.99664
0.25227	0.98277	1.00006
0.25477	0.98543	1.00280
0.25730	0.98374	1.00114
0.25986	0.97972	0.99712
0.26230	0.98000	0.99746
0.26473	0.98273	1.00030
0.26765	0.98093	0.99856
0.27135	0.97975	0.99748
0.27629	0.97968	0.99758
0.28175	0.98204	1.00019
0.28525	0.98462	1.00296
0.28778	0.98078	0.99917
0.29079	0.97860	0.99709
0.29345	0.98444	1.00315
0.29574	0.98497	1.00380
0.29850	0.98015	0.99904
0.30149	0.97917	0.99820
0.30538	0.97870	0.99793
0.31117	0.97966	0.99922
0.31694	0.97880	0.99868
0.32093	0.97824	0.99834
0.32406	0.97926	0.99957
0.32737	0.97831	0.99880
0.33060	0.97869	0.99938
0.33409	0.98083	1.00178
0.33798	0.98120	1.00239
0.34209	0.97809	0.99949
0.34638	0.97762	0.99927
0.35060	0.98058	1.00255
0.35460	0.97999	1.00220
0.35800	0.97582	0.99817
0.36063	0.97615	0.99867
0.36430	0.97977	1.00259
0.37037	0.97730	1.00044
0.37686	0.97622	0.99973
0.38266	0.97999	1.00392
0.38792	0.97941	1.00363
0.39290	0.97372	0.99810
0.39791	0.97366	0.99832
0.40297	0.97687	1.00187
0.40785	0.97376	0.99894
0.41255	0.97106	0.99642
0.41750	0.97214	0.99776
0.42204	0.97396	0.99984
0.42616	0.97303	0.99907
0.42949	0.97124	0.99739
0.43172	0.97233	0.99860
0.43379	0.97215	0.99850
0.43665	0.97276	0.99924
0.44029	0.97580	1.00249
0.44360	0.97637	1.00320
0.44641	0.97489	1.00179
0.44931	0.97443	1.00142
0.45214	0.97372	1.00079

Observations of EE Peg, Secondary Eclipse (5-Normals)

ϕ	ℓ	ϕ''	$\sin^2 \phi''$	ℓ''	$\ell'' - \ell_F^{oc}$
0.44773	0.97395	0.44745	0.105109	1.00087	+0.00087
0.45088	0.97492	0.45062	0.093229	1.00198	+0.00198
0.45340	0.97253	0.45315	0.084185	0.99961	−0.00039
0.45573	0.97164	0.45549	0.076197	0.99878	−0.00105
0.45800	0.97146	0.45777	0.068767	0.99866	+0.00029
0.46022	0.96388	0.46000	0.061843	0.99097	−0.00463
0.46341	0.96232	0.46321	0.052496	0.98946	−0.00046
0.46543	0.96048	0.46524	0.046952	0.98763	+0.00217
0.46753	0.95225	0.46735	0.041500	0.97926	−0.00096
0.46975	0.94999	0.46958	0.036088	0.97700	+0.00285
0.47227	0.94269	0.47211	0.030386	0.96958	+0.00287
0.47453	0.93065	0.47439	0.025677	0.95730	−0.00243
0.47657	0.92453	0.47644	0.021758	0.95107	−0.00221
0.47938	0.91914	0.47926	0.016881	0.94560	+0.00116
0.48133	0.91376	0.48122	0.013853	0.94013	+0.00164
0.48337	0.90503	0.48327	0.011002	0.93122	−0.00142
0.48582	0.89996	0.48574	0.008007	0.92607	−0.00038
0.48850	0.89693	0.48843	0.005272	0.92301	+0.00162

ϕ	ℓ	ϕ''	$\sin^2 \phi''$	ℓ''	$\ell'' - \ell_F^{oc}$
0.49110	0.89204	0.49105	0.003160	0.91804	−0.00168
0.49290	0.89442	0.49286	0.002012	0.92050	+0.00078
0.49537	0.89571	0.49534	0.000856	0.92186	+0.00212
0.49698	0.89508	0.49696	0.000364	0.92123	+0.00149
0.49902	0.89240	0.49901	0.000038	0.91851	−0.00123
0.50221	0.89485	0.50222	0.000195	0.92105	+0.00131
0.50666	0.89120	0.50670	0.001770	0.91735	−0.00238
0.50865	0.89197	0.50870	0.002985	0.91816	−0.00156
0.51011	0.89464	0.51017	0.004076	0.92090	+0.00093
0.51167	0.89312	0.51174	0.005428	0.91935	−0.00228
0.51345	0.89915	0.51353	0.007206	0.92554	+0.00069
0.51524	0.90187	0.51533	0.009245	0.92834	−0.00065
0.51678	0.90495	0.51688	0.011201	0.93150	−0.00156
0.51823	0.91204	0.51833	0.013211	0.93877	+0.00158
0.51964	0.91084	0.51975	0.015322	0.93755	−0.00387
0.52139	0.91739	0.52151	0.018157	0.94426	−0.00258
0.52338	0.92661	0.52351	0.021666	0.95371	+0.00059
0.52552	0.93260	0.52566	0.025777	0.95984	−0.00004
0.52730	0.93734	0.52745	0.029461	0.96470	−0.00070
0.52968	0.94250	0.52985	0.034757	0.96998	−0.00253
0.53210	0.95213	0.53228	0.040573	0.97983	+0.00058
0.53408	0.95557	0.53427	0.045651	0.98334	−0.00095
0.53653	0.96406	0.53673	0.052327	0.99202	+0.00222
0.53897	0.96505	0.53918	0.059401	0.99302	−0.00132
0.54096	0.97046	0.54119	0.065481	0.99854	+0.00133
0.54281	0.97142	0.54304	0.071378	0.99950	+0.00042
0.54586	0.97348	0.54611	0.081609	1.00157	+0.00157
0.54783	0.97008	0.54809	0.088547	0.99806	−0.00194
0.54992	0.96888	0.55019	0.096186	0.99680	−0.00320
0.55293	0.97357	0.55321	0.107678	1.00155	+0.00155

Observations of EE Peg, Second Top (Running Means of 5-Normals)

ϕ	ℓ	ℓ''	ϕ	ℓ	ℓ''
0.54887	0.96948	0.99743	0.59222	0.97115	0.99794
0.55143	0.97123	0.99918	0.59442	0.97414	1.00095
0.55474	0.97302	1.00096	0.59657	0.97774	1.00453
0.55898	0.97253	1.00037	0.59831	0.97682	1.00348
0.56329	0.97114	0.99885	0.59979	0.97594	1.00252
0.56708	0.97039	0.99799	0.60144	0.97735	1.00389
0.57093	0.97171	0.99924	0.60310	0.97590	1.00233
0.57400	0.97057	0.99799	0.60473	0.97219	0.99846
0.57631	0.97316	1.00056	0.60625	0.97277	0.99898
0.57891	0.97415	1.00150	0.60804	0.97373	0.99988
0.58139	0.97239	0.99961	0.61035	0.97375	0.99979
0.58335	0.97281	0.99997	0.61260	0.97413	1.00006
0.58510	0.97193	0.99901	0.61505	0.97405	0.99985
0.58674	0.97353	1.00059	0.61837	0.97618	1.00185
0.58836	0.97492	1.00195	0.62193	0.97604	1.00152
0.59013	0.97330	1.00022	0.62556	0.97538	1.00064

ϕ	ℓ	ℓ''
0.63046	0.97450	0.99951
0.63544	0.97064	0.99528
0.63940	0.97164	0.99600
0.64327	0.97495	0.99914
0.64734	0.97672	1.00068
0.65237	0.97841	1.00207
0.65760	0.97643	0.99971
0.66131	0.97399	0.99698
0.66486	0.97718	0.99999
0.66848	0.97990	1.00247
0.66986	0.97749	0.99996
0.67115	0.97539	0.99774
0.67244	0.96938	0.99153
0.67414	0.97360	0.99566
0.67577	0.97477	0.99679
0.67683	0.97828	1.00029
0.67867	0.97932	1.00122
0.68082	0.97825	0.99999
0.68642	0.97766	0.99901
0.69598	0.97926	1.00000
0.70553	0.98133	1.00150
0.71458	0.98200	1.00163
0.72188	0.98172	1.00093
0.72628	0.98157	1.00055
0.73140	0.98349	1.00224
0.73659	0.98563	1.00417
0.74043	0.98432	1.00268
0.74482	0.97993	0.99805
0.74978	0.98112	0.99908
0.75416	0.98197	0.99980
0.75802	0.98135	0.99907
0.76212	0.98253	1.00017
0.76933	0.98028	0.99776
0.78259	0.98264	1.00006
0.79498	0.98329	1.00081
0.80669	0.97912	0.99682
0.81816	0.97918	0.99728
0.82553	0.98018	0.99862
0.83202	0.97725	0.99598
0.83914	0.97757	0.99672
0.84686	0.97986	0.99956
0.85219	0.98018	1.00027
0.85495	0.98182	1.00214
0.85769	0.98221	1.00275
0.86082	0.98101	1.00178
0.86440	0.98061	1.00166
0.86851	0.98239	1.00382
0.87231	0.97953	1.00122
0.87547	0.97785	0.99979
0.87861	0.97940	1.00164
0.88199	0.97896	1.00150
0.88545	0.97646	0.99926
0.88975	0.97882	1.00202
0.89419	0.98116	1.00481
0.89847	0.97936	1.00342
0.90218	0.97654	1.00088
0.90532	0.97030	0.99479
0.90923	0.96979	0.99463
0.91584	0.97217	0.99766
0.92653	0.97265	0.99908
0.93803	0.97234	0.99970
0.94598	0.97243	1.00038
0.95072	0.97342	1.00172

APPENDIX B

Individual V Observations of CM Lac (Barnes, Hall, Hardie), Primary Eclipse

ϕ	ℓ	ϕ''	$\sin^2 \phi''$	ℓ''	$\ell'' - \ell_F^{tr}$ (Pr = Tr)	$\ell'' - \ell_F^{oc}$ (Pr = Oc)
0.9445	0.9781	0.9441	0.118439	0.9982	−0.0018	−0.0018
0.9457	0.9692	0.9453	0.113580	0.9893	−0.0093	−0.0103
0.9470	0.9790	0.9466	0.108416	0.9993	+0.0038	+0.0027
0.9488	0.9638	0.9484	0.101440	0.9840	−0.0049	−0.0055
0.9513	0.9471	0.9509	0.092094	0.9673	−0.0086	−0.0076
0.9514	0.9603	0.9510	0.091728	0.9806	+0.0053	+0.0064
0.9533	0.9428	0.9529	0.084909	0.9631	+0.0005	+0.0027
0.9545	0.9290	0.9541	0.080725	0.9492	−0.0044	−0.0015
0.9552	0.9281	0.9549	0.078329	0.9483	+0.0002	+0.0036
0.9583	0.9037	0.9580	0.068116	0.9238	+0.0033	+0.0079

ϕ	$\mathscr{L}$	ϕ''	$\sin^2 \phi''$	$\mathscr{L}''$	$\mathscr{L}'' - \ell_F^{oc}$ (Pr = Tr)	$\mathscr{L}'' - \ell_F^{tr}$ (Pr = Oc)
0.9601	0.8702	0.9598	0.062489	0.8901	−0.0124	−0.0074
0.9632	0.8395	0.9629	0.053331	0.8592	−0.0093	−0.0041
0.9639	0.8504	0.9636	0.051358	0.8702	+0.0098	+0.0150
0.9651	0.8241	0.9648	0.048057	0.8437	−0.0023	+0.0026
0.9663	0.8017	0.9660	0.044860	0.8211	−0.0100	−0.0054
0.9670	0.8061	0.9667	0.043044	0.8256	+0.0033	+0.0078
0.9694	0.7663	0.9692	0.037089	0.7855	−0.0056	−0.0019
0.9695	0.7755	0.9693	0.036850	0.7948	+0.0051	+0.0087
0.9725	0.7298	0.9723	0.030029	0.7487	+0.0000	+0.0022
0.9732	0.7218	0.9730	0.028535	0.7406	+0.0018	+0.0035
0.9751	0.6880	0.9749	0.024666	0.7065	−0.0053	−0.0046
0.9757	0.6912	0.9755	0.023501	0.7097	+0.0065	+0.0069
0.9776	0.6540	0.9774	0.019994	0.6722	−0.0035	−0.0041
0.9795	0.6304	0.9793	0.016765	0.6484	+0.0004	−0.0012
0.9819	0.6087	0.9818	0.013086	0.6265	+0.0134	+0.0107
0.9838	0.5686	0.9837	0.010492	0.5860	+0.0001	−0.0032
0.9844	0.5670	0.9843	0.009732	0.5844	+0.0070	+0.0036
0.9857	0.5425	0.9856	0.008182	0.5596	+0.0004	−0.0033
0.9875	0.5267	0.9874	0.006256	0.5437	+0.0090	+0.0051
0.9882	0.5167	0.9881	0.005576	0.5336	+0.0081	+0.0043
0.9900	0.4871	0.9899	0.004007	0.5037	+0.0008	−0.0027
0.9900	0.4880	0.9899	0.004007	0.5046	+0.0017	−0.0018
0.9931	0.4592	0.9930	0.001909	0.4755	+0.0069	+0.0046
0.9950	0.4426	0.9950	0.001003	0.4587	+0.0070	+0.0055
0.9962	0.4262	0.9962	0.000579	0.4422	−0.0010	−0.0020
0.9969	0.4235	0.9969	0.000386	0.4394	+0.0001	−0.0006
0.9994	0.4184	0.9994	0.000014	0.4343	+0.0030	+0.0030
0.0013	0.4184	0.0013	0.000064	0.4343	+0.0019	+0.0018
0.0018	0.4123	0.0018	0.000133	0.4281	−0.0058	−0.0060
0.0037	0.4317	0.0038	0.000564	0.4477	+0.0048	+0.0038
0.0049	0.4293	0.0050	0.000979	0.4453	−0.0059	−0.0074
0.0054	0.4442	0.0054	0.001161	0.4604	+0.0056	+0.0039
0.0056	0.4467	0.0057	0.001267	0.4629	+0.0061	+0.0043
0.0074	0.4567	0.0075	0.002213	0.4730	−0.0009	−0.0035
0.0105	0.4898	0.0106	0.004459	0.5064	−0.0032	−0.0069
0.0106	0.4966	0.0107	0.004510	0.5133	+0.0029	−0.0007
0.0119	0.5138	0.0120	0.005633	0.5307	+0.0044	+0.0006
0.0130	0.5234	0.0131	0.006807	0.5404	−0.0016	−0.0054
0.0131	0.5263	0.0132	0.006870	0.5433	+0.0005	−0.0033
0.0150	0.5613	0.0151	0.008964	0.5786	+0.0101	+0.0065
0.0155	0.5603	0.0157	0.009645	0.5776	+0.0012	−0.0022
0.0168	0.5872	0.0169	0.011281	0.6048	+0.0104	+0.0073
0.0182	0.5867	0.0183	0.013158	0.6043	−0.0096	−0.0122
0.0210	0.6240	0.0212	0.017654	0.6419	−0.0140	−0.0153
0.0211	0.6391	0.0213	0.017821	0.6572	−0.0002	−0.0014
0.0218	0.6486	0.0220	0.018996	0.6668	−0.0006	−0.0015
0.0242	0.6619	0.0244	0.023233	0.6801	+0.0211	−0.0208
0.0243	0.6686	0.0245	0.023424	0.6869	−0.0157	−0.0154
0.0243	0.6842	0.0245	0.023539	0.7027	−0.0008	−0.0004
0.0243	0.6861	0.0245	0.023539	0.7046	+0.0011	+0.0015
0.0261	0.7099	0.0263	0.027139	0.7286	−0.0008	+0.0006
0.0262	0.7152	0.0264	0.027263	0.7340	+0.0038	+0.0052
0.0267	0.7138	0.0269	0.028219	0.7325	−0.0042	−0.0025
0.0286	0.7399	0.0288	0.032497	0.7588	−0.0054	−0.0027
0.0287	0.7440	0.0289	0.032631	0.7630	−0.0020	+0.0007

ϕ	ℓ	ϕ''	$\sin^2 \phi''$	ℓ''	$\ell'' - \ell_F^{oc}$ (Pr = Tr)	$\ell'' - \ell_F^{tr}$ (Pr = Oc)
0.0311	0.7677	0.0314	0.038318	0.7869	−0.0109	−0.0071
0.0313	0.7684	0.0315	0.038781	0.7876	−0.0127	−0.0088
0.0337	0.8106	0.0339	0.044781	0.8301	−0.0006	+0.0040
0.0342	0.8113	0.0345	0.046259	0.8308	−0.0069	−0.0021
0.0355	0.8181	0.0358	0.049804	0.8376	−0.0161	−0.0111
0.0374	0.8418	0.0377	0.055079	0.8615	−0.0140	−0.0088
0.0375	0.8379	0.0378	0.055253	0.8575	−0.0187	−0.0135
0.0386	0.8590	0.0390	0.058715	0.8788	−0.0105	−0.0053
0.0404	0.8774	0.0407	0.063905	0.8973	−0.0099	−0.0050
0.0428	0.9045	0.0432	0.071828	0.9246	−0.0067	−0.0024
0.0430	0.9061	0.0433	0.072351	0.9262	−0.0065	−0.0023
0.0443	0.9350	0.0447	0.076738	0.9553	+0.0111	+0.0147
0.0449	0.9307	0.0452	0.078601	0.9509	+0.0022	+0.0055
0.0466	0.9255	0.0469	0.084521	0.9456	−0.0163	−0.0139
0.0474	0.9332	0.0477	0.087322	0.9533	−0.0141	−0.0122
0.0491	0.9497	0.0495	0.093488	0.9699	−0.0082	−0.0075
0.0492	0.9497	0.0496	0.094115	0.9699	−0.0092	−0.0085
0.0514	0.9621	0.0518	0.102090	0.9823	−0.0074	−0.0081
0.0522	0.9594	0.0526	0.105290	0.9795	−0.0135	−0.0146
0.0530	0.9754	0.0534	0.108337	0.9956	+0.0001	−0.0009
0.0549	0.9854	0.0553	0.115796	1.0056	+0.0056	+0.0056

Observations of CM Lac, First Top

ϕ	ℓ	ℓ''	ϕ	ℓ	ℓ''
0.0573	0.9863	1.0064	0.2231	0.9790	0.9906
0.0578	0.9754	0.9953	0.2320	0.9982	1.0097
0.0586	0.9881	1.0081	0.2411	0.9872	0.9984
0.0587	0.9576	0.9773	0.2891	0.9963	1.0070
0.0603	0.9781	0.9979	0.2969	0.9908	1.0015
0.0634	0.9808	1.0004	0.3044	0.9872	0.9980
0.0653	0.9836	1.0031	0.3134	0.9890	1.0000
0.0665	0.9790	0.9984	0.3215	0.9927	1.0040
0.0696	0.9763	0.9954	0.3306	0.9854	0.9970
0.0728	0.9817	1.0006	0.3393	0.9799	0.9920
0.0734	0.9854	1.0043	0.3486	0.9836	0.9964
0.0802	0.9665	0.9847	0.3582	0.9872	1.0008
0.0872	0.9890	1.0069	0.3667	0.9890	1.0035
0.0941	0.9754	0.9927	0.3754	0.9872	1.0027
0.1488	0.9799	0.9938	0.3842	0.9763	0.9928
0.1513	0.9790	0.9928	0.3926	0.9745	0.9921
0.1538	0.9863	1.0000	0.4010	0.9754	0.9941
0.1795	0.9963	1.0091	0.4094	0.9656	0.9854
0.1868	0.9817	0.9942	0.4172	0.9683	0.9893
0.1963	0.9991	1.0114	0.4247	0.9585	0.9804
0.2054	0.9836	0.9956	0.4328	0.9763	0.9995

Note: The six observations at ϕ = 0.3842 to 0.4247 inclusive, J.D. 2427224.7462 to .8112, were omitted from the solution.

Observations of CM Lac, Secondary Eclipse

ϕ	$\mathcal{L}$	ϕ''	$\sin^2\phi''$	$\mathcal{L}''$	$\mathcal{L}''-\ell_F^{oc}$ (Pr = Tr)	$\mathcal{L}''-\ell_F^{tr}$ (Pr = Oc)
0.4652	0.9120	0.4649	0.047787	0.9382	+0.0081	+0.0073
0.4677	0.8962	0.4674	0.041263	0.9225	+0.0060	+0.0051
0.4696	0.8954	0.4694	0.036611	0.9218	+0.0161	+0.0150
0.4715	0.8742	0.4713	0.032228	0.9005	+0.0060	+0.0046
0.4733	0.8598	0.4731	0.028324	0.8861	+0.0024	+0.0008
0.4758	0.8410	0.4756	0.023310	0.8672	−0.0012	−0.0031
0.4758	0.8511	0.4756	0.023310	0.8774	+0.0090	+0.0071
0.4762	0.8356	0.4760	0.022551	0.8618	−0.0041	−0.0061
0.4780	0.8279	0.4778	0.019291	0.8541	−0.0007	−0.0028
0.4783	0.8257	0.4781	0.018772	0.8519	−0.0010	−0.0031
0.4793	0.8234	0.4791	0.017092	0.8496	+0.0030	+0.0007
0.4796	0.8166	0.4794	0.016603	0.8428	−0.0020	−0.0042
0.4807	0.8083	0.4805	0.014870	0.8344	−0.0035	−0.0058
0.4812	0.8083	0.4810	0.014113	0.8345	−0.0003	−0.0026
0.4814	0.8098	0.4812	0.013816	0.8360	+0.0024	+0.0001
0.4832	0.7943	0.4831	0.011281	0.8204	−0.0020	−0.0044
0.4833	0.7995	0.4832	0.011147	0.8256	+0.0038	+0.0014
0.4855	0.7878	0.4854	0.008412	0.8139	+0.0054	+0.0031
0.4858	0.7820	0.4857	0.008068	0.8081	+0.0013	−0.0009
0.4864	0.7805	0.4863	0.007403	0.8066	+0.0034	+0.0012
0.4874	0.7755	0.4873	0.006356	0.8015	+0.0041	+0.0019
0.4877	0.7748	0.4876	0.006058	0.8008	+0.0051	+0.0030
0.4888	0.7600	0.4887	0.005025	0.7859	−0.0037	−0.0057
0.4893	0.7572	0.4892	0.004587	0.7831	−0.0038	−0.0057
0.4895	0.7656	0.4894	0.004417	0.7916	+0.0057	+0.0039
0.4917	0.7461	0.4916	0.002762	0.7719	−0.0028	−0.0042
0.4939	0.7420	0.4938	0.001492	0.7678	+0.0026	+0.0018
0.4951	0.7406	0.4951	0.000963	0.7664	+0.0055	+0.0051
0.4955	0.7305	0.4955	0.000812	0.7562	−0.0034	−0.0037
0.4958	0.7305	0.4958	0.000708	0.7562	−0.0025	−0.0028
0.4976	0.7298	0.4976	0.000231	0.7555	+0.0011	+0.0011
0.4980	0.7258	0.4980	0.000161	0.7515	−0.0023	−0.0022
0.4988	0.7305	0.4988	0.000058	0.7562	+0.0034	+0.0036
0.4992	0.7238	0.4992	0.000026	0.7495	−0.0030	−0.0028
0.4995	0.7258	0.4995	0.000010	0.7515	−0.0009	−0.0006
0.5014	0.7291	0.5014	0.000079	0.7548	+0.0018	+0.0020
0.5017	0.7244	0.5017	0.000116	0.7501	−0.0033	−0.0031
0.5019	0.7291	0.5019	0.000145	0.7548	+0.0012	+0.0013
0.5032	0.7332	0.5032	0.000411	0.7590	+0.0029	+0.0029
0.5041	0.7291	0.5041	0.000674	0.7548	−0.0036	−0.0039
0.5044	0.7338	0.5044	0.000777	0.7595	+0.0002	−0.0001
0.5060	0.7489	0.5060	0.001444	0.7748	+0.0100	+0.0092
0.5061	0.7393	0.5062	0.001492	0.7651	−0.0001	−0.0009
0.5069	0.7461	0.5070	0.001909	0.7719	+0.0034	+0.0024
0.5076	0.7489	0.5077	0.002316	0.7748	+0.0033	+0.0021
0.5085	0.7523	0.5086	0.002896	0.7782	+0.0025	+0.0011
0.5086	0.7440	0.5087	0.002965	0.7698	−0.0064	−0.0078
0.5100	0.7551	0.5101	0.004007	0.7810	−0.0022	−0.0039
0.5101	0.7614	0.5102	0.004087	0.7873	+0.0036	+0.0018
0.5104	0.7551	0.5105	0.004333	0.7810	−0.0043	−0.0061
0.5110	0.7677	0.5111	0.004847	0.7937	+0.0052	+0.0033
0.5120	0.7720	0.5121	0.005766	0.7980	+0.0040	+0.0019

ϕ	$\mathscr{L}$	ϕ''	$\sin^2 \phi''$	$\mathscr{L}''$	$\mathscr{L}'' - \ell_F^{tr}$ (Pr = Tr)	$\mathscr{L}'' - \ell_F^{oc}$ (Pr = Oc)
0.5123	0.7677	0.5124	0.006058	0.7937	−0.0020	−0.0041
0.5145	0.7820	0.5146	0.008412	0.8080	−0.0005	−0.0028
0.5145	0.7899	0.5146	0.008412	0.8160	+0.0075	+0.0052
0.5157	0.7958	0.5158	0.009857	0.8219	+0.0062	+0.0038
0.5159	0.7995	0.5160	0.010109	0.8257	+0.0087	+0.0064
0.5163	0.7914	0.5164	0.010622	0.8175	−0.0019	−0.0043
0.5164	0.8009	0.5165	0.010752	0.8271	+0.0071	+0.0047
0.5176	0.8143	0.5177	0.012376	0.8406	+0.0132	+0.0109
0.5183	0.7995	0.5184	0.013375	0.8256	−0.0061	−0.0085
0.5184	0.8264	0.5185	0.013521	0.8528	+0.0205	+0.0181
0.5188	0.8083	0.5190	0.014113	0.8345	−0.0003	−0.0026
0.5201	0.8121	0.5203	0.016121	0.8382	−0.0047	−0.0070
0.5209	0.8356	0.5211	0.017421	0.8619	+0.0140	+0.0118
0.5213	0.8257	0.5215	0.018090	0.8519	+0.0015	−0.0007
0.5219	0.8341	0.5221	0.019117	0.8604	+0.0063	+0.0041
0.5234	0.8527	0.5236	0.021805	0.8791	+0.0156	+0.0137
0.5237	0.8371	0.5239	0.022364	0.8633	−0.0020	−0.0040
0.5238	0.8472	0.5240	0.022551	0.8735	+0.0076	+0.0056
0.5251	0.8325	0.5253	0.025060	0.8586	−0.0154	−0.0172
0.5257	0.8558	0.5259	0.026261	0.8821	+0.0045	+0.0027
0.5269	0.8566	0.5271	0.028746	0.8828	−0.0021	−0.0037
0.5270	0.8678	0.5272	0.028958	0.8941	+0.0086	+0.0070
0.5273	0.8686	0.5275	0.029598	0.8949	+0.0076	+0.0060
0.5282	0.8654	0.5284	0.031560	0.8916	−0.0011	−0.0025
0.5288	0.8638	0.5290	0.032902	0.8900	−0.0063	−0.0076
0.5291	0.8750	0.5293	0.033583	0.9013	+0.0032	+0.0019
0.5294	0.8750	0.5296	0.034270	0.9012	+0.0014	+0.0001
0.5300	0.8798	0.5302	0.035666	0.9061	+0.0027	+0.0016
0.5313	0.8847	0.5315	0.038781	0.9109	+0.0001	−0.0010
0.5316	0.8831	0.5319	0.039518	0.9093	−0.0032	−0.0043
0.5325	0.8880	0.5328	0.041768	0.9142	−0.0034	−0.0043
0.5335	0.8995	0.5338	0.044337	0.9257	+0.0026	+0.0017
0.5343	0.9028	0.5346	0.046445	0.9290	+0.0015	+0.0008
0.5357	0.9095	0.5360	0.050246	0.9356	+0.0007	+0.0001
0.5369	0.9154	0.5372	0.053616	0.9415	+0.0005	0.0000
0.5369	0.9273	0.5372	0.053616	0.9535	+0.0125	+0.0120
0.5375	0.9213	0.5378	0.055339	0.9474	+0.0034	+0.0029
0.5388	0.9273	0.5391	0.059162	0.9533	+0.0030	+0.0025
0.5394	0.9238	0.5397	0.060966	0.9497	−0.0034	−0.0039
0.5399	0.9298	0.5402	0.062489	0.9558	+0.0004	−0.0001
0.5412	0.9247	0.5415	0.066530	0.9505	−0.0108	−0.0112
0.5413	0.9393	0.5416	0.066846	0.9652	+0.0035	+0.0031
0.5424	0.9445	0.5427	0.070364	0.9704	+0.0040	+0.0036
0.5431	0.9462	0.5434	0.072646	0.9720	+0.0028	+0.0023
0.5449	0.9532	0.5452	0.078668	0.9789	+0.0027	+0.0022
0.5456	0.9541	0.5460	0.081069	0.9797	+0.0010	+0.0004
0.5480	0.9567	0.5484	0.089549	0.9821	−0.0044	−0.0052
0.5528	0.9772	0.5532	0.107630	1.0023	+0.0047	+0.0040
0.5537	0.9701	0.5541	0.111183	0.9950	−0.0036	−0.0044
0.5541	0.9772	0.5545	0.112778	1.0021	+0.0031	+0.0024

Observations of CM Lac, Second Top

ϕ	ℓ	ℓ''	ϕ	ℓ	ℓ''
0.5566	0.9826	1.0073	0.6956	0.9927	1.0035
0.5568	0.9754	1.0000	0.7029	0.9890	0.9997
0.5584	0.9808	1.0052	0.7099	0.9854	0.9960
0.5593	0.9736	0.9978	0.7169	0.9917	1.0024
0.5624	0.9772	1.0011	0.7232	0.9881	0.9988
0.5649	0.9772	1.0007	0.7293	0.9826	0.9933
0.5674	0.9718	0.9950	0.7593	0.9890	1.0002
0.5724	0.9781	1.0006	0.7618	0.9881	0.9994
0.5748	0.9772	0.9994	0.7714	0.9863	0.9978
0.5780	0.9745	0.9962	0.7733	0.9908	1.0023
0.5805	0.9781	0.9995	0.7932	0.9881	1.0001
0.5829	0.9772	0.9982	0.7945	0.9872	0.9992
0.5846	0.9972	1.0182	0.7970	0.9927	1.0048
0.5854	0.9745	0.9952	0.7988	0.9890	1.0011
0.5865	0.9954	1.0161	0.8194	0.9908	1.0035
0.5883	0.9826	1.0029	0.8213	0.9854	0.9982
0.5910	0.9854	1.0054	0.8231	0.9908	1.0036
0.5981	0.9781	0.9970	0.8256	0.9863	0.9992
0.6047	0.9817	0.9997	0.8456	0.9872	1.0009
0.6113	0.9845	1.0016	0.8474	0.9845	0.9983
0.6193	0.9954	1.0116	0.9140	0.9817	0.9997
0.6251	0.9890	1.0044	0.9171	0.9836	1.0018
0.6314	1.0000	1.0148	0.9202	0.9826	1.0010
0.6372	0.9826	0.9967	0.9233	0.9808	0.9994
0.6378	0.9863	1.0003	0.9264	0.9836	1.0025
0.6397	0.9908	1.0047	0.9302	0.9799	0.9990
0.6451	0.9799	0.9932	0.9364	0.9826	1.0022
0.6520	0.9836	0.9963	0.9389	0.9727	0.9924
0.6810	0.9745	0.9856	0.9402	0.9963	1.0163
0.6877	0.9936	1.0046	0.9421	0.9863	1.0063
0.6892	0.9872	0.9981	0.9426	0.9799	0.9999
0.6895	0.9826	0.9935			

Environmental Sciences

FLORIDA'S AIR QUALITY, PRESENT AND FUTURE

ALEX E. S. GREEN, DANIEL E. RIO AND ROBERT A. HEDINGER

Interdisciplinary Center for Aeronomy and (other) Atmospheric Sciences,
University of Florida, Gainesville, Florida 32611

ABSTRACT: *Air quality is a matter of great importance to future development of Florida. In this analysis we attempt to quantify Florida's air quality by using reports based upon measurements of air pollution levels. To carry out this analysis we must utilize some form of Air Quality Index (AQI). Because there is no universally established AQI we utilize several of the proposed air quality indices which have appeared in the literature as well as an AQI which we have developed ourselves. To place these indices on a common scale we calculate factors of safety (FS), by using an air pollution "load limit" specified in terms of the current National Ambient Air Quality Standards (NAAQS). With this common feature we can assign factors of safety using the combinative rules involved in a variety of air quality indices. This methodology is applied to a number of cities in Florida, from which we develop a pattern demonstrative of the present quality of Florida's air. We also examine two possible regulatory practices which are presently under consideration by the Florida Department of Environmental Regulation. The Factors of Safety which would result should these regulatory scenarios be adopted, show patterns which should be of interest in public considerations of Florida regulations.**

A RECENT STUDY (Hedinger et al., 1978) of public policy questions relative to regulations of sulfur dioxide emissions from Florida's electric power plants by the Florida Sulfur Oxide Study (FSOS) has focused considerable attention upon the question of Florida's air quality. Specific air pollution questions were addressed in relation to electric power generation. However, data acquired by the Florida Department of Environmental Regulation (FDER) in this connection (and as a result of earlier efforts to measure air pollution in Florida) make it possible to address a broader spectrum of questions about Florida air quality.

During the course of the FSOS study it became clear that the present state of knowledge of health effects relevant to low levels of pollutants is still at a very primitive stage. Indeed, Congressional hearings held in November 1975 (Brown, 1975) on "The Costs and Effects of Chronic Exposure to Low Level Pollutants in the Environment" indicate that we know almost nothing about the health effects of long-term exposure to low levels of pollutants. Furthermore, aerometric methods for measuring pollutant concentrations were also found to be of questionable validity.

Basic uncertainties in what must represent fundamental components of any decision machinery make it very difficult to apply a comprehensive cost benefit analysis to the public policy decision-making process for air pollution regulations. This state of affairs makes it prudent to examine the key health questions from a simplified point of view to obtain optimum regulatory policies in Florida. Towards this end we examine the status of Florida's air quality at present (sum-

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

mer, 1978) and consider how this quality would change if we modify our regulatory policies in ways that are presently under consideration at the national and state level. We utilize in the analysis various air quality indices which have been, or could be, used as quantitative measures of air quality in terms of the reported concentrations of the major pollutants. Table 1 gives the levels of pollutants for 1976 for regions with instruments to measure the five major pollutants as reported by the Florida Department of Environmental Regulation (FDER). The row labeled NAAQS give the National Ambient Air Quality Standards for these time periods. The row labeled FAAQS represents the present Florida Ambient Air Quality Standards. The row labeled ACGIH-TLV shows the 8 hr limits (Threshold Limit Value, TLV) for the working place recommended by the American Council of Governmental Industrial Hygienists (ACGIH, 1976). The row labeled EACGIH represents estimated standard values for the corresponding time periods of this table (see ACGIH *Index*).

TABLE 1. Pollution levels at various locations in Florida in 1976 reported by the Florida Department of Environmental Regulation.

Loc.	POLLUTION LEVELS	C_{TSP}	C_{SO}	C_{NO}	C_{O}	C_{CO}
Loc.	1976	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	1 hr max ppm	1 hr max ppm
1.	Tampa-Hillsborough	69.3	39.6	58.0	.13	18.5
2.	Miami-Dade	64.4	8.7	31.3	.07	22.0
3.	Jacksonville-Duval	59.7	22.3	59.0	.18	17.5
4.	St. Pete.-Pinellas	59.7	18.3	43.1	.132	12.0
5.	Gainesville-Alachua	47.1	5.62	26.4	.110	5.0
6.	Tallahassee-Leon	37.3	6.0	26.4	.114	2.4
7.	Orlando-Orange	49.4	6.3	2.9	.130	5.0
8.	Palm Beach	56.4	26.2	23.4	.148	10.5
9.	Ft. L'dale. Broward	59.0	5.24	35.6	.105	23.0
NAAQS		75.0	80.0	100.0	.08	35
FAAQS		60.0	60.0	100.0	.08	35
ACGIH-TLV		10,000	13,000	9,000	.1	50
EACGIH		1,111	1,444	1,000	.4*	200*

1/9 TVL *4×TLV

FACTORS OF SAFETY (FS)—For the purposes of evaluating Florida's air quality it is desirable to put all index systems on a common basis. Towards this end we utilize what we call a Factor of Safety (FS). To define the FS in engineering practice the best technical judgment first must be used to estimate the load limit, i.e. the load level at which the system would be expected to fail. The factor of safety is then defined as this load limit divided by the maximum applied load that is reported or foreseen for the structure. For example, in aircraft design where weight is such an important factor in terms of economical utilization of the aircraft, a factor of safety of 1.5 is applied, the smallest factor of safety in all engineering practice. Essentially the aircraft structure is designed to cope with 1.5 times the worst combination of loads in the form of passenger weight, luggage weight, freight, fuel weight and gust loads at maximum aircraft speed. In the case of buildings and bridges, factors of safety from 1.5 to 3 are now applied. In radiation protection, factors of safety of 10 are applied. In general, the greater our ignorance on the effects of the load, the greater is the factor of safety customarily applied.

Our present lack of knowledge about effects of low pollutant levels make it impossible to specify a precise load limit for the human pulmonary system. However, for now, we identify as the pulmonary load limit an index corresponding to air in which all five major pollutants are present at NAAQS *simultaneously.* The air quality factor of safety based upon any index I_j is then defined as the ratio

$$FS_j = \frac{I_j\,(C_1^*, C_2^*, C_3^*, C_4^*, C_5^*)}{I_j\,(C_1, C_2, C_3, C_4, C_5)} \qquad (1)$$

where the $C^*_1, C^*_2, C^*_3, C^*_4, C^*_5$ denote the NAAQS concentration for the five major pollutants TSP, SO_2, NO_2, Ox and CO and the C_1, C_2, C_3, C_4, C_5 denote the actual reported concentrations. Tables calculated by the indices described in the following sections will give the factors of safety for each of the locations given in Table 1 relative to this chosen standard. Let's discuss the common patterns in these factors and their possible implications.

Pollutant Standards Index (PSI)—The PSI Index (Ott and Thom, 1976; Ott and Hunt, 1976) has been recommended for use by the Council on Environmental Quality and by the Environmental Protection Agency as a common air pollution reporting system (EPA, 1976). This index consists of an array of sub-indices each based upon concentrations of the five major pollutants. Algebraic prescriptions are given for calculating these sub-indices and the PSI is defined as the largest of all these sub-indices. With one exception, the sub-indices are all based upon single pollutants. The exception, in recognition of the synergistic involvement of total suspended particulates and sulfur dioxide utilizes a sixth sub-index based upon products of the concentration of SO_2 and TSP. If the sub-index based upon this product is higher than the other component sub-indices then this product index becomes the PSI. The reporting scheme involves giving the value of the PSI and identifying its related pollutant.

The PSI scheme is primarily for day-to-day reporting of air quality on a common system. It is particularly intended for the purposes of alerting citizens to times when air pollution approaches the unhealthy level. For present purposes we use the PSI Index scheme to provide some quantitative assessment of the overall average air quality in various regions of Florida. This is a somewhat different objective but nevertheless some reasonable transformation of the input data and two minor modifications of the PSI Index will make possible and plausible this application.

In order to apply data in Table 1 to the PSI scheme we must convert the annual averages for TSP, SO_2 and NO_2 to a 24 hr basis. To do this strictly on a scientific basis would require a detailed analysis of the frequency distribution of the concentrations of the diverse pollutant levels in these various regions (Larsen, 1970). However, to avoid ambiguity we have simply utilized the rule of proportioning the reported Florida levels on an annual average basis by the ratio of the 24 hr NAAQS over the annual NAAQS standard. Thus we use

$$C_i\,[24\text{ hr}] = C_i\,(1\text{ yr}) \times [C_{istd}(24\text{ hr})/C_{istd}(1\text{ yr})] \tag{2}$$

The factors of safety, based on the highest sub-index of the PSI are given in Table 2, Column 2. The FS's based upon the second highest PSI sub-index, are given in Column 3. In all instances the major pollutants are O_x TSP or $SO_2 \times$ TSP. We have dealt with the problem of lack of definition of the sub-indices of NO_2 and TSP $\times$ SO_2 below 200 by assuming for both a linear function passing through the 200 level and the origin.

The load limit corresponding to 75 $\mu g/m^3$ TSP and 80 $\mu g/m^3$ SO_2 associated with TSP $\times$ SO_2, is the PSI value 200. However, to avoid the unrealistic discontinuity associated with the PSI system, we will assume SO_2 is only present at 79 $\mu g/m^3$ which gives the load limit 100.

OTHER AIR QUALITY INDICES—*The ICAAS Air Quality Index*: We can use approximate scaling of the PSI, but allow for genuine combinational involve-

TABLE 2. Safety factors for 1976 concentrations for various indices.

(1) LOC	(2) PSI-1	(3) PSI-2	(4) ICAAS	(5) ORNL	(6) TOR	(7) ACGIH
1	0.87(4)	0.75(6)	1.14	1.29	1.60	1.06
2	1.36(1)	1.14(4)	1.74	2.23	2.71	1.57
3	0.67(4)	1.17(1)	0.98	1.18	2.32	0.90
4	0.86(4)	1.17(1)	1.27	1.66	2.51	1.19
5	0.98(4)	1.35(1)	1.62	2.61	4.23	1.60
6	0.96(4)	1.54(1)	1.64	2.84	5.54	1.65
7	0.87(4)	1.31(1)	1.43	2.54	3.93	1.99
8	0.78(4)	1.21(1)	1.18	1.65	2.32	1.16
9	1.01(4)	1.18(1)	1.48	1.85	3.22	1.27
FAAQS	1.23(6)	1.00(4)	1.13	1.14	1.42	1.05
L.L.	100	100	2.55	98.6	28.1	0.60

(1) TSP, (2) SO_2, (3) NO_2, (4) O_x, (5) CO, (6) TSP $\times$ SO_2

ments of all pollutants in a biophysically reasonable and mathematically continuous fashion, by using the biquadratic form

$$I_3 = I(ICAAS) = [\Sigma_i (C_i/S_i)^2 + b_{ij}(C_i/S_i)(C_j/S_j)]^{1/2} \quad (3)$$

where the C_i's are the concentrations, S_i are scale factors and the b_{ij} is an interaction term. Biquadratic forms of this nature have played important roles in many fields such as the special theory of relativity, the optimization of industrial processes, and non-linear least square minimization. Biquadratic forms have many versatile properties which make them a powerful basis for utilization. The only cross product term used here is $b_{1.2} = 1.5$ to represent the synergism between TSP and SO_2. In the present work, we will scale each pollution concentration by the NAAQS air quality standards for the reported time period for each pollutant as given in Table 1. For this index we obtain a "load limit" = 2.546 based upon the NAAQS. Using this load limit and actual loads with the ICAAS index we find the safety factors given in Column 4 of Table 2. Hedinger, Rio and Green (1978) have used this biquadratic form with somewhat different scaling to find air pollution dose response relationships.

The Oak Ridge National Laboratory Air Quality Index (ORNL): In the Oak Ridge National Laboratory Air Quality Index (Thomas, Babcock and Schults, 1971), each pollutant concentration is scaled by the National Ambient Air Quality Standard corresponding to the time periods of interest and the results are compounded according to the formula

$$I_4 = I(ORNL) = [\Sigma_i\, 5.7\, C_i/S_i]^{1.37}. \quad (4)$$

If one inserts the National Ambient Air Quality Standards one obtains the load limit = 98.4. In Column 5, Table 2, we list FS for the ORNL index.

Toronto Index (TOR): The Toronto Index (Shenfeld, 1970) is similar to the ORNL index and is given by the formula

$$I_5 = I(TOR) = 0.2\,(30.5\, COH + 126.0\, SO_2)^{1.35} \quad (5)$$

where COH is the coefficient of haze. There is a close correlation between total suspended particles and the COH (FDER, 1977). We can therefore judge the effects of various TSP and SO_2 concentrations on the equivalent Toronto index. Column 6 of Table 2 gives the FS for this index.

American Council of Governmental Industrial Hygienists (ACGIH): ACGIH, The American Council of Governmental Industrial Hygienists, has established a simple rule of combination for pollutants in the working area (ACGIH, 1977), which in effect is based on the index

$$I_6 = I(ACGIH) = \Sigma_i\, C_i/T_i \quad (6)$$

where T_i are the so-called threshold limit values (TLV). These levels are very high by air pollution standards, presumably because persons in the working place are generally healthy. On the other hand, National Ambient Air Quality Standards, when present *simultaneously*, certainly represent a realistic load limit for the general population. To convert the threshold limit values T_i for 8 hr to equivalent annual limits, we use a factor of 1/9 for TSP, SO_2 and NO_2. To convert to equivalent hourly levels we use a factor of 4. These are reasonable conversions based upon U.S.A. and Canadian standards for various time periods (Stern, 1977). The load limit for these EACGIH values is 0.589. The corresponding factors of safety are given in Column 7 of Table 2.

FUTURE REGULATORY SCENARIOS—The Clean Air Act of 1977 has interpreted the long debated concept of nondegradation (Stern, 1977; Hovey, 1977) by dividing air quality regions into Class 1, underdeveloped; Class 2, developing; and Class 3, overdeveloped air quality areas. In Class 1, mostly national parks, it provides for the minor increases in levels of TSP and SO_2 concentrations. In Class 2, to which most populated centers of Florida belong, it allows for increments of 19 $\mu g/m^3$ for TSP and 20 $\mu g/m^3$ for SO_2, the so-called PSD (particulates and sulfur dioxide) increments.

If these increments are allowed in the areas of Florida listed in Table 1, then the FS values for the various indices are given in Table 3. Since in several instances the PSD increment would bring Florida beyond national primary standards, in these locations concentrations are set at the NAAQS.

A philosophy is emerging which, if put into practice, could have an even more serious impact upon air in Florida than would the PSD clauses of the Clean Air Act of 1977. The philosophy may be stated as follows: "There is no firm evidence that SO_2 pollution levels up to the Florida standard have an impact on human health. Accordingly, if we restrict the pollutant concentrations of SO_2 to be at any level up to the Florida Ambient Air Quality standards, we will insure adequate protection for human health." In effect, this philosophy accepts 60 micrograms per cubic meter of SO_2 as a safe limit of SO_2 tolerance no matter what other pollutants are present. When this concentration is taken together with the

TABLE 3. Safety factors with PSD increments of 19 $\mu g/m^3$ TSP and 20 $\mu g/m^3$ SO_2 (up to NAAQS).

LOC	PSI-1	PSI-2	ICAAS	ORNL	TOR	ACGIH
1	0.61(6)	0.71(4)	1.07	1.18	1.28	1.03
2	0.65(6)	1.11(1)	1.35	1.68	1.35	1.43
3	0.67(4)	0.57(6)	0.91	1.03	1.42	0.86
4	0.71(6)	0.70(4)	1.13	1.38	1.42	1.13
5	0.89(6)	0.81(4)	1.33	1.88	1.66	1.45
6	0.96(4)	0.92(6)	1.36	2.00	1.91	1.50
7	0.85(6)	0.77(4)	1.22	1.84	1.62	1.36
8	0.74(6)	0.64(4)	1.08	1.41	1.47	1.11
9	0.71(6)	0.83(4)	1.22	1.42	1.43	1.17
FAAQS	1.00(6)	1.00(1)	1.00	1.00	1.00	1.00

(1) TSP, (2) SO_2, (3) NO_2, (4) Ox, (5) CO, (6) TSP $\times$ SO_2

1976 levels of pollutants for TSP and other Florida pollutants, one obtains the various factors of safety in Table 4.

Discussion—Let us now examine the factors of safety presented in Tables 2 to 4. First, it must be recognized that the load limit we have chosen in which all five major pollutants are *simultaneously* present at the NAAQS would undoubtedly cause significant pulmonary stress for the average citizen and severe stress for the young, aged and infirm. By current best judgments, if only one were present above these "standards" ("limits" would be a better descriptor!) the air would be viewed as unhealthful. Accordingly, relative to this composite load limit, one might hope that various air quality control regions would have large factors of safety (i.e., 3-5). Column 2 of Table 2 gives the FS based upon the conventional PSI. It might come as a shock to the reader that there is no safety factor (i.e., FS is 1) in all but two Florida locations. This is due to the oxidant problem in Florida, a problem recognized in numerous EPA non-attainment citations (Federal Register, 1978). Let us accept the oxidant problem as a seasonal phenomenon associated with Florida's high ultraviolet levels and use the second largest PSI sub-index. We then find only small factors of safety—small because of the heavy particulate loadings.

The PSI, while attaining official standing as a reporting system, is almost universally recognized to be oversimplified as a genuine measure of air quality from standpoint of health effects. The other indices described represent various attempts to encompass the now generally accepted view (Committee on Medical, etc., 1978) that air loaded with several pollutants simultaneously is more harmful than air with only one pollutant. The ICAAS index gives (Column 4 of Table 2) very marginal FS factors. The ORNL index gives a slightly more favorable picture but only half the locations have FS greater than two.

The TOR index gives the most favorable picture, undoubtedly due to its neglect of Ox, NO_2 and CO which are important pollutants in many areas of Florida. The ACGIH index system gives results very similar to the ICAAS system. Overall, when viewed from the standpoint of comfortable factors of safety (e.g. 3-5), one cannot help but be disappointed in the quality of Florida's air in most of these urban locations.

The FAAQS row in Table 2 gives the FS factors associated with the FAAQS themselves. It should be noted that these FS factors are marginal, considering the makeup of Florida's population.

As shown in Table 3 the picture would worsen in many areas of Florida if the PSD increments of the Clean Air Act of 1977 are permitted. The FS factor decreases particularly for the TOR index since both pollutants used in that index scheme are increased. A similar pattern of reduced FS values would follow if SO_2 levels of 60 $\mu g/m^3$ were permitted (see Table 4).

Summary and Conclusions—Our analysis suggests that Florida's air quality is not quite as good as we might hope or is widely believed to be. This is confirmed by the number of non-attainment citations (Federal Register, 1978) of Florida cities, mostly in connection with the oxidant problem. Here the fact that we are a southern state and photochemical processes are particularly strong un-

TABLE 4. Safety factors of SO_2 if increased to 60 $\mu g/m^3$.

LOC	PSI-1	PSI-2	ICAAS	ORNL	TOR	ACGIH
1	0.60(6)	.71(4)	1.05	1.16	1.20	1.02
2	1.17(6)	1.00(1)	1.49	1.87	1.70	1.48
3	0.67(4)	0.65(6)	0.92	1.04	1.45	0.86
4	0.86(4)	0.71(6)	1.14	1.40	1.52	1.13
5	0.98(4)	1.09(1)	1.41	2.03	2.01	1.48
6	0.98(4)	1.21(1)	1.43	2.17	2.34	1.52
7	0.87(4)	1.06(1)	1.26	1.98	1.93	1.38
8	0.73(6)	0.64(4)	1.06	1.38	1.39	1.10
9	1.02(4)	1.00(1)	1.30	1.55	1.77	1.20
FAAQS	1.23(6)	1.00(4)	1.13	1.14	1.42	1.05

(1) TSP, (2) SO_2, (3) NO_2, (4) O_x, (5) CO, (6) TSP $\times$ SO_2

doubtedly plays an important role. From the SO_2 standpoint we are generally in good shape and most areas are considerably below federal or state standards. Unfortunately we are generally fairly high in TSP, and this unfortunate situation makes our air quality worse than it would be based upon the SO_2 levels alone. If Florida were to utilize the full PSD increments, the air quality of Florida would begin to fall into rather poor categories. It would appear, therefore, that in these instances the Clean Air Act of 1977 would actually permit significant degradation and Florida should probably be more restrictive than Federal law permits. Also Florida should not permit SO_2 to reach the FAAQS levels to avoid air quality which by most measures would be very marginal.

The fundamental problem in judging air quality at present is lack of knowledge about the effects of chronic exposure to low levels of pollutants—particularly upon the young, elderly and infirm (Brown, 1975, Committee on Medical, etc., 1977). It is quite unlikely that the standard methodologies used in estimating air pollution health effects will resolve these problems in the near future. Under such circumstances it is usually helpful if a discipline (e.g., air pollution science and engineering) reaches beyond its normal boundaries for new ideas and approaches. In the present instance the use of the Factor of Safety concept as a guide to the judgment of air quality is, in fact, a time tested approach used in many other fields of science and engineering. It might be noted that the factors of safety computed here with the ICAAS index correlate well with the ACGIH-FS ($r=0.78$), the ORNL-FS ($r=0.58$) and the PSI-1-FS ($r=0.56$).

In conclusion, we hope that this article called this very complex issue to the attention of other Florida scientists and engineers and that we have stimulated development of new ways to think about this difficult problem.

ACKNOWLEDGMENTS—The authors thank Florida Sulfur Oxide Study, Inc., the Florida Department of Environmental Regulation and the State University System Star Grant Program for the support of this work. Helpful discussions were held with Edward D. Palmes, Jerome M. Schwartz, J. P. Subramani, Hamilton S. Oven, Lewis Nagler, Bernard M. Leadon, Morris W. Self and William G. Wagner.

LITERATURE CITED

ACGIH. 1977. TLVs: Threshold limit values for chemical substances and physical agents in the workroom environment with intended changes for 1977. American Conference of Governmental Industrial Hygienists. c/o Secretary, P. O. Box 1937, Cincinnati, Ohio 45201.

Brown, G. E., Jr. 1975. The costs and effects of chronic exposure to low-level pollutants in the environment. Subcommittee on the Environment and the Atmosphere of the Committee on Science and Technology, U. S. House of Representatives, 94th Congress. No. 49, November 17.

Committee on Medical and Biological Effects of Environmental Pollutants. 1977. Airborne particles. National Research Council Rept. National Technical Information Service, Springfield, Virginia 22161.

EPA. 1976. Guideline for public reporting of daily air quality—Pollutant Standards Index (PSI). Guideline Ser. OAQPS No. 1.2-044, EPA-450/2-76-013. Washington, D. C.

FDER. 1977. Ambient air quality. Florida Dept. of Environmental Regulation. Tallahassee. March.

Federal Register. 1978. National ambient air quality standards: state attainment status. Federal Register No. 43, EPA, Part II. Friday, March 3, 1978. Washington, D. C.

Hedinger, R. A., D. E. Rio and A. E. S. Green. 1978. An interdisciplinary study of the health, social and environmental economics of sulfur oxide pollution in Florida. Rept. to Sulfur Oxide Study, ICAAS. Univ. Florida. Gainesville. (copy deposited in Florida Academy of Sciences library)

Hovey, H. H., Jr. 1977. Prevention of significant deterioration discussion papers. J. Air Poll. Contr. Assoc. 27:849-851.

Larsen, R. I. 1970. Relating air pollutant effects to concentration and control. J. Air Poll. Contr. Assoc. 20:214-225.

Ott, W. R., and W. F. Hunt, Jr. 1976. A quantitative evaluation of the pollutant standards index systems in the U. S. and Canada. J. Air Poll. Contr. Assoc. 26:1050-1054.

________, and G. C. Thom. 1976. A critical review of air pollution index systems in the United States and Canada. J. Air Poll. Contr. Assoc. 26:460-470.

Shenfield, L. 1970. Note on Ontario's air pollution index and alert system. J. Air Poll. Contr. Assoc. 20:612-614.

Stern, A. C. 1977. Prevention of significant deterioration: a critical review. J. Air Poll. Contr. Assoc. 27:440-460.

Thomas, W. A., L. R. Babcock and W. B. Schults. 1971. Oak Ridge air quality index. ORNL-NSF-EP-8. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Wilson, S. U., D. S. Anthony, E. R. Hendrickson, C. L. Jordan and P. Urone. 1978. Final Report of Florida Sulfur Oxides Study. Project Management by Post, Buckley, Schuh and Jernigan, Inc. Orlando, Florida.

Florida Sci. 41(3):183-190. 1978.

EASTERN WOODRATS (*NEOTOMA FLORIDANA*) IN SOUTHCENTRAL FLORIDA—*Roy E. Greer*, Texas Instruments Incorporated, Ecological Services, Dallas, Texas, 75222

ABSTRACT: *Eastern woodrat occurs throughout southeastern United States in suitable forested habitats but in Florida, woodrats previously have been reported inland only from northern counties. I found woodrats occurring in at least disjunct populations throughout southcentral Florida as far south as DeSoto County.*

EASTERN WOODRAT (*Neotoma floridana*) is typically an inhabitant of hammocks, swamps, and cabbage palm thickets in the Southeast (Burt and Grossenheider, 1964). Goertz (1970) trapped the woodrat in northern Louisiana in pine woods and bottom thickets that combined ground litter, stumps, fallen logs, brush, and trees covered with dense tangles of vines. In Florida, Kale (1972) captured the eastern woodrat in a dense oak-palm coastal hammock near Vero Beach, Indian River County. The single Vero Beach record is the most southern encounter of the woodrat along Florida's east coast. Sherman (1944) reported a single woodrat taken at Murdock, Charlotte County, Florida, the most southern capture along Florida's west coast. Some 100 mi nw of Murdock, Brown (in Cowell, 1974) reported woodrat densities of 1-4 per acre in river flood plain forest along the Hillsborough River.

Lee (1968) reported woodrat nests in southcentral Florida from bridges along State Route 60 between Lake Placid and Okeechobee. Layne (1974) noted that the circumstances and surrounding habitats raised the suspicion that the animals observed actually may have been Black Rats (*Rattus rattus*). Several accounts of woodrat inhabitation of inland non-coastal areas have been presented in Development of Regional Impact (DRI) statements prepared by phosphate mining companies. For example, Conservation Consultants (1975a), reported woodrats to be common in hydric hardwoods approximately 20 mi se of Tampa on the W.R. Grace Four Corners mining site bordering Hillsborough and Manatee Counties. In addition, Conservation Consultants (1975b) found woodrats common in similar habitat on the Phillips Petroleum mining site bordering Manatee and DeSoto County approximately 20 mi nw of Arcadia. During 1976, I captured seven individuals in central DeSoto County while conducting an ecological baseline study for Florida Power and Light Company. These animals represent the most southcentral Florida record of woodrats inhabiting natural areas. All 7 individuals were taken within a river floodplain forest 8 mi n of Arcadia between the Peace River and State Route 17. Vegetation consisted primarily of an admixture of laurel oak (*Quercus laurifolia*), longleaf pine (*Pinus palustris*), slash pine (*Pinus elliotti*), and saw palmetto (*Serenoa repens*). Carolina ash (*Fraxinus caroliniana*), persimmon (*Diospyros virginiana*), black gum (*Nyssa sylvatica*), winged sumac (*Rhus copallina*), wax myrtle (*Myrica cerifera*) and saw palmetto were the main contributors to the understory. The sparse ground layer included sedge (*Carex lupulina*), poison ivy (*Rhus radicans*), greenbriar (*Simlax bona-nox*), dropseed (*Sporobolus indicus*), milkweed (*Asclepias perennis*), several panic grasses (Panicum spp.) and muscadine grape (*Vitis rotundifolia*).

Three adult males av 338 mm total length, 3 adult females av 300 mm total length and one sub-adult male 290 mm were captured in (LF40) Sherman folding type livetraps baited with rolled oats and sunflower seeds. All were captured within 120 m of each other and were toe clipped using a standard technique. One individual was retained as a reference specimen. Four individuals were captured over a 4 night period, April 25-28, 1976. Trapping periods in January and August 1976 failed to yield any captures. However, woodrat droppings were found in January, and during August, an active woodrat nesting site was found and photographed. During October, 1976, three additional woodrats were captured.

The nest site occurred in a stand of saw palmetto, and was built in a hollow log. Saw palmetto fronds, oak leaves, and a number of longleaf pine cones were piled around the entrance in a typical woodrat (pack rat) fashion. The entrance to the hollow was at the top of the log.

Two explanations may account for these recent woodrat finds: 1) that woodrat populations in southcentral Florida are so localized that past studies have been of insufficient intensity to discover small woodrat populations and 2) coastal development may be forcing an inland expansion of woodrats. Whichever is the case, future studies in Florida should provide further accounts of the range and ecology of this species.

LITERATURE CITED

Burt, W. H., and R. P. Grossenheider. 1964. A Field Guide to the Mammals. Riverside Press. Boston.

Conservation Consultants. 1975a. Terrestrial Ecology. In W. R. Grace and Company. Four Corners Mine, Hillsborough and Manatee County., Florida. Development of Regional Impact.

Conservation Consultants. 1975b. Terrestrial Ecology. In Phillips Petroleum Company. Phosphate Mining and Beneficiation, Desoto and Manatee Counties, Florida. Development of Regional Impact Application for Development Approval.

Cowell, B. C., et al. 1974. Biological assessment of the lower Hillsborough Flood Detention Area. Submitted to the Southwest Florida Water Manag. Dist.

Goertz, J. W. 1970. An ecological study of *Neotoma floridana* in Oklahoma. J. Mammal. 51:94-104.

Kale, H. W. 1972. A high concentration of *Cryptotis parva* in a forest in Florida. J. Mammal. 53:216-218.

Layne, J. N. 1974. The land mammals of south Florida. Miami Geol. Soc. Mem. 2:385-413.

Lee, D. S. 1968. The woodrat in southcentral Florida. Florida Nat. 41:171.

Sherman, H. B. 1944. Recent literature and some new distribution records concerning Florida mammals. Proc. Florida Acad. Sci. 7:199-202.

Florida Sci. 41(3):191-192. 1978.

INSTRUCTIONS TO AUTHORS

Individuals who publish in the *Florida Scientist* must be active members in the Florida Academy of Sciences.

Submit a typewritten original and one copy of the text, illustrations, and tables. All typewritten material—including the abstract, literature citations, footnotes, tables, and figure legends—shall be double-spaced. Use one side of 8 1/2 × 11 inch (21 1/2 cm × 28 cm) good quality bond paper for the original; the copy may be xeroxed. Margins should be at least 3 cm all around. Number the pages through the Literature Cited section. Avoid footnotes and do not use mimeo, slick, erasable, or ruled paper. Use metric units for all measurements. Assistance with production costs will be negotiated directly with authors of papers which exceed 10 printed pages of text.

Address follows the author's name.

Abstract—All manuscripts shall have a short, concise, single-paragraphed abstract. The abstract follows immediately the author's address.

Acknowledgments are given in the body of the text preceding immediately the Literature Cited section.

Literature cited section follows the text. Double-space every line and follow the format in the current issue.

Manuscripts of 5 or less, double-spaced typewritten pages should conform to the short article protocol. See recent issue for proper format of both long and short articles.

Tables shall be typed on separate sheets of paper, double-spaced throughout. Each table shall contain a short heading. Do not use vertical rulings. Maximum character width, including spaces, of tables is 98.0. This includes a minimum space of 5 characters between columns. Tables are charged to authors at $25.00 per page or fraction.

Illustrations—All drawings shall be done in good quality India ink, on good board or drafting paper. Letter by using a lettering guide or equivalent. Typewritten letters on illustrations are unacceptable. Drawings and photographs should be large enough to allow 1/3 to 1/2 reduction in size. Photographs shall be glossy prints of good contrast. Whenever possible, mount photographs in lots size.

The author's name and figure number should be penciled lightly on the back of each figure. Figure legends must be listed on a separate page and *not* on the drawing or photograph. The legend must be double-spaced. Illustrations are charged to authors at $20.00 per page or fraction.

Proof must be returned promptly. Notification of address change and proofreading are the author's responsibility. Alterations after the type has been set will be charged to the author.

Reprints may be ordered from the printer on forms provided when the corrected proofs are returned to the Editor.

FLORIDA ACADEMY OF SCIENCES

Institutional Members for 1976

Archbold Expeditions
Barry College
Eckerd College
Edison Community College
Florida Atlantic University
Florida Institute of Technology
Florida Southern College
Florida State University
Florida Technological University
Gulf Breeze Laboratory
Jacksonville University
John Young Museum and Planetarium
Manatee Junior College
Miami-Dade Community College
Stetson University
University of Florida
University of Miami
University of South Florida
University of Tampa
University of West Florida

Membership applications, subscriptions, renewals, changes of address, and orders for back numbers should be addressed to the Executive Secretary, Florida Academy of Sciences, 810 East Rollins Street, Orlando, Florida 32803.

PUBLICATIONS FOR SALE

by the *Florida Academy of Sciences*

Complete sets. Broken sets. Individual numbers. Immediate delivery. A few numbers reprinted by photo-offset. All prices strictly net. No discounts. Prices quoted include postage.

PROCEEDINGS OF THE FLORIDA ACADEMY OF SCIENCES (1936-1944)
Volumes 1-7—$10.00 per volume; single numbers $3.50
QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES (1945-1972)
Volumes 8-35—$10.00 per volume; single numbers $3.50
FLORIDA SCIENTIST (1973-1975)
Volumes 36-38—$10.00 per volume; single issues $3.50
except for symposium numbers priced separately.
Volumes 39 onward—$13.00 per volume; single numbers $4.25 except for symposium numbers priced separately.
Florida's Estuaries—Management or Mismanagement?—Academy Symposium
FLORIDA SCIENTIST 37(4)—$5.00
Land Spreading of Secondary Effluent—Academy Symposium
FLORIDA SCIENTIST 38(4)—$5.00
Solar Energy—Academy Symposium
FLORIDA SCIENTIST 39(3)—$5.00 (includes do-it-yourself instructions)

Individual orders should be sent with payment. A statement will be sent in response to a bona fide purchase order over $10.00 from a recognized institution. Address all orders to:

The Florida Academy of Sciences, Inc.
The John Young Museum
810 East Rollins Street
Orlando, Florida 32803

PLAN NOW TO ATTEND THE ANNUAL MEETING
AT FLORIDA INTERNATIONAL UNIVERSITY, MIAMI
MARCH, 1979

Do your friends a favor—invite them to join the Florida Academy of Sciences.

ISSN: 0098-4590

Florida Scientist

Volume 41 | Fall, 1978 | No. 4

CONTENTS

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

FLORIDA SCIENTIST

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

The FLORIDA SCIENTIST is published quarterly by the Florida Academy of Sciences, Inc., a non-profit scientific and educational association. Membership is open to individuals or institutions interested in supporting science in its broadest sense. Applications may be obtained from the Executive Secretary. Both individual and institutional members receive a subscription to the FLORIDA SCIENTIST. Direct subscription is available at $13.00 per calendar year.

Original articles containing new knowledge, or new interpretation of knowledge, are welcomed in any field of Science as represented by the sections of the Academy, viz., Biological Sciences, Conservation, Earth and Planetary Sciences, Medical Sciences, Physical Sciences, Science Teaching, and Social Sciences. Also, contributions will be considered which present new applications of scientific knowledge to practical problems within fields of interest to the Academy. Articles must not duplicate in any substantial way material that is published elsewhere. Contributions are accepted only from members of the Academy and so papers submitted by non-members will be accepted only after the authors join the Academy. Instructions for preparation of manuscripts are inside the back cover.

Published by the Florida Academy of Sciences, Inc.
810 East Rollins Street
Orlando, Florida 32803

Printed by the Storter Printing Company
Gainesville, Florida

Florida Scientist

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Walter K. Taylor, *Editor* Henry O. Whittier, *Editor*

Volume 41 Fall, 1978 No. 4

Biological Sciences

SEASONAL AND DIURNAL ZOOPLANKTON INVESTIGATIONS OF A SOUTH-CENTRAL FLORIDA LAKE[1]

Jerome V. Shireman and Randy G. Martin

School of Forest Resources and Conservation, University of Florida, Gainesville, Florida 32611

Abstract: *Zooplankton was collected from Lake Wales, Florida, from October, 1974, through September, 1975. Cladocera were the most numerous and diverse group of organisms: seven to nine species were collected each month. Cladocera abundance was seasonal, increasing in the spring as the water warmed. Copepod abundance was also related to season, with greater numbers collected in April, August and September. Rotifers were not well represented in monthly samples, but were abundant during January, April and August. Diurnal studies indicated that both Cladocera and cyclopoid copepod numbers differed significantly between day and night. Cladocera distributions were depth related, with greater numbers collected at mid-depth (1-2 m). Rotifers and calanoid copepod numbers were not correlated with either time of day or depth. The Lake Wales zooplankton community is similar to those in other central Florida lakes studied previously, but with a greater diversity of Cladocera and a paucity of rotifers.*°

Lake Wales contains a profuse growth of *Hydrilla verticillata*. For this reason, Lake Wales was chosen to evaluate the potential impact of grass carp (*Ctenopharyngodon idella*) on lake ecosystems. Because zooplankton are an essential part of fish food chains, we felt it imperative to study the zooplankton prior to vegetation control, in order to assess changes in zooplankton caused by reduction of aquatic vegetation.

Zooplankton studies have been conducted in other non-hydrilla Florida lakes (Nordlie, 1976; Maslin, 1969; Confer, 1971). We investigated seasonal and diurnal zooplankton dynamics in Lake Wales and our data are probably representative of zooplankton assemblages found in central Florida lakes that contain large stands of submerged aquatic vegetation.

Study Area—Lake Wales is a 133.5 ha lake located within the city of Lake Wales, Florida, in Polk County (lat 27°34′13″, long 81°34′44″). It is situated within the Lake Wales ridge, an area characterized by porous permeable deep

[1]Study supported by the Florida Department of Natural Resources.

°The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

sand. Generally these sands do not permit surface runoff (Stewart, 1966). Most of the circular-shaped closed lakes in the area are believed to be of solution origin. Lake Wales has a drainage basin of 6.27 sq km, most of which is located within the urban area. Several storm sewers enter the lake, causing considerable turbidity near their outlets during and after heavy rains. Although the water level of the lake responds to surface runoff, it shows seasonal fluctuations characteristic of the Floridian aquifer to which it is connected. The most outstanding feature of the lake is the dense stand of *Hydrilla verticillata*, which covers approximately 80% of the surface during summer months. Shallows and flats (0.5-1.0 m) are vegetated primarily by *Vallisneria americana* interspersed with hydrilla. Species of plants along the shorelines (except for dredged areas along the north shore) are cattail (*Typha latifolia*), hydrocotyle (*Hydrocotyle runculoides*), panicum (*Panicum* sp.), fuirena (*Fuirena* spp.) and spikerush (*Eleochris* sp.).

The lake bottom is similar to most solution basins with gradual sloping contours. The maximum depth is approximately 4 m with a mean depth of approximately 2 m. The bottom is primarily sand with detritial deposits in deep areas. Several small sink holes are located along the western shore. Water temperatures in Lake Wales ranged from 15 to 32°C during the year. The lake does not stratify thermally, but does show oxygen stratification. Oxygen stratification exists in deeper water beneath dense beds of hydrilla.

Utilizing the limnological lake classification scheme of Shannon and Brezonik (1972), Lake Wales would be considered eutrophic in three categories and mesotrophic in two other categories (Tables 1 and 2). Chlorophyll definitely indicated Lake Wales to be mesotrophic. In Lake Wales, however, chlorophyll is probably not a good indicator of trophic conditions because hydrilla competes with phytoplankton for nutrients and light.

Materials and Methods—Study stations were chosen to depict different vegetation types, various water depths, and open water. Zooplankton samples were taken each month from 7 stations from October, 1974 to September, 1975, and diurnally in February, May and December, 1975 and February, 1976.

Duplicate zooplankton samples were collected monthly at 1.0 m depths with a 2.0 l Van Dorn bottle. The 2.0 l sample was concentrated by passing it through a #70 plankton bucket and washing it into a 50 ml vial until 2/3 full. Approximately 0.5 ml of Lugal's solution was added as a preservative. Organisms within these samples were later identified to species, when possible, and enumerated. Three to 10 counts depending on sample density were made of each sample in a Sedgewick rafter counting cell. Quarterly diurnal samples were handled in the same manner with samples collected at 2 hr intervals in February, 1975, and at 3 hr intervals for the three other dates.

Water-chemistry values were determined from samples collected monthly with a vertical 1.0 l haul. Water samples were collected during one day, placed on ice, and analyzed the next day. These analyses included determinations for organic nitrogen, total phosplate and chlorophyll (Standard Methods, 1971). Conductance and pH values were taken for each 1.0 l sample immediately. Oxygen and temperature were measured electronically at 1.0 m intervals at the site where water samples were collected.

TABLE 1. Water chemistry values for Lake Wales, Florida, November, 1974, through July, 1975.

MONTH	PARAMETERS									
	Conductance	pH	Sulfate	Turbidity	Calcium	Magnesium	Ammonia	Organic N	Total P	Chlorophyll a
Nov. 74	147.6^{b}	9.1^{bc}	11.0^{d}	8.2^{cd}	12.7^{bc}	3.4^{cd}	0.08^{abc}	0.83^{bc}	0,09^{c}	0.0^{a}
Dec. 74	147.6^{b}	8.5^{d}	11.0^{d}	14.4^{ab}	16.8^{a}	3.8^{ab}	0.10^{ab}	0.82^{bc}	0.16^{bc}	10.4^{a}
Jan. 75	99.5^{c}	8.0^{e}	11.0^{d}	13.5^{abc}	17.7^{a}	3.9^{a}	0.03^{c}	0.61^{c}	0.41^{a}	
Feb. 75	142.0^{b}		11.0^{d}	16.8^{a}	17.7^{a}	3.5^{bcd}	0.10^{ab}	1.14^{ab}	0.22^{bc}	
Mar. 75	166.0^{a}	9.5^{ab}	11.6^{cd}	3.2^{d}	14.8^{ab}	3.7^{abc}	0.05^{bc}	1.33^{a}	0.16^{bc}	3.2^{a}
Apr. 75	-		11.7^{cd}	4.3^{d}	12.0^{bc}	3.9^{a}	0.02^{c}	0.89^{bc}	0.16^{bc}	5.1^{a}
May 75	159.3^{a}	9.6^{a}	12.5^{b}	5.0^{d}	14.9^{ab}	3.6^{abc}	0.12^{a}	0.96^{bc}	0.12^{c}	9.6^{a}
June 75	159.5^{a}	9.0^{c}	12.0^{bc}	6.3^{cd}	13.5^{bc}	3.3^{d}	0.03^{c}	0.89^{bc}	0.19^{bc}	4.3^{a}
July 75	158.0^{a}	9.2^{abc}	13.6^{a}	7.0^{cd}	11.2^{c}	3.5^{bcd}	0.04^{c}	0.80^{c}	0.26^{b}	10.4^{a}

^{abcde}Means with same letter(s) are not significantly different at $P = 0.05$.

TABLE 2. Trophic state indicators for Florida clear lakes (from Shannon and Brezonik, 1972) and Lake Wales, Florida.

GROUP		Primary Prod. ($mgCm^{-3}hr^{-1}$)	Chlorophyll a (mg/m^3)	Total-PO_4 (mgN/1)	Total-Org. N (mgN/1)	Conductivity umho/cm	Cation ratio
Oligotrophic	x	1.3	1.8	0.013	0.25	38.5	0.61
	s	1.0	0.5	0.003	0.08	8.5	0.08
Mesotrophic	x	5.8	4.3	0.023	0.73	61.5	0.86
	s	6.3	2.5	0.014	0.30	35.1	0.38
Eutrophic	x	150.2	39.5	0.306	1.98	244.0	3.61
	s	119.5	26.3	0.251	1.10	129.0	2.13
Lake Wales	x		7.7	0.195	0.89	147.0	3.27
	s		4.8	0.096	0.21	19.2	0.54

RESULTS—*Monthly sampling*: Cladocera were the most numerous and diverse of the zooplankton groups collected. From 7 to 9 species of Cladocera were collected monthly. *Daphnia ambigua* and *Macrothrix* sp. were the only species not collected every month. In general, zooplankton numbers were lowest during the winter and increased through April when a major peak occurred (Fig. 1). This peak was predominately *Diaphanosoma brachyurum, Ceriodaphnia pulchella* and *Bosmina coregoni* (Fig. 2). Fewer Cladocera were collected during May, June and July. A secondary peak of abundance, attributable principally to *D. brachyurum*, occurred in August. The increases in Cladocera numbers were concomitant with rising water temperatures. Two species, *C. pulchella* and *B. coregoni*, peaked earlier than others, being most abundant during February, March and April (Fig. 2).

Diaphanosoma brachyurum was by far the most abundant Cladoceran from May through August. After peaking in May, the population declined during June and July as did the numbers of all zooplankton. This genus is well suited to warm waters and often flourishes at high water temperatures (Hutchinson, 1967). The decline in numbers during June and July was possibly related to decreased food supply and/or increased predation. Several fish species, the young of which feed on zooplankton, are abundant in Lake Wales, and spawn during the summer months.

Abundance of cyclopoid copepods was significantly different ($P < 0.05$, least squares analysis) over the study period (Fig. 3). A major peak of abundance in August, which was preceded by relatively low levels of abundance during May, June and July, was followed by a sharp decline in September. Numbers were relatively constant during the winter. Calanoid copepods were slightly less abundant than cyclopoids. Their numbers also differed statistically ($P<0.05$, least squares analysis) with season, being most abundant in September, with smaller peaks in April, May and December (Fig. 3). Nauplii distributions were similar to adult copepod distributions with greatest numbers occurring in August and April (Fig. 3). Fewest numbers were collected during May, June and July.

Rotifers showed greater seasonal differences than other zooplankton groups. Numbers of rotifers were low except during January, April and August (Fig. 4). The two most abundant rotifers were *Keratella* spp. and *Conochilus unicornis* with *C. unicornis* most abundant during January (80%) and April (94%). *Keratella* was predominant during the August peak. Hutchinson (1967) described these species as being perennial limnoplanktonic rotifers, showing a large maximum in late spring, a minimum in June, a secondary maximum in July, and are ordinarily not abundant during the winter. The Lake Wales rotifers exhibited a similar pattern of abundance, the exception being that *C. unicornis* peaked during January. This January peak occurred as the water temperatures began to rise. At this latitude, January temperatures correspond to late spring in more northern latitudes.

Diurnals: Cladocera were the dominant group of zooplankton collected during diurnals. Of the cladocerans, *Diaphanosoma brachyurum* was the most numerically abundant species, followed by *Ceriodaphnia pulchella, Bosmina core-*

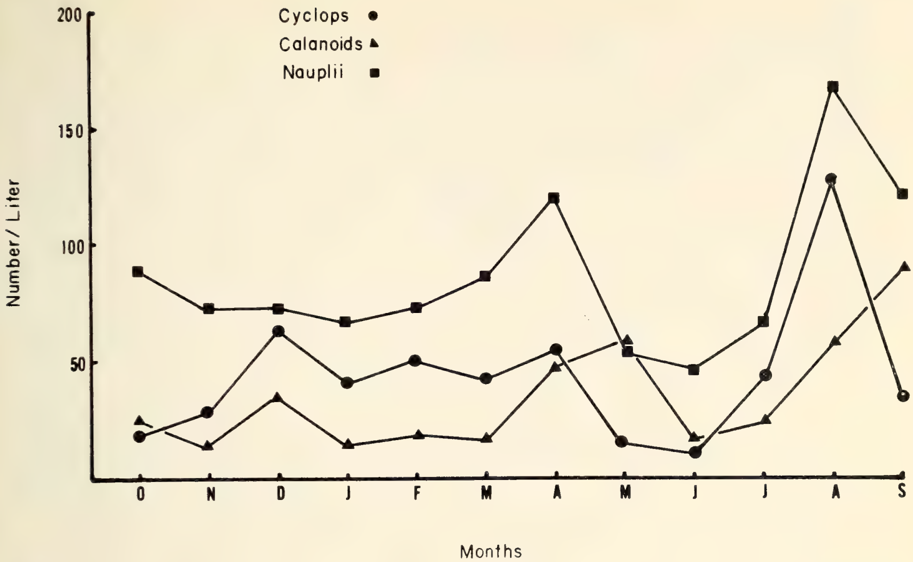


FIG. 1. Mean number of cladocera per liter collected from Lake Wales, Florida, October, 1974, through September, 1975.

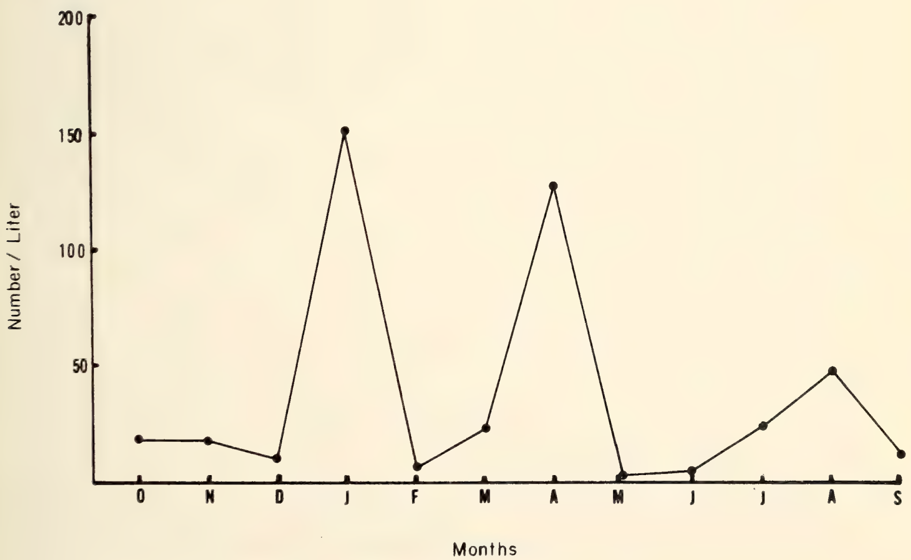


FIG. 2. Mean numbers of five major cladocerns per liter collected from Lake Wales, Florida, October, 1974 through September, 1975.

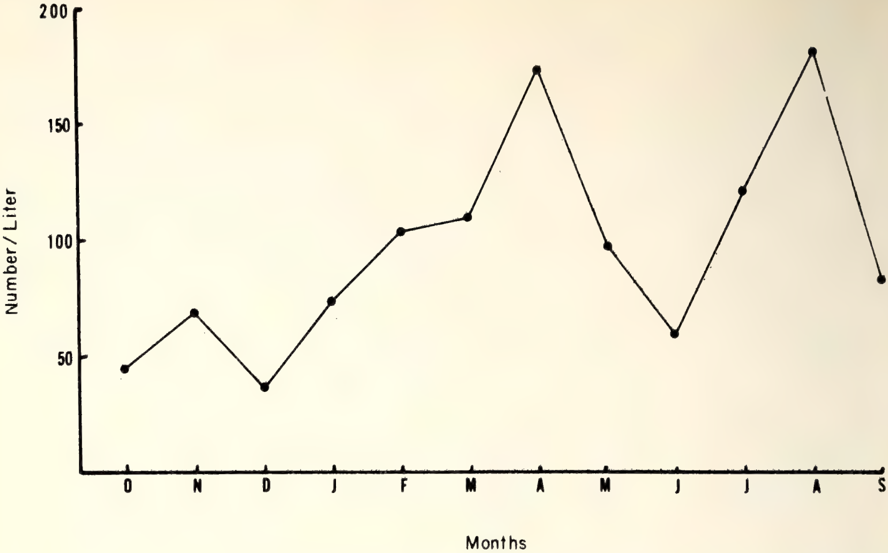


FIG. 3. Mean numbers of copepods per liter collected from Lake Wales, Florida, October, 1974 through September, 1975.

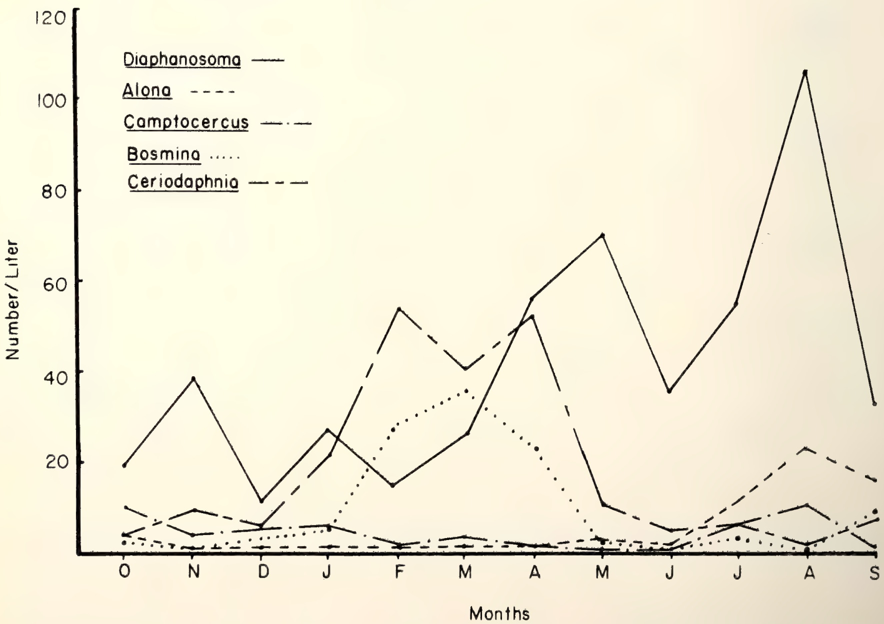


FIG. 4. Mean number of rotifers per liter collected from Lake Wales, Florida, October, 1974, through September, 1975.

goni, and *Chydorus sphaericus*. Occasional individuals of *Camptocercus rectirostris*, *Alona costata*, *Macrothrix laticornis* and *Daphnia ambigua* were collected. For all diurnal samples combined, Cladocera distribution showed a significant correlation with depth ($P < 0.05$). Fewer individuals were collected at the surface at all hours. Greatest numbers were collected at 1.0 and 2.0 m. Numbers of organisms per l increased during the afternoon (1400 to 2000 hr). The greatest differences between the surface and 2 m occurred at 1800 hr.

Although Cladocera were the predominant zooplankton group in Lake Wales, Reid and Blake (1969) found few Cladocera in diurnal samples collected in a phosphate-pit lake. They found that rotifers were the predominant zooplankton. Nordlie (1976) found that although the abundance of Cladocera was low and that of rotifers high in Bevin's Arm Lake, Alachua County, Florida, the reverse was true in nearby Newnan's Lake. In Lake Wales the Cladocera assemblage is rich whereas rotifers were usually poorly represented. Also, Cladocera numbers increased whereas rotifer numbers decreased with water depth in Lake Wales.

Rotifer distribution exhibited three distinct peaks of diurnal abundance: one at 0600 hr, another between 1200 and 1400 hr and a final weak pulse at 2000 hr. During February and May, 1975, rotifers were sparse and consisted of a few *Keratella* sp. They were more abundant during the December 1975 and September 1976 diurnals, and consisted almost entirely of *Conochilus unicornis*, a colonial form.

Adult and immature copepods demonstrated variable patterns of abundance. Adult calanoids (*Diaptomus floridanus*) had the most consistent distribution pattern of all zooplankton categories. Nauplii distributions were variable. Depth distributions were very similar from 0200 hr through 1200 hr, but became more inconsistent during late afternoon. Abundance also increased during the afternoon hours near the surface.

The pattern of cyclopoid abundance exhibited a direct and statistically significant ($P < 0.05$, least squares analysis) relationship with respect to water depth. Greater numbers were collected at 1 and 2 m depths during daylight hr; fewer numbers were found at the surface during all hr.

Discussion—Only two extensive zooplankton studies have been conducted in Florida recently. Maslin (1971) studied 2 sand-hill lakes in east-central Florida and Nordlie (1976) studied 3 lakes in north-central Florida. Zooplankton communities have been studied also in 2 phosphate-pit lakes in south-central Florida (Reid and Blake, 1969; Reid and Squibb, 1971) and in a small sand-hill lake adjacent to those lakes studied by Maslin (Confer 1971). Nordlie (1976) who reviewed these papers, concluded that 2 types of zooplankton assemblages occurred in Florida lakes. One type is poor in Cladocera and rich in rotifers, the other one rich in Cladocera with variable numbers of rotifers. The first assemblage is correlated with clinograde oxygen distributions in deeper waters and the presence of *Chaoborus* in large numbers. The second assemblage is found in lakes with no permanent oxygen stratification and few or no *Chaoborus*. Lake Wales definitely fits the second classification, since thermal and oxygen stratification are usually minimal and *Chaoborus* are not present in the plankton. Furthermore, Cladocera populations were numerous and diverse and the rotifer population variable.

After comparing Lake Wales zooplankton with those collected by Maslin (1969) and Nordlie (1976) we conclude that cladoceran populations in Lake Wales show considerable species diversity. We collected from 7 to 9 species each month, whereas Nordlie collected no more than 6 species, and typical diversity consisted of 2 to 4 species. According to Pennak (1957) the typical cladoceran fauna in small to medium-sized lakes throughout the world numbers from 2 to 4 species.

The diversity of Cladocera in Lake Wales might be related to the large amount of vegetation found there. Quade (1969) investigated several Minnesota lakes where community-type analysis supported the hypothesis that littoral Cladocera are associated with aquatic macrophytes. The cladocerans collected from Lake Wales represent mostly littoral species, which exist in and near vegetation where they obtain food from both epiphytic organisms and tychoplankton associated with the plants. This tychoplankton is rich in numbers and abundance of phytoplankton.

Differences in common species of cladocera were also noted among Florida lakes. *Diaphanosoma brachyurum* was commonly collected by both Maslin (1969) and Nordlie (1976) in their study lakes, the most common species collected in Lake Wales. Both Nordlie and Maslin commonly collected *Daphnia ambigua* and *Holopedium amazonicum*; Nordlie also found *Eurycercus tubican* common in Newnan's Lake. *Daphnia ambigua* was rarely collected in Lake Wales, *H. amazonicum* and *E. tibican* not at all. Nordlie, however, found considerable variation in species composition among his study lakes and investigated the possibility that differences might be due to predation. He suggested that the lakes with the greatest numbers of predators had the largest zooplankton (except for rotifers), and no large Cladocera. This predator-prey size relationship has been investigated by Brooks (1968), who found that whenever planktivores are absent large zooplankton predominated, Brooks' findings do not explain why he found no large cladocerans. Large cladocerans were common in Lake Wales, where relatively few obligate planktivores, such as *Dorosoma cepedianum*, exist. Cladocera are preyed upon by facultative planktivores such as small centrarchids and killifish. These fish switch to larger food organisms when large zooplankton are no longer available (Brooks, 1968). Warner (1969) found that bluegills selectively fed upon zooplankton until they reached 22-25 mm. Other zooplankton (copepods and rotifers) did not show great species diversity in Lake Wales. Usually 1-2 species of rotifers were collected and 2-3 species of copepods. These results are similar to those of Nordlie (1976).

In summary, Lake Wales zooplankton populations are similar to other central Florida lakes studied previously, with the exception that Cladocera populations are more diverse and rotifer populations more poorly represented.

Acknowledgments—We thank Drs. Frank G. Nordlie and William T. Haller, University of Florida for reviewing the manuscript and Homer Royals, Florida Game and Fresh Water Fish Commission, for water analysis.

LITERATURE CITED

Brooks, J. L. 1968. The effects of prey size selection by lake planktivores. Syst. Zool. 17:273-291.

Confer, J. L. 1971. Intrazooplankton predation by *Mexocyclops edax* at natural prey densities. Limnol. Oceanog. 16:663-666.

Hutchinson, G. E. 1967. A Treatise on Limnology, Vol. II. Introduction to Lake Biology and the Limnoplankton. John Wiley and Sons. New York.

Maslin, P. E. 1969. Population Dynamics and Productivity of Zooplankton in Sandhill Lakes. Ph.D. Dissert. Univ. Florida. Gainesville.

Nordlie, F. G. 1976. Plankton communities of three central Florida lakes. Hydrobiologia 48:65-78.

Pennak, R. W. 1957. Species composition of limnetic zooplankton communities. Limnol. Oceanog. 2:222-232.

Quade, H. W. 1969. Cladoceran faunas associated with aquatic macrophytes in some lakes in northwestern Minnesota. Ecology 50:170-179.

Reid, G. K., and N. J. Blake. 1969. Diurnal zooplankton ecology in a phosphate pit lake. Quart. J. Florida Acad. Sci. 32:275-284.

Shannon, E. E., and P. L. Brezonik. 1972. Limnological characteristics of north and central Florida lakes. Limnol. Oceanog. 17:97-110.

Stewart, J. G., Jr. 1966. Ground-water resources of Polk County. Florida Geol. Surv. Rept. 44:1-170.

Warner, R. G. 1969. Ecology of limnetic bluegill (*Lepomis macrochirus*) fry in Crane Lake, Indiana. Amer. Midl. Nat. 81:164-181.

Florida Sci. 41(4):193-201. 1978.

REPRODUCTIVE NOTES ON FLORIDA SNAKES—*John B. Iverson*, Department of Natural Sciences, Florida State Museum, Gainesville, Florida 32611

Abstract: *Reproductive data for 15 species of snakes in Florida are presented. The reproductive seasons of* Coluber constrictor, Diadophis punctatus, Natrix fasciata, Thamnophis sauritus, *and* T. sirtalis *are extended and may allow production of more than one annual clutch. The second known captive hatching of Florida* Pituophis melanolencus *is reported.**

Reproduction of the squamate reptiles in Fitch's (1970) literature review indicates a surprising paucity of reproductive data for many of our most common species, as well as for rarer species known to be locally common. Collection of simple reproductive information is essential for the analysis of geographic variation in reptilian reproductive strategies. While such geographic studies are common for lizards (thanks mainly to Donald Tinkle and his students), those for snakes have been neglected except in literature reviews for single species (e.g., Fitch 1960, 1963, 1965; Clark 1970; Platt 1969).

Fitch's (1970) review is supplemented by presenting basic reproductive information about ophidian species inhabiting one geographic area as related to that in the literature.

Methods—Ophidian reproductive information was collected whenever possible in Florida from summer, 1972, through summer, 1976. No attempt was made to make regimental collections. Snakes killed on highways were the source for some data. Collected gravid females were maintained in captivity (in no case more than 5 wk) until oviposition or parturition. Eggs were incubated to hatching at 27°-30°C. Females and progeny were either released or preserved for ref-

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

erence in the Florida State Museum Collection (FSM). Supplemental reproductive data were obtained by dissection of pre-1972 specimens preserved in the FSM collection.

The majority of observations presented pertain to snakes collected in Alachua County, Florida; those from other localities are indicated by the county of origin. Precise locality data are available from Museum files. Abbreviations used here include snout-vent length (SV) and total length (TL). All measurements are in mm. Means are followed by ± one standard deviation.

Results and Discussion—Reproductive data collected during this study are presented in Table 1. Most data compare favorably with the available literature. Reproductive information from species of the genera *Drymarchon*, *Elaphe*, *Farancia*, *Lampropeltis*, *Storeria*, *Heterodon*, and *Sistrurus* does not differ significantly from that recorded from other portions of the individual range. However, the following data are new and warrant publication.

Coluber constrictor. The April 28 oviposition record antedates the earliest previously recorded laying by nearly 5 weeks; Ortenburger (1928) noted oviposition by a Texas specimen on June 1. It is suggested that the reproductive season begins earlier in the year in Florida than anywhere else in its range (Fitch, 1963).

Diadophis punctatus. A female which laid eggs on September 14 had been collected only 9 da before. The latest previously recorded oviposition for this species is early August (Myers, 1965). Fitch (1970) suggested that this species may lay more than one clutch of eggs during its extended nesting season (May—September) in Florida.

Pituophis melanoleucus. This report represents only the fifth recorded egg-laying and the second successful captive hatching of this species in Florida (Lee, 1967; Neill, 1951).

Natrix fasciata. The latest date of parturition previously recorded for this species is August 2 (Wright and Wright, 1957). My November record as well as the abundance of birth records as early as mid-June (Fitch, 1970) suggests the possibility that multiple annual clutches are produced in Florida.

Thamnophis sauritus. The October 14 parturition observed supports the speculation by Neill (1962) and Tinkle (1957) that some *T. sauritus* in Florida may produce 2 broods per yr.

Thamnophis sirtalis. My data indicate that parturition in north Florida occurs much later than in other parts of the species' range (usually July or August; Fitch, 1970).

The extension of the annual reproductive season in these several snakes in Florida and its implications concerning multiple annual clutches deserves further study; the production of more than one annual clutch has not been documented in any non-captive North American snake (Fitch, 1970).

Acknowledgments—I thank Walter Auffenberg for allowing me access to the herpetological collection of the Florida State Museum. Peter Meylan, Brick Rainey, and C. R. Smith aided field collecting. The University of Florida and Florida State Museum provided support.

LITERATURE CITED

Clark, D. R. 1970. Ecological study of the worm snake *Carphophis vermis* (Kennicott). Univ. Kansas Publ. Mus. Nat. Hist. 19(2):85-194.

Fitch, H. S. 1960. Autecology of the copperhead. Univ. Kansas Publ. Mus. Nat. Hist. 13(4):85-288.

———. 1963. Natural history of the racer, *Coluber constrictor*. Univ. Kansas Publ. Mus. Nat. Hist. 15(8):351-468.

———. 1965. An ecological study of the garter snake *Thamnophis sirtalis*. Univ. Kansas Publ. Mus. Nat. Hist. 15:493-564.

———. 1970. Reproductive cycles of lizards and snakes. Univ. Kansas Mus. Nat. Hist. Misc. Publ. 52:1-247.

TABLE 1. Reproductive data from Florida snakes. Single dimensions for egg size are egg lengths. All sizes in mm.

Species	Location (County)	Female Size	Clutch or Brood Size	Mean Egg Size (Range)	Incubation period (days)	Notes, Dates, etc.	Mean Size of Young or Embryos (Range)
Coluber constrictor	Alachua		22		61	April 28, 1972 (oviposition) June 8, 1972 (hatched)	
Diadophis punctatus	Alachua		6			Sept. 2, 1975 (eggs found) Sept. 10, 1975 (hatched)	
	Alachua	SV 324	5	$19.4 \pm 2.0 \times 8.9 \pm 0.5$ ($16.0\text{-}21.6 \times 8.0\text{-}9.3$)	38	Sept. 14, 1972 (oviposition) Oct. 22, 1972 (hatched)	TL 106.2 ± 3.3 (100-109)
Drymarchon corais	Alachua		3+			July 8, 1972 (hatched)	
Elaphe guttata	Dade		16		83	May 31, 1973 (oviposition)	
	Gilchrist		7			June 27, 1972 (oviposition)	
	Alachua		28			July 7, 1972 (oviposition)	
	Marion		8			July 21, 1972 (oviposition)	
Farancia abacura	Alachua		86	35×25		July 9, 1923 (eggs found)	

	Alachua		69	35 x 20		July 20, 1925 (oviducal eggs)	
	Alachua	SV 880	12			Sept. 15, 1974 (hatched)	
	Alachua		37			Oct. 20, 1973 (hatched)	SV 219 (203-230) TL 252 (232-268)
Farancia erytrogramma	Marion		22	40.0 x 22.5		July 28, 1928 (oviducal eggs)	
Lampropeltis getulus	Washington		17			No date (oviducal eggs)	
	Alachua		6	49.8±5.9 (42.6-60.0)	54	May 28 (oviposition) July 21 (hatched)	
Pituophis melanoleucus	Alachua	SV 1380 TL 1560	5	88.5±4.7 x 37.3±0.5 (83.3-94.7 x 36.6-37.8	67	June 7, 1976 (oviposition) Sept. 12, 1976 (hatched)	SV 520 TL 595
Natrix fasciata	Dade		14			Nov. 23, 1972 (parturition)	
Storeria dekayi	Alachua	SV 241	10			March 3, 1949 (enlarged follicles)	
	Alachua	SV 229 TL 286	7			March 6, 1949 (enlarged follicles)	
	Alachua	SV 225 TL 283	13			March 26, 1950 (enlarged follicles)	
	Alachua	SV 244 TL 276	11			May 1 (enlarged follicles)	
	Alachua	SV 217 TL 275	8			May 19, 1973 (enlarged ovarian eggs)	

	Dade	SV 257 TL 324	7	May 20, 1973 (nearly full-term fetuses; fully pigmented)	
	Alachua	SV 276 TL 343	17	June (nearly full-term fetuses; one aborted)	
	Alachua	SV 206 TL 258	7	July 23, 1973 (parturition)	SV 67.7 ± 1.7 (65-70) TL 88.6 ± 2.1 (84-91)
	Alachua	SV 207 TL 263	8	Aug. 18, 1973 (parturition)	SV 69.8 ± 1.4 (67-72) TL 92.6 ± 2.3 (89-96)
	Alachua	SV 208 TL 262	8	Aug. 19, 1973 (parturition)	SV 75.6 ± 1.2 (74-78) TL 101.4 ± 1.6 (98-104)
	Alachua	SV 254	8	Sept. 1, 1976 (partially developed fetuses)	
	Alachua	SV 254 TL 314	6	Sept. 21, 1976 (nearly full-term fetuses; 2 aborted)	SV 78 TL 100
Storeria occipitomaculata	Alachua		3+		SV 60.0 TL 78.3
Thamnophis sauritus	Alachua	SV 391 TL 594	8	July 1, 1972 (embryos)	
	Alachua	SV 429 TL 654	2+	July 16, 1959 (nearly full-term fetuses)	TL 206

	Alachua	SV 565 TL 806	22	July 16, 1959 (nearly full-term fetuses)	TL 201
	Alachua	?	?	Oct. 14, 1972 (parturition)	SV 143 TL 213 (N = 1)
Thamnophis sirtalis	Alachua	SV 665	15	May 23, 1976 (enlarged ovarian follicles)	
	Alachua		32	Aug. 11, 1922 (nearly full-term fetuses)	SV 120.8 ± 2.9 TL 158.6 ± 3.7
	Gilchrist		?	Oct. 11, 1975 (full-term embryos)	
	Alachua		15	Oct. 19, 1972 (parturition)	
	Alachua		9	Nov. 4, 1972 (parturition)	
Heterodon platyrhinos	Marion		19	June 9, 1972 (eggs found) July 19, 1972 (hatched)	TL 150 (N = 1)
	Alachua	SV 546 TL 648	19	July 2, 1954 (eggs found)	
Sistrurus miliarius	Marion	SV 430 TL 490	7	Jan. 7, 1948 (enlarged ovarian follicles)	
	Marion	SV 435 TL 490	6	July 2, 1975 (partly developed embryos)	
	Alachua		10	July 15, 1973 (parturition)	
	Alachua		2 +	Aug. 2, 1973 (parturition)	SV 122 TL 143 (N = 2)

LEE, D. S. 1967. Eggs and hatchlings of the Florida pine snake, *Pituophis melanoleucus mugitus*. Herpetologica 23:241-242.

MYERS, C. W. 1965. Biology of the ringneck snake, *Diadophis punctatus*, in Florida. Bull. Florida State Mus. Biol. Sci. Univ. Florida 10:43-90.

NEILL, W. T. 1951. Notes on the natural history of certain North American snakes. Publ. Res. Div. Ross Allen's Rep. Inst. 1:47-60.

———. 1962. The reproductive cycle of snakes in a tropical region, British Honduras. Quart. J. Florida Acad. Sci. 25:234-253.

ORTENBURGER, A. I. 1928. The whip snakes and racers, genera *Masticophis* and *Coluber*. Mem. Univ. Michigan Mus. 1:1-247.

PLATT, D. R. 1969. Natural history of the eastern and western hognose snakes *Heterodon platyrhinos* and *Heterodon nasicus*. Univ. Kansas Publ. Mus. Nat. Hist. 18:253-420.

TINKLE, D. W. 1957. Ecology, maturation, and reproduction of *Thamnophis sauritis proximus*. Ecology 38:69-77.

WRIGHT, A. H. AND A. A. WRIGHT. 1957. Handbook of Snakes of the United States and Canada. Comstock Publ. Assoc. Cornell Univ. Press. Ithaca.

Florida Sci. 41(4):201-207. 1978.

Physical Sciences

A CLOSED SYSTEM FOR ASTRONOMICAL PHOTOGRAPHY IN THE SUB-TROPICS[1]

H. W. SCHRADER, E. E. GRAVES, A. G. SMITH, AND R. J. LEACOCK

Department of Physics and Astronomy, University of Florida, Gainesville, Florida 32611

ABSTRACT: *Because of the unusual humidity of the Florida environment a special closed system has been developed for handling the sensitive photographic plates used in astronomical photography. In this system the plates are protected by a dry nitrogen atmosphere at all critical stages, including exposure at the telescope. The system confers substantial advantages over unprotected plates in stability, consistency, and sensitivity.*[*]

AN ASTROPHOTOGRAPHER working in a warm, humid sea-level climate like that of Florida faces problems not encountered at the more traditional mountain observatories, most of which are located in deserts. The central problem is illustrated by Fig. 1, derived from a 2-yr nightly log of the relative humidity inside the dome housing the University of Florida's 76-cm telescope at Rosemary Hill near Bronson, Florida. The histogram peaks at humidities between 90% and 95%, and only rarely does the humidity drop below 70%. Nearly all photographic work is done at the Newtonian focus, at the upper end of the telescope tube near the open slit. Often condensed water can be wiped from the metal at the top of the open-framework tube. Fortunately the mirrors are well protected by their cells and dewing of the optics is rare.

[1] Contribution No. 78 of the Rosemary Hill Observatory. Presented at the 1977 meeting of the Florida Academy of Sciences.

[*] The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

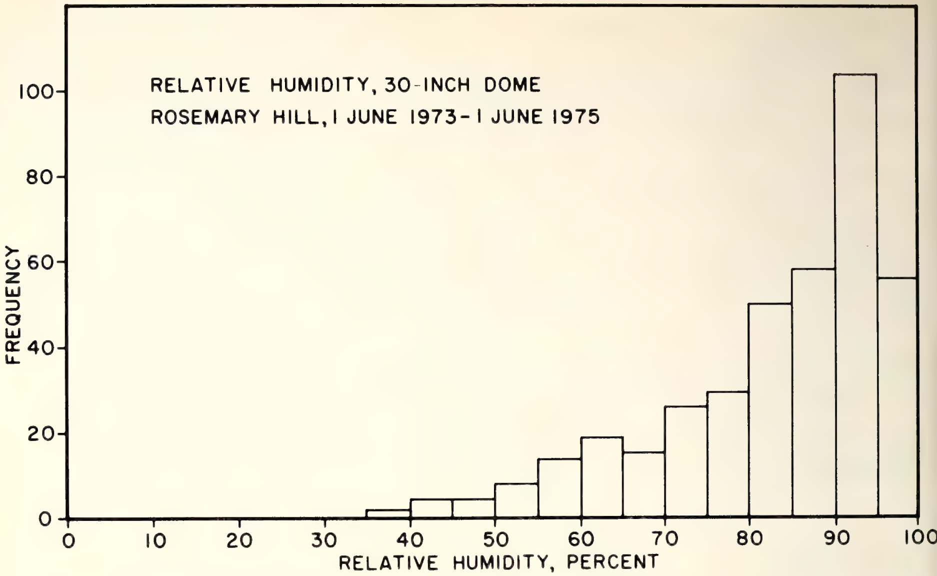


Fig. 1. Two-year record of relative humidity at the Rosemary Hill Observatory. The data were compiled in five-percent increments of relative humidity.

The unusual humidity at Rosemary Hill Observatory has led to the development of a closed system for protecting sensitive photographic materials from the ambient moisture. While the scientific advantages of the system have been cited, the system itself has never been described adequately in the technical literature.

Calibration Problems—The seriousness of the moisture problem became evident soon after the 76-cm telescope first went into service in 1968. Attempts were made to calibrate sequences of comparison stars in the fields of variable quasars by the classical method of photographing the quasar field on one half of a 4 × 5-inch plate and a known field such as a star cluster or Selected Area on the other half of the plate. Stellar magnitudes then could, in principle, be transferred from the known field to the unknown field by means of an iris astrophotometer. Although considerable care was taken to make both exposures identical in duration, and to have the two fields at about the same distance from the zenith, the results were clearly suspect because it was obvious even to the unaided eye that the background sky densities on the two halves of the plate were not equal. Table 1 illustrates this difficulty in four attempts to calibrate the field of the quasar PKS 0906+01 against the globular cluster M3. In each case the density of the field that was exposed second (the cluster) was less by at least 0.1 density unit, and the avg difference was 0.14. The implication was clear that during the hr required for the two exposures the sensitivity of the plate had somehow decreased. If this was the case, the calibrations were indeed worthless.

Development of a Sealed Cassette—At this point the writers recalled comments in the photographic literature to the effect that moisture might in-

TABLE 1. Density differences in identical 30-minute exposures of two fields on the same Kodak type 103a-0 spectroscopic plate exposed in ambient air.

Date in 1969	First Field (0906+01)	Second Field (M3)	ΔD
3/23	0.94	0.84	-0.10
4/12	.54	.40	- .14
4/19	.81	.60	- .21
5/10	.70	.60	- .10
Average	0.75	0.61	-0.14

fluence the sensitivities of at least some emulsions, and a decision was made to construct a sealed cassette that would protect the plates from the damp ambient atmosphere while they were being exposed. Figure 2 shows the design that evolved. The body of the cassette, at the right, is machined with a narrow ledge on which the 4 × 5-inch plate rests with its emulsion 1/8-in above the bottom. Dry gas can be introduced into this space through the valve at the upper right. Two 2-in windows are sealed into the bottom with 0-rings and retaining flanges, and a dark-slide is provided. The lid, at the left, carries a second valve through which gas can escape for flushing. On its underside are two leaf springs that gently hold the plate in place. The lid seats on an 0-ring in a groove milled in the body. Both the lid and the body are anodized flat black. The original cassette used 1/16-in thick windows of optical quality fused quartz. Subsequent cassettes were constructed with 2-mm thick optical filters serving as windows; this has the advantage that filter photography can be performed without introducing additional optical surfaces. The particular cassette shown in Fig. 2 has a U (ultraviolet) filter on the left and a B (blue) filter on the right. At present, 10 cassettes of this design with various combinations of windows are in regular use at Rosemary Hill with the 76-cm and 46-cm telescopes.

Investigation quickly showed that it would be much easier to flush and fill the cassettes with commercial dry nitrogen than to attempt to provide really dry, clean compressed air. The nitrogen is very cheap and readily available in 224-cubic ft cylinders, each of which lasts several months. Figure 3 shows Dr. Karen Hackney flushing a cassette with nitrogen after loading a plate in the darkroom at Rosemary Hill, an operation that adds roughly a minute to the normal loading procedure. Cassettes are filled to about 5 lb/in^2 above ambient pressure so that any leakage will be outward rather than inward. The windows obviously serve as safety valves in the event of dangerous over-inflation, but no window has in fact ever broken in thousands of fillings by a dozen operators.

SKY TESTS—The initial cassette was tested in April of 1970, and it was an immediate success. Calibrations performed with the plate immersed in dry nitrogen displayed excellent consistency from exposure to exposure, indicating that the previous changes in sensitivity had been eliminated. An unexpected bonus was the discovery that the sensitivities of the plates had not only been stabilized, but they had also increased by a factor of about two. With fast Kodak type

103a-0 spectroscopic plates exposed in ambient air, approximately 35 min had been required to reach the sky limit—that is, to expose the plate so fully that further exposure would not record any fainter objects, a condition generally attained when the sky background density is in the range 0.7 to 1.0. The same plates exposed in dry nitrogen reached the sky limit in about 18 min, a considerable saving in telescope time which meant that much more work could be done during a night.

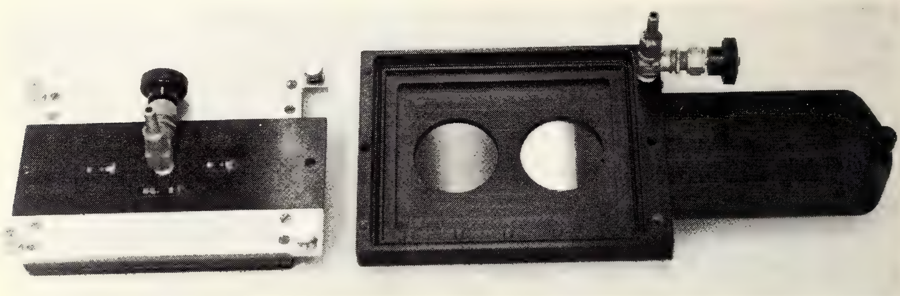


FIG. 2. One of the ten sealed cassettes now in use at Rosemary Hill. The dark-slide is shown partially withdrawn. A system of channels and grooves aids gas flow throughout the body of the cassette.

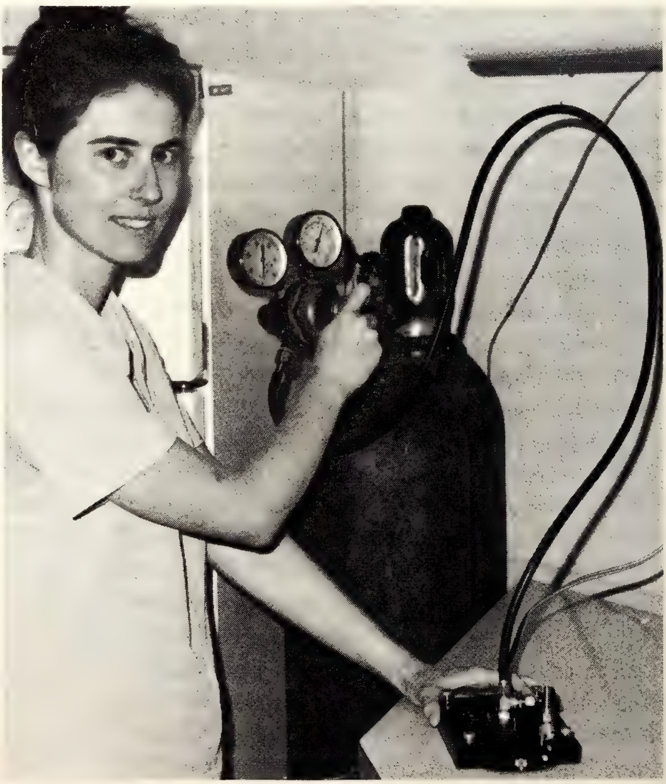


FIG. 3. Filling a loaded cassette with dry nitrogen from a commercial cylinder kept in the dark-room at Rosemary Hill.

While the initial cassette was under construction, an important paper by Lewis and James (1969) of the Kodak Research Laboratories was published that shed additional light on the problem and convinced us we were on the right track. In a series of careful quantitative experiments performed in a vacuum system, Lewis and James showed that both moisture and oxygen adversely affected the sensitivities of certain specially prepared laboratory emulsions, particularly for long exposures. They hypothesized that oxygen might inhibit the formation of the latent image by capturing photoelectrons before they could contribute to the image. Since oxygen diffuses more readily through damp gelatin, Lewis and James felt that moisture might simply facilitate the damage done by the oxygen.

With one exception, no optical problems have been experienced with the cassette windows, although care is taken to keep them clean and free of dust. The exception occurs when the temperature in the telescope dome is high. If a cassette is allowed to chill to the 20°C temperature of the dark-room, the outside surfaces of the windows may fog when the cassette is taken to the telescope. Since it is of course impossible to withdraw the dark-slide and inspect the windows without exposing the plate, the window fog unfortunately goes undetected until the plate has been exposed and developed and badly blurred images are discovered. The simple solution, which is completely effective, is to keep the cassettes in the dome on warm nights except for brief intervals when they are being loaded or unloaded. The fogging of the windows, incidentally, illustrates what can happen to a photographic plate, chilled by being kept in the dark-room, when it is taken into the dome in an ordinary unsealed plate-holder.

The telescope is focussed to an accuracy of .001–.002 in by means of a Foucault knife-edge that can be clamped to the camera bed. As each sealed cassette was placed in service, focus plates were made by photographing a bright star field at a number of focal settings on either side of the focus indicated by the knife-edge (a dial on the camera allows the focal setting to be read to about .0005 in). By selecting the best images, an "offset" from the knife-edge focus could be determined for each new cassette, and this value is permanently marked on the cassette. Focal variations among the cassettes due to machining tolerances and differing window thicknesses amount to about 0.015 in.

Transportation and Storage of Plates.—For decades astronomers have increased the sensitivities of their photographic plates by baking them a number of hours at temperatures in the range 50° - 70°C, a process that presumably extends the chemical "ripening" begun during manufacture of the emulsion (Miller, 1970). The success of the nitrogen-filled cassettes, together with the work of Lewis and James, led us to develop a procedure for baking the plates in a slow flow of nitrogen gas (Smith et al., 1971). Although the nitrogen-baked plates were much superior to those baked in air, tests indicated that they deteriorated in both speed and background fog in a matter of hr if they were stored in humid air. It thus became necessary to store the baked plates in dry nitrogen, preferably at low temperature to slow their deterioration still further.

Figure 4 shows the type of box that was developed for both baking and storage. The body is machined from a solid block of aluminum or magnesium, and it is equipped with inlet and outlet valves. Perforated partitions serve to distribute the gas flow and to hold the plates. The partitions have 8 sets of slots that can hold 8 single 4 × 5-in plates, or 16 plates placed back-to-back in pairs. The lid is sealed with a high temperature 0-ring.

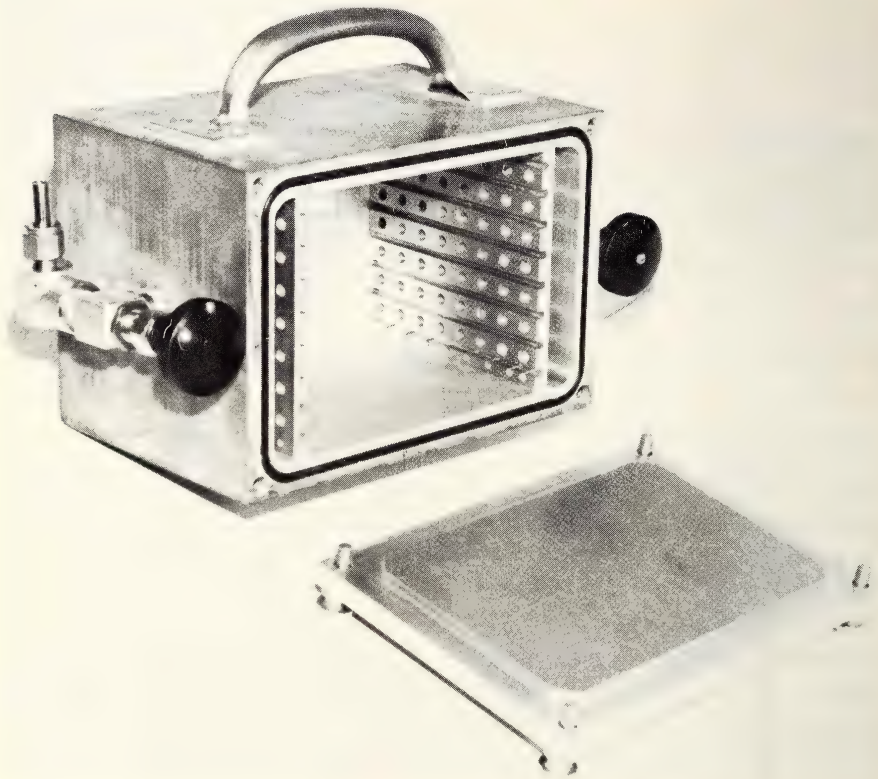


FIG. 4. Standard Rosemary Hill hypersensitizing and storage box. The slots in the perforated partitions are wide enough to hold either one or two plates. Note the black 0-ring in the rectangular groove around the periphery of the box. Shop drawings of both the boxes and the cassettes are available for those especially interested.

The plates are baked in a laboratory oven on the campus of the University of Florida with both valves open and a flow of 0.2 l per min of nitrogen through the box. At the conclusion of baking the valves are closed and the box is stored in a refrigerator until it can be taken to the observatory, which is 29 miles from the campus. At Rosemary Hill the box is stored in a deep-freeze if the plates are to be kept for long periods, or in a refrigerator if they are to be used promptly. At the beginning of a night's work the box is warmed to room temperature. Each time a plate is removed to be loaded into a sealed cassette, the box is recharged with nitrogen at a pressure of about 5 lb per in^2 above ambient. At the end of the night the box, with its remaining plates, is returned to the refrigerator. Most types of baked plates can be stored in this way for several months without serious deterioration.

Subsequent to our introduction of nitrogen baking, additional gas hypersensitization processes have been described. Some of these involve evacuation of the plates followed by the introduction of pure hydrogen gas (Babcock et al., 1974) and others involve combined use of nitrogen and hydrogen, either sequentially or simultaneously (Scott and Smith, 1976; Scott et al., 1977). In all cases the boxes illustrated in Fig. 4 are used both in the hypersensitization treatments and for subsequent storage in nitrogen gas, since all of the hypersensitized plates deteriorate rapidly in air. Currently, 10 boxes of the type shown in Fig. 4 are in regular use at Rosemary Hill with 6 different types of photographic emulsions.

SUMMARY—The unusual problems imposed by a humid sub-tropical climate have led to the development of a closed system for handling the special photographic plates used at Rosemary Hill Observatory. An avg of about 600 plates per yr are currently being handled smoothly and routinely by this system. Plates are received from the manufacturer in cardboard boxes, refrigerated in dry ice. These boxes, each containing 36 plates, are immediately sealed in plastic bags with zipper-type closures, with a small commercial canister of silica gel desiccant in each bag. The plates are stored in a freezer until they are needed, at which time they are hypersensitized by gas treatment. The hypersensitized plates are stored and transported to the observatory under nitrogen in the metal boxes in which they were hypersensitized; they are kept under refrigeration except during actual observing periods, when they are transferred to sealed, nitrogen-filled cassettes for exposure. Nearly all plates are processed immediately after exposure; if logistics require postponement of processing, the exposed plates are kept refrigerated under nitrogen until they can be developed.

Once the necessary equipment has been constructed, utilization of this closed system for handling plates takes little additional operator time. This small amount of time is recovered many-fold through greatly reduced exposures at the telescope. Most important of all, a high degree of consistency is achieved from exposure to exposure, and from one observing session to another. While the spectroscopic emulsions used in astrophotography are particularly sensitive to their environment, the principles described here are not without significance for all branches of photography, especially if they are practised under unusual conditions.

ACKNOWLEDGMENT—The work described here has been performed under a series of grants from the National Science Foundation; the current grant is AST77-24821.

LITERATURE CITED

BABCOCK, T. A., M. H. SEWELL, W. C. LEWIS, AND T. H. JAMES. 1974. Hypersensitization of spectroscopic films and plates using hydrogen gas. Astron. J. 79:1479-1487.

LEWIS, W. C., AND T. H. JAMES. 1969. Effects of evacuation on low intensity reciprocity failure and on sensitization by dyes. Phot. Sci. Eng. 13:54-64.

MILLER, W. C. 1970. Reduction of low intensity reciprocity failure in photographic plates by controlled baking. AAS Photo-Bull. No. 2:15-17.

SCOTT, R. L., AND A. G. SMITH. 1976. Comparison of nitrogen and hydrogen separately and in combination for hypersensitizing Kodak emulsions 103a-0 and IIIa-J. AAS Photo-Bull. No. 12:6-8.

————, ————, AND R. J. LEACOCK. 1977. The use of forming gas in hypersensitizing Kodak spectroscopic plates. AAS Photo-Bull. No. 15:12-15.

SMITH, A. G., H. W. SCHRADER, AND W. W. RICHARDSON. 1970. Response of Kodak spectroscopic plate, Type IIIa-J, to baking in various controlled atmospheres. Appl. Optics 10:1597-1599.

Florida Sci. 41(4):207-214. 1978.

SOME CHARACTERISTICS OF COLONIAL ANIMALS—*David Nicol*, Department of Geology, University of Florida, Gainesville, Florida 32611

ABSTRACT: *Colonial animals comprise slightly less than 1.0% of all of the extant species of animals and are restricted to a marine or fresh-water environment.**

COATES AND OLIVER (1973) define a colony "a group of individuals, structurally bound together in varying degrees of skeletal and physiological integration, all genetically linked by descent from a single founding individual. 'Colony,' then, includes a range of structures grading from those in which all polyps are completely individualized with independent functions and no soft-part connections, to those in which soft parts, skeleton, and functions are communal." This broad definition of a colonial animal will be followed throughout this paper. It is obvious, therefore, that a clump of shell-attached oysters would not be colonial animals because each individual is genetically distinct; they are not clones. However, some solitary species, even though they live in aggregations, originate by clones. In a few instances it is difficult to tell whether or not an animal represents a colony. Species of Porifera are a good example. Hartman and Reiswig (1973) assume that each sponge is an individual and not a colony, and that is the consensus among biologists who work on the Porifera. I, too, regard the Porifera as solitary animals, not colonial animals. Some biologists consider the ctenostome *Monobryozoon* a solitary animal, whereas others consider it to be a colonial animal.

I have taken data on the number of living animal phyla and the estimated number of species in each phylum previously listed (Nicol, 1977), and sources for these data are also given in this paper. Table 1 is a numerical analysis of the numbers of colonial and solitary species in the 36 phyla that are listed.

Amongst the Protozoa, a few species of radiolarians and some ciliates (species of *Peritricha*) can be considered colonial animals. The total number of these colonial species may be 500. Colonial animals are common and highly developed in the hydrozoans and anthozoans of the phylum Coelenterata. Of the approxi-

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

mately 10,000 extant species of coelenterates, about 6,500 species are colonial. The Calyssozoa or Entoprocta is a small phylum, but about one-half, 30 species, are colonial animals. The Bryozoa are exceptional in that all, or possibly almost all, are colonial animals, and the number of species is about 4,000. Approximately 900 of the 1,600 extant species of Tunicata are colonial animals. At least five species of the small phylum Pterobranchia are colonial. Of the 36 extant animal phyla, only six or 17.0% of them, have colonial species. The estimated number of colonial species is 11,935, and this comprises slightly less than 1.0% of all extant animal species, which number about 1,239,139. Even if one considered all Porifera as colonial animals, the colonial species would still be less than 2.0% of all living animal species.

TABLE 1. The extant animal phyla with the number of colonial species in each.

Phylum	Colonial	Solitary
1. Protozoa	500	34,500
2. Porifera	0	5,000
3. Mesozoa	0	50
4. Monoblastozoa	0	1
5. Coelenterata	6,500	3,500
6. Ctenophora	0	100
7. Platyhelminthes	0	13,000
8. Rhynchocoela	0	750
9. Acanthocephala	0	600
10. Rotifera	0	1,500
11. Gastrotricha	0	350
12. Kinorhyncha	0	100
13. Priapuloidea	0	8
14. Nematoda	0	50,000
15. Gordiacea	0	230
16. Calyssozoa	30	30
17. Bryozoa	4,000	0
18. Phoronida	0	25
19. Brachiopoda	0	300
20. Mollusca	0	58,000
21. Sipunculoidea	0	330
22. Echiuroidea	0	150
23. Myzostomida	0	150
24. Annelida	0	9,300
25. Tardigrada	0	350
26. Pentastomida	0	70
27. Onychophora	0	75
28. Arthropoda	0	1,000,000
29. Chaetognatha	0	75
30. Pogonophora	0	100
31. Echinodermata	0	6,000
32. Pterobranchia	5	20
33. Enteropneusta	0	100
34. Tunicata	900	700
35. Cephalochordata	0	30
36. Vertebrata	0	41,700
Species Totals	11,935	1,227,194

Of the six phyla with colonial representatives, all are marine, four also live in fresh-water, and only one, the Protozoa, also lives in a terrestrial environment. Most of the 11,935 species of colonial animals are marine. Probably no more than 1,000 of these species live in fresh-water; but, most importantly, none of these species is terrestrial. It appears that colonial animals are restricted by their adaptations to an aquatic environment. Food for these animals is suspended in water, but such is not the case for an animal exposed to the atmosphere. Most of the colonial animals are sessile and benthic, but others are able to swim or float in the water. Many, if not the majority, are suspension feeders, but some capture prey with their tentacles. None is a deposit feeder, and very few could be considered infaunal.

Some of these colonial animals are soft bodied, and they are generally planktonic or nektonic. Many have a skeleton of an organic substance such as chitin or tunicine, as in the tunicates. Some of these colonial animals have a skeleton with a chitinous base and a certain amount of embedded calcium carbonate. The majority of the colonial animals secrete calcium carbonate in the forms of calcite or aragonite, as, for example, the corals and bryozoans. All forms of calcium phosphate appear to be absent, and siliceous skeletons are rare and confined to the protozoans.

The graptolites are the most important group of extinct animals that are not closely related to any extant phylum. These animals were all marine, either planktonic or sessile benthos, and most likely suspension feeders because of the small size of the individuals in the colony. Other extinct groups such as the Tabulata, Heliolitoidea, and Rugosa were also restricted to a marine environment.

It is most likely that the percentage of colonial animal species in the entire fauna of the earth was higher in the past. This would probably be true before the advent of terrestrial animals and also during a time when vertebrates were much less diverse than they are now. This geologic time would certainly include the Ordovician, Silurian, and Devonian Periods, and probably to a lesser extent the Mississippian, Pennsylvanian, and Permian. In other words, throughout most, if not all, of the Paleozoic, the percentage of colonial animal species (not necessarily total number of colonial species) was higher than it is in the earth's fauna today.

Although colonial animals have many interesting adaptations and are certainly significant in the fossil record as well as in the aquatic environments today, coloniality has imposed certain restrictions on what these animals are able to do. The solitary animals have been able to invade more diverse habitats and occupy many more niches than the colonial animals.

LITERATURE CITED

Coates, A. G., and W. A. Oliver, Jr. 1973. Coloniality in Zoantharian corals. Pp. 3-27. In Boardman, R. S., A. H. Cheetham, and W. A. Oliver, Jr. (eds.). Animal Colonies: Development and Function Through Time. Dowden, Hutchinson, & Ross. Stroudsburg, Pa.

HARTMAN, W. D., AND H. M. REISWIG. 1973. The individuality of sponges. Pp. 567-584. In BOARDMAN, R. S., A. H. CHEETHAM, AND W. A. OLIVER, JR. (eds.). Animal Colonies: Development and Function Through Time. Dowden, Hutchinson, & Ross. Stroudsburg, Pa.
NICOL, D. 1977. The number of living animal species likely to be fossilized. Florida Sci. 40:135-139.

Florida Sci. 41(4):214-217. 1978.

BLUE CRAB PREDATION ON JELLYFISH—*James A. Farr*, Faculty of Biology, University of West Florida, Pensacola, Florida 32504[1]

ABSTRACT: *Blue crabs (*Callinectes sapidus*) fed on the scyphomedusae* Cyanea capillata *and* Stomolophus meleagris.

FEW REPORTS are known of crustaceans preying on medusae. Phillips et al. (1969) reviewed the literature and reported that only 3 species of crustaceans feed on living jellyfish. According to these authors, the spider crab (*Libinia dubia)* fed on the sea nettle (*Chrysaora quinquecirrha),* the cabbagehead (*Stomolophus meleagris),* and the sea wasp (*Chiropsalmus quadrumanus).* At other times in the Mississippi Sound, *Libinia* lives commensally with these species. Two hermit crabs, *Pagurus floridanus* and *P. pollicaris,* also ate *Stomolophus meleagris* and *Cyanea capillata,* the lion's mane, in aquaria when no other food was present. Thomas (1963) mentioned a report by Williamson that the larvae of *Jasus,* a palinurid lobster, feed on scyphozoans. Herrnkind et al. (1976) found phyllosoma larvae of a scyllarid lobster attached to the exumbrellar surface of *Aurelia aurita* in the Bahamas, and these authors summarized other reports of lobster/medusa relationships. None of these involved additional predator/prey interactions. Stone crabs (*Menippe mercenaria*) feed on the remains of *Stomolophus meleagris* (Powell and Gunter, 1968), and the ghost crab (*Ocypode quadrata*) feeds on *Physalia physalis* stranded on the beach (Phillips et al., 1969). Finally, blue crabs (*Callinectes sapidus*) are often observed atop the exumbrellae of *Chrysaora quinquecirrha* (Phillips et al., 1969), but they have never been reported to feed on medusae.

I observed predation by *Callinectes sapidus* on two species of medusae in East Bay, Santa Rosa County, Florida during late March and early April, 1977. On two occasions, crabs approximately 10 cm in carapace width fed on *Cyanea capillata.* In both cases, the living medusae had a bell diameter of about 15 cm. In one case, I startled the crab and the jellyfish swam away. In the second instance, the crab was observed for almost 1 hr, and during this time it fed on the exumbrella, the tentacles, and the oral arms. At one point, the crab carried the medusa along a pier for 10 m. Both instances of predation on *Cyanea* were recorded by still photography; the second instance was also filmed with an 8mm movie camera.

In a third instance, two blue crabs of approximately 10 cm carapace width fed on a large living *Stomolophus meleagris.* One crab fed actively on the exum-

---

[1]Present address: Institut für Biologie, Gesellschaft für Strahlen- und Umweltforschung, Ingolstädter Landstrasse 1, D-8042 Neuherberg bei München, Federal Republic of Germany.

brella, and the other fed on the tentacles and in the oral area. All predation occurred in less than 1 m of water, and it is possible that the medusae had been damaged prior to being encountered by the blue crabs. In every observation, the 4 crabs were on the bottom of the bay, but they could easily have moved to the surface to capture the medusae.

Although blue crabs from 2 - 15 cm carapace width were abundant in East Bay during these observations, only crabs of about 10 cm carapace width fed on medusae. *Cyanea* and *Stomolophus* were very abundant in various sizes, and were presumably available in the shallow water to all sizes of crabs. Even more abundant than the scyphomedusae were two ctenophores, *Mnemiopsis* and *Beroe*, but no crabs fed on them. These facts are intended only to provide a general description of sizes and numbers of crabs, medusae, and ctenophores in East Bay, and not to conclude anything about restriction of predation on medusae to certain sizes of crabs or about lack of predation on ctenophores.

Callinectes is a predator and opportunistic scavenger which feeds on a great variety of food items, although molluscs and crustaceans are the most common items taken (Carriker, 1967; Darnell, 1958; Hamilton, 1976; Tagatz, 1968). Because blue crabs feed on so many types of food, two questions arise about their predation on medusae. First, what nutritional benefit is derived from the medusoid tissue? No data on nutritional content are known for *Stomolophus* or *Cyanea*, but another scyphomedusa, *Aurelia aurita*, is comprised of 96.0% water and only 0.67% protein (Nicol, 1967, p. 30). If *Stomolophus* and *Cyanea* are similar to *Aurelia* in nutritional content, blue crabs probably gain very little by eating them. Second, how do blue crabs solve the problem of the stinging nematocysts? If the crabs are affected by the nematocysts, one would expect them to avoid medusae and select other prey. One possible explanation to both questions is there was a shortage of more nutritious food items as a result of the preceding severe winter. Only 2 mo prior to these observations, the shallow water in East Bay (salinity 15-20 o/oo) froze on two separate occasions, and large kills of fish, small crustaceans, and other invertebrates were observed in the estuaries and shallow bays of Santa Rosa and Escambia counties. If more suitable prey were scarce or absent as a result of extreme weather, scyphomedusae might have represented the only alternative to starvation. As noted above, Phillips et al. (1969) reported predation by hermit crabs on medusae only in the absence of other food.

Acknowledgments:—I thank Jason Byers for insisting that I watch jellyfish with him, thus allowing me to make these observations. Dan Adkison and Paul Hamilton (University of West Florida), and William Herrnkind (Florida State University) insisted that the phenomenon was noteworthy and convinced me to publish. This work was supported by EPA Grant No. R804458010 to Dr. Charles N. D'Asaro, Faculty of Biology, University of West Florida, Pensacola.

LITERATURE CITED

Carriker, M. R. 1967. Ecology of estuarine benthic invertebrates: a perspective, Pp. 442-487. *In* G. H. Lauff (ed.) Estuaries. AAAS Publ. 83, Washington, D.C.

Darnell, R. M. 1958. Food habits of fishes and larger invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. Publ. Univ. Texas Inst. Mar. Sci. 5:353-416.

Hamilton, P. V. 1976. Predation on *Littorina irrorata* (Mollusca: Gastropoda) by *Callinectes sapidus* (Crustacea: Portunidae). Bull. Mar. Sci. 26:403-409.

Herrnkind, W., J. Halusky, and P. Kanciruk. 1976. A further note on phyllosoma larvae associated with medusae. Bull. Mar. Sci. 26:110-112.

Nicol, J. A. C. 1967. The Biology of Marine Animals. John Wiley and Sons, Inc., New York.

Phillips, P. J., W. D. Burke, and E. J. Keener. 1969. Observations on the trophic significance of jellyfishes in Mississippi Sound with quantitative data on the associative behavior of small fishes with medusae. Trans. Amer. Fish. Soc. 98:703-712.

Powell, E. H., Jr., and G. Gunter. 1968. Observations on the stone crab *Menippe mercenaria* Say, in the vicinity of Port Aranas, Texas. Gulf Res. Rept. 2:285-299.

Tagatz, M. E. 1968. Biology of the blue crab, *Callinectes sapidus* Rathbun, in the St. Johns River, Florida. U.S. Fish Wildl. Serv., Fish. Bull. 67:17-33.

Thomas, L. 1963. Phyllosoma larvae associated with medusae. Nature 198:208.

Florida Sci. 41(4):217-219. 1978.

Medical Sciences

ANTIGENIC FRACTIONS OBTAINED FROM MILD ACID HYDROLYSIS OF YEAST PHASE *HISTOPLASMA CAPSULATUM* CELL WALLS, I-III*

Michael J. Sweeney,[1], Roseann S. White,[1] John V. Calcagno, Bonita S. Rosenberg and Helen C. Oels

Department of Microbiology and Immunology, Temple University School of Medicine Philadelphia, Pennsylvania 19140

I. FLUORESCENT AND HEMAGGLUTINATING ANTIBODY REACTIVITY OF HYDROLYSIS SUPERNATES AND RESIDUAL CELL WALLS—*Michael J. Sweeney, Roseann S. White, John V. Calcagno and Helen C. Oels*

Abstract: *Fluorescent antibody reactivity of yeast phase cell walls of* Histoplasma capsulatum *hydrolyzed in mild acid decreases rapidly to a point of no reactivity, then reappears upon continued hydrolysis. Rate of decrease as well as intensity of the returned fluorescence depends upon the normality of the acid used. As the fluorescent antibody reactivity of the walls decreased, material released into the supernates of hydrolysis inhibited passive hemagglutination of histoplasmin-sensitized sheep erythrocytes and inhibited the fluorescence of unhydrolyzed cell walls. These activities disappeared with continued hydrolysis and did not reappear with the return of fluorescence of the hydrolyzed cell walls.*

Antigenic materials have been demonstrated from both the mycelial and the yeast phase forms of *Histoplasma capsulatum*. They are active in delayed hypersensitivity and in various serologic tests such as complement fixation, precipitation, agglutination and immunofluorescence (Campbell, 1971; Salvin, 1963). Although the mycelial phase of *H. capsulatum* is the infectious phase of the organism in man and animals, it is the yeast phase which grows in the tissues of the infected host. One would expect, therefore, to find antigenic material more relevant to the immune response in infection associated with the yeast phase of the organism.

---

[1] Present address: Department of Biological Sciences, Florida Technological University, Orlando, Florida 32816

* The costs of publication of these articles were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of the articles. In accordance with 18 U. S. C. 1734, these articles must therefore be hereby marked "advertisement" solely to indicate this fact.

Materials associated with the cell wall of the yeast phase of *H. capsulatum* have been shown to be highly antigenic and may indeed be more active than non-cell wall components (Garcia and Howard, 1971; Pine et al., 1966; Salvin and Ribi, 1955; Sweeney and Oels, 1972). Salvin and Ribi separated yeast phase *H. capsulatum* into cell wall and protoplasm. They found that the cell wall contained the antigenic activity associated with complement fixation. Although both fractions elicited delayed hypersensitivity reactions, it was felt that the active material in the protoplasm could be a soluble antigen dissolved out of the cell wall. Pine et al. (1966) also obtained high immunological reactivity from purified yeast phase *H. capsulatum* cell walls as well as an antigenically active soluble material from the cell wall using the complement fixation test. Garcia and Howard (1971) extracted yeast phase *H. capsulatum* cells and cell walls with phenol and with ethylenediamine and found the water-soluble ethylene-diamine extract from the cell wall to be most immunogenic.

We sought to analyze the antigenic activity of materials solubilized and removed from the intact purified cell walls of the yeast phase of *H. capsulatum* using mild acid hydrolysis. We now describe ability of the supernates of hydrolysis to inhibit passive hemagglutination and the fluorescence of unhydrolyzed cell walls, as well as the changes in fluorescent antibody reactivity of the sequentially acid-hydrolyzed cell walls. The precipitin and delayed hypersensitive reactivities of these cell wall hydrolysates were also studied and are reported by Sweeney et al. (1978b) and Sweeney et al. (1978c).

Materials and Methods—*Organism*: Yeast phase *H. capsulatum*, strain 6651, was used in this study. The organism was grown in Salvin's liquid medium at 37°C. for 21 da (Oels, 1971).

Preparation of cell walls: Washed, whole *H. capsulatum* cells were mechanically disrupted using 0.2 mm glass beads and washed repeatedly with 0.01 M sodium phosphate buffered saline (PBS) and deionized water. Electron microscopy was used to monitor the preparations until free of cellular debris, and the supernates were monitored until free of detectable protein, carbohydrate and nucleic acid (Oels, 1971). These non-fragmented purified cell walls were then lyophilized and stored at -40° C.

Continuous acid hydrolysis: To 10 mg of cleaned, lyophilized cell walls were added 2 ml of the appropriate normality acid (0.025N or 0.1N H_2SO_4). The walls were hydrolyzed under reflux conditions in a constant temperature oil bath at 100° C for various times. The hydrolysis tubes were removed, chilled in an ice bath, and the contents centrifuged at 3,000 × g for 10 min. The supernate was removed, and the pellet washed twice with 2 ml of deionized water and centrifuged at 3,000 × g for 10 min after each washing. The supernates of the hydrolysis and the washings were pooled, yielding approximately 6 ml of solution for each hydrolysis tube.

The pooled supernates of each period of hydrolysis were neutralized with barium carbonate, centrifuged at 3,000 × g for 10 min to remove the precipitate, and then gravity filtered, using Whatman no. 5 paper. All neutralized supernates were lyophilized and stored at −70° C. The pellets of each hydrolysis were suspended in 2 ml of deionized water and stored at −70° C.

Fractional acid hydrolysis: In this method of hydrolysis 2 tubes were used, each receiving 50 mg of clean lyophilized cell walls. To one was added 5 ml of 0.025N H_2SO_4, and to the other 5 ml of 0.1N H_2SO_4. Hydrolysis was performed in a constant temperature oil bath at 100° C under reflux conditions in the following manner: The reaction was allowed to continue until the first time period had been reached, then the hydrolysis tubes were chilled in an ice bath to stop the reaction. The pellets were centrifuged and washed as above, and immediately after the second wash, 5 ml of fresh acid of the appropriate normality was added to each tube. The tubes were returned to the oil bath and the reaction was allowed to proceed to the next time period, where the washing and addition of fresh acid were repeated. The pooled hydrolysis and washing supernates of each time period were neutralized and lyophilized as above. After 48 hr, the two pellets were suspended in 2 ml of deionized water and stored at −70° C.

Dilution of lyophilized supernatant material: Lyophilized supernatant material was weighed, and deionized water added to a final concentration of 1 mg/ml for each time period.

Fluorescent antibody: Immune serum to yeast phase *H. capsulatum* and fluorescent antibody were prepared according to the method of Calcagno et al. (1973). For use, fluorescent antibody was titrated and the highest dilution giving an acceptable 4+ reaction for the positive controls was used to study the fluorescence of the hydrolyzed cell wall pellets and the ability of the supernates of hydrolysis to inhibit the fluorescence of unhydrolyzed cell walls.

Fluorescence of hydrolyzed cell walls: Cell walls in deionized water suspension were applied to glass slides precleaned with 70% ethanol, air-dried and heat-fixed. Staining with fluorescent antibody was performed as described elsewhere (Calcagno et al., 1973). Unhydrolyzed cell walls treated with fluorescent antibody served as positive controls, and unstained cell walls as negative controls. Fluorescence was graded on a scale of 1+ to 4+ with 4+ being the maximum fluorescence obtained with the positive controls.

Fluorescence inhibition: Equal volumes of fluorescent antibody and supernatant material were combined and incubated for 1 hr at 37° C. These mixtures were used to stain unhydrolyzed cell walls. A positive control was obtained by mixing equal volumes of fluorescent antibody and PBS and gave a 3+ reaction. Negative controls were unstained, unhydrolyzed cell walls. Fluorescence was graded as above and the degree of inhibition was calculated by subtracting the fluorescence obtained using the supernate-antibody mixture from that obtained with the positive control.

Fluorescence microscopy: Fluorescence microscopy was performed on a Zeiss photomicroscope using a Zeiss power supply with an Osram HBO 200 W light source, a Zeiss BG-12 exciter filter, and a Zeiss No. 53 barrier filter.

Sensitization of sheep erythrocytes: Sheep erythrocytes (SRBC) were sensitized with optimum concentrations of histoplasmin by incubating 3.15 mg histoplasmin, 5.88 ml PBS and 0.12 ml of packed SRBC for 1 hr at 37° C. The sensitized SRBC were then washed 3 times with PBS. For use, 0.12 ml of sensitized SRBC was added to 11.76 μml PBS and 0.12 ml of a 1% gelatin solution, resulting in a final dilution of SRBC of 1:1000. Histoplasmin was prepared from a 9-month mycelial phase growth filtrate of strain 6651 *H. capsulatum.*

Inhibition of passive hemagglutination: Rabbit antiserum to whole yeast phase *H. capsulatum* cells with a hemagglutinin titer of 1:2048 was decomplemented at 56° C for 30 min and was absorbed twice with equal volumes of packed SRBC for 1 hr at 37° C.

Twenty-five μl of absorbed serum were mixed with 25 μl of each supernatant fraction to be tested in the first well of a microtiter plate (Cooke Engineering Co.) and incubated for 30 min at 37° C and then for 30 min at room temperature. Two-fold serial dilutions were made using PBS, and 25 μl of sensitized SRBC were added to each well. Serum and PBS controls were also done. The plates were then shaken and placed in the cold overnight and read the next day.

RESULTS—*Fluorescence of hydrolyzed cell walls*: Figure 1 shows the intensity of fluorescence of hydrolyzed cell walls plotted against the time of hydrolysis expressed in hr. After 1 hr of hydrolysis, both normality acids had reduced the intensity of fluorescence to 50% of the level of unhydrolyzed cell walls. At 2 hr, all detectable fluorescence had disappeared from the O.1N acid-hydrolyzed walls and remained absent through 12 hr. The milder conditions of the 0.025N acid required a longer time in order to eliminate all fluorescent antibody reactivity of the residual cell walls, and no fluorescence could be detected from 6 to 12 hr at this normality. At 15 hr, fluorescence was seen to return to 25% of the control levels. Fluorescence remained at this intensity with the 0.025N acid, but increased to 50% of control levels under the more severe conditions of the stronger acid. This return of fluorescent antibody reactivity along with the stepwise decrease in fluorescence intensity at early times with the 0.025N acid suggested a layering of fluorescent antibody-reactive material in the yeast phase cell wall.

Inhibition of fluorescence by hydrolysis supernates: Figure 2 shows the ability of the supernatant fractions to inhibit the fluorescent antibody staining of unhydrolyzed cell walls, and compares the 0.025N acid supernates of both the continuous and fractional hydrolyses. By this method, fluorescent antibody-reactive material was detected in the supernates of the 0.025N continuous hydrolysis up to 10 hr. The fractional hydrolysis indicated that the maximum reactive material was removed from the walls at early times and that no active material was actually removed from the walls beyond 6 hr. The fact that activity could be detected at high levels beyond 4 hr with the continuous hydrolysis seemed to be due to the acid stability of the material released from the cell walls. No activity was detected at 12 hr or beyond by either method of hydrolysis, even though the fluorescent antibody reactivity of the hydrolyzed walls was seen to return at these times. The patterns of fluorescence inhibition obtained using 0.1N acid were similar and indicated that no active material was either released from the walls after the first 2 hr of hydrolysis or detectable in the supernates of the continuous hydrolysis beyond this time.

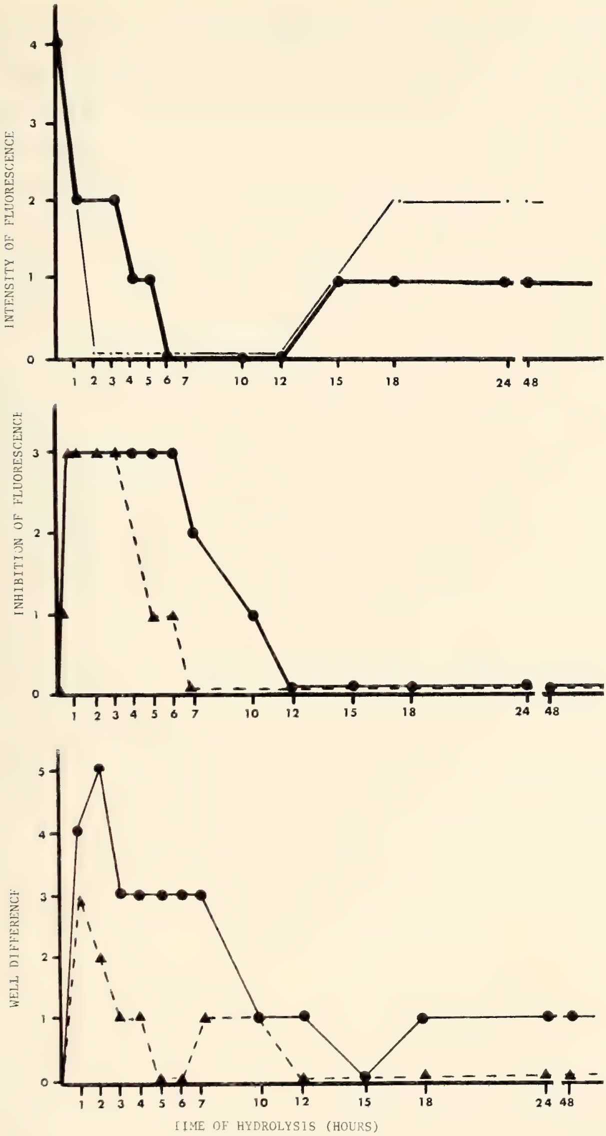


FIG. 1. (top) Fluorescence of acid-hydrolyzed cell walls of yeast phase *H. capsulatum*.• ——— • 0.025N H_2SO_4; • ——— •0.1N H_2SO_4.

FIG. 2. (middle) Inhibition of fluorescence of unhydrolyzed cell walls by the supernates of hydrolysis.• ——— •, 0.025N H_2SO_4, continuous hydrolysis;▲ ——— ▲, 0.025N H_2SO_4, fractional hydrolysis.

FIG. 3. (bottom) Inhibition of passive hemagglutination of histoplasmin-sensitized SRBC by the supernates of hydrolysis.• ——— •, 0.025N H_2SO_4, continuous hydrolysis;▲ ——— ▲0.025N H_2SO_4, fractional hydrolysis.

Inhibition of passive hemagglutination: Figure 3 is a comparison of the ability of the supernates of the 0.025N continuous and fractional hydrolyses to inhibit passive hemagglutination of histoplasmin-sensitized SRBC. Once again activity was present up to 7 hr in the supernates of the continuous hydrolysis, but the fractional hydrolysis indicated that the active material was removed early. Later detectable activity appeared to be due to the presence of acid-stable material in the supernates of the continuous hydrolysis. As with the fluorescence inhibition assay, there was no detectable activity at 10 hr or beyond, despite the return of fluorescence of the hydrolyzed walls. We do not consider a difference between the supernates and the antibody controls to be a significant indicator of activity.

Discussion—Two variations of acid hydrolysis, continuous and fractional, were used in these studies. In the continuous method, one aliquot of acid was added to the cell walls, and hydrolysis was allowed to proceed without interruption for the desired time. In this way, antigenic activity could be removed from the cell walls, and the range of time in which the activity was recoverable could be determined. This did not provide information as to when in the hydrolysis the material was actually removed from the walls but it did show its acid stability. The fractional method differed from the continuous in that an aliquot of acid was added to the walls, the reaction was allowed to proceed for specific times, and then discontinued. At this point, the supernate was removed and a fresh aliquot of the same normality acid was added to the residual cell walls, and the hydrolysis of the walls continued. In this way, material removed from the walls within a particular time frame, for example between 1 and 2 hr, could be collected and assayed for activity. Thus the time in which the active material was removed from the walls could be determined. Further, the persistence of activity in the supernates of the continuous hydrolysis, when compared with the actual time of removal of the active material, gave some indication of the relative acid stability of the material.

Our data show that antigenic material could be solubilized and removed from the clean, non-fragmented, and insoluble yeast phase cell walls of *H. capsulatum* using mild acid hydrolysis. The antigenic activity of the supernates of hydrolysis, as well as of the residual cell walls, was investigated using fluorescent and hemagglutinating antibody techniques.

Hydrolysis with 0.1N H_2SO_4 eliminated the fluorescent antibody reactivity of the cell wall within 2 hr, and no fluorescence was detected in walls hydrolyzed up to and including 12 hr. With the 0.025N acid, the decrease in fluorescence was stepwise and did not disappear until 6 hr in contact with the acid. As with the 0.1N acid, the fluorescence was absent through the 12 hr time period. The return of fluorescent antibody reactivity beginning at 15 hr suggested that, after the stepwise removal of 1 or more layers of antigenic material near the surface of the cell wall, continued exposure of the walls to acid resulted in uncovering a deeper layer of fluorescent antibody-reactive material. As would be expected, the 0.1N acid was more effective in exposing this layer as determined by the return of fluorescence to 50% of control levels as opposed to

25% for the weaker acid. The long-term stability of this returned fluorescent antibody reactivity indicated that it was either relatively resistant to attack by the acid, or that an underlying, repeating backbone structure had been exposed. Microscopically, the structural integrity of the walls was destroyed by long periods of hydrolysis.

Using the continuous method of hydrolysis, we have determined that antigenic material solubilized and removed from the yeast phase cell walls of *H. capsulatum* with 0.025N H_2SO_4 had the ability to inhibit passive hemagglutination of histoplasmin-sensitized SRBC, and the fluorescence of unhydrolyzed cell walls. The material remained active in the supernates of hydrolysis for as long as 7 to 10 hr. The 0.1N acid also removed active material from the walls, but this material was removed more quickly by the stronger acid.

Use of the fractional hydrolysis has shown that the material active in passive hemagglutination and fluorescence inhibition was removed relatively early in the hydrolysis. The continued presence of activity in the supernates of the longer-term continuous hydrolysis was due then to the acid stability of at least a portion of the material being released. It was found, however, that extended periods of hydrolysis would destroy the antibody reactivity of this relatively acid-stable material.

The reappearance of fluorescent antibody reactivity of the acid-hydrolyzed cell walls did not appear to be accompanied by a similar reappearance of fluorescent and hemagglutinating antibody-reactive material in the supernates.

These cell wall hydrolysates also contained precipitin-reactive materials which were found to be different from those active in hemagglutination and fluorescence of cell wall. These studies are reported in the following paper.

ACKNOWLEDGMENTS—This investigation was supported by Public Health Service grant AI 09903 from the National Institute of Allergy and Infectious Diseases, by an institutional grant to Temple University from the American Cancer Society, and by Public Health Service General Research Support grant RR 05417-11. H. C. Oels is the recipient of Public Health Service Research Center Career Development Award K4-AI-9094 from the National Institute of Allergy and Infectious Diseases.

II. PRECIPITIN REACTIVITY OF SUPERNATANT FRACTIONS—

Michael J. Sweeney, Roseann S. White, John V. Calcagno, and Helen C. Oels

ABSTRACT: *Mild acid hydrolysis of yeast phase* Histoplasma capsulatum *cell walls yielded precipitin-reactive material in the supernates of hydrolysis. Three distinct bands were present at various times by means of double diffusion in agar gel employing rabbit anti-*H. capsulatum *antiserum. Band 1 was acid-labile, while bands 2 and 3 were acid-stable. All 3 bands were removed from the walls early in the hydrolysis. Precipitin-reactive material was found to be different from fluorescent and hemagglutinating antibody-reactive material.*

PRECIPITIN-REACTIVE MATERIALS obtained from both the mycelial and yeast phase forms of *Histoplasma capsulatum* have been described by several authors. Heiner (1958) reported the presence of 6 precipitin bands using concentrated histoplasmin and sera from various patients. Tompkins (1965) reported similar precipitinogens in a yeast phase growth filtrate, as well as a heat-stable precipitin-reactive material which he designated "YP". This material could be extracted from whole, yeast phase cells using dioxane or phenol. Markowitz (1964) isolated polysaccharide-containing materials from the yeast phase growth filtrate of *H. capsulatum* which showed precipitin reactivity. Salvin and Hottle (1948) obtained precipitinogens from whole and ground cells and their products. The antigens from the mycelial and yeast phases were similar. Sweet (1971) obtained a maximum of 10 precipitinogens from the yeast phase broth filtrate, and from mechanically and sonically disrupted yeast phase cells. Eight of the 10 were inactivated by heat, and 3 of these 8 were inactivated by acid pH. Garcia and Howard (1971) used ethylenediamine extraction of whole cells or cell walls to obtain 2 precipitin bands. When phenol extraction was employed, 3 precipitin bands were obtained.

We have shown in our laboratory that materials solubilized and removed from yeast cell walls of *H. capsulatum* 6651 by mild acid hydrolysis exhibit both fluorescent and hemagglutinating antibody reactivity (Sweeney et al., 1978a). The work presented here is an analysis of the precipitin reactivity exhibited by the supernate of the mild acid hydrolysis of yeast phase *H. capsulatum* cell walls.

MATERIALS AND METHODS—*Supernatant fractions*: Supernatant fractions were prepared by mild acid hydrolysis of yeast phase *H. capsulatum* cell walls (Sweeney et al., 1978a).

Immunodiffusion: Rheophoresis plates (Abbott Scientific Products Division) were used in the immunodiffusion studies to assay 40 μliters of solution containing approximately 40 μg of supernatant material against 20 μliters of rabbit anti-*H. capsulatum* antiserum having a hemagglutination titer of 1:2048. Diffusions were done at room temperature. Patterns were read on unstained gels before and after washing, and again after staining.

Staining of diffusion patterns: Gels were washed for 3 da in several changes of 0.01 M sodium phosphate-buffered saline, pH 7.2 (PBS). After washing, the gels were stained for 15 min with Amido Schwartz, and destained with 1% acetic acid in 70% ethanol. After destaining, gels were washed in 2% glycerol for 15 min and allowed to dry.

RESULTS—*Precipitin bands in the continuous hydrolysis supernates*: Figure 4 is a representative gel showing the precipitin bands obtained from the 0.025N and 0.1N continuous hydrolyses. Three distinct bands were found to be present at various times. Band 1 was the outermost from the antiserum well, band 3 the closest to the antiserum well, and band 2 lay in between bands 1 and 3. The presence of precipitin lines of identity has established that bands 1, 2 and 3 are the same in both the continuous and fractional hydrolyses, and with both normalities of acid.

Figure 5 (upper) is a comparison of the precipitin bands obtained from the supernates of the continuous hydrolysis. Band 1 was present in the 0.025N supernates from 30 min to 4 hr inclusive, but not beyond. Band 2 was found in the 0.025N supernates up to and including 24 hr, but not at 48 hr, and band 3 was found up to and including 48 hr. No bands were present in the 5-min supernate. With the 0.1N acid, band 1 was present only in the 30-min supernate. Band 2 was present to 10 hr and band 3 to 12 hr. As with the weaker acid, no bands were present in the 5-min supernate.

Precipitins in the fractional hydrolysis supernates: Figure 5 (lower) is a comparison of the precipitin bands obtained from the supernates of the 0.025N and 0.1N fractional hydrolyses. Bands 1, 2 and 3 are again defined as those present outermost, central and innermost, respectively, in relation to the central antiserum well. All of band 1 was found to be removed with 0.025N acid by 4 hr. That is, no further material was removed between 4 and 5 hr or beyond. Bands 2 and 3 were also removed from the walls by 4 hr, but there was apparently some material more strongly bound which was removed in the 7 to 10-hr hy-

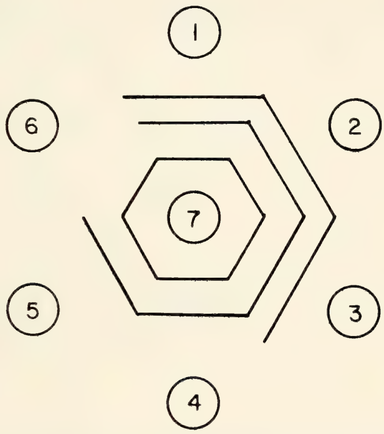


FIG. 4. Representative immunodiffusion gel showing the three precipitin bands obtained during hydrolysis. 1: 0.025N, continuous, 3 hr; 2: 0.025N, fractional, 3 hr; 3: 0.1N, fractional or continuous, 30 min.; 4: 0.1N, fractional, 2 hr; 5: 0.025N, continuous, 5 hr; 6:0.025N, continuous, 48 hr; and 7: rabbit anti-*H. capsulatum* antiserum.

drolysis period. No precipitin-reactive material was removed beyond 10 hr. With the 0.1N acid, all of band 1 was removed by 30 min, and all of bands 2, and 3 by 3 hr. As with the continuous hydrolysis, no bands were present in the 5-min supernate of either normality acid.

DISCUSSION—As in the previous study, two forms of acid hydrolysis were used (Sweeney et al., 1978a). With the continuous hydrolysis it was possible to determine under what conditions of time and normality activity could be recovered in the supernates. The fractional hydrolysis, when compared with the continuous, gave two important pieces of information. First, it was possible to determine during which time intervals active material was removed from the walls. Secondly, it was possible to determine the relative acid stability of the active material removed from the walls.

Three precipitin bands were present in both forms of hydrolysis and at both normalities of acid. Band 1 was the band which precipitated farthest from the antiserum well of the diffusion plate. It was removed from the cell walls only up to 4 hr, as determined by the 0.025N fractional hydrolysis, and its absence in the supernates of the continuous beyond 4 hr indicated that it was quite acid-labile. This high degree of acid lability was substantiated by the 0.1N acid hydrolyses. The band could be removed from the cell walls at 30 min as

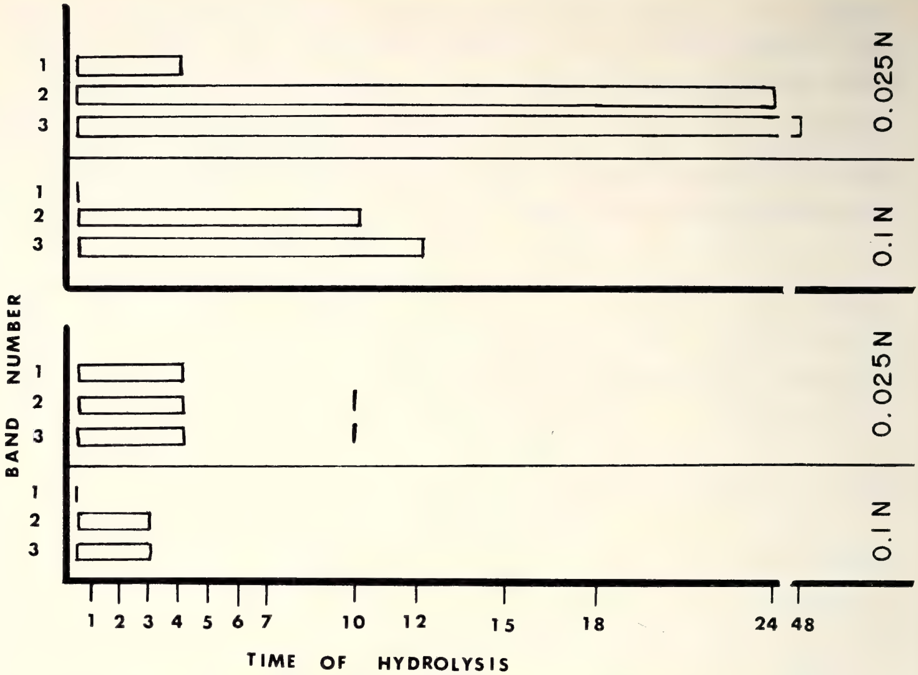


FIG. 5. Precipitin bands obtained in immunodiffusion with supernates from 0.025N and 0.1N acid hydrolysis, continuous (upper) and fractional (lower).

determined by the fractional hydrolysis, and did not persist beyond 30 min in the continuous hydrolysis supernates.

Band 2 was the central precipitin band and was removed from the cell wall in the first 4 hr of hydrolysis, and then again between 7 and 10 hr with the 0.025N acid. It persisted in the supernates of the 0.025N continuous hydrolysis up to and including 24 hr, and thus appeared quite acid-stable. With 0.1N acid all of band 2 was removed in the first 3 hr of hydrolysis, but it was found to be stable up to 10 hr with the continuous hydrolysis supernates. The differences in persistence between the 0.025N and 0.1N acid fractions appeared to be due to the band's increased lability in the presence of the stronger acid.

Band 3 was found closest to the central antiserum well. It followed a pattern similar to that observed for band 2 in that the material seemed to have been removed by the 0.025N acid at the end of 4 hr of hydrolysis, but some further material was released between 7 and 10 hr. It persisted in the 0.025N continuous hydrolysis supernates up to and including 48 hr and thus appeared to be more acid-stable than band 2, which was found only up to 24 hr. The 0.1N acid had removed all of band 3 at the end of 3 hr of hydrolysis, but the band was found to persist to 12 hr in the 0.1N continuous hydrolysis supernates, substantiating the greater acid stability of band 3 over band 2.

The absence of precipitin bands in the 5-min hydrolyses indicated that this material was indeed being hydrolyzed from the cell walls and not merely being eluted by the acid.

The removal of bands 2 and 3 between 7 and 10 hr may have been a result of their resistance to attack by the 0.025N acid and/or a result of their position in the wall. The 0.1N acid effectively removed all of this material at quite early times.

The fluorescent and hemagglutinating antibody reactivity described by Sweeney et al. (1978a) could not be correlated with the precipitin bands described in this study. Bands 2 and 3 persisted in the supernates of the continuous hydrolysis when no fluorescent or hemagglutinating antibody reactivity was detectable. Fluorescent and hemagglutinating antibody reactivity was present several hr after the last appearance of band 1 in the continuous hydrolysis supernates. Therefore, the precipitin-reactive materials obtained by mild acid hydrolysis of yeast phase *H. capsulatum* cell walls were different from those materials reactive with fluorescent and hemagglutinating antibody, and from those active in delayed hypersensitivity which are reported in the following paper (Sweeney et al., 1978c).

ACKNOWLEDGMENTS—This investigation was supported by Public Health Service grant AI 09903 from the National Institute of Allergy and Infectious Diseases, by an institutional grant to Temple University from the American Cancer Society, and by Public Health Service General Research Support grant RR05417-11. H. C. Oels is the recipient of Public Health Service Research Career Development Award K4-AI-9094 from the National Institute of Allergy and Infectious Diseases.

III. ELICITATION OF DELAYED HYPERSENSITIVITY BY SUPERNATANT FRACTIONS—*Michael J. Sweeney, Roseann S. White, Bonita S. Rosenberg, John V. Calcagno, and Helen C. Oels*

ABSTRACT: *Supernatant fractions obtained by mild acid hydrolysis of yeast phase* Histoplasma capsulatum *cell walls were active in eliciting delayed hypersensitivity skin reactions in* H. capsulatum *sensitized guinea pigs. Two peaks of activity occurred. The first or early activity was recoverable from the supernates almost immediately and persisted for 7 hr. The second or later activity became apparent at 15 hr and persisted through 48 hr of hydrolysis. The majority of the early activity was found to be released in the first 2 hr, while the later activity was released continuously between 15 and 48 hr. At least a portion of the material exhibiting the early activity was acid-stable. Skin-reactive materials were shown to be different from those involved in passive hemagglutination and fluorescence of the cell wall, as well as from those involved in precipitin reactions.*

ABILITY of antigenic materials from yeast phase as well as mycelial phase *Histoplasma capsulatum* to produce delayed hypersensitivity skin reactions in a sensitized patient and in experimental animals was first shown in 1941. Since then numerous attempts have been made to purify, standardize and improve the specificity of the antigenic substances present in these crude mixtures.

Although most of the work has been done with histoplasmin from the mycelial phase of *H. capsulatum*, some antigenic fractions active in eliciting delayed hypersensitivity have been obtained by various means from the yeast phase of *H. capsulatum* (Dyson and Evans, 1955; Knight et al., 1959; Markowitz, 1964; Oels, 1971.) Several studies have suggested that the major antigenic activity of yeast phase *H. capsulatum* is present in the cell wall (Garcia and Howard, 1971; Pine et al., 1966; Salvin and Ribi, 1955.)

Previous papers from our laboratories have shown that several antigens which are active in hemagglutination, precipitation and fluorescence of the cell wall can be obtained by mild acid hydrolysis of the cleaned cell wall of yeast phase *H. capsulatum.* Isolation of antigenic materials by mild acid hydrolysis of the cell wall achieves isolation of two kinds of antigenic materials—1) those which are active in delayed hypersensitivity and 2) fractions which demonstrate serological reactivity.

Materials and Methods—*Supernatant fractions:* Supernatant fractions containing antigenic material solubilized and removed from the yeast phase cell walls of *H. capsulatum* by mild acid hydrolysis were prepared as described previously using 0.025N and 0.1N H_2SO_4 at 100°C for varying amounts of time.

Guinea pig sensitization: Adult female Hartley strain guinea pigs were inoculated intraperitoneally with 10^8 live yeast cells of *H. capsulatum* strain 6651 on day 0, were boostered on day 21, and tested for sensitivity on day 28 with a 10-μg intradermal injection of strain 6651 histoplasmin in 0.1 ml deionized water.

Skin testing: Three or 4 injections were applied to each side of the back of each animal. Each injection contained 100 μg of the test antigen in 0.1 ml of deionized water. Histoplasmin at a concentration of 10 μg/0.1 ml water was used as a positive control, and deionized water as a negative control for each animal. All material was tested in duplicate on separate animals, and each experiment was done in a double-blind manner. The animals were observed at 4 and 6 hr for immediate type reactions and the diameter of skin induration was measured in mm at 24 and 48 hr after skin testing. Histological sections of the lesions at 24 and 48 hr showed perivascular round cell infiltration characteristic of delayed hypersensitivity skin reactions.

Results—*Delayed hypersensitivity*: Figure 6 shows the results of skin testing with the supernates of the continuous hydrolysis. The results are plotted as mm of induration of the lesion at 24 hr vs time of hydrolysis. It can be seen that both early and late activities were recovered in the supernates, the early activity being maximal between 1 and 7 hr, and the late activity appearing at 18 hr and remaining even after 48 hr in contact with the 0.025N acid. A similar pattern was seen with the 0.1N acid, although the early activity was lower than that obtained with the 0.025N acid, probably due to an increased sensitivity to the stronger acid. The later activity was much the same as that obtained with the weaker acid.

Figure 6 shows also the results of skin testing with the supernates of the fractional hydrolysis. The maximum reactive material was removed from the walls by 2 hr with a more or less constant and low level release of material from 3 to 7 hr. No active material was released between 7 and 12 hr. Beginning at 15 hr, material active in eliciting delayed hypersensitivity was once again released and this material could be detected up to 48 hr.

Discussion—The supernates obtained by the continuous hydrolysis of yeast phase cell walls of *H. capsulatum* were active in eliciting delayed hypersensitivity reactions in *H. capsulatum*-sensitized guinea pigs. The activity occurred

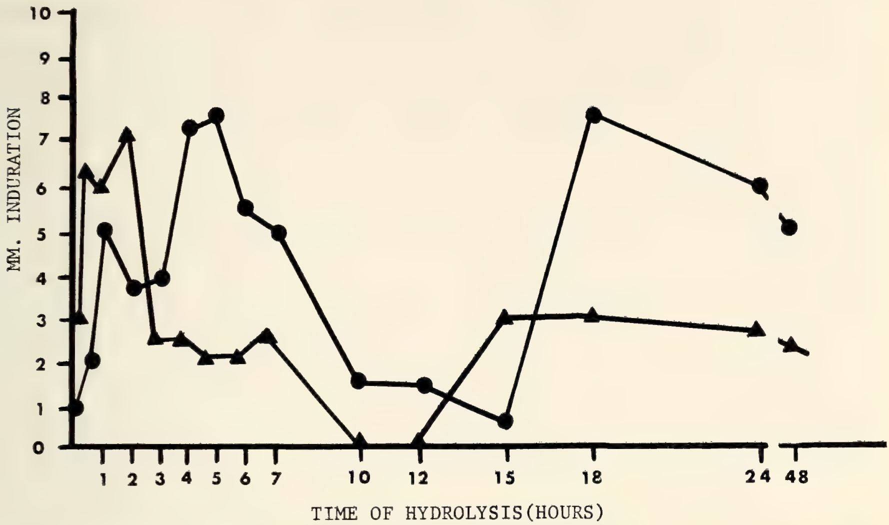


FIG. 6. Activity of the supernatants of 0.025N acid hydrolysis in delayed hypersensitivity skin tests.● —— ●, continuous; ▲ —— ▲, fractional.

both early and late in the hydrolysis. The early activity was seen almost immediately and persisted in the supernates of hydrolysis for as long as 7 hr, when it began to drop off quite rapidly to a very low level. Between 15 and 18 hr, the later activity first became apparent and was recovered in the supernates through 48 hr of hydrolysis.

The fractional method of hydrolysis showed that the majority of the early activity present to 7 hr in the supernates of the continuous hydrolysis was actually removed within the first 2 hr of hydrolysis. The presence of a high level of activity beyond the first 2 hr in the continuous hydrolysis led to the conclusion that at least a portion of this material was relatively acid-stable. The later activity observed beginning at 15 hr in the continuous hydrolysis supernates was found to be released almost continuously from the 15- to 48-hr period, and thus the degree of acid stability of the material responsible for this later activity could not be conclusively determined.

We have described antigenic analysis of materials solubilized and removed from the yeast phase cell walls of *H. capsulatum* using mild acid hydrolysis. We examined the fluorescent, hemagglutinating, and precipitating antibody reactivity of materials released into the supernates of hydrolysis, and the fluorescent antibody reactivity of the residual cell walls. Here we have demonstrated the ability of these supernatant fractions to elicit delayed hypersensitivity skin reactions in guinea pigs sensitized to yeast phase *H. capsulatum*.

As the yeast phase cell walls of this organism were hydrolyzed in mild acid, their fluorescent antibody reactivity decreased rapidly, disappeared, and later reappeared. The materials solubilized and released from the walls into the supernates were found to be active in various immunological assays. As wall fluorescent antibody reactivity decreased, fluorescent and hemagglutinating antibody reactivity appeared in the supernates. This was accompanied by the presence of 1 acid-labile and 2 acid-stable precipitin bands, and by the presence of material capable of eliciting delayed hypersensitivity skin reactions in sensitized guinea pigs.

As hydrolysis was continued beyond the 7- to 10-hr time period, the hemagglutinating and fluorescent antibody reactivity, as well as the delayed hypersensitivity activity, were seen to disappear from the supernates. Delayed hypersensitivity was the only activity seen to return at later times along with the corresponding return of fluorescent antibody reactivity of the hydrolyzed walls. Two precipitin bands persisted in the supernates for long periods of time, even when the other activities were found to be absent, implying that the precipitating materials were not involved in the other serological activities or active in eliciting delayed hypersensitivity skin reactions. The second, later peak of delayed hypersensitivity had no corresponding fluorescent or hemagglutinating antibody-reactive counterpart. This indicates that the materials in the cell were different with regards to serological and delayed hypersensitivity reactivity.

Acknowledgments—These investigations are supported by Public Health Service grant AI 09903 from the National Institute of Allergy and Infectious Diseases, by an institutional grant to Temple University from the American Cancer Society, and by Public Health Service General Research Support grant RR 05417-11. H. C. Oels is the recipient of Public Health Service Research Career Development Award K4-AI-9094 from the National Institute of Allergy and Infectious Diseases.

LITERATURE CITED

Calcagno, J. V., M. J. Sweeney and H. C. Oels. 1973. A rapid batch method for the preparation of FITC-conjugated antibody. J. Infect. Immunity 7:366-369.

Campbell, C. C. 1971. History of the development of serologic tests for histoplasmosis. Pp. 341-357. *In* Ajello, L., E. W. Chick, and M. L. Furcolow (eds.). Histoplasmosis. C. C. Thomas. Illinois.

Dyson, J. E., and E. E. Evans. 1955. Delayed hypersensitivity in experimental fungus infections: The skin reactivity of antigens from the yeast phase of *Histoplasma capsulatum*. J. Lab. Clin. Med. 45:449-454.

Garcia, J. P., and D. H. Howard, 1971. Characterization of antigens from the yeast phase of *Histoplasma capsulatum*. Infect. Immunity 4:116-125.

Heiner, D. C., 1958. Diagnosis of histoplasmosis using precipitin reactions in agar gel. Pediatrics 22:616-627.

Knight, R. A., and S. Marcus. 1958. Polysaccharide skin test antigens derived from *Histoplasma capsulatum* and *Blastomyces dermatitidis*. Amer. Rev. Tuberc. Pulmon. Dis. 77:983-989.

———, S. Coray and S. Marcus, 1959. *Histoplasma capsulatum* and *Blastomyces dermatitidis* polysaccharide skin tests in humans. Amer. Rev. Resp. Dis. 80:264-266.

Markowitz, H., 1964. Polysaccharide antigens from *Histoplasma capsulatum*. Proc. Soc. Exp. Biol. Med. 115:697-700.

Oels, H. C. 1971. Properties of fractions from mechanically disrupted yeast phase *Histoplasma capsulatum*. Ph.D. Dissert. Univ. Minnesota.

Pernis, P. A. van, M. E. Benson and P. H. Holinger. 1941. Specific cutaneous reactions with histoplasmosis. Preliminary report of another case. J. Amer. Med. Assoc. 117:436-437.

Pine, L., C. J. Boone and D. McLaughlin. 1966. Antigenic properties of the cell wall and other fractions of the yeast phase of *Histoplasma capsulatum*. J. Bacteriol. 91:2158-2168.

Salvin, S. B., 1963. Immunological aspects of the mycoses. Progr. Allergy 7:213-331.

———, and G. A. Hottle. 1948. Serologic studies from *Histoplasma capsulatum* Darling. J. Immunol. 60:57-66.

———, AND E. RIBI. 1955. Antigens from yeast phase *Histoplasma capsulatum.* II. Immunological properties of protoplasm vs. cell walls. Proc. Soc. Exp. Biol. Med. 90:287-294.

———, AND R. F. SMITH. 1959. Antigens from the yeast phase of *Histoplasma capsulatum.* III. Isolation, properties and activity of a protein-carbohydrate complex. J. Infect. Dis. 105:45-53.

SWEENEY, M. J., AND H. C. OELS. 1972. Antigens from purified cell walls of yeast phase *Histoplasma capsulatum.* Bacteriol. Proc. 72:131.

———, R. S. WHITE, J. V. CALCAGNO AND H. C. OELS. 1978a. Antigenic fractions obtained from mild acid hydrolysis of yeast phase *Histoplasma capsulatum* cell walls. I. Fluorescent and hemagglutinating antibody reactivity of hydrolysis supernates and residual cell walls. Florida Sci. 41(4):

———, ———, ——— AND ———. 1978b. Antigenic fractions obtained from mild acid hydrolysis of yeast phase *Histoplasma capsulatum* cell walls. II. Precipitin reactivity of supernatant fractions. Florida Sci. 41(4).

———, ———, B. S. ROSENBERG, J. V. CALCAGNO AND H. C. OELS. 1978c. Antigenic fractions obtained by mild acid hydrolysis of yeast phase *Histoplasma capsulatum* cell walls. III. Elicitation of delayed hypersensitivity by supernatant fractions. Florida Sci. 41(4):

SWEET, G. H. 1971. Antigens of *Histoplasma capsulatum.* I. Conditions for assay of yeast-phase precipitinogens. Amer. Rev. Resp. Dis. 104:394-400.

TOMPKINS, V. N. 1965. Soluble antigenic constituents of yeast-phase *Histoplasma capsulatum.* Amer. Rev. Resp. Dis. 92:126-133.

ZARAFONETIS, C. J. D., AND R. B. LINDBERG, 1941. Histoplasmosis of Darling: Observations on the antigenic properties of the causative agent. A preliminary report. Univ. Hosp. Bull. Ann Arbor 7:47-48.

Florida Sci. 41(4):219-233. 1978.

Physical Sciences

HETEROSITE X-RAY POWDER DIFFRACTION DATA

FRANK N. BLANCHARD AND B. RENEE ALFORD

Department of Geology, University of Florida, Gainesville, Florida 32611

ABSTRACT: *The card for heterosite in the Powder Diffraction File lists 14 lines of which 3 do not belong to the mineral. We observe 55 lines for heterosite of composition* $(Fe_{.82}Mn_{.18})PO_4$, *and these have been indexed, checked against the known structure by calculation, and should serve as better reference data for identification of this mineral.**

THE X-ray powder diffraction data for heterosite in the Powder Diffraction File (card #11-457) are incomplete and include three lines (out of the 14 listed) which do not belong to the mineral. Heterosite is the iron end member of the purpurite-heterosite series which ranges in composition from $MnPO_4$ to $FePO_4$. We provide better data for this mineral, including calculated and observed powder patterns. The observed data are for heterosite, with a specific composition of $(Fe_{.82}Mn_{.18})PO_4$, from the Palermo mine, North Groton, New Hampshire, while the calculated pattern is based upon the crystal structure of heterosite as refined by Eventoff, Martin, and Peacor (1972) to $R = 5\%$, with modifications of density and composition to correspond with the composition of our sample.

*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked *"advertisement"* solely to indicate this fact.

METHODS—The heterosite was ground to less than 325 mesh and the powder was (1) prepared directly as a smear on a glass slide, (2) sprinkled onto a glass slide previously coated with a very thin layer of vaseline, and (3) mixed 1:1 with synthetic corundum (Al_2O_3, 0.3 micron, Linde A) prior to preparing as a smear and sprinkled. A preparation with corundum was used to determine the observed intensity ratio I/I_c (c = corundum). This is consistent with the selection of "Linde A" as an intensity standard by the Joint Committee on Powder Diffraction Standards. The vaseline mount was used to decrease preferred orientation thereby allowing more reliable measurements of relative intensities of the diffraction lines. The smear was used to obtain the *d*-spacings of the diffraction lines. Immediately before the analysis, the diffractometer (General Electric XRD-5) was realigned and the specimen support was shimmed so that at 0° 2Θ the primary beam was split in half by the sample and slide which was used to obtain *d*-spacings. Scans were made from 2° to 90° 2Θ using Ni-filtered Cu-radiation and using monochromatic Cu Kα-radiation, a 3° divergence slit, 0.2°, 0.1°, and 0.05° detector slits, and a scanning speed of either 0.4° or 0.2° 2Θ per min. The patterns obtained with monochromatic radiation proved to be the best, and these were used to obtain the *d*-spacings and relative intensities given in Table 1. The observed X-ray reflections were indexed with a computer (Appleman and

TABLE 1. Calculated and observed X-ray powder diffraction data for heterosite. I_1 is relative intensity corrected for flat-plate absorption (diffractometer) while I_2 is corrected for Debye-Scherrer absorption. Observed intensities are peak heights, while calculated intensities are integrated areas.

Calculated d A	I_1	I_2	hkl	Observed d A	I	hkl	Card 11-457 d A	I	hkl
							6.28	40	NI
							5.51	10	NI
4.9108	66.8	57.4	020	4.94	66	020	4.85	25	020
4.2995	100.0	100.0	011	4.31	100	011	4.29	75	011
3.7547	26.6	31.2	120	3.76	28	120	3.87	40	120 (?)
3.6962	2.9	3.4	101	3.71	7	101			
3.4593	87.1	113.4	111	3.46	91	111	3.48	100	111
3.4260	21.1	27.8	021	3.44	24	021	3.06	25	NI
2.9532	33.7	54.5	121	2.96	38	121	2.93	50	200,121
2.9127	80.2	132.1	200	2.92	93	200			
2.7014	12.9	23.5	031	2.705	17	031	2.73	75	031
2.5052	2.1	4.3	220	2.511	4	220	2.51	10	220
2.4507	97.3	203.2	131	2.452	110	131	2.43	40	040,131
2.4115	34.8	74.3	211	2.412	42	211			
2.3232	17.2	38.8	012	2.325	18	012	2.32	10	012
2.2626	11.5	27.0	140	2.264	9	140			
2.2191	10.3	24.9	221	2.220	15	221			
2.1843	15.1	37.5	041	2.186	17	041	2.16	10	230,112+
2.1579	10.3	26.0	112	2.156	16	112,022			
2.1498	5.9	14.9	022						
2.0452	3.2	8.8	141	2.046	3	141			
2.0168	6.6	18.3	122	2.018	6	122			
1.9807	9.8	28.0	231	1.980	8	231			
1.9309	2.6	7.7	032	1.932	2	032			
1.8773	2.5	7.7	240	1.878	2	240			
1.8481	15.2	48.5	202	1.848	15	202			
1.8328	4.2	13.7	132	1.836	5	132			
1.8162	15.4	50.4	212	1.816	13	212			
1.7991	2.6	8.8	301	1.800	3	301			
1.7697	12.7	43.6	311	1.769	11	311			
1.7346	11.4	40.3	151	1.731	31	222,151			
1.7297	22.4	79.5	222						
1.7130	9.7	34.9	042	1.714	11	042			
1.6893	12.4	45.8	321	1.689	12	321			
1.6434	12.0	46.2	142	1.643	10	142,060			
1.6369	2.7	10.4	060						
1.6094	1.8	7.2	232	1.609	1	232			
1.5767	22.8	94.5	331	1.576	32	331,160+			
1.5759	17.2	71.4	160						
1.5734	1.2	5.1	013						
1.5231	9.3	40.9	340						
1.5190	5.6	24.5	113	1.522	11	340,113+			

Calculated d A	I_1	I_2	hkl	Observed d A	I	hkl	Card 11-457 d A	I
1.5178	1.2	5.3	052					
1.5162	1.9	8.3	023					
1.4899	2.5	11.3	312	1.491	3	312		
1.4766	3.2	14.8	242					
1.4688	11.1	51.6	152					
				1.468	19	123,152+	1.46	25
1.4673	15.7	73.4	123					
1.4564	13.7	64.9	400	1.456	13	400		
1.4270	13.9	68.0	260	1.427	13	260		
1.3962	2.1	10.9	420	1.394	3	420		
1.3917	1.3	6.4	133					
1.3844	1.4	7.0	213	1.381	4	411,213		
1.3794	4.2	21.6	411					
1.3692	1.2	6.5	332					
1.3507	3.3	17.9	062					
1.3463	6.6	35.5	071					
1.3460	1.5	8.0	252	1.345	14	223,071+		
1.3449	13.3	72.1	223					
1.3267	3.8	20.9	351	1.328	2	351		
1.3158	2.0	11.2	162	1.326	1	162		
1.3031	10.2	58.3	143	1.304	6	143		
1.2846	1.0	6.0	342	1.285	2	431,342		
1.2819	2.0	11.8	431					
1.2516	7.0	42.9	360	1.252	5	360		
1.2378	1.6	10.1	053	1.235	5	412,053		
1.2339	4.0	25.5	412					
1.2225	2.3	14.5	313	1.222	6	271,313		
1.2221	8.7	55.6	271					
1.2151	1.2	7.9	243	1.213	3	361,243		
1.2108	1.3	8.7	361					
1.2101	1.5	9.6	072					
				1.208	3	422,072		
1.2057	2.5	16.7	422					
1.1958	5.5	37.1	352	1.196	6	352,323		
1.1950	4.4	29.6	323					
1.1868	4.7	31.6	014	1.188	3	014		
1.1651	1.3	8.8	181					
				1.162	1	181,024		
1.1616	1.1	7.8	024					
1.1392	2.9	20.9	253	1.140	2	253		
1.1245	2.1	15.6	511					
1.1175	2.5	19.2	272					
1.1096	2.3	17.8	442					
1.1088	1.0	7.5	362					
1.1060	1.0	7.4	204					
1.1012	7.6	59.2	343					
1.1009	3.6	27.7	281	1.101	8	343,214+		
1.0990	7.5	58.5	214					

Evans, 1967), using some information from the calculated powder diffraction pattern (described below). The computer program of Appleman and Evans also produced a least-squares refinement of the lattice parameters of heterosite. In this least squares refinement a weighting factor of $1/d$ was used for each reflection to minimize the relatively larger errors inherently present at lower 2Θ angles.

In addition to the observed powder diffraction pattern, a computer-simulated diffractometer chart and calculated *d*-spacings and relative intensities were obtained for heterosite of composition $(Fe_{.82}Mn_{.18})PO_4$ and for the heterosite and purpurite end members of the series. This was accomplished using the FORTRAN IV program for calculating X-ray powder diffraction patterns—version 5 (Clark, Smith, and Johnson, 1973), with crystal structure data for heterosite (Eventoff, et al., 1972), and the chemical composition and density of the heterosite used in this study. The resulting calculated patterns are useful in indexing the observed pattern, for identification standards, for evaluating the quality of existing powder diffraction data, in determining absolute intensities for quantitative analysis, and in evaluating the reliability of the structure determination.

Quantitative chemical analysis for iron and manganese was done by atomic absorption spectrophotometry, and qualitative analysis for elements from aluminum through uranium was done by X-ray fluorescence. Except for minor calcium and potassium no significant amount of any element other than iron, manganese, and phosphorous, was detected, and the chemical formula was calculated as if in a simple solid solution series from iron to manganese phosphate.

RESULTS AND DISCUSSION—Table 1 includes the calculated *d*-spacings (indexed) and relative intensities for heterosite. The first column of intensity is integrated intensity corrected for flat-plate absorption (diffractometer), and the second column is integrated intensity corrected for Debye-Scherrer absorption. Reflections with intensity less than 1.0 (in the first column) have been omitted. Fig. 1 includes the computer-simulated diffractometer chart based on Cu Kα-radiation, a Cauchy line profile, and a half-width at 40° 2Θ of 0.1°.

Hubbard, Evans, and Smith (1976) recommend reporting a standard scale factor (γ) with calculated powder diffraction patterns. This practice permits conversion from relative intensity to absolute/relative intensity. They also point out that the scale factor, γ, may be used with appropriate data for corundum to calculate "the reference intensity ratio" I/I_c. I/I_c is the integrated intensity ratio of the strongest line of a sample to the strongest line of corundum. For heterosite $\gamma = 0.1533 \times 10^{-3}$ and $I/I_c = 1.25$. The reference intensity ratio was computed using the computed value of γ for heterosite and values of γ, linear absorption coefficient, and density for corundum given by Hubbard, et al. (1976).

Table 1 also includes the observed *d*-spacings and relative intensities (peak height) for heterosite of composition $(Fe_{.82}Mn_{.18})PO_4$. Refined lattice parameters and standard errors obtained from these *d*-spacings are a = 5.824 (±.001), b = 9.823 (±.002), and c = 4.786 (±.001). Fig. 1 shows a representative diffractometer chart with the computer-simulated chart.

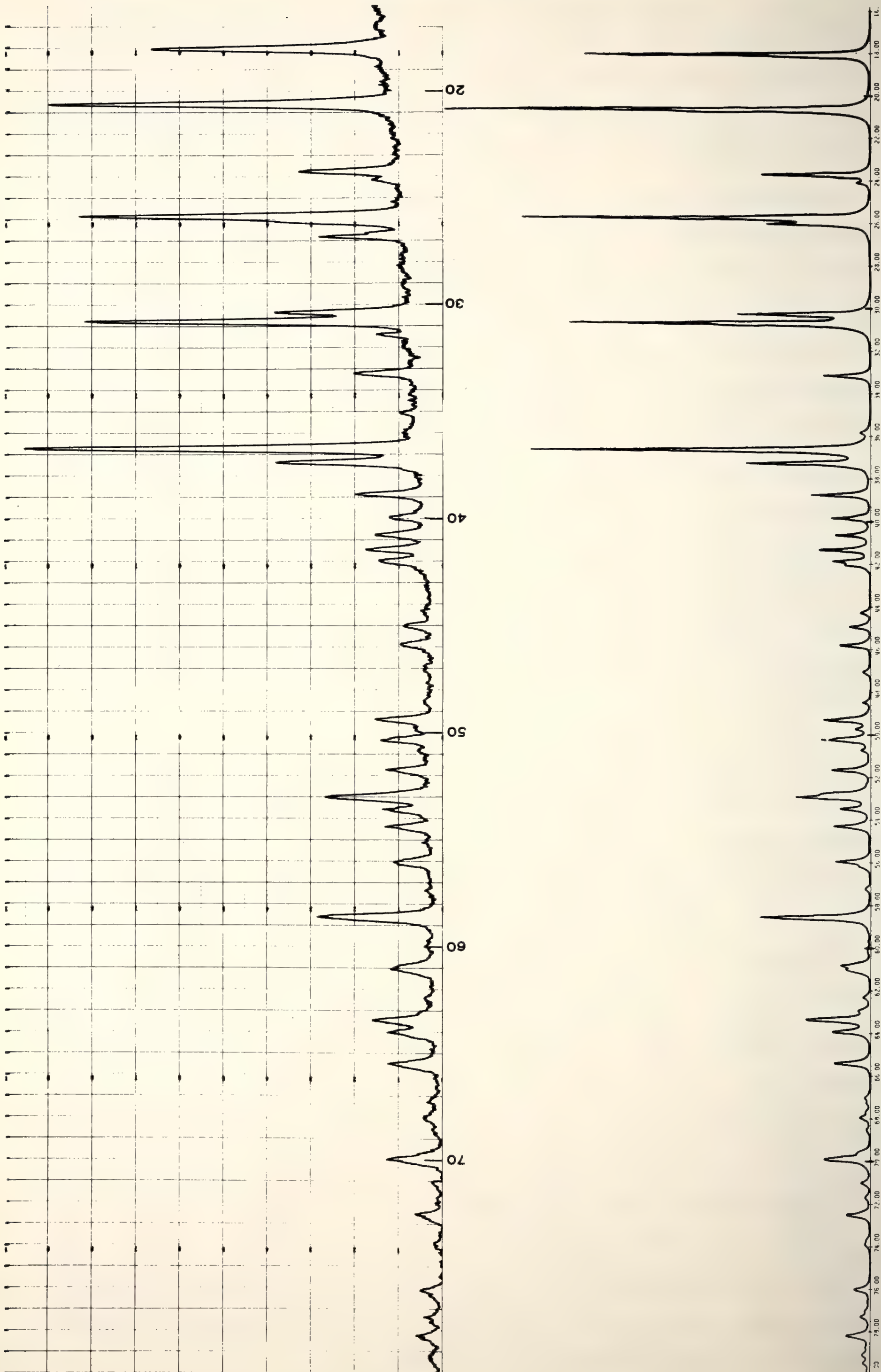


FIG. 1. Observed diffractometer chart (top) and computer-simulated chart (bottom) for heterosite, $(Fe_{.82}Mn_{.18})PO_4$. 2Θ angles are indicated every 10°.

Intensity measurements of the 011 line (computed to be the most intense) of heterosite and the 113 line (the most intense) of corundum yield values for I/I_c which average 0.69 (peak height) and 0.74 (integrated intensity). This observed value of I/I_c is significantly less than the calculated value, probably partly due to preferred orientation in the powder sample resulting in increased intensity of reflections from lattice planes which are parallel with cleavage planes, at the expense of the intensities of the remaining lines.

Comparison between the observed pattern and the calculated pattern for heterosite shows reasonably good correlation. The lower-than-predicted relative intensity of the 011 line probably results from preferred orientation due to the $\{100\}$ and $\{010\}$ cleavages which over-emphasizes all orders of 100 and 010, at the expense of other lines in the pattern. Considerable variation in the intensity ratio of 200 to 011 can be obtained by differing the method of sample preparation. Those methods which tend to decrease preferred orientation tend to decrease the relative intensity of 200. The observed intensity of the 131 reflection is greater than predicted and this may be due to a cleavage which has not been reported for heterosite. Because calculations indicate that the intensity of 011 should be the greatest, this line is assigned an observed intensity of 100 (one hundred), and this makes it necessary to assign an intensity greater than 100 (one hundred) to the 131 line.

The *d*-spacings, intensities, and indices from card #11-457 are included in Table 1 for comparison. The card lists 14 lines, while we recognize 55 lines to $d=1.099$ ($2\Theta\tilde{}90°$ with Cu-radiation). The lines from the card at $d=6.28$, $d=5.51$ and $d=3.06$ do not correspond to any lines which we observed or calculated, and we conclude that these reported lines are from a contamination.

Calculated powder diffraction patterns for the heterosite and purpurite end members of the series show very little differences in relative intensities of the various lines. This is expected because the atomic scattering factors for iron and manganese are similar. We do not have adequate material to evaluate variations in lattice parameters through the series.

ACKNOWLEDGMENTS—Calculation of the powder diffraction patterns was done with the facilities of the Northeast Regional Data Center of the State University System of Florida. R. A. Wicker adapted the program written by Clark, Smith, and Johnson to the NERDC computer and wrote the plot routine.

LITERATURE CITED

APPLEMAN, D. E., AND H. T. EVANS, JR. 1967. Experience with computer self-indexing and unit-cell refinement of powder data (abst.). Geol. Soc. Amer. Spec. Pap. 115.

CLARK, C. M., D. K. SMITH, AND G. G. JOHNSON. 1973. A FORTRAN IV program for calculating X-ray powder diffraction patterns—version 5. Pennsylvania State Univ. University Park.

EVENTOFF, W., R. MARTIN AND D. R. PEACOR. 1972. The crystal structure of heterosite. Amer. Mineral. 57:45-51.

HUBBARD, C. R., E. H. EVANS AND D. K. SMITH. 1976. The reference intensity ratio, I/I_c, for computer simulated powder patterns. J. Appl. Crystalogr. 9:169-174.

JOINT COMMITTEE ON POWDER DIFFRACTION STANDARDS. Selected Powder Diffraction Data for Minerals. 1974. Swarthmore, Pennsylvania.

Florida Sci. 41(4):233-237. 1978.

Biological Sciences

PARTIAL PURIFICATION OF "TOXOTOXIN" PRODUCED BY *TOXOPLASMA GONDII*

Robert N. Gennaro[1] and B. G. Foster

Department of Biology, Texas A & M University College Station, Texas 77843

Abstract: *"Toxotoxin" produced in Yale Swiss mice by intraperitoneal infection with the Rh strain of* Toxoplasma gondii *was subjected to mild purification methods. These methods included: ammonium sulfate fractionation, Sephadex molecular sieve chromatography, and differential ultracentrifugation. A sequential procedure was used employing ammonium sulfate fractionated crude "Toxotoxin" (20-40%) which was centrifuged at 150,000 × g for 90 min. The pelleted toxic fraction was chromatographed on Sephadex G-200. This three-step sequential procedure resulted in a toxic fraction which contained 6 of the original 14 components found in the crude toxin. Our data confirm the high molecular weight of "Toxotoxin." Evidence was obtained which indicates that "Toxotoxin" is composed of aggregate subunits.*[*]

Toxoplasma gondii was first isolated and named in 1908 by Nicolle and Manceaux (1909). The disease, toxoplasmosis, is prevalent in birds and various mammals, including man (Feldman and Miller, 1965; Jacobs and Anastasia, 1960; Jacobs et al. 1952; Nicolle and Manceaux, 1909).

Weinman and Klatchko (1950) were the first to describe the presence of a substance in the peritoneal fluid of *Toxoplasma* infected mice, which they called "Toxotoxin". This substance is lethal to mice only by the intravenous route. The most notable characteristics of "Toxotoxin" are its extreme rapidity of action and its heat stability. Woodworth and Weinman (1960) reported a 4-10 fold increase in toxicity by heating the toxin for 30 min. at 56°C. The toxic activity was precipitated by ammonium sulfate (20-40% saturation) and also precipitated when the pH was lowered to 6.2. Fulton (1965) reported that "Toxotoxin" produced in the cotton rat was destroyed by hyaluronidase, which suggests a protein-hyaluronic acid complex. Weinman and Klatchko (1950) and Fulton (1965) demonstrated that the toxic effect was destroyed by pepsin and trypsin and was non-dializable. "Toxotoxin" is thought to be a protein or a complex which is intimately associated with a high molecular weight protein.

Pettersen (1970) used a method called ice-filtration to isolate a toxic fraction of extremely high molecular weight from crude "Toxotoxin" and has speculated that Toxotoxin is a large, fibrinous molecule or particle formed by aggregation of smaller molecules.

We describe a method for the partial purification of "Toxotoxin" by a system involving ammonium sulfate fractionation, ultracentrifugation, and chromoto-

[1] Present address: Department of Biological Sciences, Florida Technological University, Orlando, Florida 32816.

[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

graphy on Sephadex G-200. Purification was monitored by using polyacrylamide gel electrophoresis.

PREPARATION OF CRUDE "TOXOTOXIN".—The Rh strain of *Toxoplasma gondii* was used to produce peritoneal exudate containing "Toxotoxin" in Yale Swiss mice, according to the methods described by Weinman and Klatchko (1950). The tail vein assay of Weinman and Klatchko (1950) was used to determine toxicity.

GEL ELECTROPHORESIS—Conventional gel electrophoresis was conducted at pH 9.5 in 7% polyacrylamide gel (Canalco) at 5°C in a Buchler Polyanalyst. Each gel contained μg of protein per ml. The method of Lowry et al. (1951) was used to estimate the protein concentration. The gels were run at 2.5 ma per tube until the tracking dye (bromophenol blue) migrated off the gel. The gels were removed from the tubes and stained overnight with 0.5% (w/v) Aniline black in 7% (w/v) acetic acid. Destaining was done electrophoretically in 7.5% (w/v) acetic acid. Line drawings were made of the bands in the gels. Ammonium sulfate precipitation of the crude toxin was conducted according to the methods described by Weinman and Klatchko (1950).

ULTRACENTRIFUGATION—Crude toxin was centrifuged at 40,000 × g for 60 min. in an ultracentrifuge (IEC, model B60, with a swinging bucket head # SB 405) at 4°C. The supernatant was removed and recentrifuged at 150,000 × g in 0.1 M phosphate buffer pH 7.2. Determination of toxicity, protein estimation, and disc electrophoresis were performed according to the methods previously described.

GEL CHROMATOGRAPHY—Sephadex G-200 (Pharmacia Fine Chemicals, Inc., Piscataway, New Jersey) was used. The Column was a K 25/45 Sephadex glass Column with a packed bed height of 63 cm and operated with a Mariotte bottle to give a head pressure of 12 cm. The buffer was a 0.1 M tris-(hydroxymethyl)-aminomethane pH 8.2. Ten ml fractions were collected. Elution patterns were monitored on a Gilson Analyzer (Gilson Medical Electronic, Middleton, Wisconsin) at 280 nm and recorded on a Model PP (Texas Instruments) strip chart recorder. The fractions representing a peak were pooled, dialized against distilled water, and lyophilized. The fractions were reconstituted with physiological saline to one-half original volume. Determination of toxicity, protein estimation, and disc electrophoresis were performed according to methods previously described.

TOXIN PURIFICATION—Crude "toxotoxin" when analyzed with polyacrylamide electrophoresis contained at least 14 different components (Fig. 1). "Toxotoxin", precipitated by ammonium sulfate, is found in the 20-40% saturation fraction (Woodworth and Weinman, 1960). The toxic 20-40% fraction contained 10 components when analyzed with polyacrylamide electrophoresis (Fig. 1).

Ammonium sulfate precipitated crude "Toxotoxin" was subjected to ultracentrifugation at 150,000 × g for 60 min. A toxic fraction was sedimented, which when dissolved in physiological saline, was toxic to mice. The supernatant was non-toxic. Polyacrylamide electrophoresis of this toxic fraction separated 8 components in the fraction (Fig. 1).

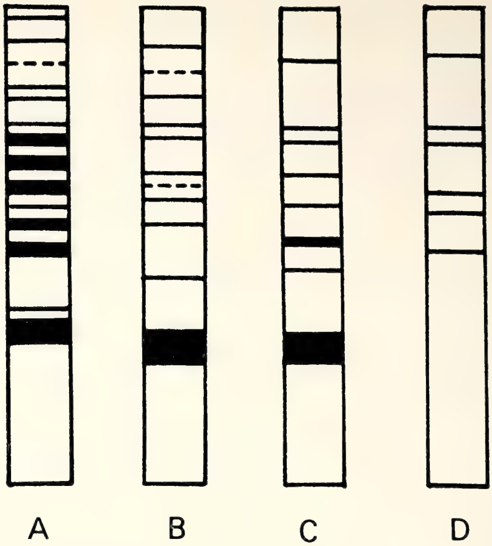


Fig. 1. Diagrammatic representation of polyacrylamide electrophoresis of: (A) Crude "Toxotoxin", (B) 20-40% Ammonium sulfate precipitated crude "Toxotoxin", (C) Toxic fraction of ammonium sulfate (20-40%) precipitated crude "Toxotoxin" sedimented by 150,000 × g, (D) Toxic fraction of ammonium sulfate (20-40% precipitated crude "Toxotoxin" sedimented by 150,000 × g separated on Sephadex G-200.

Gel filtration of the toxic 150,000 × g fraction of ammonium sulfate precipitated crude "Toxotoxin" on Sephadex G-200 resulted in one peak. This one fraction came out in the void volume and was toxic to mice after concentration (Fig. 2). Polyacrylamide gel electrophoresis separated 6 components that were associated with the toxic fraction (Fig. 1).

A summary of the purification procedures used in partial purification of crude Toxotoxin is shown in Fig. 3.

Discussion—Weinman and Klatchko (1950) and Fulton (1965) demonstrated that "Toxotoxin" was non-dializable and that the toxic effect was destroyed by pepsin and trypsin. They speculated that "Toxotoxin" was a large molecular weight protein or a protein complex. We found that "Toxotoxin" is a substance of large molecular weight by using Sephadex gel G-200 and ultra centrifugation. The exclusion limit for the G-200 gel is 800,000. Because "Toxotoxin" was found in the void volume, no exact estimation of molecular weight could be made. The only conclusion possible from the Sephadex gel data is that "Toxotoxin" has a molecular weight in excess of 800,000. "Toxotoxin" was not sedimented by ultracentrifugation at 40,000 × g for 90 min. This datum again indicates a substance of high molecular weight. Analysis by a polyacrylamide electrophoresis of the toxic fraction obtained by ultracentrifugation revealed at least 10 different components.

Pettersen (1970) used a method called ice-filtration to isolate a toxic fraction of extremely high molecular weight from crude "Toxotoxin." He recently speculated that "Toxotoxin" is a large, fibrinous molecule or particle formed by aggregation of smaller molecules.

From this study and the work of others (Fulton, 1965; Pettersen, 1971; Weinman and Klatchko, 1950; Woodworth and Weinman, 1960) one may conclude that "Toxotoxin" is an aggregate of low molecular weight substances which form a complex which is in excess of 800,000. In view of the aggregate nature of the toxin and the strong possibility that it is in reality a mixture of toxic substances, purification to a single chemical substance seems unlikely.

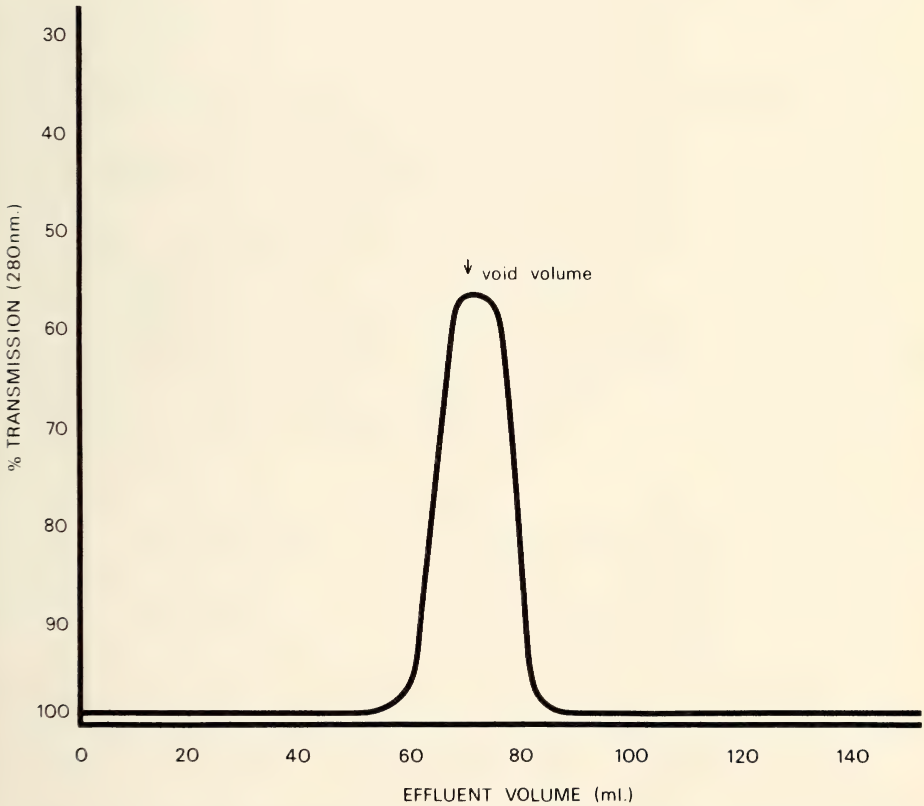


FIG. 2. Gel filtration of the 150,000 × g fraction of ammonium sulphate (20-40%) precipitated crude "Toxotoxin" on Sephadex G-200.

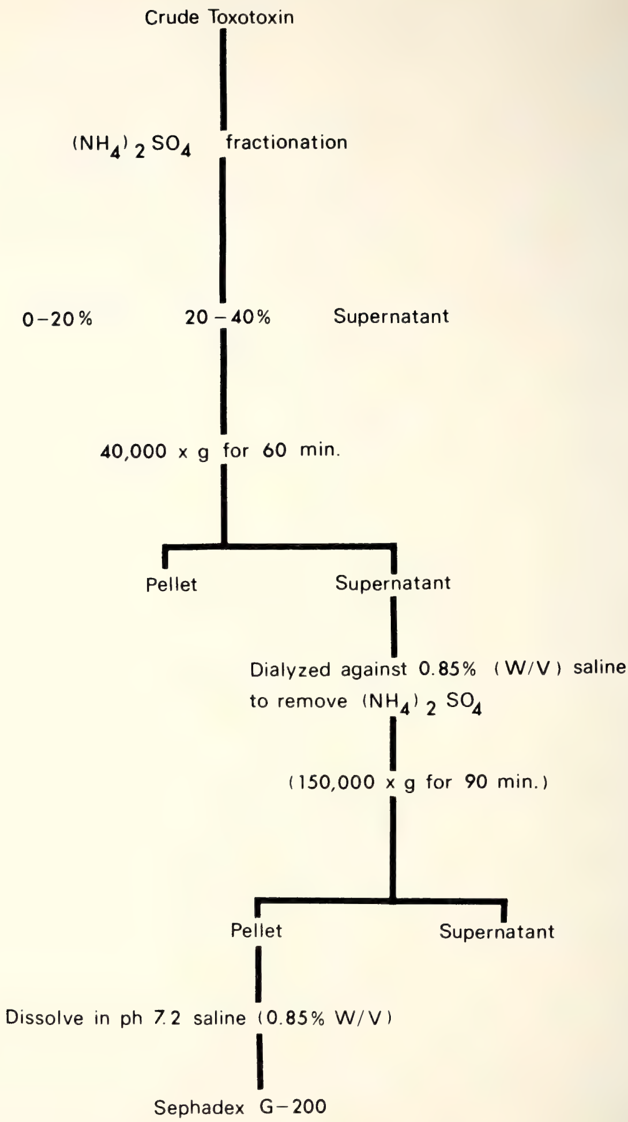


FIG. 3. Flow diagram of the procedure used for preliminary purification of "Toxotoxin".

LITERATURE CITED

FELDMAN, H. A., AND L. T. MILLER. 1965. Serological study of toxoplasmosis prevalence. Amer. J. Hygiene. 64:320-335.

FULTON, J. D. 1965. Toxic exudates in *Toxoplasma gondii* infections. Exptl. Parasitol. 17:252-260.

JACOBS, L., AND A. M. ANASTASIA. 1962. Prevalence of toxoplasma antibodies in rabbits, squirrels and raccoons collected in and near the Patuxent wildlife research center. J. Parasitol. 48:550.

———, M. L. MELTON AND F. E. JONES. 1952. The prevalence of toxoplasmosis in wild pigeons. J. Parasitol. 38:457-461.

Lowry, O. H., N. J. Rosebrough, A. L. Farr and R. J. Randall. 1951. Protein measurement with the folin phenol reagent. J. Biol. Chem. 193:265-275.

Nicolle, C., and L. Manceaux. 1909. Sur un protozoaire nouveau de gondi, toxoplasma. Arch of the Inst. of Pasteur de Tunis. 2:97-103.

Pettersen, E. K. 1970. Isolation of toxotoxin as a large molecule or particle by a method called "ice-filtration". Acta Path. Microbiol. Scand. Section B. 78:669-672.

__________. 1971. An explanation of the biological action of toxotoxin based on some in vitro experiments. Acta Path. Microbiol. Scand. Section B. 79:33-36.

Weinman, D., and H. J. Klatchko. 1950. Description of toxin in toxoplasmosis. Yale J. Biol. and Med. 22:323-326.

Woodworth, H. C., and D. Weinman. 1960. Studies on the toxin of toxoplasma (toxotoxin). J. Infect. Diseases. 107:318-324.

Florida Sci. 41(4):238-243. 1978.

Biological Sciences

STATUS OF THE NAME *SPHAERODACTYLUS CINEREUS* WAGLER AND VARIATION IN "*SPHAERODACTYLUS STEJNEGERI*" COCHRAN

Eugene D. Graham, Jr. (1) and Albert Schwartz (2)

Abstract: Sphaerodactylus cinereus *Wagler is shown to be the name for the Hispaniolan lizard currently called* S. stejnegeri *Cochran. The proper name for the former is* S. elegans *MacLeay.* S. cinereus (sensu nobis) *has 2 subspecies:* S. c. cinereus *which occupies the Cul de Sac plain in Haiti, and* S. c. stejnegeri *which occurs in northern Haiti from Gonaïves east to St. Michel de l'Atalaye, and south along the Golfe de la Gonâve as far as Pont Sondé and St. Marc. No intergrades are known. An isolated population at Plaine Thoman on the northern slopes of the Massif de la Selle remains unnamed.*[0]

One of the 2 most widely distributed sphaerodactyls in Cuba is *Sphaerodactylus cinereus* Wagler. The species long has been known from the Haitian third of Hispaniola, where it is widespread on both the north and south islands (*sensu* Williams, 1961). It has remained unknown from the adjacent República Dominicana until 1975, when a series was taken at the village of Los Pinos, Independencia Province (elev. 520 m). *S. cinereus* has been found on the Florida Keys (Key West, Boca Chica Key), where it presumably was introduced. It occurs also on 2 of the Hispaniolan satellite islands (Ile Grande Cayemite, Ile de la Gonâve) and on islands satellite to Cuba (Isla de Pinos; both the Jardines de la Reina in the south, and the Archipiélago de Sabana-Camagüey in the north). Mittleman (1950) suggested that the Cuban and Hispaniolan populations differed from each other, and that 2 species should be recognized. However, no herpetologist has either checked his results nor followed his suggestion.

Sphaerodactylus cinereus is a moderately large sphaerodactyl (snout-vent length (SVL) maximum 37 mm). It commonly occurs about human habitations,

[0]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

foraging on walls adjacent to electric lights at night. Adults of both sexes are tan to brown dorsally and uniformly flecked with pale spots or striae (buff to yellowish or white). Their venters are often black, especially in males. Juveniles, in contrast to other sphaerodactyls, have many black, bands (5-7 body bands) on a tan ground color and with reddish to orange-red legs, feet, and tail (see Conant, 1975: plate 13); other sphaerodactyls whose juveniles are known hatch having the female pattern. This pattern in males gradually changes to that of the adult, whereas the juvenile pattern may simply become more intense or more blurred in adult females. Thus, despite the fact that adult S. *cinereus* are not sexually dichromatic, they do show a strong ontogenetic change in pattern between young and adults. The differences between juvenile and adult patterns led one author (MacLeay, 1834) to name the juveniles as a distinct species from that of the adults. The name, *elegans* MacLeay, is based upon a Cuban specimen. Two other names, *punctatissimus* Duméril and Bibron, 1836, and *alopex* Cope, 1862, are based upon Haitian specimens (see Schwartz and Thomas, 1975, for complete synonymy of S. *cinereus*).

Several years ago, while Schwartz and Thomas were preparing their check-list of Antillean amphibians and reptiles, Thomas pointed out to the junior author (*in litt.*) that he had checked the original description of S. *cinereus*. The Wagler (1830) name is based upon figure 2 of Lacépède's (1788) "le sputateur." There is no known holotype, but the description and plate are extremely detailed and well executed. The plate (plate 28) must serve as a surrogate holotype. The plate shows a life-sized female (figure 1) and a male (figure 2) gecko. The female is pale in color with an occipital, a nuchal, 2 body, and 1 postsacral dark bands. The tail is strongly banded. This pattern is like that of female "S. *stejnegeri* Cochran." Lacépède (1788), however, considered these lizards as identical to Sparrman's S. *sputatator*, 1784, a rather dissimilar species (see figure 2 in King, 1962) that occurs in the Lesser Antilles from Sombrero Island in the north to St. Christopher and Nevis in the south. Considering the dates of Sparrman and Lacépède's papers and the fact that the species-diversity of *Sphaerodactylus* in the Antilles was still unrealized, it is not surprising that Lacépède thought that his female lizard was identical to Sparrman's S. *sputator*.

It is Lacépède's figure 2 that concerns us more in the present context; there is no doubt that the figure 1 lizard is "S. *stejnegeri*" as that name is now used (Schwartz and Thomas, 1975). The lizard in figure 2 is patternless, although Lacépède's verbal description states that it is much like his "le sputateur" except in color. The total length of this lizard (converted from the English system used by Lacépède) is 55 mm with a tail length of 30 mm; thus, the SVL is 25 mm. Lacépède (1788) also stated that the lizards shown in his figures 1 and 2 are always found together and suggested that the unpatterned lizard was a "sexual variety" of the banded lizard shown in his figure 1.

Adult S. *cinereus* of both sexes are tan to brown and are dotted (see Conant, 1975: plate 13); the dots at time are vaguely aligned into longitudinal rows. They are never "varié par de très-petites ondes d'un brun noirâtre" as Lacépède described his figure 2 lizard. However, some male "S. *stejnegeri*" (for instance

ASFS V44863) show this condition precisely, and another (ASFS V44865) shows this pattern as well as remnant juvenile crossbands; the SVL of these males are 28 mm and 27 mm, respectively. Thus, they are slightly larger than Lacépède's figure 2 lizard. Because Lacépède was studying preserved specimens, he was unaware that males were much more brightly colored than his description indicates. Apparently, he had a single specimen and he placed too much emphasis on a pattern phase that is fugitive in the ontogeny of the males.

We interpret, as did Lacépède, that the 2 geckos shown in his plate 28, represent a male and a female of the same species; neither is *S. sputator* Sparrman. But figure 2 is the holotype of *S. cinereus* Wagler, and that name has been misapplied for some 140 yr to the Cuban-Hispaniolan lizard whose name is properly *S. elegans* MacLeay. The name *S. cinereus* is properly applied to that lizard in Hispaniola that has plain (in preservative) males and contrastingly banded females—namely "*S. stejnegeri*" Cochran (1931).

"*Sphaerodactylus stejnegeri*" has been a relatively rare lizard in collections from the Haitian portion of Hispaniola. It has not been taken in the República Dominicana, yet it probably will eventually be found there. Thomas and Schwartz (1966) studied only 29 specimens of "*S. stejnegeri*" which came from two areas in Haiti: the Pont Sondé area north of St. Marc, and the Cul de Sac plain between Port-au-Prince and the Dominico-Haitian border. The type-locality was slightly emended by them to St. Michel de l'Atalaye, Dépt. de l'Artibonite. The holotype has been the only specimen known from the northern region of Haiti on the Plateau Central. There are 2 paratypes: one from "Southwestern Haiti," a patently incorrect locality, and the other from Thomazeau, Dépt. de l'Ouest, in the Cul de Sac plain. Other than the original description and its repetition by Cochran (1941), very little has been published on "*S. stejnegeri.*" Thomas and Schwartz (1966) assigned it to the *decoratus* (= *nigropunctatus*) complex of Cuban and Bahamian sphaerodactyls and briefly described the scutellation and female pattern. Grant (1944) recognized the sexual dichromatism and briefly quoted notes by Anthony Curtiss concerning the male coloration. Grant presented an excellent photograph of females from Hatte Lathan on the Cul de Sac plain. Ober (1971) refined the description of the female coloration in life and reported the bright colors of the living males. Finally, Schwartz and Garrido (unpublished MS) commented on the similarity between both the female pattern and male coloration of "*S. stejnegeri*" and the Cuban *S. torrei* Barbour, 1914, a species with a limited distribution in the eastern Oriente province. *S. torrei* is also a member of the *nigropunctatus* group, whose headquarters are in Cuba, with one Bahamian member (*S. nigropunctatus* Cope) and one Hispaniolan member ("*S. stejnegeri*"). They considered "*S. stejnegeri*" a relatively recent adventive to Hispaniola from Cuba.

During August 1977, we collected a long series of "*S. stejnegeri*" from several localities between Gonaïves and Ennery in northern Haiti. These are the first specimens from this region and logically can be associated with the holotype. Later, we collected a series from the Cul de Sac plain. The 2 samples differ markedly from each other; the Pont Sondé sample falls with the northern series.

Mertens (1939:figure 29) has an excellent photograph of an adult female (although he considered it a male) from St. Marc. It seems probable, although we do not as yet have specimens to prove the point, that the distribution is basically bipartite, with one population in the north (Gonaïves to St. Michel) and the other in the south (Cul de Sac plain). The 2 are probably connected by a narrow, virtually coastal, population from Gonaïves along the shore of the Golfe de la Gonâve (including Pont Sondé and St. Marc). Thus, the map for the species in Thomas and Schwartz (1966: figure 12) is essentially correct (see also Fig. 1 in the present paper).

FIG. 1. Map of eastern third of Hispaniola (= Haiti) showing locality records for *S. c. cinereus* (solid triangles) and *S. c. stejnegeri* (solid circles). The open triangle represents specimens from Plaine Thoman, whose affinities are predominantly with *S. c. cinereus*, but the specimens may not be that subspecies.

"*Sphaerodactylus stejnegeri*" is a xerophile. Material collected by Anthony Curtis from Hatte Lathan was taken from loose bark on upright trees (pers. comm.). Ober (1971) noted that his Cul de Sac specimens came from the dead branch of a calabash (*Crescentia cujete*). Two series recorded in the Museum of Comparative Zoology from Euax Gaillées were taken "on large trees." All of our recent specimens were taken by native collectors. When shown a preserved female "*S. stejnegeri*", they at once began searching in their houses and under the bark of upright trees. However, "S. *stejnegeri*" also occurs in upland mesic localities as well as xeric lowlands.

Because we feel that "S. *stejnegeri*" is a synonym of S. *cinereus*, we will use the latter name. This species is geographically variable and may be divided, on the basis of pattern, into northern and southern populations. The illustrations in Lacépède (1788) are so well-drawn there is no problem associating them with the southern population of S. *cinereus*. The type-locality and the holotype of "S. *stejnegeri*" conform to the northern population of S. *cinereus*. For the Cuban and Hispaniolan gecko, which has formerly been called S. *cinereus*, there are 3 names available; the earliest and valid name is S. *elegans* Macleay.

Sphaerodactylus cinereus Wagler, 1830
Type locality: St. Domingue (= Haiti). Name based upon Plate 28, Figure 2, in Lacépède, 1788.

Description: A sexually dichromatic species of *Sphaerodactylus* reaching a maximum SVL of 32 mm in both males and females. Males are patternless drab in preservative. Living males have tan to very pale gray bodies and bright yellow-orange heads and tails. Females have 2 black body bands, either boldly outlined with white or very clear pale gray (the dorsal ground color), as well as a black occipital band joined by a pair of canthal lines, enclosing a pale snout which may or may not have a median dark line or figure. There is a black nuchal band. The interspaces between the bands have either fine wavy lines or scribblings, or bold, heavy, or dark interband markings, depending upon the populations. The occipital band may or may not be complete ventrally across the throat. The dorsal scales in axilla to groin distance are 40-61, and the ventrals in the same distance are 27-38. Scales around the midbody are 46-65; fourth toe lamellae are 5-14; supralabial scales to center of eye are usually 4 bilaterally; and internasal scales 0-2. The escutcheon in males is composed of 2-7 × 7-23 scales. The dorsal scales are flattened to slightly swollen, smooth, rounded, and slightly imbricate. The head scales are granular, relatively large, and cobble-like. The dorsal scales have a few large hair-bearing organs on their tips; the ventral scales are smooth, flattened, rounded, and imbricate. The dorsal scales of the tail are smooth, flat-lying, rounded, and imbricate; those beneath the tail are enlarged midventrally. The tail is often swollen and disproportionately broad.

Sphaerodactylus cinereus cinereus, new combination

Description: A subspecies of S. *cinereus* characterized by the combination of (in females) dark body bands broad and boldly outlined with white to pale gray on a gray ground. The bands are typically not lost with increasing size or age. There is a median dark snout line or figure. The interband markings are very dark and coarse. The occipital band extension on the throat is often reduced in adults but is never absent (Fig. 2). Males are unpatterned gray dorsally and tinged with brown or tan anteriorly. The head is yellow dorsally and yellow-orange or orange ventrally. The tails are orange. The juveniles are patterned like females but the interspaces are clear pale gray to pinkish gray. The dark bands extend ventrally and sometimes form almost complete rings around the body. The dark snout markings are absent in young specimens and do not appear until a SVL of about 21 mm is attained.

Variation: The series of 64 S. c. *cinereus* has the following scale counts: dorsals, axilla to groin 41-58 ($\bar{x}$ = 48.7); ventrals, axilla to groin 27-38 ($\bar{x}$ = 31.6); midbody scales 47-65 ($\bar{x}$ = 56.4); fourth toe lamellae 10-14 ($\bar{x}$ = 11.7; M_o = 11 or 12); supralabials to eye-center 4/4 (59 individuals), 4/5 (2); internasals 1 (41 individuals) or 2(22); escutcheon 3-7 × 7-23.

Juveniles are as described above. The ground color is pale gray to pinkish gray, with all body bands prominent and solid black. Markings on the snout and in the interband spaces are lacking. The tail has 3 or 4 dark bands on a pale ground. At about 21 mm SVL, a series of fine wavy lines in the interband spaces begins to develop; these lines become darker and coarser with increasing size. Simultaneously, the dark bands develop clear pale broad edgings. Ventrally, the juvenile bands are lost in adult females, except for the ventral extension of the occipital bands across the throat. This band may become reduced, but it is never lost completely. Likewise, regardless of size, the dorsal body bands (broad with pale edging) are retained. Dorsally, the occipital band lacks a medial notch. The snout has a medial line. Males are as previously described, but 2 males already mentioned are pertinent. ASFS V44865 with a SVL of 27 mm shows vague remnants of the juvenile banding (with pale edges), but this is overlaid with slightly wavy longitudinal lines. ASFS V44863 with a SVL of 28 mm has the bands even fainter, and the longitudinal wavy lines are extremely faint and give a rippled effect to the dorsal pattern. Larger males lack banding remnants and are completely patternless dorsally.

Specimens examined: Haiti, Dépt. de l'Ouest, Port-au-Prince (USNM 121044); Hatte Lathan (MCZ 52158-62, USNM 117165-69, USNM 128145-46); Eaux Gaillées (MCZ 59488-94, MCZ 63172-73, MCZ 84353); Coutard (MCZ 13442); Source Zebeth, rd. to Ganthier (LDO 7-5975-77); 8.3 km E Croix des Bouquets (ASFS V40465, ASFS V44856-82); Thomazeau (MCZ 13481); Manneville (MCZ 123717-18); Gloré (USNM 121044).

Sphaerodactylus cinereus stejnegeri, new combination
Type locality (as emended by Thomas and Schwartz, 1966): St. Michel de l'Atalaye, Dépt. de l'Artibonite, Haiti. *Holotype:* USNM 76640.

Description: A subspecies of *S. cinereus* characterized by the combination of (in females) narrow dark body bands, never outlined by pale edging. The bands tend to become fragmented or lost completely with increasing size. There is no median snout line. The occipital band has a middorsal V-shaped notch and is reduced or absent across the throat in old specimens. The interband markings are fine and gray (Fig. 2). The entire dorsum becomes longitudinally lineate with irregular wavy lines with the disappearance of the black body bands. Males are colored as in *S. c. cinereus*. Juveniles are basically patterned like females but even small specimens have the interband spaces finely and longitudinally lineate and without the clear aspect of juvenile *S. c. cinereus*.

Variation: The series of 97 *S. c. stejnegeri* has the following scale counts: dorsals, axilla to groin 44-61 ($\bar{x}$ = 51.7); ventrals, axilla to groin 29-38 ($\bar{x}$ = 32.0); midbody scales 46-65 ($\bar{x}$ = 57.1); fourth toe lamellae 5-13 ($\bar{x}$ = 10.8; M_o = 11); supralabials to eye-center 4/4 (78 individuals), 3/3 (1), 3/4 (1), internasals 0 (3 individuals), 1 (88), 2 (5); escutcheon 2-6 × 11-23.

Juveniles are banded like adult females. The bands are rather narrow; the interspaces have fine longitudinal striae. The occipital band in juveniles and females has a tiny median V-shaped excision middorsally. With increasing size and the assumption of the adult female pattern, the ground color becomes dark gray. The interband spaces typically are filled with fine longitudinal striae. The body bands are narrow (thus the interspaces are relatively wider than in *S. c. cinereus*) and are not outlined with white or pale gray. Because the ground color is dark gray, the entire pattern seems very subdued and much less contrasting than in the nominate subspecies. At SVLs of 28-30 mm, the dark body bands tend to disappear; some adult females lack the bands completely (ASFS-SVL 32 mm). The ventral extension of the occipital band accross the throat is complete in young adult females. It, however, will disappear completely; the throat then, is marked only with fine dark stipples. The venter is pale yellow in adult females.

Males are dark brown to grayish tan dorsally, with the heads and tails pale yellow to dull orange. The iris is yellow in both sexes. The venter is bright yellow to yellow-orange, with the deepest pigmentation occurring on the throat. This simple pattern and coloration may be modified. Field notes on ASFS V40262 (SVL 23 mm and thus not the largest male) state: "dorsal ground color streaked dark and light grays and brown; snout yellowish; iris pale gray; a white postocular bar followed by 2 lateral black dashes; chin and throat bright yellow with 2 transverse rows of white dots; venter yellowish gray." Con-

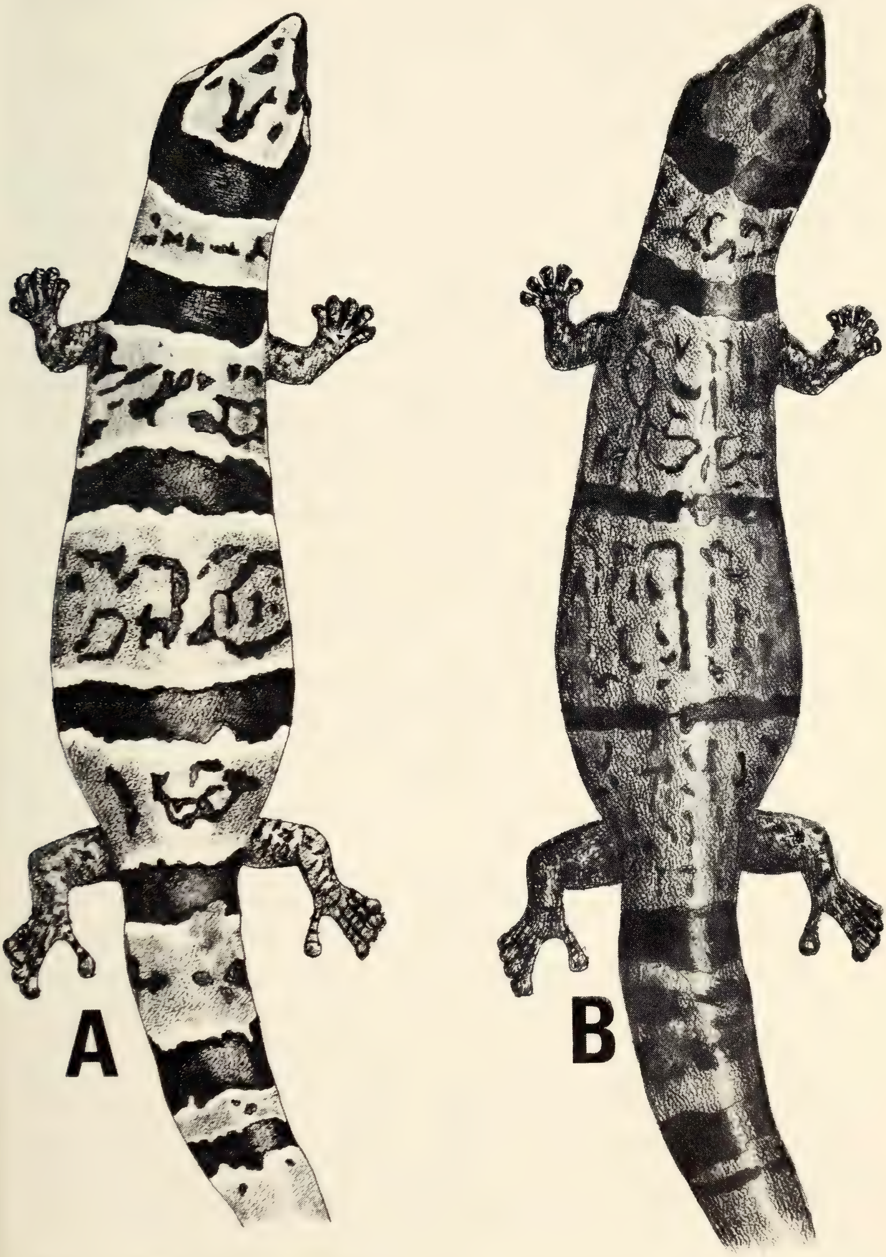


FIG. 2. A. Dorsal view of adult female *S. c. cinereus* (ASFS V44869, SVL 29 mm), from 8.3 km E Croix des Bouquets, Dépt. de l'Ouest, Haiti. B. Dorsal view of female *S. c. stejnegeri* (ASFS V40308, SVL 29 mm), from Ennery, 305 m, Dépt. de l'Artibonite, Haiti.

sidering the size of this specimen and that male S. *c. stejnegeri* reach a maximum SVL of 30 mm, this individual may be changing from the juvenile condition to the adult male unpatterned condition. Still, the pattern is peculiar because all body bands have disappeared except for what appear to be remnants of the occipital band. Some males (ASFS V40162 - SVL 29 mm) are finely dotted dorsally, whereas others (ASFS V40205 - SVL 28 mm) have pale band remnants and longitudinal striae.

COMPARISONS—The 2 subspecies of S. *cinereus* are very distinct in both living and preserved material. The drawing of the holotype of S. *c. stejnegeri* in Cochran (1941:110) shows the characteristics of that population: the disintegrating body bands, the fine striae, the absence of a snout line, and the notched occipital band. However, the broad pale edges to the bands appear to be overemphasized in the drawing. The specimens we have examined from northern Haiti lack the band edgings. The drawing in Thomas and Schwartz (1966:19) shows the southern population (S. *c. cinereus*). It also indicates the broad, entire body bands, the coarse markings between the bands, the presence of some snout markings, and the broad white edges of the bands. Grant's (1949) photographs of the Hatte Lathan specimens are typical of S. *c. cinereus*. Our own figure (Fig. 2) shows females of both populations; both are of the same SVL and the pattern of the S. *c. stejnegeri* has just begun to deteriorate.

The differences in pattern are the basis for recognizing the 2 subspecies of S. *cinereus*. The scale counts for the 2 subspecies are comparable. Means from the body scale counts are slightly higher in S. *c. stejnegeri*. One scale difference is the greater frequency of 2 internasals (35%) in S. *c. cinereus*, in contrast to 5% in S. *c. stejnegeri*. No S. *c. cinereus* lacks an internasal scale, whereas 3 of 97 S. *c. stejnegeri* lack an internasal.

REMARKS—We have left for brief discussion 2 samples of S. *cinereus*. One of these (ASFS V40444-46) is from Plaine Thoman, 11.4 km SE Fond Parisien, 550 m, Dépt. de l'Ouest, Haiti. This sample consists of 1 adult male and 2 adult females. There is nothing distinctive in scutellation or size of these lizards, although 1 female has the maximum SVL (32 mm) of all specimens examined. In life, the females were very dark gray, with wide black bands bordered by pale cream. The male had a yellow head and throat with a pale yellow chin, a throat band, a pale gray postocular band, and the snout was "frosted" with white. The tail was yellow. In all specimens, the venter was pale dull gray. Snout markings are barely discernible in females. The interspaces have scattered markings and are less contrasting than those of S. *c. cinereus* females from adjacent lowland localities. When these 3 lizards are placed with other S. *c. cinereus*, they are at once very conspicuous, most especially the male. Dorsa in all are brown (as preserved), and the female interband markings are fine. Also, the pale edging of the bands in females is narrower than that of "typical" females. We suspect these lizards represent a local subspecies of S. *cinereus* on the northern slopes of the Massif de la Selle. However, we are unwilling at this time to separate them nomenclaturally.

The second sample consists of 1 juvenile, 2 females, and 6 males from Pont Sondé north of St. Marc. On the basis of the female pattern, including band width, interband markings, notched occipital band, and incomplete or almost absent throat band, these specimens are S. *c. stejnegeri* without question. The males are undistinguishable except for 1 (MCZ 59481, SVL 26 mm) which still has vague remnants of the juvenile banded pattern. Although we assign this series to S. *c. stejnegeri*, it stands geographically alone with geographical hiatuses of 35 km to the nearest northern locality and 70 km to the nearest southern locality. Specimens from the intermediate areas are needed before definite conclusions can be made now. It seems that S. *c. cinereus* is limited to the Cul de Sac plain in Haiti (including the northern slopes of the Massif de la Selle?), and that S. *c. stejnegeri* occupies the Plateau Central eastward to the coast near Gonaïves, and thence south as far as the Rivière de l'Artibonite (Pont Sondé; St. Marc).

Specimens examined: Haiti, Dépt. de l'Artibonite, St. Michel de l'Atalaye (USNM 76640—holotype); Ennery, 305 m (ASFS V40162-64, ASFS V40302-12, ASFS V45930-33); 1.9 km W Ennery, 336 m (ASFS V40211, ASFS V40327-29); 17.2 km N Carrefour Joffre, 183 m (ASFS V40428); 17.6 km N Carrefour Joffre, 31 m (ASFS V40438-40); Terre Sonnain, 1.6 km N Les Poteaux (ASFS V40228-40, ASFS V40262, ASFS V40266-99, ASFS V45936-53); Pont Sondé (MCZ 59478-87).

ACKNOWLEDGMENTS—We are grateful to Thomas M. Thurmond for his assistance in the field, and to Ernest E. Williams, George R. Zug, and Ronald I. Crombie for loans of specimens in the Museum of Comparative Zoology (MCZ) and the National Museum of Natural History (USNM). We have also examined specimens from the collection of Lewis D. Ober (LDO). Most specimens are in the Albert Schwartz Field Series (ASFS). Mr. Crombie has been most helpful in matters of older literature. We wish also to thank William S. Fitterman for his illustrations in this paper.

LITERATURE CITED

COCHRAN, D. M. 1931. A new lizard from Haiti (*Sphaerodactylus stejnegeri*). Copeia. 3:89-91.

———. 1841. The herpetology of Hispaniola. Bull. U.S. Nat. Mus. 177.

COPE, E. D. 1882. On the genera Panolopus, Centropyx, Aristelliger, and Sphaerodactylus. Proc. Acad. Nat. Sci. Philadelphia. 13:494-500.

CONANT, R. 1975. A Field Guide to Reptiles and Amphibians of Eastern and Central North America. Houghton Mifflin Co., Boston.

DUMÈRIL, A. M. C., AND G. BIBRON. 1836. Erpétologie générale, vol. 3. Imprimerie et Fonderie de Fain, Paris.

GRANT, C. 1949. Sexual dichromatism in *Sphaerodactylus stejnegeri*. Copeia. 1:74-75.

KING, W. 1962. Systematics of Lesser Antillean lizards of the genus *Sphaerodactylus*. Bull. Florida State Mus., Biol. Sci.

LACÉPÈDE, B. G. E. DE LA VALLE. 1788. Histoire naturelle des quadrupèdes ovipares et des serpens, 1. l'Académie Royale des Sciences, Paris.

MACLEAY, W. S. 1834. A few remarks No. XIV. Proc. Biol. Soc. London. II:9-12.

MERTENS, R. 1939. Herpetologische Ergebnisse einer Reise nach der Insel Hispaniola, Westindien. Abh. senckenberg. naturf. Ges., 449:1-84.

MITTLEMAN, M. B. 1950. Insular variation in the lizard *Sphaerodactylus cinereus*. Herpetologica. 6:60-66.

OBER, L. D. 1971. Redescription of *Sphaerodactylus stejnegeri* Cochran. Quart. J. Florida Acad. Sci. 33:244-246.

SCHWARTZ, A., AND O. H. GARRIDO. The Cuban lizards of the genus *Sphaerodactylus*. II. The *nigropunctatus* group. (unpublished MS)

———, AND R. THOMAS. 1975. A check-list of West Indian amphibians and reptiles. Carnegie Mus. Nat. Hist. Spec. Publ. 1:216 pp.

THOMAS, R., AND A. SCHWARTZ. 1966. The *Sphaerodactylus decoratus* complex in the West Indies. Brigham Young Univ. Sci. Bull. Biol. Ser. 7:1-26.

WAGLER, J. 1830. Naturliches System der Amphibien:vi. J. G. Cotta'schen Buchhandlund, München, Stuttgart, und Tübingen.

WILLIAMS, E. E. 1961. Notes on Hispaniolan herpetology. 3. The evolution and relationships of the *Anolis semilineatus* group. Beviora, Mus. Comp. Zool. 136:1-8.

Florida Sci. 41(4):243-251. 1978.

Biological Sciences

EFFECTS OF PREDATOR STOCKING ON A LARGEMOUTH BASS–BLUEGILL POND FISHERY

FRANK M. PANEK[1]

Rutgers State University, Department of Zoology and Physiology, Newark, New Jersey 07102

ABSTRACT: *After a predator fish* (Esox niger) *was stocked in a 0.23 ha New Jersey pond, there occurred a decrease in population size and standing crop of bluegill* (Lepomis macrochirus), *an increase in abundance and standing crop of largemouth bass* (Micropterus salmoides), *and an increase in the potential harvestability of the fish community. Schumacher–Eschmeyer population estimates for bluegill indicated a 72.9% decrease in abundance 1 yr after stocking chain pickerel* (Esox niger). *At the same time, largemouth bass increased 22.2% in abundance. Standing crop of bluegill decreased 49.2%; that of the largemouth bass increased 24.4%. Biological balance (F/C) decreased from 9.5 - 2.1 and potential harvestability (A_t)* increased from 38.1 - 76.5% from 1970 to 1972.*

POPULATIONS of largemouth bass *(Micropterus salmoides)* and bluegill *(Lepomis macrochirus)* in small ponds are generally unstable and have low potential harvestability (Regier, 1963). Management of these small pond fish communities has been difficult (Swingle, 1947; Wingard, 1955; Dugan, 1956; Hall, 1959; and Regier, 1963). The use of introduced predaceous fishes for controlling overcrowded populations in small ponds has resulted in varying degrees of success. Most studies have involved stocking northern pike, muskellunge, or walleyes in ponds generally not suited for their successful reproduction (Stroud and Jenkins, 1962; and Moorman and Kowalski, 1966). The chain pickerel *(Esox niger)* will reproduce in many ponds in New Jersey (Stewart, 1971), and its feeding habits are largely piscivorous (Raney, 1942; Foote and Blake, 1945; Karvelis, 1965; Carlander, 1969; and Warner, 1972). The ecological impact of chain pickerel predation in a small pond bass–bluegill community and the species potential use in fish management were studied.

MATERIALS AND METHODS—The study pond (Ryan's Pond) is located within the Highlands Subarea of the Appalachian Province in Morris County, New Jersey. It is part of the Black River Fish and Wildlife Management Area. The pond has a maximum depth of 2.9 m, mean depth of 1.2 m, maximum length of 68.3 m, and a surface area of 0.23 ha.

The bass–bluegill community of the pond was censused prior to stocking in October and November of 1970 and in September and October of 1972 subsequent to stocking. In July 1971, 12.7 kg/ha of chain pickerel at a density of 65/ha were stocked in Ryan's Pond. The fish were obtained from Canistear Reservoir and Lake Wawayanda under an agreement with the New Jersey Division of Fish, Game and Shellfisheries. The age–group composition of the stock was 13.3% young of the year and 40%, 33%, and 13% fish in the second, third and fourth year classes.

---

[1] Present address: New York State Dept. of Environmental Conservation, State Office Building, Watertown, New York 13601.

* The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked *"advertisement"* solely to indicate this fact.

Shumacher–Eschmeyer population estimates were determined following the techniques of Schaefer (1951). Fish were captured by shoreline seining with a 21.3 m standard seine (1.3 cm mesh) and a 18.3 m bag seine with a 0.65 mm mesh bag. Fish less than 100 mm total length (TL) were finclipped, while individuals 100 mm and larger were tagged with a Floy R67F anchor tag. Tags were modified by removal of the pennant to minimize loss of tags by fish in heavy vegetation. Time intervals of 3-5 da were maintained between samples, allowing marked individuals to redistribute throughout the population.

Age-group distributions were determined from scale analysis. The percent relative abundance of each age-group was determined from mean weights for each age-group and the estimated number of fish in that age-group.

New Jersey modified F/C and A_t values (Stewart, 1971) were used as measures of biological balance and potential harvestability. A F/C ratio between 1.4 and 10.0 is typical of a balanced fish community. Potential harvestability (A_t) is a measure of the percent standing crop of harvestable size. An A_t value greater than 40% is considered satisfactory with values between 60 and 85% being acceptable by New Jersey criteria.

Results and Discussion—Population estimates and standing crop values for bluegill indicated a 72.9% decrease in abundance and a 49% decrease in standing crop subsequent to predator stocking. Shumacher-Eschmeyer population estimates, including standard errors, were 8001 $\pm$ 891/ha in 1970 and 2164 $\pm$ 251/ha in 1972. The standing crop was estimated at 113.6 kg/ha in 1970; this decreased to 57.8 kg/ha in 1972. The population age structure and biomass distributions for bluegill in 1970 and 1972 are in Table 1.

The largemouth bass population was not adversely affected by the pickerel. Population estimates and standing crop values indicate a 22.2% increase in abundance and a 24.4% increase in standing crop during the study. Population estimates were 841 $\pm$ 55/ha in 1970 and 1028 $\pm$ 176/ha in 1972. The standing crop was estimated at 40.6 kg/ha in 1970 and 50.4 kg/ha in 1972. Population age structure and biomass distributions for largemouth bass from 1970 and 1972 illustrate low mortality and increased reproductive success following predator stocking (Table 2).

A 1970 prestocking F/C ratio of 9.5 and its associated harvestability of 38.1% indicate biological balance with unsatisfactory potential yield (Table 3). In 1972, the F/C and A_t values were 2.1 and 76.5%, respectively, indicating a biological balance with desirable harvestability (Table 3). The improved F/C ratio in 1972 results from a 72.9% decrease in abundance of bluegills and a 22.2% increase in abundance of largemouth bass. The increase in potential harvestability in 1972 resulted from a combination of the following factors: 1) the attainment of harvestable size by a dominant age-group of largemouth bass, 2) the contribution of introduced pickerel to the fishery, and 3) a major numerical reduction of non-harvestable bluegills.

A reproducing population of chain pickerel was established at Ryan's Pond subsequent to stocking in 1971. In 1972, the population was estimated at 67 $\pm$ 4/ha with 51.5% of the population comprised of young of the year. Chain pickerel were found to spawn both during the spring and fall of 1972. This unusual reproductive pattern has been previously reported in New Jersey (McCabe, 1958).

TABLE 1. Population age structure, percent relative abundance, and percent standing crop of *Lepomis macrochirus* at Ryan's Pond during 1970 and 1972.

Year:	1970		1972	
Age-Group	Relative Abundance	Standing Crop	Relative Abundance	Standing Crop
O	45.8	10.6	44.3	10.3
I	15.6	8.3	10.3	3.7
II	14.6	16.3	13.5	9.3
III	11.9	17.6	5.4	7.0
IV	11.5	33.6	4.9	9.7
V	0.6	3.5	16.2	41.8
VI			5.4	18.2

Table 2. Population age structure, percent relative abundance, and percent standing crop of *Micropterus salmoides* at Ryan's Pond during 1970 and 1972.

Year:	1970		1972	
Age-Group	Relative Abundance	Standing Crop	Relative Abundance	Standing Crop
O	59.5	8.0	72.3	7.6
I	16.7	20.2	1.7	1.7
II	12.5	31.8	5.9	10.4
III	11.3	40.0	13.6	40.8
IV			5.9	32.6
V			0.8	6.9

TABLE 3. New Jersey modified F/C ratio and A_t values for the fishery at Ryan's Pond during 1970 and 1972.

Year:	1970		1972		
Species	Bluegill	Bass	Bluegill	Bass	Pickerel
Standing Crop (kg/ha)					
Harvestable	42.8	16.0	40.3	40.5	13.1
Nonharvestable	70.8	24.5	17.5	9.9	1.9
Totals	113.6	40.6	57.8	50.4	15.0
Population Size:	8001	841	2164	1028	67
F/C Ratio:	9.5		2.1		
A_t:	38.1		76.5		

Ponds in New Jersey can support small populations of chain pickerel, usually about 14 kg/ha (Stewart, 1971). This low standing crop coupled with failure to reproduce may eliminate the species under intense angling pressure. Because reproduction for this species was successful at Ryan's Pond, a mechanism is needed to regulate predator harvest. Although the 15-inch minimum size limit in New Jersey has not met with success in large lakes (Smith and Gross, 1955), a size regulation may be warranted for the perpetuation of a small pond fishery utilizing pickerel for management. Further study is needed to fully assess the efficiency of chain pickerel in controlling overcrowded bluegills.

LITERATURE CITED

Carlander, K. D. 1969. Handbook of Freshwater Fishery Biology, Vol. 1. Iowa State Univ. Press, Ames.

Dugan, R. F. 1956. Farm fish ponds in West Virginia. West Virginia Univ. Agr. Exp. Sta. Circ. 84.

Foote, L. E., and B. P. Blake. 1945. Life history of the eastern pickerel in Babcock Pond, Connecticut. J. Wildl. Mgmt. 9:89-96.

Hall, J. F. 1959. Final report on the success of largemouth bass-bluegill and largemouth bass-shell-cracker rates and ratios in Kentucky Farm Ponds. Proc. SE. Assn. Game Fish Comm. 12:91-116.

Karvelis, E. G. 1965. The true pikes. U.S. Fish Wildl. Serv., Fish Bull. 569.

McCabe, B. C. 1958. Tabular treatment of the life history and ecology of the chain pickerel. Masters thesis. Springfield Coll., Massachusetts.

Moorman, R. B., and R. E. Kowalski. 1966. For better fishing-control fish populations in farm ponds. Iowa Farm Sci. 21:5-7.

Raney, E. C. 1942. The summer food habits of the chain pickerel *(Esox niger)* of a small New York pond. J. Wildl. Mgmt. 6:58-66.

Regier, H. A. 1963. Ecology and management of largemouth bass and bluegills in farm ponds in New York. New York Fish Game J. 10:1-89.

Schaefer, M. B. 1951. Estimation of the size of animal populations by marking experiments. U.S. Fish Wildl. Serv., Fish. Bull. 69.

Smith, R. F., and R. W. Gross. 1955. An evaluation of the fifteen inch minimum size limit on pickerel in three New Jersey lakes. New Jersey Division of Fish, Game, and Shellfisheries, Fish. Lab. Misc. Rept. 15.

Stewart, R. W. 1971. Studies of the standing crops of fish in New Jersey lakes and ponds. New Jersey Division of Fish, Game, and Shellfisheries, Fish. Lab. Misc. Rept. 34.

Stroud, R. H., and R. M. Jenkins. 1962. Predator stocking ineffective. SFI Bull. 127.

Swingle, H. S. 1947. Management of farm fish ponds. Alabama Polyt. Inst., Agr. Exp. Sta. Bull. 254.

Warner, K. 1972. Further studies of fish predation on salmon stocked in Main lakes. Progr. Fish. Cult. 34:217-221.

Wingard, R. G. 1955. Fish in your farm ponds. Pennsylvania State Univ., Agr. Ext. Circ. 452.

Florida Sci. 41(4):252-255. 1978.

Outstanding Scientist Award

CITATION FOR JOHN EDWARD DAVIES

It was Florida's good fortune that a Welsh general practitioner accepted an assistant professorship in the Division of Preventative Medicine at the University of Miami in 1962. This Welsh practitioner, Dr. Davies, immediately became very actively involved in a great array of fields bearing on health throughout the state, and in many cases, throughout the nation and the world. He has become a foremost authority on the effects of environmental variables upon human biology and health.

His most extensive research pertains to pesticides—acute pesticide poisoning, occupational and general population exposure, pesticide-induced genetic defects, transplacental passage of pesticides, association of drugs and pesticides, effects of liver enzyme induction and pesticides, occurrence, diagnosis and treatment of organophosphate pesticide poisoning in man, human cancer and pesticides, pesticide poisoning in South Florida, pesticide problems in developing countries, global pesticide transport, pest management, et cetera.

Dr. Davies is also engaged in studies of serum copper and zinc, polychlorinated biphenylis, organochlorine, and trace metal levels in human carcinogenesis. He is studying the epidemiology of hemoglobinopathies in U.S. and foreign populations, heart attack prevention and intervention and the cause of high incidence of lung cancer in northeastern Florida. His research also extends to drug addiction in Dade County and its relationship to crime, health problems of migrant workers in Florida, and sickle cell disorders in the school population of Dade County.

Another segment of his involvement on health care and epidemiology is his directorship of research in the Department of Family Medicine in the island of Bimini.

While still in Wales, his studies of chronic brucellosis in the rural community of over three thousand for which he was the lone practitioner, resulted in his receipt of the award of the British Medical Association Annual prize for best systematic observational research and record in General Practice in the United Kingdom. His sojourn as Assistant Health Officer of the City of Winnipeg, Canada, before coming to the United States saw Dr. Davies engaged with the epidemiologies of multiple sclerosis, hepatitis, and poliomyelitis. He has worked on malarial control for the Pan American World Health Organization and on pesticide problems for the government of Indonesia.

Dr. Davies serves on numerous commissions, committees and panels of the U. S. Department of Health, Education and Welfare, the Department of State, the Department of Agriculture, the Environmental Protection Agency, the International Epidemiological Association, the United Nations World Health Organization, the Comprehensive Cancer Center for the State of Florida, the National Research Council, and the National Academy of Sciences.

The Florida Academy of Sciences takes great pleasure and satisfaction in awarding its 1978 Medal to the University of Miami's Professor of Medicine and Chairman of the Department of Epidemiology and Public Health, *Dr. John Edward Davies.*

INSTRUCTIONS TO AUTHORS

Individuals who publish in the *Florida Scientist* must be active members in the Florida Academy of Sciences.

Submit a typewritten original and one copy of the text, illustrations, and tables. All typewritten material—including the abstract, literature citations, footnotes, tables, and figure legends—shall be double-spaced. Use one side of 8 1/2 × 11 inch (21 1/2 cm × 28 cm) good quality bond paper for the original; the copy may be xeroxed. Margins should be at least 3 cm all around. Number the pages through the Literature Cited section. Avoid footnotes and do not use mimeo, slick, erasable, or ruled paper. Use metric units for all measurements. Assistance with production costs will be negotiated directly with authors of papers which exceed 10 printed pages of text.

ADDRESS follows the author's name.

ABSTRACT—All manuscripts shall have a short, concise, single-paragraphed abstract. The abstract follows immediately the author's address.

ACKNOWLEDGMENTS are given in the body of the text preceding immediately the Literature Cited section.

LITERATURE CITED section follows the text. Double-space every line and follow the format in the current issue.

MANUSCRIPTS of 5 or less, double-spaced typewritten pages should conform to the short article protocol. See recent issue for proper format of both long and short articles.

TABLES shall be typed on separate sheets of paper, double-spaced throughout. Each table shall contain a short heading. Do not use vertical rulings. Maximum character width, including spaces, of tables is 98.0. This includes a minimum space of 5 characters between columns. Tables are charged to authors at $25.00 per page or fraction.

ILLUSTRATIONS—All drawings shall be done in good quality India ink, on good board or drafting paper. Letter by using a lettering guide or equivalent. Typewritten letters on illustrations are unacceptable. Drawings and photographs should be large enough to allow 1/3 to 1/2 reduction in size. Photographs shall be glossy prints of good contrast. Whenever possible, mount photographs in lots size.

The author's name and figure number should be penciled lightly on the back of each figure. Figure legends must be listed on a separate page and *not* on the drawing or photograph. The legend must be double-spaced. Illustrations are charged to authors at $20.00 per page or fraction.

PROOF must be returned promptly. Notification of address change and proofreading are the author's responsibility. Alterations after the type has been set will be charged to the author.

REPRINTS may be ordered from the printer on forms provided when the corrected proofs are returned to the Editor.

Membership applications, subscriptions, renewals, changes of address, and orders for back numbers should be addressed to the Executive Secretary, Florida Academy of Sciences, 810 East Rollins Street, Orlando, Florida 32803.

PUBLICATIONS FOR SALE

by the *Florida Academy of Sciences*

Complete sets. Broken sets. Individual numbers. Immediate delivery. A few numbers reprinted by photo-offset. All prices strictly net. No discounts. Prices quoted include postage.

PROCEEDINGS OF THE FLORIDA ACADEMY OF SCIENCES (1936-1944)
Volumes 1-7—$10.00 per volume; single numbers $3.50
QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES (1945-1972)
Volumes 8-35—$10.00 per volume; single numbers $3.50
FLORIDA SCIENTIST (1973-1975)
Volumes 36-38—$10.00 per volume; single issues $3.50
except for symposium numbers priced separately.
Volumes 39 onward—$13.00 per volume; single numbers $4.25 except for symposium numbers priced separately.
Florida's Estuaries—Management or Mismanagement?—Academy Symposium
FLORIDA SCIENTIST 37(4)—$5.00
Land Spreading of Secondary Effluent—Academy Symposium
FLORIDA SCIENTIST 38(4)—$5.00
Solar Energy—Academy Symposium
FLORIDA SCIENTIST 39(3)—$5.00 (includes do-it-yourself instructions)

Individual orders should be sent with payment. A statement will be sent in response to a bona fide purchase order over $10.00 from a recognized institution. Address all orders to:

The Florida Academy of Sciences, Inc.
The John Young Museum
810 East Rollins Street
Orlando, Florida 32803

Do your friends a favor—invite them to join the Florida Academy of Sciences.

Florida Scientist

Volume 40 Supplement 1

Program Issue

THE FORTY-FIRST ANNUAL MEETING OF THE ACADEMY

in conjunction with
THE FLORIDA JUNIOR ACADEMY OF SCIENCE
and
THE FLORIDA SECTION OF
THE AMERICAN ASSOCIATION OF PHYSICS TEACHERS

featuring the General Sessions
CAN FLORIDA AFFORD PHOSPHATE MINING?
CAN FLORIDA SURVIVE A HURRICANE?

and the banquet program
INTERACTION BETWEEN APPLIED AND PURE SCIENCE:
Searching for Superheavy Elements

The University of Florida
Gainesville, Florida
March 24, 25, 26

1977

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES
PROGRAM ISSUE PRICE $2.00

FLORIDA ACADEMY OF SCIENCES OFFICERS
1976-1977

TABLE OF CONTENTS

INVITE YOUR FRIENDS AND COLLEAGUES TO JOIN THE ACADEMY AND ATTEND THE MEETING

PUBLISHED BY

Florida Academy of Sciences, Inc.

810 East Rollins Street • Orlando, Florida 32803

FORTY-FIRST ANNUAL MEETING OF THE FLORIDA ACADEMY OF SCIENCES

at

THE UNIVERSITY OF FLORIDA, GAINESVILLE, FLORIDA

24,25,26 MARCH 1977

All registrants for the Senior and Junior Academy meetings and the meeting of the American Association of Physics Teachers are welcome to attend all sessions of all organizations, including the banquet.

The University of Florida

The University is located near the center of Gainesville, at the intersections of State Road 26 (University Avenue) and U.S.441 (13th Street). The meeting hotel (Flagler Inn) is also on that intersection. The University can be approached from north or south on U.S. 44, from the east on State Road 20 which joins S.R. 26, or from the west (I-75) on S.R. 26.

Limousine (cab) service from the airport to the University and Flagler Inn is usually $2.00. Confirm the price with the driver.

The maps on the back cover show approaches to the University, and parking areas.

Registration

A registration desk will be set up in the Flagler Inn from 7:30-9:30 pm on Thursday, March 24. On Friday and Saturday, the registration desk will be located in Little Hall.

The registration fee is $5.00 for members and $7.00 for non-members. This fee is waived for students.

Lodging

Blocks of rooms have been reserved until 10 march 1977 for FAS members and guests. Only the Flagler Inn is within walking distance of the University. All rates are subject to tax.

Flagler Inn (904) 376-1661
W. University Ave. & N.W. 13th St.
P.O. Box 1406
Gainesville, Fl 32601
(Single/$17, Double/$22+$4 each
for additional persons)

Ramada Inn (904) 376-1692
I-75 & S.R. 26
Gainesville, FL 32601

Econo-travel Motor Hotel (904) 378-2346
I-75 & S.R. 26
Gainesville, Fl 32601
(1 person-1 bed $9.95)(2 persons-1 bed $12.95) (2-4 persons-
2 beds $15.95)

Food Service

The University cafeteria in the Reitz Union will be serving during the meetings. There are also a number of restaurants on W. University Ave. within walking distance of the Flagler. There is also a fine Chinese restaurant, the Joy Loy, near the I-75 & S.R. 26 motels. Other restaurants are nearby. Except for the Econo-Travel, all hotels mentioned have dining facilities.

Academy Banquet and Cocktails

The banquet will be held at the Flagler Inn at 7:30 pm , Friday, March 25. The cost is $5.94 per person. A cocktail hour beginning at 6:30 pm will precede the banquet. Drinks will be $1.40.

FIELD TRIP

Meet at the Flagler Inn parking lot at 1:00 pm, Saturday, March 26. Trip will last until approximately 5:00 pm. Travel will be by private car. Drivers are asked to cooperate in taking passengers. Please register at the registration desk.

Stops will include:

Paynes Prairie. geologic, hydrologic, zoologic, botanic, and anthropologic features.

Austin Cary Forest. University of Florida Center for Wetlands Study of cypress domes and their use for treated waste disposal.

Devil's Millhopper. the geological processes and botanical significance of one of the largest sink holes in the United States.

Local Arrangements Committee

Chairman----------William R. Maples

Annual Banquet----Leslie S. Lieberman

Audio-Visual------Richard Franz

Publicity,
Refreshments------Barbara Purdy

Registration------Elizabeth Sarris

PROGRAM OF EVENTS

Thursday pm, 24 March 1977

3:00	Council Meeting	Flagler Inn
7:30 - 9:30	Registration	Flagler Inn

Friday am, 25 March 1977

8:00 - 11:45	Anthropology Section	Little Hall 203	p. 2
- 11:45	Biology Section: A. Marine and FreshWater Biology I.	207	p. 9
- 10:15	Earth and Planetary Section: A. Geology and Hydrology I.	215	p. 21
- 12:00	Physics and Astronomy Section	219	p. 31
- 11:30	Science Teaching Section	221	p. 36
- 11:30	Social Sciences Section	223	p. 38
8:30 - 11:30	Agricultural Section	201	p. 1
- 11:30	Atmospheric and Oceanographic Section	205	p. 6
- 12:00	Chemistry Section	213	p. 18
- 11:45	Medical Section	217	p. 28
9:45	Business Meeting: Anthropology	203	
	Business Meeting: Atmospheric & Oceanographic	205	
	Business Meeting: Physics & Astronomy	219	
10:00	Business Meeting: Agriculture	201	
	Business Meeting: Biology	207	
	Business Meeting: Chemistry	213	
	Business Meeting: Science Teaching	221	
	Business Meeting: Social Sciences	223	
10:30 - 11:45	Earth and Planetary Section: B. Geochemistry	215	p. 23
11:45	Business Meeting: Medicine	217	

Friday pm, 25 March 1977

1:00	ANNUAL BUSINESS MEETING OF THE ACADEMY	101	
1:30	GENERAL SESSION	101	
3:15 - 5:00	Biology Section: B1. Botany	207	p. 12
- 5:15	Biology Section: B2. Physiology & Microbiology	227	p. 13
3:30 - 4:45	Earth and Planetary Sciences Section: C1. Geology and Hydrology II.	215	p. 25
- 4:45	Earth and Planetary Sciences Section: C2. Environment	225	p. 26
- 5:00	Anthropology Section	203	p. 5
- 4:30	Atmospheric and Oceanographic Section	205	p. 8
4:45	Business Meeting: Earth and Planetary Section	215	
6:30	Social Hour	Flagler Inn	
7:30	ANNUAL ACADEMY BANQUET	Flagler Inn	

Saturday am, 26 March 1977

8:30 - 11:15	Biology Section: C. Marine & FreshWater Biology II	207	p. 15
- 10:15	Physics and Astronomy Section	219	p. 35
10:15 - 11:30	American Association of Physics Teachers	219	p. 39
11:30	Business Meeting: American Association of Physics Teachers	219	

Saturday pm, 26 March 1977

1:00	ACADEMY FIELD TRIP	Flagler Inn (parking lot)

GENERAL SESSION

Friday, 25 March 1977

Little Hall 101 Auditorium

1:30 to 2:20 pm CAN FLORIDA AFFORD PHOSPHATE MINING?

A Dialogue Between

William H. Taft
Director of Graduate Studies
and Sponsored Research
University of South Florida

AND

Homer Hooks
Executive Director
The Phosphate Council

2:30 to 3:15 pm CAN FLORIDA SURVIVE A HURRICANE?

Niel L. Frank
National Hurricane Center
Coral Gables, Florida 33124

Are we building toward a hurricane disaster in Florida? This question is being asked by many officials who are concerned with the tremendous increase in our coastal population. Can we provide adequate warnings? We now have population concentrations where people may not be given enough lead time to take the necessary precautions. If the right severe hurricane develops, we could have an historical death toll.

AGRICULTURAL SCIENCES SECTION

Friday 8:30 am Little Hall 201

David Hubbell, University of Florida, presiding

8:30 am AGS-1. Nitrogen and Phosphorus Release from Pond Sediments After a Drawdown, Donald A. Graetz, William T. Haller and James E. Struble, Soil Science Department, 106 Newell Hall, University of Florida, Gainesville, FL 32611. Nitrogen and P released from sediments collected from a small pond subjected to a drawdown were determined by a laboratory incubation study. Sediment samples were selected based on extent of dryness and/or extent of exposure to air. Nitrogen released ranged from 269 μg/gm from air dried sediment to 3,079 μg/gm for undried, but exposed to air, sediment. Corresponding values for P ranged from 134 to 803 μg/gm. Calculations taking into account sediment density and active depth show that these release rates are well above the often quoted dangerous loading levels of 2.0 and 0.13 g/m^2 lake surface area for N and P respectively. In fact, a severe algae bloom was observed upon refilling the pond.

9:00 am AGS-2. The Role of Mycorrhizae in Vegetation Changes in Abandoned Farmland in the Everglades, RAYMOND E. MEADOR, Dept. of Botany, University of Florida, Gainesville, FL 32611. Mycorrhizae, a symbiosis between plant roots and fungi, can influence the direction of succession on abandoned farmland in the Everglades. I examined the mycorrhizal status of five successional and two mature ecosystems (sampling 20 plant species in each site) and found that mycorrhizal species dominated the successional sites while the glade ecosystem which had previously occupied the site is dominated by non-mycorrhizal plants: a rare case in natural terrestrial ecosystems. Farming practices may have altered the glade soils permitting mycorrhizal plants, which may outcompete the non-mycorrhizal glade vegetation, to become established.

9:30 am AGS-3. Mechanism of action of alfalfa residues incorporated in soil on *Sclerotium rolfsii*, RONALD M. SONODA, University of Florida, IFAS Agricultural Research Center, Fort Pierce, P.O. Box 248, Ft. Pierce, Fl 33450. *Sclerotium rolfsii* propagules were added to cultivated sandy soil in petri dishes to which alfalfa residues had been added. Propagules introduced on the day residues were incorporated and those added up to 7-8 days thereafter were killed. Propagules added after this time grew normally. Although the saponin in alfalfa inhibits growth of *S. rolfsii* in vitro, it appeared that the heat-stable alfalfa saponins were destroyed or deactivated within 24 hours after the residues were incorporated in soil. The period in which fungus death occurred coincided with a period of pH increase in the soil and a parallel increase in ammonia content of the soil. The pH of the soil decreased to below the initial pH by the eighth day after the residues were incorporated. It is postulated that ammonia played a major role in the death of *S. rolfsii* propagules under the conditions of the study.

Friday 10:00 am Agricultural Sciences Section Business Meeting

BREAK

10:30 am AGS-4. Developing an Integrated Pest Management Program for Florida Celery. C. A. Musgrave, S. L. Poe, and G. H. Smerage. Department of Entomology and Nematology, 3103 McCarty Hall, University of Florida, Gainesville, FL 32611 An interdisciplinary team of University of Florida researchers are in their second year of studying celery pest problems near Zellwood and Belle Glade, FL. Rather than recommending only chemical control of various plant pathogens, mites, insects, weeds, and nematodes on celery, the group is working on four objectives of pest management: 1) to identify key pests, describe their population dynamics and interactions with competitors and natural enemies, 2) to regulate these key pests economically and effectively with appropriate pest management tactics, 3) to minimize harmful effects to the environment, and 4) to produce high yields of quality celery. These objectives are being used to develop a systems model of the entire celery pest management problem that may be applied, with modifications to pest problems encountered in other Florida vegetable crops.

11:00 am AGS-5. Effect of Environmental pH on the Attachment and Infectivity of Curly-top Virus in Pepper, Capsicum annuum L, ALEXANDER A. CSIZINSZKY, Agric. Res. & Education Ctr., 5007-60th St. E., Bradenton, Fl 33505. Early events following inoculation in the movement and attachment of labeled curly-top virus (CTV) in resistant and susceptible pepper seedlings were investigated Macro and micro autoradiography studies revealed that the ^{35}S label remained localized in the tissues where the insect vector was feeding. Light microscopic autoradiography, using cytidine-5-^{3}H label indicated that the virus is transported in the phloem, and 2 h after inoculation appeared to be attached to the nuclei of the phloem parenchyma cells in the various plant organs. There were no differences in the movement and attachment of virus between resistant and susceptible peppers. The results suggest that the hydrogen ion concentration, in the different plant tissues and in the body fluid and saliva of the insect vector, is the major factor regulating the stability of nucleocapsids, and the infectious and non-infectious forms of CTV.

Friday 11:30-1:00 pm LUNCH

Friday 1:00 pm, Little Hall 101

Annual Business Meeting of the Academy

GENERAL SESSION--Friday 1:30-3:15 pm Little Hall 101

Friday 7:30 pm Flagler Inn, BANQUET

ANTHROPOLOGICAL SCIENCES SECTION

Friday 8:00 am Little Hall 203

Prudence M. Rice, University of Florida, presiding

8:00 am ANS-1 Weeden Island Pottery from the McKeithen Site, Florida, PRUDENCE M. RICE and TIMOTHY A. KOHLER, Department of Anthropology, University of Florida, Gainesville, Fl. 32603. A program of technological analysis of Weeden Island pottery from the McKeithen site in Columbia County is beginning as one facet of a larger program of investigation into the nature of Weeden Island culture in Florida. The results of preliminary petrographic and trace element studies of this pottery are discussed, as are directions for future research.

8:15 am ANS-2 Archeology in the Ancient City: Past, Present and Future, KATHLEEN DEAGAN, Department of Anthropology, Florida State University, Tallahassee, Fl, 32603. A new era in St. Augustine archeology has occurred since 1972, when the initiation of "backyard archeology" by Charles Fairbanks took place. The goals and achievements of this era are outlined, as well as the new theoretical realizations which have shaped present goals and will shape future research in the Ancient City.

8:30 am ANS-3 Preliminary Excavations at a 16th Century Spanish-Utina Mission Station in North Florida, JERALD T. MILANICH, Florida State Museum, Gainesville, Fl. 32611. During the Spring, 1976, the University of Florida Archeological Field School excavated portions of a Spanish mission site (8-Su-65) believed to have been founded shortly after 1587 and abandoned early in the 17th century. Between five and ten of these visitas were established among various western Timucuan tribes by Franciscan priests who traveled inland from their coastal missions on Cumberland Island, Georgia, and St. Augustine. When permanent missions with resident priests were established after ca. 1610, the visitas were abandoned and the Christianized Indians moved to the new missions. This pattern--late 16th century establishment, short-term occupation, and abandonment--fits the data recovered from the site. The two-week excavations focused on the badly eroding Spanish church and the convent, both of which were completely exposed.

Also investigated was a structure within the associated aboriginal village which may have been a work area for skinning and smoking deer hides. Numerous postmolds and smudge pits, many filled with charred corncobs, were associated with the structure.

8:45 am ANS-4 Stone Implements of Prehistoric Florida, BARBARA A. PURDY, Department of Social Sciences, University of Florida, Gainesville, Fl. 32611. A stone tool kit can be recognized for each major time period that has been documented in Florida. This paper describes the typical stone implements associated with the Paleo Indian, Dalton, Preceramic Archaic, and Ceramic Periods. It is cautioned that the chronology assigned to the stone industries in Florida, particularly on the early time levels, is an assumed one based on typological similarities to stone remains from areas outside of Florida.

9:00 am ANS-5 Computer Applications for Distribution Analyses of Faunal Remains at the Maximo Park Beach Site, St. Petersburg, Florida, M.J. ANDREJKO and J. RAYMOND WILLIAMS, Department of Anthropology, University of South Florida, Tampa, Fl. 33620. This study is an initial effort in developing an easier and more accurate method for data analyses of shellfish remains in coastal middens. Marine molluscan remains recovered from a shell midden complex at the Maximo Park Beach site were compared with representative modern marine fauna of the Boca Ceiga Bay area. This allowed for an attempt at reconstruction of both environmental utilization patterns and ecological conditions for the Archaic Period occupancy of the site. Faunal analyses demonstrate that animal resources utilized near the site today were available at the time of occupation. Change in percent distribution of individual species through depth, is demonstrated.

9:15 am ANS-6 New Thoughts on Indian River Prehistory, MARILYN C. STEWART, Department of Behavioral Sciences, Rollins College, Winter Park, Fl. 32789. Excavations are being carried out on sites in the middle St. Johns area. Recent work on a shell mound suggests some unusual patterns of similarities and differences of sites in this area and implications for the prehistory of the Indian River.

9:30 am ANS-7 Archeological Research Strategy: Paynes Prairie State Preserve, ROCHELLE MARRINAN, Department of Anthropology, Georgia Southern College, Statesboro, Ga. 30458, and SUE MULLINS, Department of Anthropology University of Florida, Gainesville, Fl. 32611. In March of 1976, the University of Florida was commissioned by the Florida Division of Archives, History and Records Management to undertake an archeological survey of the Paynes Prairie State Preserve. This survey of approximately 2500 acres in the 17,000 acre Preserve, was carried out in what is considered to be one of the most unique environmental areas of Florida. A research strategy was designed to adequately exploit and represent what was felt would be one of the richest archeological regions in Florida. This paper will examine the methodology and results of the survey.

9:45-10:15 am Business Meeting of the Anthropological Sciences Section

BREAK

Friday 10:15 am Little Hall 203

William E. Carter, University of Florida, presiding

10:15 am ANS-8 Sociocultural Drug Use Research Strategies in San Jose, Costa Rica, DR. BRIAN PAGE, Department of Anthropology, University of Florida, Gainesville, Fl. 32603. Drug use research has concentrated traditionally on medical, psychiatric, and psychological aspects of drug use phenomena. Socio-cultural drug use studies have recently contributed to holistic understanding of human drug use patterns. A transdisciplinary study of Cannibis use in San Jose, Costa Rica centrally included anthropologists in its research design. Field observation and life history materials, combined with other sociocultural data yielded the study's most significant differentiations between user and non-user groups.

10:30 am ANS-9 Coca, Cocaine, and Racism in the American South and South America, RODERICK E. BURCHARD, Visiting Assistant Professor, Department of Anthropology, University of Florida, Gainesville, Fl. 32603. This paper examines some of the many parallels in the covert and overt racism present in the scientific and popular literature concerning the use of cocaine by blacks in the American South and the use of coca leaf by Indians in South America at the turn of the present century.

10:45 am ANS-10 Street vs. Clinic: Differences in Drug Research Approaches, WILLIAM R. TRUE, Department of Psychiatry, University of Miami, Miami, Fl. 33124. Contrasting access to study population of drug users reveals striking differences in the kind, quantity and quality of data gathered. Street access seems to provide evidence about the function of drug use in society while clinic access accentuates pathological aspects of social adjustment. Research results will be examined from Miami, Florida and San Jose, Costa Rica.

11:00 am Anthony Paredes, Florida State University, presiding

11:00 am ANS-11 Drugs and South African Students: Attitudes and Use, BRIAN M. duTOIT, Department of Anthropology, University of Florida, Gainesville, Fl. 32603. Testifying before the U.S. House of Representatives Select Committee on Crime, the director of a youth service program which provides services to 1,800 school age children from Dade and Broward Counties stated that "ninety percent of our kids have been well into downs - barbiturates, tranquilizers. That is the dangerous thing of today". This paper will report on drug use and attitudes about drugs held by South African students of all ethnic backgrounds. Their views and patterns of use will be compared with information for other comparable samples.

11:15 am ANS-12 Maritime anthropology in Florida: An overview and prospects for the future, MARCUS HEPBURN, Department of Anthropology, University of Florida, Gainesville, Fl. 32603. While Florida has one of the longest coastlines as well as a thriving seafood industry, research by anthropologists of this rich and varied area has been relatively slight. Though recent work carried out through the University of Florida and Florida State University on small gulf coastal fishing communities has helped to remedy this lacunae, there remains many areas in need of study. Tarpon Springs and St. Augustine are both communities with strong fishing traditions among ethnically identifiable groups. More recently, Miami has become the site of a fast-developing Cuban immigrant fishing fleet whose economic position, as well as those of other fishermen in the area, has been jeopardized by the closing of large areas to U.S. fishermen by the Bahamian government. While some of these communities above, and others, hold especial interest for ethnohistorically oriented research, the prospects for anthropologists to make a positive contribution to the management and administration of the Florida fisheries is increasing.

11:30 am ANS-13 Hurricanes and Anthropologists, ANTHONY PAREDES, Department of Anthropology, Florida State University, Tallahassee, Fl. 32306. On September 23, 1975, Hurricane Eloise hit the Florida Panhandle, causing extensive property damage and the evacuation of thousands. Several months later social scientists, sponsored by the State University System of Florida Sea Grant Program, conducted a study of the social impact of Hurricane Eloise on Panama City. This paper describes the role of anthropology in that study, presents some of the results of the study, and provides suggestions for the future involvement of anthropologists in disaster research in Florida.

11:45-1:00 pm LUNCH

Friday 1:00 pm Little Hall 101

Annual Business Meeting of the Academy

Patrick J. Gleason, President, presiding

Friday 1:30-3:15 pm Little Hall 101

GENERAL SESSION

Friday 3:30 pm Little Hall 203

Leslie Sue Lieberman, University of Florida, presiding

3:30 pm ANS-14 Levy County-TAHRG Community Resource Initiative in Preventive Health Care, OTTO vonMERING, Department of Anthropology, and CHARLES MAHAN, Department of Obstetrics and Gynecology, University of Florida, Gainesville, Fl. 32603. Scientific and pedogogical dimensions of community health care require an integrated approach to preventative medicine which involves parents, students, and schools. The program's primary target is the development of positive, active early preventative health care attitudes and skills among 10th and 11th grade teenagers. The application of scientific knowledge about the acquisition of health knowledge and care to meet community needs is emphasized.

3:45 pm ANS-15 Anthropological Evaluation of a Community Health, Self-Care Learning Program, CAROL ALBERT, KATHERINE HAGEN and MICHELLE LAPORE, Department of Anthropology, University of Florida, Gainesville, Fl. 32603. Concepts and results of an innovative community health program are reviewed in the context of a North Florida county where public schools and county health department worked with University of Florida faculty and students. In particular, this paper will evaluate the experience developed in the middle and high school setting in training students in health self-care learning. The program has particular significance for populations with limited direct access to medical centers.

4:00 pm ANS-16 Salivary Amylase Activity in Samoan Migrants, LESLIE SUE LIEBERMAN, Department of Anthropology, University of Florida, Gainesville, Florida, 32603. Whole saliva was collected from (200) adults and children in three communities of Samoan migrants in Hawaii. Amylase isoenzymes were separated by electrophoresis on cellulose acetate membranes. Measurements were made of amylase activities and protein content. As compared to reports of other populations, Samoans have a reduced number of a-amylase isoenzymes and standard levels of salivary amylase and protein. The results do not support the genetotrophic hypothesis linking high starch diets with high levels of salivary a-amylase. However, the biochemical variables are related to genetic, geographic, socio-cultural and dietary changes in the three communities.

4:15 pm ANS-17 The Rhesus Monkeys of Florida, WILLIAM R. MAPLES, Florida State Museum, University of Florida, Gainesville, Fl. 32611. The continuing investigation of the population of rhesus monkeys in the area of Silver Springs, Florida, will be discussed. Rhesus monkeys were introduced in 1936 during the filming of a Tarzan movie. This ongoing study is producing important information on the adaptation of these animals to the Florida habitat.

4:30 pm ANS-18 What Do Primates Eat?, E.H.SARRIS, Department of Anthropology, University of Florida, Gainesville, Fl. 32608. Accurate, specific information about the diet of free ranging non-human primates is limited. Florida's own free ranging rhesus monkeys (*Macaca mulatta*) are contributing to knowledge in this field.

4:45 pm ANS-19 Some Notable Dental Distinctions Among Early Hominids, MICHAEL J. HANSINGER, Department of Anthropology, University of Florida, Gainesville, Fl. 32611. The distribution of the length and breadth variates of the cheek teeth of early African hominids was analyzed, together with samples of *Ramapithecus* and *Homo erectus*. Results showed that for most of the time between 14 and 2 million years ago, the cheek teeth were specialized for very large size. For most hominid groups, the cheek teeth were absolutely large when compared with the fully "human" *Homo erectus*, or relatively large for the estimated body weights of the populations themselves. With an average body weight of not over 20 kg., *A. Africanus* for example, had teeth the size of female gorillas' averaging 75 kg.

Friday 7:30 pm Flagler Inn, BANQUET

ATMOSPHERIC AND OCEANOGRAPHIC SCIENCES SECTION

Friday 8:30 am **Little Hall 205**

Robert C. Sheets, National Hurricane and Experimental Meteorology Laboratory, **presiding**

8:30 am AOS-1 Project STORMFURY, Recent Results and Future Plans, ROBERT C. SHEETS, National Hurricane and Experimental Meteorology Laboratory, P. O. Box 8265, Coral Gables, Fl 33124. Investigations of means of modifying hurricanes to decrease their destructive forces continues. No actual seeding experiments have been conducted since 1971. However, results from recent field investigations support the potential for modification as hypothesized for the STORMFURY experiments. That is, convective elements which have the potential for growth through seeding appear to exist in the proper locations within the hurricane. New state of the art instrumentation and aircraft are scheduled to be completed for field operations in 1977. One seeding experiment may be conducted in 1977 with the full program resumed in 1978.

8:45 am AOS-2 Hurricane Modeling with Explicit Latent Heat Release, STANLEY L. ROSENTHAL, NOAA-National Hurricane & Experimental Meteorology Laboratory, Box 8265, Coral Gables, Fl 33124. Our recent work indicates that we may be able to dispense with the problem of cumulus parameterization entirely when horizontal resolution is a few 10's of kilometers. We have successfully modeled hurricane development to a mature steady state in which the convective release of latent heat is computed explicitly from the resolvable moisture budgets. Reexamination of the models of the early 1960's, that attempted to proceed with explicit calculations of latent heat release and failed, indicates that the failures resulted from weaknesses in *model design* and because of model crudities (as measured by standards of today). The failures were not intrinsic to the *concept* of explicit latent heating as is indicated by a number of authors in the middle and late 1960's.

9:00 am AOS-3 Results of Cloud Seeding for Rain Enhancement in Florida, WILLIAM L. WOODLEY, Cumulus Group, National Hurricane and Experimental Meteorology Laboratory, P. O. Box 248265, Univ. of Miami Branch, Coral Gables, FL 33124. The Florida Area Cumulus Experiment (FACE) is a research experiment aimed at determining the feasibility of augmenting natural convective rainfall over an area by seeding groups of supercooled convective clouds near their tops. After obtaining 75 days of randomized experimentation, there is persuasive evidence that dynamic seeding as employed in FACE is effective in altering cloud behavior and increasing their rainfalls. There are also indications that these localized increases in rainfall result in a net increase in the rainfall over the target area ranging in magnitude between 20 and 50%. These results and other relevant aspects of the FACE program will be discussed.

9:15 am AOS-4 Altitude corrections for airborne infrared radiometer measurements of sea surface temperature, PETER G. BLACK, National Hurricane and Experimental Meteorology Lab., Box 8265, 1365 Memorial Drive, Coral Gables, Fl 33124. A least-squares extrapolation technique is outlined which allows sea surface temperature to be estimated from airborne infrared radiometer measurements at several levels in the vertical. The extrapolated sea surface temperatures are compared with independent estimates obtained by integrating the radiative transfer equations. Aircraft-derived vertical sounding data is used in the integrations. The average absolute difference between the extrapolated and integrated estimates was .07°C below 400 m aircraft altitude and .22°C between 400 m and 1200 m aircraft altitude. Although the measurements used in the study were made in the vicinity of three hurricanes, it is felt that the results are general enough to use in any maritime tropical environment.

9:30 am AOS-5 Determination of Nighttime Sky Brightness Over East-Central Florida, E. F. STROTHER, D. M. SHARPE, and R. F. FRITSCHE, Department of Physics and Space Science, Florida Institute of Technology, Melbourne, Florida 32901. By employing a highly stable, cooled cathode (PMT) photoelectric system and photometry techniques, the brightness of the night sky can be readily determined. This information is a rather sensitive optical atmospheric measure of the quality of sky conditions and is of importance in both Astronomy and the Space Sciences in determining the limiting magnitude of stellar objects or orbiting space hardware, respectively, which can be observed and photographed. Representative values of sky brightness expressed in magnitudes per square arc second will be presented under a variety of atmospheric seeing conditions.

9:45 am Business Meeting of the Atmospheric and Oceanographic Sciences Section

BREAK

10:30 am Little Hall 205

Raymond C. Staley, Florida State University, presiding

10:30 am AOS-6 The Use Of Wide Band Photoelectric Photometry To Characterize The Transparency Of The Night Sky In The Cape Area Of Central Florida.* E.F. STROTHER, J.H. BLATT, Florida Institute of Technology, Melbourne, Fl 32901 and W.C. SCHUPP, Range Measurements Lab, Eastern Test Range, PAFB, Fl 32925. While atmospheric transparency can be understood in terms of Rayleigh Scattering and molecular absorption bands, other factors and meteorlogical variables, such as humidity, air mass type, particulate matter, ocean aerosols, and pollution all contribute spacial and temporal complexities which can not be predicted theoretically. Therefore, a systematic program based on the regular observations of selected stars has been established in order to monitor and calculate the atmospheric extinction coefficients in visible light for Eastern Central Florida. Techniques of analysis and graphical results will be presented from the on-going program in atmospheric optics being conducted at Florida Institute of Technology. *Supported in part by A.F. Contract FO 8606-74-C-0050.

10:45 am AOS-7 A Practical Method for Determining Radon Concentrations in Air, RICK HENRY, Department of Nuclear Engineering, University of Florida, Gainesville, Florida, 32611. A project to determine radon concentrations caused by emanations from phosphate rock throughout Florida has led to the development of a simple and relatively inexpensive method for determining radon concentrations. These may be found by collecting a sample of air in a small transparent container which has been coated with ZnS(Ag) scintillator and counting it with a calibrated photomultiplier. After field and laboratory testing of several types of scintillation cells, a design by HASL was chosen. Several calibration techniques were tried. The best results were obtained using a pneumatic collection bottle. Several cells can be calibrated simultaneously. Radon determinations throughout Florida's phosphate district have been made using this technique.

Work supported by Florida Phosphate Council.

11:00 am AOS-8 Establishing Radon Flux and Concentration Levels, M. R. TATE, R. HENRY, AND N. SAVANI, Department of Nuclear Engineering Sciences, University of Florida, Gainesville, Florida, 32611. Two procedures, activated charcoal cannisters and drum trapping, are currently being used to detect radon-222 diffusion from the ground. Air circulation and duration of trapping were examined for the drum method in order to arrive at an optimum sampling technique. Concentrations were obtained, using the drum trapping method, with minimum limits of detection amounting to fractions of a pCi/ℓ. Flux measurements were calculated from concentration levels. Charcoal cannisters implanted for extended lengths of time to give average fluxes. Both methods have been deployed on reclaimed phosphate lands. Studies conducted by the Health and Safety Laboratory of U.S.E.R.D.A. and the University of Florida indicate satisfactory agreement between laboratories.

Work supported by Florida Phosphate Council

11:15 am AOS-9 Statistical Analysis of Radon Measurements at the Earth-Air Interface, NOORALI K. SAVANI, Department of Nuclear Engineering Sciences, University of Florida, Gainesville, Florida 32611. This paper is concerned with radiation exposure associated with emanation of radon from the ground with particular emphasis on a statistical analysis of the radon source. A drum sampling technique was employed on a site at the University of Florida. Data obtained from the samples were examined for variations caused by (1) spacing between sources, (2) time between samples, (3) spacing and time, and (4) changes of source strength. A statistical model was formulated to establish how many drums needed to be implanted and how many times each drum should be sampled in order to ascertain the radon emanation rate at any desired level of confidence. This model can be applied to any sampling technique.

Work supported by Florida Phosphate Council.

11:30-1:00 pm LUNCH

Friday 1:00 pm Little Hall 101

Annual Business Meeting of the Academy

Patrick J. Gleason, President, presiding

Friday 1:30-3:15 pm Little Hall 101

GENERAL SESSION

Friday 3:30 pm Little Hall 205

Robert C. Sheets, National Hurricane and Experimental Meteorology Laboratory, presiding

3:30 pm AOS-10 Some evidence of circulation response to local winds in two north Florida estuaries, RAYMOND C. STALEY, Department of Oceanography, Tallahassee, Fl 32306. Limited summer and fall current, salinity and temperature data from Pensacola and Apalachicola Bays show that local winds may almost overwhelm tidal motion, producing anomalous circulation in both bays.

3:45 pm AOS-11 A model of wind-driven circulation in a shallow lagoon. P.S. Dubbelday, R.W. Nenart, Florida Inst. of Tech., Melbourne, Fl. 32901. -- This paper proposes a model for a vertical circulation cell generated in a shallow basin by a steady wind, at low Reynolds number. By assuming zero stress at the rectangular boundaries to replace the usual no-slip condition it is possible to separate the pertinent biharmonic equation into a sequence of two harmonic problems, for which an analytic solution was determined. The ensuing profiles are in qualitative agreement with laboratory measurements of other investigators, and the value of the surface current can be made to reproduce field observations by reasonable values for the eddy viscosity coefficient and wind stress. It is felt that this model may serve as a starting point for more refined closed models of the vertical circulation in shallow waters, and as a check on numerical schemes for solving similar models with more realistic boundary conditions, and parametrization of the turbulent state.

4:00 pm AOS-12 Measurement of Water Turbidity by a Photogrammetric Modulation Transfer Function, JOHN W. SHELDON, Florida International University, Miami, Fl 33199. A simple underwater camera-light source-target system which can be used to determine photogrammetric modulation transfer functions is described. The device retains the simplicity of a Secchi disk, but has the following additional advantages: 1) Produces a permanent record of the result; 2) Data can be recorded and partially interpreted by an unskilled observer; 3) It can be used at variable depth. Use of the instrument is demonstrated by observing the temporal variation in the turbidity of water in southern Biscayne Bay during the passage of a barge-tug vehicle.

4·15 pm AOS-13 A Comparison Between the Summer Algal Communities Inhabiting Offshore Platforms on the Louisiana and Northwestern Florida Nearshore Continental Shelves, THERESA M. MUELLER, M.R.I.T. Box 2545, Fl. Coop. Ext. Serv., Key West, Fl 33040. The marine algal community of the U.S. Navy Stage II platform off Panama City, Florida was compared with that of the offshore petroleum platforms on the nearshore continental shelf Louisiana. Sixty-six species were collected from the Stage; 18% Cyanophyta, 44% Rhodophyta, 12% Phaeophyta, and 26% Chlorophyta. Hydrographic characteristics closely resembled those of Bert's (1976) Offshore Subprovince Under the Influence of the Mississippi River Discharge Plume but the algal community, though more diverse, was more similar to that of the Offshore Subprovince beyond the influence of coastal runoff. However, the character of the flora exhibits far more tropical elements than any other in the northern Gulf of Mexico. The proportion of Phaeophyta in the flora is indicative of regions in the tropics. Differences are attributed to several unique features in the environment surrounding the Stage.

Friday 7:30 pm Flagler Inn, BANQUET

BIOLOGICAL SCIENCES SECTION

Friday 8:00 am Little Hall 207

Sheldon Dobkin, Florida Atlantic University, presiding

Session A: MARINE AND FRESH-WATER BIOLOGY I

8:00 am BS-1 Mate Preference Studies of *Gambusia affinis*, the Common Mosquitofish, MARY ELLEN AHEARN, Jacksonville University, Jacksonville, Fla. 32211. Four sets of experiments concerning mate preference of *Gambusia affinis* were conducted. The first set tested the preference of males for females based upon deme, the second set of tests were based upon the size of the female. The third and fourth sets of experiments tested melanistic and non-melanistic males with "normally" pigmented females from the same deme and from different demes. Melanistic males were found to have a higher frequency of mating attempts than "normally" pigmented males.

8:15 am BS-2 An inexpensive Custom Multiple-Use Tag Suitable for Marine Studies, JAMES A. BOHNSACK, Department of Biology, University of Miami, Coral Gables, Fl. 33124. A method is described for making inexpensive, weatherproof numbered tags of desired size, shape and color. Tags can be attached by various methods and have been successfully tested on fish, crabs, and mollusks. Tags are easy to make and can be labeled as desired. A binomial coding method is described by which tags can be read even after excessive abrasion.

8:30 am BS-3 An Ethological Study of Cleaning Symbiosis on a Caribbean Limestone Bench, LINDA B. MCGREGOR, Dept. of Zoology, Univ. of Fl., Gainesville, Fl., 32601. A study of a cleaning station in the Bahamas occupied by fifteen *Thalassoma bifasciatum* and one *Pomacanthus paru* revealed a diurnal cycle of activity, with a peak of activity from 0600 to 0700 AM. The host fish *Acanthurus bahianus* exhibited a pattern of color change which is dependent upon the entering color phase of the fish. The colors may be communicative signals in that fish entering or turning dark are cleaned more frequently than fish in the light phase, and fish blanch prior to departing. The ecology of the area and its effect on the symbiotic interactions are discussed.

8:45 am BS-4 The Relative Importance of Predation on Infauna in the York River, Virginia and the Indian River, Florida. ROBERT W. VIRNSTEIN, Harbor Branch Institution, RFD 1, Box 196, Ft. Pierce, Fla. 33450. Wire-mesh cages were used to exclude large mobile predators (crabs and fish) from areas of subtidal soft sediments. These experiments have been done in the York River, Virginia and in the Indian River, Florida. The density of benthic infauna increased in exclosures much more in the York River than in the Indian River. This difference in response is attributed to the greater abundance in the Indian River of small decapod predators which could move through the wire mesh and were thus not effectively excluded from cages.

9:00 am BS-5 The effect of particle size frequency distribution of the substratum on the burrowing ability of Chiridota rigida (Semper) (Echinodermata: Holothuroidea). J. M. LAWRENCE AND J. MURDOCH, Univ. of South Florida, Tampa 33620. Chiridota rigida (Semper) burrows easily into well-sorted substrata, moving between particles in coarse substrata and pushing aside particles in fine substrata. Chiridota rigida does not burrow easily into poorly sorted substrata because spaces which can be penetrated are not available and because the particles cannot be moved as a result of increased stability of the substratum. In poorly sorted substrata, burrowing ability increased with increases in the proportion of fine particles. It would appear that the distribution and abundance of Chiridota rigida and other chiridotids would be affected by the effect of the substratum on their ability to burrow. Work done at the Mid-Pacific Marine Laboratory, Enewetak, Marshall Islands. The study was supported by ERDA No. AT(26-1)-628.

9:15 am BS-6 The Suitability of the Bivalve Donax variegatus as an Adequate Nutritional Source for the Starfish Luidia clathrata, PAULA DEHN, Biology, Univ. of So. Fla., Tampa, 33620.--Luidia were collected in December and July from Tampa Bay. The former contained gonads and the latter did not. Both groups were maintained in the laboratory (for 6 and 4 months respectively) and fed Donax. In both cases the digestive gland indices of the laboratory animals were greater than the field animals sampled at the same time. The gonad indices of the laboratory animals showed little or no development. This suggests that Donax is more suitable for somatic growth than gonadal growth, although other factors may have affected the gonadal development.

9:30 am BS-7 Comparison of Blue-Green Algal Mats in the Everglades, LEONARD J. GREENFIELD AND LINDA WIENER, Biology Department, University of Miami, Coral Galbes, Fl 33124. During the summer, 1976, selected locations in Dade Co. were surveyed for species and quantity of blue-greens and associated forms. Wherever a mat exists, there is prodominance of Scytonema crispum and Schizothrix calcicola. A considerable variation in numbers and form was observed in different locations. This was correlated with such disturbances as land clearance, spoil banks, and farming resulting in changes to algal form and soil chemistry. Continued study is necessary to determine whether correlations are based on cause by these factors or natural annual sequences.

9:45 am BS-8 Halodule wrightii: A Preliminary Model of Seasonal Dynamics and Responses to Environmental Factors, N.J. EISEMAN, Harbor Branch Foundation RFD 1, Box 196, Ft. Pierce, FL 33450. A quantitative study of the standing stocks of the seagrass Halodule wrightii was made from June 1974 to July 1975 at five stations in the Indian River lagoon. It was found that the seasonal variation in standing stocks could be described by a polynomial equation. During 1976 additional samples were taken to test the predictive capability of this equation. Multivariate analysis of standing stocks vs. environmental factors shows light energy and temperature to be the most significant variables determining standing stocks and shoot density. Salinity changes have a strong effect on the standing stock of the photosynthetic blades. The preexisting state of the population is important in determining standing stocks of non-photosynthetic tissue.

10:00 am Business Meeting of the Biological Sciences Section

BREAK

10:30 am BS-9 Seasonal Occurrence and Variation in Standing Crop of a Drift Algal Community in the Indian River, CHARNER BENZ, Harbor Branch Foundation, Rt. 1, Box 196, Ft. Pierce, Fl. 33450. Quantitative collections of unattached macroalgae were made monthly from September 1975 through August 1976 at three stations in seagrass beds near Ft. Pierce. Major species include Dictyota dichotoma, Acanthophora spicifera, Hypnea cervicornis, H. musciformis, and Spyridia filamentosa. Chondria tenuissima occurs as a winter-spring dominant. Species composition at the study site differs from the makeup of drift species in several other areas of Florida where these algae have been studied. Multiple regression analysis of total biomass verses the environmental parameters, temperature, salinity, and light energy, showed little correlation with any one factor. Variables appeared to have a synergistic effect on standing crop, with a multiple correlation coefficient of 0.61. Seasonal changes in standing crop of major species are discussed.

10:45 am BS-10 Benthic Macrofaunal Associations in Lake Worth, Florida, JOHN K. REED, Harbor Branch Foundation, Rt. 1, Box 196, Ft. Pierce, Florida 33450. Bimonthly benthic samples taken at 11 stations provide quantitative reference data on the estuarine benthic communities of Lake Worth in Palm Beach County, Florida. Distribution and structure in relation to sediment types and sources of pollution were studied. One hundred seventy-one taxa were identified. Stations were grouped as sand, silty-sand, mud, and outfall stations based on similarity of faunal composition and sediment type. The sand and silty-sand stations had the highest diversity (H') and species richness (spp/180) values. The mud and outfall stations had low H' and spp/180 values which were similar to values reported for pollution-stressed areas in other studies.

11:00 am BS-11 Problems and Potentials of Amberjacks (Pisces: Carangidae, Seriola spp.), FREDERICK H. BERRY, National Marine Fisheries Service, 75 Virginia Beach Drive, Miami, FL 33149. Five species of amberjacks live in the western Atlantic Ocean, and four of these are common around Florida. Problems and potentials for effective use and management of these fishes are projected. Problems: Literature is meager and confused; species are unknown to or confused by fishing and fisheries research communities; biological parameters are very inadequately known, especially those fundamental to fishery management; some individual amberjacks have been indicted in ciguatera and others have obvious parasites; and there is no extant effective program to resolve these problems. Potentials are very high for this multiple-use, essentially untapped, marine fishery resource.

11:15 am BS-12 The Distribution of Infaunal Gammaridean Amphipods in Hillsborough Bay, Florida, KRIS W. THOEMKE, Department of Biology, University of South Florida, Tampa, Fl. 33620. Approximately 35 gammaridean amphipod species have been observed in subtidal core samples taken in Hillsborough Bay. The majority of species are infaunal tube builders or burrowers. The local distribution of these species appears to be controlled by the type of substratum present. About 20-30% of these predominate in muddy bottoms while the remaining species are primarily restricted to sandy bottoms. Densities vary considerably and for some species may exceed 100,000/m^2. Of the 35 gammarids, 4 species are numerically dominate.

11:30 am BS-13 Results of Marine Turtle Studies at the Merritt Island National Wildlife Refuge, Summer, 1976,* L. M. EHRHART, Florida Technological Univ., Orlando, Fl 32816 AND R. G. YODER, U.S. Fish and Wildlife Service, Box 6504, Titusville, Fl 32780. Studies of the marine turtle rookery at the Merritt Island NWR, Brevard County, Florida, were continued for a fourth year in the summer of 1976. Three green turtles (Chelonia mydas) and 318 loggerheads (Caretta caretta) were measured, tagged, weighed and released on a 40 km stretch of beach, as a result of 53 nightly patrols from 18 May to 20 August.

We estimate, with 95% confidence, that 598 $\pm$ 130 loggerheads nested at least once at Merritt Island in 1976. Mean weights of loggerheads (117.3 kg) and green turtles (131.1 kg) were similar to those observed in previous years. Means of carapace and plastron measurements were also similar to those observed previously. Notes regarding weight and length changes, season length and nesting intensity, and re-emergence intervals are also included.
*Research supported by NASA contract NAS10-8986; U.S. Fish & Wildlife Service.

11:45-1:00 pm LUNCH

Friday 1:00 pm Little Hall 101

Annual Business Meeting of the Academy

Patrick J. Gleason, President, presiding

Friday 1:30-3:15 pm Little Hall 101

GENERAL SESSION

Friday 3:15 pm Little Hall 207

Session B1: BOTANY

Daniel F. Austin, Florida Atlantic University, presiding

3:15 pm BS-14 The Phytogeographic History of Cayo-Costa Island, Lee County, Florida, S.R.HERWITZ, New College, Sarasota, Fl 33580. A comprehensive phytogeographic study of Cayo-Costa Island was completed via photointerpretation techniques and extensive ground-truthing. Topographic profiles were correlated with the twelve habitats recognized on the basis of dominant plant associations. Eight of these plant communities were found to represent stages in the two patterns of succession operative on the Island. The undisturbed nature of the vegetation facilitated the identification of truncation lines between discrete beach-ridge sets. Based on the inferred chronology of these ridge sets, and on geomorphogenetic trends observed in Hydrographic Charts since 1863 and aerial photographs since 1944, a correlation between Cayo-Costa Island's phytogeographic succession and geomorphic history is proposed.

3:30 pm BS-15 Observations and analysis of *Melaleuca quinquenervia* in Florida, Jeanne M. Hall, Box 386, Eckerd College, St. Petersburg, Florida 33733. The exotic *Melaleuca quinquenervia* (cajeput or punk tree) has evolved into a controversial species due to its extremely rapid and successful adaptation to central and southern Florida ecosystems. This study analyzes the development of *Melaleuca* in Florida's native environments. Among the factors considered are populations of anoles, ants, beetles, and spiders that inhabit the *Melaleuca*, the interrelationship of *Melaleuca* with soil salinity and water and the effects of *Melaleuca's* invasion of plant communities. Particular emphasis will be on disturbed and undisturbed mangrove sites.

3:45 pm BS-16 Comparison of transpiration of cajeput (Melaleuca quinquenervia) and sawgrass (Cladium jamaicense), TAYLOR R. ALEXANDER, RONALD H. HOFSTETTER AND FRANCES PARSONS, Department of Biology, University of Miami, POB 249118, Coral Gables, Fl 33124. The objective was to compare transpirational water loss from the native and the exotic species in the Everglades. Data are presented on transpiration amounts and rates under several environmental conditions. Weight losses were measured on well established potted plants.

4:00 pm BS-17 Biosystematic Investigation of the Dyschoriste oblongifolia (Acanthaceae) Complex in Florida. RICHARD A. HILSENBECK and ROBERT W. LONG. Dept. of Biology, Univ. of South Florida, Tampa, FL. 33620. Research directed toward the clarification of systematic problems in the three Florida species of the genus Dyschoriste will be discussed. Chromatography of phenolic compounds, breeding system investigations, and hybridization studies have beem employed to determine relationships of D. oblongifolia and D. humistrata, distributed in north and central Florida, and D. angusta, endemic to south Florida. As a result of these investigations, the retention of D. humistrata as a member of the genus Dyschoriste appears warranted. In addition, Long's earlier treatment of D. angusta as a variety of D. oblongifolia has been reevaluated. It is now suggested that D. angusta be maintained as a valid species. Research supported in part by NSF grant BMS 72-02209 A03.

4:15 pm BS-18 Leaf Coloration in Begonia. JAMES A. MCARTHUR, Department of Biological Sciences, Florida International University, Miami, Florida 33199.

A combination of pigments in Begonia leaves produces colors which range through varying shades of green, to metallic silvers and reds to tones of brown and near black. Color differences also occur from variations in leaf anatomy and morphology. Preliminary spectral comparisons of the pigments of black and green leaves show that black leaves have in excess of 30% more chlorophyll. The black leaves also have a substantial amount anthocyanin. Variations in leaf anatomy and morphology affecting coloration will be reviewed.

4:30 pm BS-19 Impact of intensive reforestation activities on higher plant species diversity and frequency on a coastal pine - cypress - titi site: first year results, LOUIS F. CONDE, J. E. SMITH AND C. A. HOLLIS, School of Forest Resources and Conservation, Gainesville, FL 32611. Species diversity, frequency, and density of successional vegetation within the first year following reforestation practices were compared with an undisturbed site. The number of species on the treatment block was double that of the control block. The frequency and density of herbs, particularly beak-rushes and sedges, was greatly increased on the treatment block while the frequency and density of woody species characteristic of the original cover type was greatly decreased. Virtually all species characteristic of the control block occurred on the reforested block within one year after treatment.

4:45 pm BS-20 Some Aspects of North American Lycopod Spores from the Pennsylvanian, Sheila D. Brack-Hanes, Eckerd College, St. Petersburg, Florida, 33733. Spores and pollen grains are found in almost all sediments and for this reason are useful in paleobotany, stratigraphy and taxonomy. This presentation will be a review of the impact on taxonomy and stratigraphy of ontogenetic studies carried out with fossil lycopod spores. Ontogenetic studies are possible because in recent years many spore and pollen producing plants have been found preserved either as compressions or permineralizations with intact fructifications. In addition, through the use of such material, information about plant distributions can be correlated with data obtained from spores widely dispersed in sediments and in this way provide more insight into ancient environments.

Session B2: PHYSIOLOGY and MICROBIOLOGY

Frank E. Friedl, University of South Florida, presiding

Friday: 3:15 pm Little Hall 227

3:15 pm BS-21 Insect Juvenile Hormones and Their Mimics: Applications In Crustacean Research.* MATTHEW LANDAU AND COLIN FINNEY, New York Ocean Science Laboratory, Drawer EE, Montauk, N.Y. 11954. Experiments showed that juvenile hormone (JH) and Farnesol had little effect on molting, however, Farnesol was toxic at levels of 10 mg/l or greater on the larvae of the brine shrimp, Artemia salina. Abnormalities in metamorphosing cyprids of the barnacle Balanus eburneus were observed when washed in Farnesol, 1-heptanol, or 6,7-epoxy-3,7-dimethyl-1-[3,4-(methylenedioxy)-phenoxy]-2-nonene. D,L-mevalonic acid lactone displayed no activity. The role of JH in insects and the history of JH-Crustacean research will be briefly discussed.
*Supported in part by a Jessie Smith Noyes fellowship to M. L.

3:30 pm BS-22 Primitive Immunity?: Recognition of Self from Non-Self in Crustaceans, LARRY McCUMBER AND WILLIAM CLEM, Whitney Marine Lab., Rt. 1, Box 121, St. Augustine, Fl. 32084. Crustaceans, such as blue crabs and crayfish, possess recognition mechanisms for non self (foreign) components. This recognition is manifest by rapid clearance from the circulation of xenogeneic proteins and certain viruses. It appears to be attributable to naturally occurring humoral receptor molecules possessing quasi-specificity. This initial recognition and clearance followed by subsequent organ localization and degradation indicates these "lower" animals are capable of relatively sophisticated "immune" reactions in the normal or "nonimmunized" state.
(Supported by Center for Environmental Programs, IFAS, Univ. Fla., and NSF Grant BMS75-16749).

3:45 pm BS-23 Uptake of Ion-Exchange Resin Beads by Marine Isopods in Tampa Bay, Florida. E.D. Estevez, Department of Biology, University of South Florida, Tampa, FL 33620. Collections of Sphaeroma from mangroves in Tampa Bay have produced specimens containing amber ion-exchange resin beads used in purification of industrial and domestic waters. The beads were found in males and females of S. terebrans and S. quadridentatum, within the gut, haemocoel, or body wall. Possible sources and dispersal modes of the beads in Tampa Bay are described; characteristics of affected animals are provided; and possible methods of bead uptake are assessed.

4:00 pm BS-24 New Morphological and Color Mutants of *Neurospora Crassa*, Steven A. Warner, Eckerd College, Box 1167, St. Petersburg, Florida 33733. A number of morphological mutants of *Neurospora crassa* have been isolated by other investigators. Two new mutants not previously reported have been isolated in this study. The first is characterized by small colonies exhibiting small aerial hyphal stalks perpendicular to the surface of each colony. The second exhibits a transient yellow pigmentation when incubated at elevated temperature (34°C), shifting to the wild-type coloration after the fourth day of growth.

4:15 pm BS-25 Properties and Replication of CELO Virus-an Avian Adenovirus, L. A. JARDINES, J.E. SPIELMAN and C.K. OKUBO, Dept. of Biological Sciences, Florida International University, Miami, FL 33199. Chick embryo lethal orphan (CELO) has been shown to be an adenovirus based on physical and chemical characteristics similar to human adenovirus. It is oncogenic producing tumors in newborn hamsters. CELO virus can be purified by CsCl equilibrium density gradient centrifugation to a high titer. A tissue culture system susceptible to CELO virus infection and a quantal plaque assay system have been developed. With these methods, we have been able to determine the time of viral maturation and of viral DNA synthesis using cytosine arabinoside (ara-C). Studies are being conducted to determine the time of viral specific m-RNA synthesis by the DNA RNA hybridization technique.

4:30 pm BS-26 Hydroxycinnamoyl:Coenzyme A Transferase involved in the Biosynthesis of Acylated Flavonol Triglucosides in *Pisum sativum*, MARIE H. SAYLOR AND RICHARD L. MANSELL, University of South Florida, Tampa, FL 33620. The biosynthesis of acylated flavonoids has long been thought to involve the transfer of an activated acyl derivative. In this study we have been able to demonstrate the cell-free synthesis of kaempferol-3-(p-coumaroyl triglucoside) and quercetin-3-(p-coumaroyl triglucoside) in crude enzyme preparations from pea seedlings. The substrates for the reaction include the flavonol-3-triglucoside (kaempferol or quercetin) and p-coumaroyl Coenzyme A. Partial characterization of the flavonol-3-(p-coumaroyl triglucoside)acyl transferase and reaction product identification will be presented.

4:45 pm BS-27 Changing Patterns of Glycogen Distribution in the Embryonic Chick Lagena, A. J. SEIGEL and G. M. COHEN, Dept. of Biol. Sci., Fl. Inst.Tech. Melbourne, Fl 32901. Preliminary electron microscopic studies of the auditory (lagenar) portion of the inner ear suggest that glycogen stores change their distribution during development. In 10-13 day embryos, glycogen particles are not regularly demonstrable in either hair or supporting cells of the basila papilla but are distributed throughout the cytoplasm of the tegmentum vasculosum, with a relatively constant density for the remainder of development. Shortly thereafter, between the 13th and 16th days, glycogen particles become evident in the apical regions of both hair and supporting cells. However, during the 16th day glycogen particles are lost by the hair cells, but are retained by the adjacent supporting cells. This occurs during the developmental stage when the chick's auditory system is structurally differentiated and believed to be functional, possibly reflecting changing metabolic capacities prior to hatching

5:00 pm BS-28 Some aspects of Nitrogen Catabolism in the Freshwater Pulmonate Snail, *Lymnaea stagnalis*. FRANK E. FRIEDL, Department of Biology, University of South Florida, Tampa 33620. *Lymnaea stagnalis* produces both ammonia and urea and an average percent partition of excretory nitrogen found in ambient media approximated: Ammonia, 50; Urea, 30; and unidentified residual, 20. To investigate the metabolic origins of ammonia, some deaminating reactions were studied using a microdiffusion method to estimate ammonia produced by homogenates of *Lymnaea*. L-amino acid substrates ARG, HIS, ILE, LEU, LYS, MET, PHE, and VAL gave evidence of ammonia production aerobically; GLY, PRO, and THR did not. Only with L-Glutamine was appreciable ammonia produced both aerobically and anaerobically. No urease activity was found. The results suggest L-amino acid oxidase activity accepting basic amino acids as substrates and appear to be qualitatively in general agreement with findings of Olomucki et al. (Colloques Internationaux du CNRS, XCII, 1960) using manometry. Glutaminase activity is also suggested. (Assisted by NSF Grant GB 3158)

Friday 7:30 pm Flagler Inn. BANQUET

Saturday 8:30 am Little Hall 207

Session C: MARINE and FRESHWATER BIOLOGY II.

Sheldon Dobkin, Florida Atlantic University, presiding

8:30 am BS-29 The Distribution of Mysidacea of the Inshore Waters of the Texas Coast, W. Wayne Price, Div. of Science and Math, University of Tampa, Tampa, Florida 33606. Ten species of mysids have been reported from the shallow waters of the Texas coast. *Mysidopsis almyra* is the dominant species in the shallow waters of most bays and is often found with *Mysidopsis bahia*. *Mysidopsis bigelowi* is taken in the deeper waters of bays and offshore. *Taphromysis louisianae* is a fresh-brackish water mysid which is collected in rivers and river mouths along the coast. *Brasilomysis castroi* and *Promysis atlantica* maintain populations offshore and occasionally wander into the bays. Two benthic species, *Bowmaniella brasiliensis* and *B. dissimilis*, are found in bays and the surf zone of the front beach. *Metamysidopsis swifti* is taken nearly exclusively on the front beach from the surf zone to about 10 m in depth. *Mysis stenolepis* is also reported from the Texas coast but the identification is questionable

8:45 am BS-30 The Relationship between the Reproductive Rate of a Predaceous Copepod and Prey Item Abundance. GRACE A. WYNGAARD, Dept. of Biology, University of South Florida, Tampa, FL 33620. Weekly data were collected from Lake Thonotossassa, Hillsborough County on the temperature, phytoplankton chlorophyll content, abundance of the predaceous copepod *Mesocyclops edax* and its major prey item *Diaptomus dorsalis*. Correlations between the above factors and the reproductive rate (calculated using Edmondson's egg ratio model) of *M. edax* are calculated to ascertain the effect of prey item type and abundance on reproductive rate.

9:00 am BS-31 Ecology of the Copepoda of Apalachicola Bay, Florida, H. LEE EDMISTON, Harbor Branch Foundation, Rt. 1, Box 196, Fort Pierce, FL 33450. Zooplankton was sampled for 14 months in Apalachicola Bay and offshore of St. George Island to determine biomass, species diversity, and physical characteristics of estuarine and nearshore copepods. The zooplankton community was found to be made up almost entirely of one species of copepod, *Acartia tonsa*. It tolerates water from $1^{0}/oo$ to $35^{0}/oo$ salinity but prefers a salinity of $7^{0}/oo$ to $25^{0}/oo$. The high percentage of *Acartia tonsa*, generally greater than 90% of the zooplankton, seems to make this species very important in the marine food chain. Because of this dominance, any altering of the salinity by damming or channeling of the Apalachicola River should be fully investigated.

9:15 am BS-32 Some effects of predation on fouling communities, DAVID MOOK, Harbor Branch Foundation, Inc. Rt. 1, Box 196, Ft. Pierce, Fl 33450. Fouling communities on ceramic tiles were subjected to varying levels of artificial predation. Natural predators were excluded from other tiles. No significant change in rank order of common fouling animals was observed on tiles subjected to increasing artificial predation but where natural predators were excluded, changes in rank order occurred. Artificial predation produced significant changes in species diversity whereas the exclusion of natural predators did not. This suggests that natural predators may selectively feed on certain organisms thereby changing rank order. Nonselective, artificial predation removed all organisms equally, not changing rank order but opening space for other species, thus increasing species richness.

9:30 am BS-33 Annual variation in benthic invertebrate populations in stressed and unstressed habitats in Hillsborough Bay, Florida. JOSEPH L. SIMON and STUART L. SANTOS, Department of Biology, University of South Florida, Tampa, FL 33620. Monthly quantitative benthic samples at 12 sites in Hillsborough Bay, Florida, have been analysed over a two year period. The upper portion of the bay receives large quantities of municipal sewage effluent and is characterized by widely fluctuating species numbers, composition, densities and biomass. The lower, unstressed part of the bay displays more stable assemblages of a wider variety of infaunal species. Both monthly and yearly changes in infaunal invertebrates are assessed and the variations related to abiotic parameters, especially dissolved oxygen content of bottom waters. Supported by the Florida Sea Grant Program, Grant R/EM-7.

9:45 am BS-34 Response of a Tampa Bay soft-bottom community to the perturbation of mining of fossil oyster shell, JOSEPH L. SIMON AND WILLIAM G. CONNER, Dept. of Biology, Univ. of So. Fla., Tampa, FL 33620. To ascertain the effects of oyster shell dredging on a soft-bottom infaunal assemblage, two dredged areas and an unaffected control area were monitored before and after dredging. The immediate effects of dredging were reductions in biomass, species numbers, and densities, and a reduction in Czeckanowski's Index between control and experimental areas. Amphipods were least affected, bivalves most affected, with polychaetes and ophiuroids sustaining moderate losses. Despite gross changes in sediment type, the same basic community returned after dredging. After 6 months a new surface sediment had developed which was similar to the pre-dredging sediment. Within 12 months the disturbed areas had returned to the same species assemblage, number of species, and density patterns, and supported the same or slightly lower biomass than undisturbed bay bottom.

10:00 am BS-35 Grass Carp (Ctenopharyngodon idella (Val.)) for Aquatic Weed Control, and its Effect on Water Quality, MONDELL L. BEACH, Florida Department of Natural Resources, Bureau of Aquatic Plant Research and Control, Crown Building, Tallahassee, FL 32304. Aquatic vegetation and water quality were measured for 36 months in four Florida ponds stocked with grass carp. The grass carp was an effective control agent for hydrilla (Hydrilla verticillata) and fanwort (Cabomba caroliniana), but was ineffective against cattail (Typha) and bonnets (Nuphar and Nymphaea). Significant changes in the various water quality parameters occurred between years, but most remained unchanged between pre- and post-stocking periods. Except for nitrate-nitrite concentration, tannin-lignin levels, and the chlorophyll pigments, physicochemical parameters remained unchanged between pre- and post-stocking periods in most ponds. Total phosphorous was the only substrate parameter to show significant change.

10:15 am BS-36 Effects of Grass Carp (Ctenopharyngodon idella (Val.) on Macro and Microinvertebrates, MONDELL L. BEACH, Bureau of Aquatic Plant Research and Control, Department of Natural Resources, Crown Building, 202 Blount St., Tallahassee, FL 32304. Changes in the micro and macroinvertebrate communities were evaluated for 36 months in four Florida ponds stocked with grass carp. Based upon diversity indices, the planktonic community was not adversely affected, but the post-stocking macroinvertebrate community was characterized by decreased diversity and predominance by a few individuals. Total phytoplankton decreased and increased in the middle and latter stages, respectively, in two ponds, increased and subsequently decreased in another, and continually decreased in the fourth. Chlorophyta predominated most ponds, and occasional predominances by Cyanophyta, Chrysophyta, and Pyrrophyta were encountered. Total zooplankton increased in all ponds during the middle stages of the study, and later decreased. Copepods were the predominant zooplankton group, and Diptera was the predominate macroinvertebrate.

10:30 am BS-37 Status of the Black Creek Crayfish, Procambarus pictus (Decapoda:Cambaridae), RICHARD FRANZ, Florida State Museum, University of Florida, Gainesville, FL 32611. The Black Creek Crayfish, Procambarus (Ortmannicus) pictus (Hobbs) is endemic to cool, steep-gradient, headwaters creeks and larger tributaries in the Black Creek drainage in northeast Florida. Procambarus pictus is extremely susceptible to human interference, particularly alteration of headwater areas and pollution. Currently Procambarus pictus is holding its own, but with additional pressure from urbanization, particularly with its close proximity to the Jacksonville metropolitan area, this crayfish could quickly be brought to the brink of extinction. Because of this, I recommend that this species should be considered for the Special Concern category, as outlined in the Florida Audubon Society's Inventory of Rare and Endangered Biota of Florida.

10:45 am BS-38 A Photographic Method for Sampling Hard-Bottom Benthic Communities, JAMES A. BOHNSACK, Department of Biology, University of Miami, Coral Gables, Fl. 33124. Underwater 35mm photography was evaluated as a quantitative sampling technique for hard-bottom benthic community composition. Best results required artificial lighting and a reflex viewing system. Transparencies were best analyzed by random point sampling using a dissecting microscope and acetate overlays. Cover was found to be a valuable community parameter that could be quantified, computerized, and statistically treated. Cover estimates were accurate and precise. Major organisms were detected. Photographic quadrat sampling was much faster, more economical, and provided more information than direct observation or hand-collected biomass samples. The accuracy of using cover to estimate biomass or numbers of individuals varied. Photographic sampling did not disturb the organisms present and provided convenient permanent records.

11:00 am BS-39 Community Structure on Walls of Marine Man-Made Canal Systems of the Florida Keys, JAMES A. BOHNSACK, Department of Biology, University of Miami, Coral Gables, Fl. 33124. The macro-biota on walls of five man-made canal systems in the Florida Keys were quantitatively sampled using cover values determined by underwater photography. Data were subjected to computer analyses. The coefficient of community demonstrated distinct changes in community composition with depth. Each canal had a distinct community structure. One canal underwent pronounced temporal community changes possibly due to biological factors influenced by the canal design.

Saturday 1:00-5 pm FIELD TRIP, meet at the Flagler Inn parking lot.

CHEMICAL SCIENCE SECTION

Friday 8:30 am Little Hall 213

William H. Wilcox, Environmental Quality Laboratory, Inc., presiding

8:30 am CSS-1 Effects of Microwave Irradiation (2450 MHz-CW) on Selected Model Organisms: *Gymnodinium breve* and *Gomphosphaeria aponina*, DEAN F. MARTIN, S.C. BLOCH, AND BARBARA B. MARTIN, Departments of Chemistry and Physics, University of South Florida, Tampa, Florida 33620. The short-and long-term effects of irradiation by 2450 MHz-CW microwaves on sea water cultures of the unarmored dinoflagellate, *Gymnodinium breve* Davis, were evaluated in terms of cell concentrations as a function of time after irradiation. Initial experiments indicated no statistically significant effects associated with temperature rise or manipulations. Subsequent experiments indicated a significant and sharp threshold, % cell surviving as a function of energy absorbed by the system. Finally, the effect of microwave irradiation of cultures of *G. breve* and the blue-green alga, *G. aponina*, separately and together, will be described. The system appears promising as a model system for describing the effect of microwaves on the absorption of drugs by cells.

8:45 am CSS-2 Design of Removal Agents for Prevention of Lithium Intoxications. Chelating Tendencies of Model β-diketones, BARBARA B. MARTIN AND DEAN F. MARTIN, Department of Chemistry, University of South Florida, Tampa, Florida 33620. Previous studies at other institutions have demonstrated the value of lithium salts in the treatment of the manic phase of the manic-depressive syndrome. The danger of side effects, however, is real, and it seems desirable to find a method for removing excess serum lithium. Dipivaloyl methane has shown to be specific for lithium extractions of lithium from mixtures of lithium, sodium, and potassium. Other β-diketones, because of steric and solvent effects may be more specific lithium-chelating agents. Thus the factors that affect the solution stability of alkali metal complexes are being evaluated to assist the design of useful removal agents.

9:00 am CSS-3 Studies of Iron(III)-Uptake by the Marine Blue-Green Alga *Gomphosphaeria aponina*.* D.L. ENG-WILMOT AND D.F. MARTIN, Department of Chemistry, University of South Florida, Tampa, Florida 33620. Previous studies indicated the Fe(III) was growth-limiting in the cell cycle of *G. aponina*. Iron preconditioning of cells produced reduced growth rates as compared to those observed for Fe-deficient cells. Removal of Fe from culture media was rapid in illuminated cultures, at rates comparable to the exponential growth rate of the organism. Rates of ^{59}Fe(III)-uptake by cells were determined in both batch and chemostat cultures, and results confirmed earlier findings. Siderochrome synthesis and involvement in Fe-transport and metabolism was investigated; results indicated that this activity was not involved. Implications in red tide bio-control are considered.

*Research supported by SUS Sea Grant Program.

9:15 am CSS-4 Status of Purification and Characterization of the Cytolytic Factor of the Blue-green Alga, *Gomphosphaeria aponina*, LESLIE F. McCOY, JR. AND DEAN F. MARTIN, Department of Chemistry, University of South Florida, Tampa, Florida 33620. A material, called aponin, was isolated from cultures of the blue-green alga *G. aponina*. Aponin was found to by cytolytic toward the red tide organism *Gymnodinium breve* [Kutt and Martin, Environ. Letters, 9, 195 (1975)]. The method of isolation has been modified to use continuous cell centrifugation. The cytolytic activity has been evaluated for various fractions and at different stages of purification. Probit analysis has been used to linearize cytolytic activity data (% cells surviving as a function of amount of aponin added). Results of TLC and column chromatography will be described.
*Research supported by the SUS Sea Grant Program.

9:30 am CSS-5 Factors Affecting the Distribution of Trace Elements in Water-hyacinth, *Eichhornia crassipes*, THOMAS N. COOLEY AND DEAN F. MARTIN, Departments of Biology and Chemistry, University of South Florida, Tampa, Florida 33620. Waterhyacinth, which infests waterways of considerable sections of the world, and especially Florida, has been used as a model system to evaluate distribution of transition metals in plant segments. Distribution of Mg, Ca, Mn, Fe, and Cu in roots, stems, and leaves of the plant have been evaluated. Relative concentrations have been related to the solubility (as log K_{sp}) of the divalent metal carbonate. Inorganic carbon is likely to be the dominant anionic species in oxygenated fresh water. The correlation was valid for plants taken from the Hillsborough and Peace Rivers at three different times. The limitations of the correlation*are considered.
*Research supported by the Florida Department of Natural Resources, Bureau of Aquatic Research and Control.

9:45 am CSS-6 Effect of Chelated Iron on the Growth of Florida Aquatic Plants. Vallisneria, *PATRICIA M. DOORIS AND DEAN F. MARTIN, Departments of Biology and Chemistry, University of Souht Florida, Tampa, FL 33620. The rate of oxygen production by vallisneria (*Vallisneria neotropicalis* and *V. spiralis*) in Hoagland's medium has been evaluated as a function of weight of chelated iron added. In addition, the effect on net plant weight was evaluated. Under realistic conditions, the plants evidently undergo a competition for iron with a green algae. Results are compared with and without the competition effect. Differences in the effect of iron for *V. neotropicalis* and *V. spiralis* are provisionally ascribed to plant source and adaption to iron levels. Implications will be considered.
*Research supported by the Florida Department of Natural Resources, Bureau of Aquatic Research and Control.

10:00 am Business meeting of the Chemical Sciences Section

BREAK

10:30 am CSS-7 Photoelectron Study of the Electronic Structure of Purines and Pyrimidines, Alexander Padva, Environmental Quality Laboratory, Inc., Port Charlotte; Florida 33952. Assignments are given for ionization bands in the photoelectron spectra of uracil, methyl substituted uracils, 5-halouracils and adenine. These assignments are compared with results from molecular orbital calculations. Application to biochemical reactivities, mainly base stacking interactions and hydrogen bonding are discussed.

10:45 am CSS-8 An Appraisal of Factors Affecting the Freshening of Lake Tarpon Following Sink Enclosure, LEONARD F. BARTOS, Southwest Florida Water Management District, 5060 U.S. Hwy. 41 S., Brooksville, Fl. 33512. A significant delcine in the salinity(chloride concentration) of Lake Tarpon occurred subsequent to the 1969 enclosure of the Lake Tarpon Sink, which had hydraulically connected the lake to Spring Bayou, a tidal estuary. Since 1971, chloride concentrations have declined slowly compared to the initial two years of isolation. During recent investigations(1974-1976) chlorides decreased 18%. The major chloride source is subsurface input rather than surface runoff or precipitation. The subsurface input appears to be a general source(ie. sediment leaching), but high chloride concentrations in the outfall canal area warrant investigation. The flushing of the lake approximates laboratory simulations indicating that lake freshening, while initially rapid(1969-1970) will continue at a slow rate barring significant meteorological or hydrological changes.

11:00 am CSS-9 Effect of Carbon-Dioxide Rich Atmospheres on the Growth of Waterhyacinth, DOUGLAS P. DENEVE AND DEAN F. MARTIN, Department of Chemistry, University of South Florida, Tampa, Florida, 33620. The effects of carbon dioxide-rich atmospheres upon waterhyacinths are being studied in connection with possible utilization of "scrubbed" power plant stack gas. Waterhyacinths grown under these conditions may be commercially profitable as a carbon source. Preliminary data indicate a maximum growth rate for the plant under an atmosphere which is about 9% carbon dioxide, with a sharp decrease in growth rate at higher levels. The typical value for stack gas is about 15%.

11:15 am CSS-10 Heavy Metal Removal by Magnesium and Lime Coagulation and Colored and Non-colored Aqueous Environments, DONALD J. JOFFEE, Florida Institute of Technology, Melbourne, Florida 32901. Magnesium coagulation was shown to be superior to lime precipitation for heavy metal removal in colored and non-colored aqueous environments. Metals investigated included cobalt, nickel, copper, zinc and cadmium. Laboratory results suggest that zinc and cadmium are removed from solution by an electrostatic mechanism that occurs between the magnesium floc and the hydrated heavy metal. The presence of color is shown to interfere with heavy metal removal.

11·30 am CSS-11 Direct Determination of Cd, Cr, Cu, Fe, Pb and Zn in Sea Water using HGA-2100 Graphite Furnace, M. HUCKS AND G. PETERSON, Harbor Branch Foundation, Inc., Rt. 1, Box 196, Fort Pierce, Florida 33450. The direct determination of trace metals in sea water eliminates many of the problems associated with extraction/concentration techniques. The optimum conditions for the determination of Cd, Cr, Cu, Fe, Pb and Zn in sea water were established. Matrix modification using 1 mg NH_4NO_3 per 20 ul sample was necessary to reduce the non-atomic signal to acceptable levels. The drying cycle was 110^oC for 25 sec. and the charring time was 25 sec., for all metals. The charring temperatures were optimum at 500, 1300, 700, 1000, 550, and 800^oC for Cd, Cr, Cu, Fu, Pb and Zn respectively. Atomization temperatures and times were 2300^o/5 sec., 2700^o/10 sec., 2600^o/7 sec., 2700^o/7 sec., 2300^o/7 sec. and 2500^o/7 sec. respectively. The minimum detectable concentrations in sea water, calculated using the standard deviation of the blank were 0.80, 1.15, 2.70, 2.00, 1.61, 0.87 ug/l respectively. Accuracy was assessed using EPA Standards and by comparison of HGA results with those obtained using ASV and extraction techniques.

11:45 am CSS-12 In Situ Sampler for the Determination of Nutrients in Pore Water, C. ZIMMERMANN AND M. PRICE, Harbor Branch Foundation, Inc., Rt. 1, Box 196, Fort Pierce, Florida 33450. An in situ sampling device is described whereby pore water may be simultaneously collected, in an anaerobic environment, and filtered at precise depth in shallow estuarine sediments. The sampler is made of porous teflon®. Laboratory comparison studies between porous ceramic and porous teflon® were performed for NH_3, PO_4, NO_3, NO_2 and Si. Significant differences were evident between the nutrient concentrations before and after being filtered through the ceramic samplers. Percent recoveries ranged from 11% for NH_3, 43% for PO_4, 96% for NO_3, 85% for NO_2 and 111% for Si with coefficient of variation from 1 to 78%. Percent recoveries for the teflon® sampler were from 99 to 100% for all nutrients tested.

12:00-1:00 LUNCH

Friday 1:00 pm Little Hall 101

Annual Business Meeting of the Academy

Patrick J. Gleason, President, presiding

Friday 1:30-3:15 pm Little Hall 101

GENERAL SESSION

Friday 7:30 pm Flagler Inn, BANQUET

EARTH AND PLANETARY SCIENCES SECTION

Friday 8:00 am Little Hall 215

Session A: GEOLOGY AND HYDROLOGY I

Thomas M. Missimer, 2500 Del Prado Blvd., Cape Coral, presiding

8:00 am EPS-1 The Structure and Stratigraphy of the Limestone Outcrop Belt in the Florida Panhandle, CURTIS J. COE, Northwest Florida Water Management District, 325 John Knox Rd., Tallahassee, Florida 32302; WALTER SCHMIDT, Bureau of Geology, 903 W. Tennessee St., Tallahassee, Florida 32302.

The limestone outcrop belt in the Florida Panhandle is located in Holmes, Washington, and Jackson Counties. The collection of well cuttings from water and oil wells, along with the results of radioactivity logs, have made available new information allowing the authors to restudy the area with more certainty and detail than ever before. Most of this information has now been compiled in the form of lithologic logs, cross-sections and structure, contour maps to form a three-dimensional view of the subsurface. The new information has revealed an ancient post-depositional drainage pattern developed on the upper surfaces of the Ocala, Marianna, Suwannee, and Tampa limestones. This drainage pattern is the result of the uplift which created the anticlinal Chattahoochee Arch and influenced the deposition of the overlying clastics. In addition, the Cypress Fault, as defined by Moore (1955), is not required to correlate the strata due to the high angle of dip on the eastern flank of the Chattahoochee Arch.

8:15 am EPS-2 Uranium Isotopes in North Florida Waters, J. B. COWART, Dept. of Geology, Florida State University, Tallahassee, Florida 32306.

The relative abundances of the two isotopes, 234U and 238U, have been found to vary widely in natural waters. Almost always 234U is in excess of 238U relative to secular equilibrium. In Florida, however, 234U deficient ground water is found extensively in the areas of surface or near surface limestones along the Gulf coast from Tampa to the vicinity of Tallahassee. In deep parts of the aquifer or those parts overlain by an aquatard, excess 234U is found. The cause of this phenomenon may be related to lithology, hydrologic and climatic history, and the reduction-oxidation characteristics of uranium.

8:30 am EPS-3 Late Pleistocene Fossil Vertebrates from the Cayman Islands, British West Indies, GARY S. MORGAN, Florida State Museum, University of Florida, Gainesville, Florida 32611.

Late Pleistocene cave deposits from Cayman Brac and Grand Cayman reveal an extensive vertebrate fauna, including a number of species no longer occurring in the Cayman Islands. Extinct species of a snipe (*Capella*) and an eagle (*Titanohierax*) are among the birds recovered, while the mammals include extinct species of an insectivore (*Nesophontes*) and of capromyid rodents (*Capromys* and *Geocapromys*). The former existence in the Cayman Islands of two Cuban bats (*Phyllops falcatus* and *Phyllonycteris poeyi*), a Middle American bat (*Eptesicus furinalis*), and the American crocodile (*Crocodylus acutus*) is established. Distributional patterns of both the recent and fossil vertebrates indicate that the Cayman fauna is more closely related to the Cuban fauna than to the Jamaican. Geologic evidence for the age of the most recent emergence of the islands above sea level and the overall lack of specific differentiation suggests that the entire fauna was derived by overwater dispersal during the Late Pleistocene.

8:45 am EPS-4 The Suwannee Limestone-Ocala Limestone Contact Along the Suwannee River, LOUIS G. ZACHOS, Department of Geology, University of Florida, Gainesville, Florida 32611.

The Suwannee-Ocala contact is exposed in outcrops from the confluence of the Suwannee and Alapaha Rivers to Dowling Park. The contact south of Dowling Park is transitional. Rock fabrics indicate intertidal to supratidal deposition. The contact exposed at the confluence is abrupt, indicating a pause in subtidal sedimentation rather than an erosional unconformity. Paleogeographic interpretation suggests emergent areas to the south of Dowling Park with paleoslope dipping roughly north towards the Suwannee Strait.

9:00 am EPS-5 Hydrogeology of a Karst River Basin, Alapaha River, Hamilton County, Florida, RON CERYAK, Suwannee River Water Management District, P. O. Drawer K, White Springs, Florida 32096.

The Alapaha River system in Florida has two distinct profiles resulting from variations in deposition and structure. In the north, the river is a perennial stream traversing low permeability sediments. The southern section is an intermittent stream flowing above ground only during periods of high flow. The study area is underlain by three aquifers, each characterized by distinct stratigraphic units. Factor analysis of ground-water chemical data demonstrates that each aquifer contains distinctly different water types and some samples indicate relative degrees of mixing between water types. The river disappears underground through no less than seven stream sinks. These and other sinkhole features in the area are avenues through which surface waters mix extensively with Floridan Aquifer waters. These mixed waters migrate up to five miles from the river corridor.

9:15 am EPS-6 Holocene Island Growth and Diagenesis, Joulters Cays, Great Bahama Bank: PAUL M. HARRIS, Comparative Sedimentology Laboratory, University of Miami, Fisher Island Station, Miami Beach, Florida 33139 and ROBERT B. HALLEY, Fisher Island Station, Miami Beach, Florida 33139.

The Joulters Cays are three lithified carbonate sand islands trending parallel to the shelf break, along the windward margin of Great Bahama Bank north of Andros Island. They lie along the trend and on the bankward side of an ooid sand shoal, that borders a vast shallow stabilized sand flat on its eastern margin. The islands have been important in the sedimentological development of a large ooid sand body and reveal an interesting early diagenetic history. Seven core borings were taken on the largest island to determine the island stratigraphy and to examine the extent of fresh water diagenesis. The borings penetrate (1) up to 5 meters of cemented ooid grainstone, (2) from 3 to 6 meters of lightly cemented or uncemented peloid-ooid grainstone, and (3) densely cemented Pleistocene limestone at a depth of 6 to 9 meters. Island stratigraphy, when compared to the sequence of sediments revealed by sediment coring and probing on the sand shoal seaward of the island and on the sand flat bankward of the island, indicates that the ooid sand island formed on a pre-existing muddy sand bank. Radiocarbon dates indicate that actual island growth has been extremely rapid during the last 600 years. The subsequent development of a fresh water lens on the island initiated diagenesis by meteoric water in both the vadose and phreatic zones. The ooid grainstone is cemented both above and below the fresh water table, but the style of cementation changes across it. Above the water table the ooids are cemented by a blocky mosaic of calcite with most of the crystals occurring in grain contact positions. At and below the water table the ooids are cemented by a uniform rim of decimicron-size calcite rhombohedrons. The peloid-ooid grainstone is cemented by a discontinuous fringe of micron-size calcite rhombohedrons.

9:30 am EPS-7 Late Miocene (Messinian) Glacio-eustatic Lowering of Sea Level: Evidence from the Tamiami Formation of South Florida, D. M. PECK, Chevron Oil Co., New Orleans, La.; T. M. MISSIMER, 2500 Del Prado Blvd., Cape Coral, FL; S. W. WISE and R. C. WRIGHT, Dept. Geology, Florida State Univ., Tallahassee, FL.

Detailed micropaleontological studies using planktonic and benthic foraminifera, calcareous nannofossils, and diatoms from six wells in Lee County, Florida, place the Miocene-Pliocene boundary within the Tamiami Formation at a point marked by a sharp marine regression. Where best defined, the Late Miocene regressive sequence is distinguished by a change from carbonate-rich, oxidized sediments to carbonate-poor, reduced sediments and culminates in a green diatom-rich clay with an apparent depositional hiatus near the top. The regression at the top of the upper Miocene portion of the Tamiami Formation is correlative with similar regressions previously recorded elsewhere in the Southeastern Coastal Plain. It also correlates closely in time with 1) a period of severe glaciation on the Antarctic continent and 2) the Messinian desiccation of the Mediterranean Sea. We believe the major regression observed in the Tamiami Formation is a low latitude record of the eustatic sea level drop caused by the Southern Hemisphere glaciation. Such a lowering of sea level to the limits of the outer shelf would have caused a sharp seaward migration of marine carbonate environments, the replacement of marine faunas and floras by fresh and brackish water organisms ponded in depressions along the former inner shelf, and a sudden increase in stream gradients resulting in the erosion and transportation of gravel-sized clasts from the interior.

9:45 am EPS-8 Geochemistry of Uranium and Thorium in Intrusive Rocks of the Southeastern Piedmont, M. P. DAVIS, F. N. BLANCHARD, P. A. MUELLER, D. L. SMITH, Department of Geology, University of Florida, Gainesville, Florida 32611.

Twenty samples from five Paleozoic intrusive complexes in the piedmont of Georgia and South Carolina were analyzed for major and selected trace elements, including uranium and thorium, and for modal composition. Rock types range from granodiorite to granite and contain from 67 to 78 percent silica; they exhibit a wide range of textures from fine to coarse grained and equigranular to porphyritic. Relationships between uranium and thorium and the more common indicators of igneous differentiation, such as silica content or abundance of quartz, are atypical for rocks of this compositional range. Stronger positive correlations exist between uranium and various differentiation indices (e.g. silica, quartz, Rb/Sr) than occur between thorium and the various parameters. In addition, Th/U ratios tend to decrease with increasing degrees of differentiation. No correlations, either spatially or temporally, can be made among intrusive complexes in the piedmont and no obvious explanation is available for this atypical behavior. This study, however, does outline an occurrence of anomalous behavior of uranium and thorium that will require more detailed study before any definitive model can be presented.

10:00 am EPS-9 An Adsorption Model of Trace Metal Chemodynamics in Estuaries FREDERICK BOPP III, Dept. of Geology, Univ. of South Florida, Tampa, Fla., 33620

The Delaware River is the site of effluent disposal by heavy industries. The fate of potentially hazardous trace metals in those wastes as they reach the upper estuary is open to question. Adsorption has been hypothesized to be the major control of trace metal chemodynamics, predicting that most metals associated with suspended sediments desorb, or "remobilize" in the estuary, and are flushed out to sea as aqueous complexes (deGroot, et. al., 1964, 1966, 1971; Kharkar, et. al., 1968.

A field study was carried out to ascertain: 1) the relative importance of trace metals in the adsorbed phase; 2) the kinetics of the adsorption-remobilization reaction; and 3) the degree to which metals in the adsorbed phase desorb in the upper estuary. A mass-balance adsorption model, calculations of cation preference indices, and reaction rate data show control of adsorption by the double layer.

Adsorption phenomena are not the all-pervasive control of trace metals dynamics they were once thought to be. Only 1%-5% of all metals associated with sediments are in the adsorbed phase. However, this phase is the most "environmentally active" partition of metals. The direct determination that the SHAB Concept and Double Layer theory exercise geochemical control over cation adsorption is a fundamental breakthrough in the understanding of estuarine trace metal chemodynamics.

10:15-10:30 BREAK

10:30 am Little Hall 215

Session B: GEOCHEMISTRY

Thomas H. O'Donnell, U.S. Geological Survey, presiding

10:30 am EPS-10 Chemical and Petrographic Analyses of Some Metamorphic Rocks, Beartooth Mountains, Montana, DONNA J. SINKS, FRANK N. BLANCHARD, AND PAUL A. MUELLER, Department of Geology, University of Florida, Gainesville, Florida 32611.

Forty one samples of Archean metamorphic rocks from the Quad Creek area, eastern Beartooth Mountains, Montana, have been studied chemically and mineralogically. Atomic absorption and X-ray fluorescence results have shown these gneisses to have K_2O/Na_2O ratios ranging from 0.26 to 1.1%, total FeO and MgO values from 6.2 to 17.2%, SiO_2 from 51 to 73%, and TiO_2 from 0.07 to 0.65%. These data indicate compositions ranging from amphibolitic to granitic and tonalitic compositions. Petrographic analysis shows that all the gneisses contain quartz, biotite and feldspar. The granitic ones have abundant K-feldspar, low ferromagnesians and lack biotitic foliation; the tonalitic gneisses show high sodic plagioclase, minor ferro-magnesians and slight biotite foliation. Hornblende, garnet and opaques are abundant in the biotite rich foliated amphibolitic gneisses. These rocks are shown to be similar to ones from Greenland and other Archean shield areas.

10:45 am EPS-11 Silicate Structures and Mineralogy of Sawgrass (Cladium jamaicensis Crantz) and its Associated Peats from the Florida Everglades. MICHAEL J. ANDREJKO Dept. Of Geology, Univ. of South Florida, Tampa, Florida 33620.

The Florida Everglades once extended as a continuous sheet flow of water from Lake Okeechobee south to Florida Bay. Within this area extensive deposits of sawgrass peat were formed during the past 5000 years. This study was concerned with the silicate mineralogy that is associated with the sawgrass plant and its corresponding peats. Core samples were taken in several sawgrass environments, from Lake Okeechobee south to Everglades National Park. This was to determine the diagenesis of both biogenetic (opaline) and non-opaline silica within the peats over time. Special attention was focused on the relationship of essentially natural sawgrass communities (subject to fires) to former peatlands now under cultivation.

11:00 am EPS-12 An Evaluation of the Chemical and Radioactive Properties in the Phosphate Districts of Florida, SUSAN P. GUNNING, FRANK N. BLANCHARD, and DOUGLAS L. SMITH, Department of Geology, University of Florida, Gainesville, Florida 32611.

Measurements of the mineralogy, major elements, and selected minor and trace elements of over 50 grab samples from open pits throughout the Florida phosphate mining district has revealed Th/U and P_2O_5/U values varying on a regional basis and with depth. Initial analyses by gamma-ray spectrometry of samples from the Hamilton County district yield uranium values ranging from 4 to 114 ppm, while higher abundances were found in the Bone Valley samples. X-ray diffraction and fluorescence analyses showed major-element distributions to be related to P_2O_5 and U content, but no consistent trends between the two (Polk and Hamilton Counties) areas were identified. Variations in mineralogy, chemistry, and radioactivity were apparent among the overburden, leached zones, matrix, and randomly distributed clay lenses. A comparison of trends in the data may contribute to the concept of a possible differing origins for the two phosphate districts.

11:15 am EPS-13 The Osceola Low - A Reevaluation, TOM SCOTT, Bureau of Geology, 903 W. Tennessee St., Tallahassee, Fla. 32304.

The Osceola Low has been described as a wedge shaped downthrown block bounded on the northwest and east by normal faults and open to the southwest (Vernon, 1951). The structure of the feature was interpreted from very limited data. It was believed to have formed contemporaneously with the Ocala uplift. New data have been obtained and raise doubt as to the existence of major faults bounding this structure. Interpretation of these new data suggest the existence of a basin with a "ridge" to the east which influenced the deposition of the Miocene and younger sediments in the Osceola and southeastern Orange County area.

11:30 am EPS-14 Identification of Geochemical Patterns in Ground Water by Numerical Analysis, FRED W. LAWRENCE AND SAM B. UPCHURCH, Suwannee River Water Management District, P. O. Drawer K, White Springs, Florida 32096.

One hundred fifty-two wells in the upper Floridan Aquifer near Lake City, Florida were analyzed for fifteen chemical variables. R-mode factor analysis was used to identify those variables that reflect areally significant recharge processes. Of the fifteen variables, nine convey significant information and cluster into three groups. Factor 1 reflects waters that have been in contact with the limestones and dolomites of the Floridan Aquifer for the longest period and approach equilibration with those strata. Factor 2 represents recharge waters percolating through the clastics overlying the Floridan. Factor 3 represents recharge water derived by direct connection with the surface in the area of sinkhole lakes. This study shows that factor analysis is useful in interpreting raw chemical data and in relating those data to specific hydrogeologic processes. Practical applications of this technique include water use and water resourses management.

11:45-1:00 pm LUNCH

1:00-1:30 pm Little Hall 101

Annual Business Meeting of the Academy

Patrick J. Gleason, President, presiding

1:30-3:15 pm Little Hall 101

GENERAL SESSION

3:30 pm Little Hall 215

Session C1: GEOLOGY and HYDROLOGY II

Thomas Scott, Florida Bureau of Geology, presiding

3:30 pm EPS-15 Intertidal Calcitic Muds Along The West Coast of Florida, N. SANDY NETTLES, P. E. LaMoreaux and Assoc., 4313 S. Florida Ave., Lakeland, Florida 33803.

A marine mud was recently discovered during a soil survey by members of the Florida A & M University soil department. The calcitic mud is characterized by a low diversity brackish water foraminiferal and salt marsh molluscan fauna. The presence of a highly variable, living foraminiferal population in the salt marsh, an increase in the ratio (muds: marsh sediments), of marine to terrestial molluscs and the high percent calcium carbonate of the mud indicate that the calcitic mud was not deposited in a salt marsh environment.

Carbon-14 dates on gastropods from the calcitic mud suggests a relation of the mud formation to the Gotland Emergence of Fairbridge or the Pacific I climatic event of Bryson.

A drier climate, which possibly existed in Florida during glacial stages, would favor the deposition of marine carbonates on a supratidal flat as opposed to non-deposition of carbonates in a brackish water salt marsh environment. The recent marsh sediments suggest a currently rising sea level, promoting an increasing marine influence and more normal brackish water conditions, conducive to the establishment of a *Juncus* marsh in the intertidal zone of Florida's west coast.

3:45 pm EPS-16 A Quantitive Approach to Manage the Floridan Aquifer System in South Florida, N. KHANAL and A. KREITMAN, Groundwater Division, South Florida Water Management District, West Palm Beach, FL 33402.

A digital computer model was utilized to study the Floridan aquifer of South Florida. Input to the model consisted of 1961 potentiometric heads, boundary conditions, recharge to the aquifer system, and the quantity of water being extracted from the system. The output consisted of the potentiometric heads at the end of each year for 13 years. The predicted head at the end of simulation was compared against the actual potentiometric heads, and they matched fairly well. The model shows that on the average, the aquifer system receives approximately 2 inches of recharge per year. The impact on the aquifer system from anticipated future withdrawals will be made once the projected water use estimate from the system has been made.

4:00 pm EPS-17 The Northern Brooksville Ridge, A Case for Topographic Inversion, MICHAEL S. KNAPP, Bureau of Geology, 903 W. Tennessee Street, Tallahassee, Florida, 32304.

The northern extremity of the Brooksville Ridge is located between the Withlacoochee and Santa Fe rivers. The core of the ridge is incised into the surrounding limestone plain and is composed predominantly of clastic sediments. These sediments may be part of the Hawthorn Formation and were probably deposited in a tidal channel or marine lagoon. Because of the insolubility of the clastic material they were not prone to dissolution like the surrounding limestones. The clastics have remained topographically high while the surrounding limestone plain has been reduced by dissolution.

4:15 pm EPS-18 Landsat Data: A Tool Applied To Water Management In South Florida
A. L. HIGER, 901 South Miami Avenue, Miami, Florida 33130.

Landsat data from south Florida were categorized into vegetation-water depth classes. Imagery from both wet (19 October 1974) and dry (3 March 1975) periods were processed. The vegetation-water depth classes delineated relate directly to surface water depth in Conservation Area 3A, a water management area within The Everglades. Water depths from eight data collection platforms within Conservation Area 3A and thirteen water-level stations in Everglades National Park, and Landsat multispectral reflectance from digital tapes were computer processed to determine the water depth for each Landsat picture element in Conservation Area 3A. With the October data, nine water depths, from 0.1 to 3.0 ft., were determined. The area of each water depth was tabulated and an estimate of the total volume of surface water (in acre-ft.) within Conservation Area 3A was reported for each date. When compared with the estimates made by a polygon technique (U. S. Army Corps of Engineers), the Landsat derived estimates were less by as much as twenty percent. Surfaces of the area above water level (such as tree islands) are removed from the estimates with the Landsat technique but not with the polygon technique.

4:30 pm EPS-19 Preliminary Studies of Pleistocene Lake Apopka, Orange and Lake Counties, Florida, GRAIG D. SHAAK, Florida State Museum, University of Florida, Gainesville, 32611, and TOM SCOTT, Florida Bureau of Geology, Tallahassee, 32304.

Over 500 feet of undisturbed samples were recovered from 20 drilling stations. Preliminary data from our samples and a 1967 subsurface investigation by the U.S. Army Corps of Engineers suggest a distinct sequence: sands, ranging from silty to clayey, lie unconformable on poorly consolidated Pliocene marine sediments. Interbedded limestone lenses, silts, clays, and sands cap the basal sands. The upper sands and limestone lenses contain a rich freshwater snail fauna. Locally, large lenses of recrystallized freshwater limestone are found in the upper sediments. The surface of the study area is mantled by peat or muck, ranging in thickness from less than 1 foot to over 50 feet. Most of the sediments were derived from ridges flanking the eastern and western shores of Lake Apopka. The freshwater fauna follows a predictable ecological succession.

4:45 pm Business Meeting of the Earth and Planetary Sciences Section

3:30 pm Little Hall 225

Session C2: THE ENVIRONMENT

Patrick Gleason, South Florida Water Management District, presiding

3:30 pm EPS-20 Soil Properties and Septic Tank Contaminant Migration, RAYMOND REA and S. B. UPCHURCH, Department of Geology, University of South Florida, Tampa, Florida 33620.

Previous investigators have suggested that complex, bifurcating contaminant plumes from septic tanks develop, in part, as a result of variations in adsorptive capacity and soil texture. A septic tank situated in the Leon Fine Sand was investigated to accurately assess the relative importances between and interactions among various soil parameters and effluent migration. Thirty six soil samples were taken down to a maximum depth of 20 feet and as far as 120 feet downgradient. Aqueous chloride ion was traced downgradient for a distance of 120 feet, nitrate for 90 feet and phosphate for 50 feet. Soil analyses indicate that minor variation in soil texture, clay, and organic content significantly affect the soil's adsorptive capacity, as well as ground water flow characteristics. The shape of the contaminant plumes, and the distribution of constituents within the plumes appear to be determined to a significant degree by these parameters.

3:45 pm EPS-21 Effects of Septic Tank Effluent on the Quality of Water in Some Man-made Ponds on Sanibel Island, Florida, T. M. MISSIMER and R. L. HOLZINGER, 2500 Del Prado Blvd., Suite B, Cape Coral, FL 33904; R. W. JOHNSON and F. W. BALOGH, Lee Co. Dept. of Environ. Protection, Ft. Myers, FL 33901.

More than 300 chemical and bacteriological analyses of water samples and several hundred field measurements of dissolved oxygen and salinity were used to determine the effects of septic tank effluent on the quality of water in some man-made ponds on Sanibel Island. Two different ponds were studied: one 16-year old affected pond being surrounded by 34 units, each utilizing a septic tank, and another nearby 3-year old unaffected pond being adjacent to only 2 units with septic tanks.

Both ponds were found to be in a eutrophic condition. The ponds each contained slightly saline water, low average dissolved oxygen concentrations, low dissolved nutrient concentrations, moderate BOD levels, and relatively high concentrations of total organic carbon. The affected lake had lower dissolved oxygen levels and had generally poorer water quality than the unaffected lake. This difference in water quality is related primarily to accumulation of organic bottom sediments and cannot be directly attributed to influx of septic tank effluent. Nutrient influx into both ponds is largely natural and the eutrophic condition of the ponds is primarily the result of natural factors. Influx of pathogenic organisms from the surrounding septic tanks into the ponds could not be conclusively demonstrated.

4:00 pm EPS-22 Bottom Sediments of Lake Okeechobee, PATRICK J. GLEASON, Central and Southern Florida Flood Control District, P. O. Box V, West Palm Beach, Florida 33402; P. A. STONE, Central and Southern Florida Flood Control District, P. O. Box V, West Palm Beach, Florida 33402.

Bottom sediments of Lake Okeechobee were investigated by means of eighty grab samples, thirty-two cores, and continuous accoustic reflection profiling (CRP). Data indicate that substrates include unconsolidated quartz sand, copropel, limestone-calcareous marl, and peat. An isocontour map of the copropel constructed from cores and CRP data indicates the thickest deposits are on the order of 1 meter. Up to eight strata are found in the copropel. The peat, muck, and copropel are middle-late Holocene in age whereas the rock, marl and sand exposed on the bottom are probably Pleistocene. Rangia cuneata shells collected from beneath the copropel give radiocarbon dates ranging from 31,100 yr. B.P. to 38,700 yr. B.P. X-ray analyses indicates a significant dolomite peak in the carbonate fraction of the copropel. The average SiO_2, Al_2O_3, Fe_2O_3, CaO, and MgO percentages of the total mass of the dried copropel are 36.5%, 3.2%, 2.7%, 19.7%, and 4.6%, respectively. The diatom flora and the sponge fauna found within the copropel indicate that the northeastern quadrant of the lake was trophically enriched during the last 4,000 years.

4:15 pm EPS-23 Environmental Hazards of Casuarina on Sanibel and Captiva Islands, Lee County, Florida, R. W. WORKMAN, Sanibel-Captiva Conservation Foundation, P.O. Box 25, Sanibel, Florida 33957; and T. M. MISSIMER, 2500 Del Prado Blvd., Suite B, Cape Coral, Florida 33904.

Several species of the genus Casuarina (Australian Pine) were introduced on Sanibel and Captiva Islands in about 1900 for the purpose of providing roadside landscape and wind breaks for citrus. This plant detrimentally affects the natural environment of the islands by: rapidly colonizing all disturbed areas, such as beaches, burns, spoils areas, and cleared lands; growing in such densities as to prohibit native plant succession and to reduce diversity; littering receding beach face areas with limbs and trunks which facilitates further beach erosion and inhibits sea turtles nesting. The tree is also a hazard to man because it is subject to wind throw and uprooting. A program to control Casuarina growth, should be instituted, particularly on environmentally sensative barrier islands.

4:30 pm EPS-24 Limnology of Taylor Creek Impoundment: With Reference to Other Water Bodies in the Upper St. Johns River Basin, Florida, DONALD A. GOOLSBY, U. S. Geological Survey, Reston, Va.; BENJAMIN F. MCPHERSON, U. S. Geological Survey, 901 S. Miami Ave., Miami, Florida.

Taylor Creek Impoundment, constructed on the western side of the Upper St. Johns River basin, was initially filled in late 1969. When compared with a natural water body, Blue Cypress Lake, the Impoundment was characterized by chemical and thermal stratification, a low benthic macroinvertebrate diversity, and a low zooplankton density. Stratification, which developed during spring and summer, resulted in an anaerobic hypolimnion with high concentrations of phosphorus, ammonia-N, carbon dioxide, ferrous iron, and hydrogen sulfide. Numbers of benthic macroinvertebrates averaged as high as 8,000 per square meter, and consisted almost entirely of the phantom midge, Chaoborus. Numbers of zooplankton were about five times greater in Blue Cypress Lake than in the Impoundment; copepodes dominated in the lake, whereas rotifers dominated in the Impoundment.

Water quality has improved in the Impoundment since 1970. The depth to the top of the anaerobic zone has increased gradually each year from about 6 feet in 1970 to 12 feet in 1974. The length of time anaerobic conditions prevailed also decreased from about 7 months in 1970 and 1971 to less than two months in 1974. Concentrations of phosphorus decreased from about 0.09 mg/l in 1969-70 to 0.04 mg/l in 1974. All major ions, except sulfate, also decreased in concentration during this time.

Friday 4:45 pm Little Hall 215

Business Meeting of the Earth and Planetary Sciences Section

Friday 7:30 pm Flagler Inn, BANQUET

MEDICAL SCIENCE SECTION

8:30 am Little Hall 217

Anthony F. Walsh, Orange Memorial Hospital, Orlando, presiding

8:30 am MSS-1 Benzo[a]pyrene UDP-glucuronosyl transferase: Purification and new assay. JAMES E. EPPERT AND JOHN C.M. TSIBRIS, Biochemistry Department, University of Florida, Box J-245, Gainesville, FL 32610. Carcinogenic benzo[a]-pyrene (BP) arene oxides decompose to phenols, which are autooxidized to quinones, are hydrated to diols and can react with nucleic acids, proteins and glutathione. UDP-glucuronosyl tranferase (GT) catalyzes the production of BP-glucuronides, thus greatly reducing the amounts of quinones made, as shown by high-pressure liquid chromatography. GT was purified from cholate extracts of 3-methylcholanthrene induced rat liver microsomes to specific activity of 800-1000 nmoles 1-naphthol glucuronide$\cdot$mg^{-1} protein$\cdot$min^{-1} by a single passage through a new aminimide-BP column; yield 50-60%. Disposable microcolumns of unsubstituted aminimide polymers were used to develop a very simple, fast and economical assay for GT. The BP-phenol specificity of purified GT will be discussed.

8:45 am MSS-2 Inhibitory Potential of α-Amanitin-Macromolecular Conjugates for Specific Cell Types. R. S. HENCIN and J. F. PRESTON. Department of Microbiology and Cell Science, 1053 McC, University of Florida, Gainesville, Fl. 32611. α-Amanitin, a fungal peptide toxin, is a potent and relatively specific inhibitor of eukaryotic RNA polymerase II, the enzyme responsible for messenger RNA synthesis. We have prepared macromolecular conjugates of α-amanitin by linkage of an α-amanitin-spacer derivative to various proteins via reaction with carbodiimide. The high affinities and restricted specificities of free or conjugated α-amanitin for RNA polymerase II allow that these conjugates may be useful inhibitors for investigation of cellular recognition processes, particularly if additional specificity with respect to uptake has been imparted to α-amanitin by conjugation. The partial chemical and biological characterization of conjugates of α-amanitin with bovine serum albumin and concanavalin A will be reported here.

9:00 am MSS-3 Cryoglobulinemia; An Autoimmune Disease? RICHARD J. WEBER and L.W. CLEM, Dept. of Immunology and Medical Microbiology, Univ. of Fla., Gainesville, Fla. 32610. A cryoprecipitate, isolated from the plasma of a patient with lymphoproliferative disease and bilateral gangrene of the feet, was found to contain only 19S IgM. This protein was of lambda isotype and appeared to be of monoclonal origin. Solubility studies showed the cryoimmunoglobulin to be monodisperse above 35°C and aggregated at lower temperatures. Since the temperature of blood in the capillaries of human skin is approximately 30°C, in vivo cryoprecipitation could explain the deterioration of this patient's lower extremities. Binding studies employing reductive subunits and proteolytic fragments of this protein suggest the cryophenomenon to be due to an antibody-antigen like reaction, with unusual thermal parameters of binding and solubility. These observations support the hypothesis that cryoprecipitates involving immunoglobulins represent the 'epitome of autoimmunity'. (Supported by ACS Grant 1N-62-P #10, NSF Grant BMS75-16749, and NIH Grant 5R01-CA 15373.)

9:15 am MSS-4 Correction of a Mandibular Horizontal Ramus Discontinuity with a Bioglass-Ceramic Prosthesis, K. L. KREUTZIGER, A. E. CLARK, L. L. HENCH, AND H. R. STANLEY, University of Florida, Gainesville, Fl 32610. An accepted treatment plan is lacking for discontinuity defects of the mandible which occur secondary to trauma and neoplasms. Bioglass-ceramics shown to bond to bone in the rat femur and tibia should bond to bone in the mandible and rapidly become a part of the bone structure . Using a baboon animal model a procedure for intermaxillary fixation was designed to maintain stabilization for healing after surgery on the jaw. A bioglass-ceramic prosthesis was implanted in a surgically created mandibular horizontal ramus discontinuity defect. Details of both procedures will be presented.

9:30 am MSS-5 Water Hardness and Urolithiasis, ROBERT SIERAKOWSKI AND BIRDWELL FINLAYSON, Departments of Engineering Sciences and Surgery, University of Florida, Gainesville, Fl 32610. Urinary stone disease is more common in Florida than in many other regions of the United States. A state by state correlation of the frequency of hospital discharges for urolithiasis with average water hardness shows a strong negative correlation ($r = 0.78$). This result is an apparent paradox. The cause of the paradox is not known with certainty. Reduction in calcium may predispose toward stone formation.

9:45 am MSS-6 The Utilization of Hypnosis for Breast Enlargement..........
William M. Trantham, Florida Keys Community College, Key West, FL 33040
This paper will describe the technique and application of hypnosis rather than artificial implants to bring about measurable increases in breast size in adult females.

10:00 - BREAK

10:30 am Little Hall 217

Arnold S. Bleiweis, University of Florida, presiding

10:30 am MSS-7 Commitment, the cell cycle, and initiation of DNA synthesis in endotoxin stimulated spleen cells, B.J. AXELROD AND J.W. SHANDS, JR., Department of Immunology and Medical Microbiology, University of Florida, Gainesville, FL 32610. Events associated with endotoxin induced mitogenesis in murine spleen cells were investigated. Increased levels of DNA synthesis in murine spleen cells stimulated with endotoxin were observed 12-16 hrs after the addition of the mitogen. The total cell cycle time of stimulated B-cells was 11-14 hrs. The S-phase of the cell cycle was 8 hrs. The G_2 phase was 1 hr, and the combined M plus G_1 phases of cycling cells was (2-5) hrs. A 1-4 hr exposure to LPS elicited a significant increase in DNA synthesis. Progressively longer exposures to LPS, up to 24 hrs, produced further increases in first cycle DNA synthesis. Polymyxin B, when added to endotoxin stimulated cultures from the outset, inhibited first cycle DNA synthesis. These data indicate a heterogeneity among B-cells in their responsiveness to endotoxin.

10:45 am MSS-8 Effect of pH on Respiratory Control of Mouse Heart and Liver Mitochondria. G. VLASUK, J. TSOKOS. Dept. Chem., Univ. So. Fla., Tampa, FL 33620. Most mitochondrial studies are done at pH 7.4, the extracellular fluid pH and probable intracellular pH of liver. However, we have observed that respiratory control ratios (RCRs) of isolated mitochondria (MT) vary significantly with pH. Mouse heart and liver MT were isolated by standard procedures and O_2 uptake rates measured polarographically. The substrate was succinate; State 3-4 transitions occurred after additions of 66μM ADP. RCR = state 3: State 4 rate. Heart MT exhibit maximal mean RCR at pH 6.8 in mannitol-sucrose medium. Mean RCRs at pH 6.4 and 7.4 are notably less. In contrast, liver MT show maximal mean RCR at pH 7.4, with successively lower values at pH 6.8 and 6.4. Similar trends obtain for both MT types if an isotonic salt medium is used. These data suggest that cardiac MT respire more efficiently at pH 6.8, and heart MT studies at pH 7.4 may significantly underestimate their activity.

11:00 am MSS-9 Periodontal Disease and the Differential Virulence System in Actinomyces viscosus T14V and T14AV, D.C. BIRDSELL, W. FISCHLSCHWEIGER, D.R. CALLIHAN, J.E. FITZGERALD, AND J.T. POWELL, Dept. of Basic Dental Sciences, Box J-424 JHMHC, Univ. of Florida, Gainesville, FL 32610. Periodontal disease is a chronic destructive disease process believed to result from an immunologic response of the host to antigens released from bacteria present in dental plaque. A common filamentous dental plaque bacterium, A. viscosus T14V (virulent), produces massive periodontitis in a germ-free rat model while A. viscosus T14AV (avirulent) does not. Examination of chemical extracts of these two strains by analytical serological procedures revealed the presence of unique antigens in the virulent strain (T14V). Ultrastructurally T14V possesses a fibrillar cell wall layer absent in strain T14AV. Shearing of surface components from T14V by physical methods released several antigens. The data suggest that the virulent strain (T14V) has surface antigens that are not detected in the avirulent strain (T14AV).

11:15 am MSS-10 Localization of Virulence Associated Antigens in Actinomyces viscosus T14V, J.E. FITZGERALD AND D.C. BIRDSELL, Dept. of Basic Dental Sciences, Box J-424 JHMHC, Univ. of Florida, Gainesville, FL 32610. Periodontal disease is characterized by an immune response to an antigenic stimulation from dental plaque microbiota. The characteristic bone loss and tissue destruction of periodontitis is believed to result from this response. Laurell rocket electroimmunoassay of A. viscosus T14V (virulent for germ-free rats) reveals two antigens that are not apparent in the avirulent variant (T14AV). Exponential phase T14V cells were labeled with ^{125}I using the lactoperoxidase method, and fractionated to obtain surface, cell wall, cell membrane and cytoplasmic pools. The fractions were then mild acid extracted (Lancefield Procedure) and examined by electroimmunoassay. The unique antigens were detected in both the cell membrane and cell wall fractions. In addition, the lactoperoxidase labeling revealed that the unique antigens are an external component of the cell surface.

11:30 am MSS-11 Comparison of Growth Patterns of a Virulent and an Avirulent Strain of Actinomyces viscosus T14, J.T. POWELL AND D.C. BIRDSELL, Dept. of Basic Dental Sciences, Box J-424 JHMHC, University of Florida, Gainesville, FL 32610. The bacterium Actinomyces viscosus (T14V) has been implicated as a potential etiological agent in human periodontal disease. A derivative of T14V, T14AV, has been isolated and shown to be avirulent in animal model systems. Biochemical characterization of the two strains showed identical properties with respect to carbohydrate degradations, catalase production, and end product formation. Comparisons of growth rates showed marked differences when measured by turbidometric methods, but were essentially identical when measured by dry weight or total cellular DNA assays. The results suggest that the observed loss of virulence in the variant strain (T14AV) does not correlate with a major alteration in cellular growth properties.

Friday 11:45 am Little Hall 217
Business Meeting of the Medical Sciences Section

12:00-1:00 pm LUNCH

Friday 1:00-1:30 pm Little Hall 101
Annual Business Meeting of the Academy

1:30-3:15 pm Little Hall 101
GENERAL SESSION

Friday 7:30 pm Flagler Inn, BANQUET

PHYSICS AND ASTRONOMY SECTION

Friday 8:00 am Little Hall 219

H. S. Robertson, University of Miami, presiding

8:00 am PAS-1 Hypersensitization of Kodak Emulsions IIIa-J and 103a-O by Baking in Forming Gas.* R. L. SCOTT AND A. G. SMITH, Department of Physics and Astronomy, University of Florida, Gainesville, FL 32611. Previous work at Rosemary Hill has shown that the nitrogen baking hypersensitization process pioneered by A. G. Smith (1971) and the hydrogenation process of Babcock et. al. (1974) are additive for IIIa-J and 103a-O. To overcome the explosive hazards associated with hydrogen, tests were conducted with forming gas, a non-explosive mixture of hydrogen and nitrogen. It was found that baking in forming gas is an effective means of hypersensitizing IIIa-J and 103a-O.

Smith, A.G., Schrader, H.W. and Richardson, W.W. 1971, Applied Optics, 10, 1597.
Babcock, T.A., Sewell, M.H., Lewis, W.C. and James, T.H. 1974, A.J., 79, 1479.

*Research supported by the National Science Foundation.

8:15 am PAS-2 Handling Astronomical Plates in a Sub-Tropical Environment.* H.W. SCHRADER, E.E. GRAVES, AND A. G. SMITH, Department of Physics and Astronomy University of Florida, Gainesville, Florida 32611. The humid environment of Rosemary Hill Observatory presents unusual problems in handling photographic plates if deleterious changes in sensitivity are to be avoided. All plates are hypersensitized, usually by baking in nitrogen. They are transported and stored in metal boxes under a dry nitrogen atmosphere. For exposure at the telescope they are loaded into gas-tight cassettes that are immediately filled with dry nitrogen. If optical filters are used in the photography they are incorporated as windows in the cassettes to avoid introduction of additional optical surfaces.

*Supported by NSF Grant AST 75-02182.

8:30 am PAS-3 Autoradiography: a New Tool for Astronomical Photography?* ALEX G. SMITH AND ROGER L. SCOTT, Department of Physics and Astronomy, University of Florida, Gainesville, Fl. 32611. In autoradiography the silver in a photographic negative is rendered radioactive by exposure to a radioactive isotope. This "hot" negative is then used to produce a secondary negative by contact printing. By proper choice of materials and exposure times considerable intensification of the original image can result. We will report on experiments in collaboration with U. S. Naval Intelligence in which under-exposed astronomical photographs were autoradiographed in order to increase their informational content.

*Research supported by the National Science Foundation.

8:45 am PAS-4 Optical Monitoring of Radio-Quiet Quasi-Stellar Objects,* PATRICIA L. EDWARDS AND A. G. SMITH, Department of Physics and Astronomy, University of Florida, Gainesville, Fla. 32611. Variability studies of Quasi-Stellar Radio Sources carried out at the Rosemary Hill Observatory have been expanded to include a sample of 17 Radio-Quiet Quasi-Stellar Objects located by Sandage and Bracessi.[1,2] These objects have optical spectra and U-B and B-V colors similar to QSRS's but have no radio flux above the detection levels of the radio surveys. Monitoring of the optical brightnesses has been carried out to study the characteristics of the variability of the RQQSO's for comparison with the larger sample of QSRS's. Preliminary results indicate that the percentage of RQQSO's which show variability is similar to that of the QSRS's despite their very different radio fluxes.

*Supported by NSF Grant #AST 75-02182.
[1]Sandage and Luyten, 1967, Ap. J. 148, 767.
[2]Bracessi, Lynds and Sandage, 1968, Ap. J. 152, L105.

9:00 am PAS-5 Optical Identification of Weak Radio Sources, FRANK F. DONIVAN, Department of Physical Sciences, University of Florida, Gainesville, Florida 32611. The positions of 35 weak radio sources were measured to within 5 arc sec using the three-element interferometer at the National Radio Astronomy Observatory. Some sources were selected because their radio spectra are flat, a characteristic often associated with optically variable QSO's. The remainder of the sources had been provisionally classified as "optically blank fields", however in may cases the positions were uncertain to more than 30 arc sec. Using a two-axis measuring photo-microscope it is possible to locate and photograph the radio sources's position on the Palomar Sky Survey prints. In addition to searching the prints, it is possible to use the "finding charts" to examine plates taken with the 30-inch reflector at Rosemary Hill Observatory as part of A. G. Smith's QSO photographic-photometry program.

9:15 am PAS-6 Breakdown of the Plane-Parallel Approximation to the Earth's Atmosphere, E. F. STROTHER and J. ALLYN SMITH, Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, Florida, 32901.

In the plane parallel model of the earth's atmosphere, the relative air mass between an extra-atmospheric light source and a surface observer is given as the secant of the zenith angle z. By including stars of very large zenith angles in a photoelectric photometry extinction sequence, the departure from this atmospheric approximation becomes significant and can be observed and measured. Photometry data illustrating this effect will be presented and the errors it may introduce into the determination of atmospheric extinction coefficients under various conditions will be discussed and analyzed.

*Supported in part by USAF Contracts FO 8606-74-C-0050/FO 8606 76-C-0036

9:30 am PAS-7 Photoelectric Observations of YZ Chamealeontis,* KWAN-YU CHEN, Department of Physics and Astronomy, University of Florida, Gainesville, Fla. 32611. The star was reported to be a variable in 1949 and was designated as Sonneberg variable No. 4949. The period was given as 2.228685 days (Strohmeir 1967), and as 4.457357 days (Geyer and Knigge 1974). This paper gives observations of this eclipsing variable in the Y (5000 Å), R (7000 Å) and I (9000 Å) wavelength regions. The observations were made at Cerro Tololo Inter-American Observatory in March and April 1976.

*The research program on close binary stars at the University of Florida, supported partially by the National Science Foundation grant No. MPS 73-05001.

**Visiting Astronomer, Cerro Tololo Inter-American Observatory, supported by the National Science Foundation under contract No. NSF-C866.

9:45 am Business Meeting of Physics and Astronomy Section

10:15 am PAS-8 Apollo-Soyuz Rendezvous and Docking, WILLIAM M. TRANTHAM, Florida Keys Community College, Key West, FL 33040. This paper will include a color slide presentation of the first American-Soviet joint space mission featuring activities taking place aboard both vehicles during the mission. Space ecology and the psychophysiology of weightlessness will be discussed during the presentation.

10:30 am PAS-9 Remote Sensing of the Planet Mars, WILLIAM M. TRANTHAM, Florida Keys Community College, Key West, FL 33040. This paper will include high resolution black and white as well as color slides taken by Viking Orbiter and Lander Spacecraft. A full description of the geological and exobiological sensing technology utilized at both landing sites and their preliminary findings will be discussed.

10:45 am PAS-10 The GTE/USF COMSTAR Satellite K-Band Propagation Experiments, S. C. BLOCH, Univ. of So. Fla., Tampa, FL 33620, and D. DAVIDSON, D. TANG, and O. G. NACKONEY, GTE Laboratories, Inc., 40 Sylvan Rd., Waltham, MA 02154. We describe a 3-station spatial diversity experiment in the 19 and 29 GHz bands using the beacon transmitters aboard the COMSTAR satellites. The primary obstacle to straightforward use of these frequencies is the attenuation due to rainfall; the purpose of the experiment is to obtain long-term statistics concerning meteorological effects on the space-to-earth propagation path. Anticipated data will include spatial diversity information, polarization discrimination, aperture coherence, amplitude distributions during rainfall, speed of onset of fading, and clear weather measurements of changes in the instantaneous frequency and power spectrum of phase rate fluctuations.

11:00 am PAS-11 The GTE Satellite Earth Station at Homosassa, S. C. BLOCH, Physics Department, USF, Tampa, FL 33620, W. C. HEITHAUS, GTE , P.O. Box 110, Tampa, FL 33601, and B. BLAIS, GSAT, P.O. Box 158-8, Homosassa Springs, FL 32642. The earth station at Homosassa, nearing completion for communication via the COMSTAR geostationary satellites, and others, using the 4 and 6 GHz bands, is described in some detail. Located in a quarry for electromagnetic shielding purposes, the antennas have a unique "beam-feed" optical design which completely eliminates rotating joints in the waveguide while permitting reception of two orthogonal polarizations. The antenna pointing system has provision for automatic compensation for changes in Faraday rotation. The receiving system, with a cryogenically-cooled parametric amplifier front end, and the transmitting system will also be described.

11:15 am PAS-12 Optical and X-ray Emission Associated with Jupiter. M.D. DESCH AND R.S. FLAGG, Department of Physics and Astronomy, University of Florida, Gainesville, FL 32611. The high radio luminosity of the Jovian millisecond bursts suggests that detectable optical and x-ray emission may accompany the bursts. Electron beams responsible for the radio bursts are expected to stimulate (1) optical line emission associated with the primary atmospheric constituents (H, He, NH_3, CH_4) and (2) x-ray emission through thermal and nonthermal bremsstrahlung. The Pioneer-11 magnetic field models are used to locate the source which differs from pre-Pioneer estimates by as much at 60^o in longitude and 15^o in latitude.

11:30 am PAS-13 Measurements of the Radio Luminosity of Jovian Millisecond Bursts. R. S. FLAGG AND M. D. DESCH, Department of Physics and Astronomy, University of Florida, Gainesville, FL 32611. Jovian S-burst activity has been recorded using the University of Florida Variable Time-Expansion Radio Spectrograph. Analysis of burst intensities on the frequency-time plane have produced new estimates of the energy emitted within the instantaneous burst bandwidth and also total energies emitted during the burst lifetime.

11:45 am PAS-14 Jupiter's Magnetospheric Rotation Period, T. D. CARR AND M. D. DESCH, Dept. of Physics and Astronomy, Univ. of Fla., Gainesville, Fl 32611, J. MAY, Observatorio Radioastronomico de Maipu, Casilla 68, Maipu, Chile. Twenty-four independent measurements of the rotation period of the sources of Jupiter's decametric radio emission, which are believed to be fixed relative to the magnetic field of the planet, have been measured from data obtained during the past 20 years. The mean value was found to be 9 hr 55 min 29.702 sec, with a standard deviation of the mean of 0.010 sec. No significant change in the rotation period has yet been detected. An upper limit on the secular rate of change has been established, and will be compared with the rate which one might expect if Jupiter's magnetic poles wander as rapidly as do those of the earth.

12:00-1:00 pm LUNCH

Friday 1:00-1:30 pm Little Hall 101

Annual Business Meeting of the Academy

Friday 1:30-3:15 pm Little Hall 101

GENERAL SESSION

Friday 3:30 pm Little Hall 219

Jack Noon, Florida Technological University, presiding

3:30 pm PAS-15 Search for Superheavy Elements in the Allendé Meteorite*, L. R. MEDSKER, G. W. BRASS, W. J. COURTNEY, J. D. FOX, N. R. FLETCHER, and A. H. LUMPKIN, Physics Department, Florida State University, Tallahassee, Florida 32306. A sample from the Allendé meteorite has been analyzed by the proton induced x-ray emission (PIXE) method. The sample is from the material which has yielded anomalous xenon isotopic ratios which have been interpreted[1] as evidence for the former presence of elements in the region of Z = 114. No evidence for superheavy elements has been observed in the preliminary PIXE work. The experimental technique and latest results will be discussed.

*Supported in part by NSF Grants No. NSF-GU-2612 and NSF-PHY-7503767-A01.
[1]E. Anders et al., Science 190, 1251 (1975); 1762.

3:45 pm PAS-16 The Gamma-Gamma Coincidence Technique, D. C. WILSON, L. H. FRY, JR., T. J. ANDRESEN, L. A. PARKS, J. F. MATEJA, and L. R. MEDSKER, Physics Department, Florida State University, Tallahassee, Florida 32306. The electronic technique for measuring the time sequence of nuclear events has been used for studying the γ-ray decays of nuclear levels. The data acquisition and analysis make extensive use of the computers at the FSU Tandem Accelerator Laboratory. As an illustration of the technique, recent studies of the $^{81}Br(p,n\gamma)^{81}Kr$ and $^{23}Na(p,p'\gamma)$ reactions will be discussed.

*Supported in part by NSF Grant Nos. NSF-GU-2612 and NSF-PHY-7503767.

4:00 pm PAS-17 Heavy Ion Beams for Research in Low Energy Nuclear Physics,* L. H. FRY, JR., D. C. WILSON, P. L. PEPMILLER, L. R. MEDSKER, and K. R. CHAPMAN, Physics Department, Florida State University, Tallahassee, Florida 32306. The production of heavy ion beams for the study of reactions between heavy ions has been accomplished by use of the Inverted Sputter Source[1] at the Tandem Accelerator Laboratory of the Florida State University Physics Department. After injection into the Super FN Tandem Accelerator, silicon ions have recently been obtained with energies up to 72 MeV. With this particular ion source design, one can easily change from one type of beam to another. The flexibility and reliability of this ion source allows the Florida State University group a research program in nuclear reactions which uses a wide variety of heavy projectiles. Proposed and present uses of ^{14}N, ^{24}Mg, ^{27}Al, and ^{28}Si beams will be discussed.

*Supported in part by NSF Grant Nos. NSF-GU-2612 and NSF-PHY-7503767-A01.
[1]K. R. Chapman, Nucl. Instr. and Methods 124, 299 (1975).

4:15 pm PAS-18 Analytic Yield Spectra for Electrons Impacting on Atmospheric Gases, C.H. JACKMAN, R.H.GARVEY and A.E.S. GREEN, Department of Physics and Astronomy, Williamson Hall, University of Florida, Gainesville, Fl. 32611. Electrons impinging on gases create a "yield spectrum" of electrons comprising both the primary and all subsequent generations of particles. This yield spectra is a simple yet powerful function which can account for many energy deposition consequences. For example, the yield spectra for Ar, H_2, H_2O, O_2, N_2, O, CO, CO_2 and He can be used to predict populations of excitation or ionization states resulting from the degradation of electrons with incident energy in the range 50 to 10,000 eV. Using an analytic function to represent the yield spectra along with an analytic representation for the probability of ionization, we have been able to analytically present a formula for expressing the ion yield per energy loss and its reciprocal, the energy loss per ion pair.

4:30 pm PAS-19 The Cell Theory for Non-Polar Liquids in Terms of a Variable Coordination Number: Variation with Volume as Determined by Measured Sound Speed, RICHARD A. RHODES II, BRYAN G. WALLACE AND WILBUR F. BLOCK, Eckerd College, St. Petersburg, FL. 33733. The cell theory for classical non-polar liquids has been modified such that the co-ordination number c, or number of nearest neighbors surrounding a given particle, varies with temperature and hence volume from a high value near the freezing point to a low one near the vaporization point. The partition function $\mathcal{Z}$ of Maxwell-Boltzmann statistics was constructed using the Lennard-Jones 12-6 potential, and c was varied by degrading the packing state from face-centered (12) through body-centered (8) to simple cubic (6). The theory was applied to liquid argon, and pressure and energy equations of state were derived from Z and used to find the sound speed v. An iterative-process computer model used assumed c-values to compute v and compare with measured values. The resulting "correct" c-values have been compared with those obtained from the experimentally more complicated processes of x-ray and neutron diffraction.

Friday 7:30 pm Flagler Inn, BANQUET

Saturday 8:30 am Little Hall 219

Jack Noon, Florida Technology University, presiding

8:30 am PAS-20 Landau Damping Without Contour Integration, ROBERT W. FLYNN, Physics Department, University of South Florida, Tampa, FL 33620. Many of the mathematical difficulties in the Landau Damping problem are associated with the inversion of a Laplace transorm using contour integration. These difficulties can be circumvented by directly solving the time dependent equations. When this is done, Landau's result can be derived rigorously using straightforward mathematics.

8:45 am PAS-21 Pseudo-Square Linear Pulse Synthesis Using Gaussian Pulse Stacking, HARRY E. BATES, B.J. HENDERSON, RONDALD W. ELLIOTT, AND LEON C. HARDY, FLORIDA TECHNOLOGICAL U., Orlando, FL 32816. We will report on results of an investigation of the process of generating pseudo-square temporal amplitude functions linearly synthesized using gaussian functions of identical shape. We have determined that spacings and amplitude distributions exist which minimize the mean square deviation of the synthesized from the ideal function. In addition, we will discuss theoretical limits on the optimum transmission for passive linear pulse stackers.

9:00 am PAS-22 A Proposed Procedure for Thermal Evaluation of Flat-Plate Solar Collector, HARRY S. ROBERTSON, Dept. of Physics, U. of Miami, Coral Gables, Fl 33124. Analysis of the basic equations governing the performance of flat-plate collectors shows that the measurement of two basic parameters, one related to the rate of energy loss in the dark and the other to the maximum attainable temperature at zero flow rate for a particular insolation, permits the calculation of efficiencies and output temperatures for whatever ambient conditions and flow rates may exist. It is suggested that collectors should be evaluated in terms of these parameters rather than by the usual procedures.

9:15 am PAS-23 A Three Terminal Capacitance Method for Measuring the Dielectric Constants of Solids from Room Temperature to 77 K, J. STEVE BROWDER, DAVID DONOHO*, RICHARD HEBB, AND STUART MACRAE, Jacksonville Univ., Jacksonville, Fla. 32211. A three terminal capacitance technique has been used to make high-resolution measurements of the dielectric constants of solids in the temperature range from 77 K to room temperature. Emphasis was placed on determining the temperature derivative of the dielectric constant. The technique will be described and the results of measurements on teflon, CaF_2, BaF_2, KCl and MgF_2 will be presented. Also, the results of a study of a phase transition observed at 290.6 K in teflon will be discussed. Our data will be compared with those reported elsewhere.(* Presenting.)

9:30 am PAS-24 Laser Brillouin Measurements of in-Depth Seawater Temperature*. J.G. HIRSCHBERG, A.W. WOUTERS, J.D. BYRNE and C.E. DEVERDUN, Laboratory for Optics and Astrophysics of the Department of Physics, University of Miami, Coral Gables, FL 33124. The Brillouin Effect may be utilized to determine seawater temperatures by means of back scattering. An argon ion laser was used together with a Fabry-Perot interferometer. Preliminary results are presented.

*Supported by NASA on contract NAS10-8954.

9:45 am PAS-25 Inexpensive system for Recording and Reproducing Analog Data, JOHN P. OLIVER AND FRANK DONIVAN, Department of Physics and Astronomy, University of Florida, Gainesville, FL 32611. Analog data in the dc to 1 kilohertz frequency range can be accurately recorded and reproduced using simple electronics and an ordinary audio tape recorder. The electronics convert the analog data to a frequency modulated (FM) signal for recording, and detect the FM signal to reproduce the analog input on play back. A tape speed of 3 3/4 inches per second provides adequate reproduction fidelity for most experimental purposes. Using this system, analog data can be recorded in the field and played back in the laboratory for analysis by equipment not suitable for field use. In addition an event can be played back repeatedly for re-analysis if needed.

10:00 am PAS-26 Computer Designed Jib Sails*, T. J. ANDRESEN, Physics Department, Florida State University, Tallahassee, Florida 32306. A working jib sail on a small racing yacht has been expressed as a triangular surface $z = s(x,y)$ $(\kappa>0)$. The surface has been mapped with geodesics perpendicular to the leech edge. Transverse inter-geodesic distances have been computed to determine the shape of flat ($\kappa=0$) panels required to approximate the sail surface. The method has been used to determine broadseams and luff curves as they relate to the sail shape and edge parameters.

*Supported in part by NSF Grants No. NSF-GU-2612 and NSF-PHY-7503767-A01.

Also see the program of the American Association of Physics Teachers, which starts at 10:15 am in this room

---

SCIENCE TEACHING SECTION

Friday 8:00 am Little Hall 221

Fred Prince, University of South Florida, presiding

8:00 am STS-1 On-Site Examination of Community Ecology Through Experiential Methodology..
William M. Trantham, Florida Keys Community College, Key West, FL 33040
This paper will include a color slide presentation of student exposure to environmental problems at their site of origin. It will discuss the educational and public relations value of hands-on student involvement with industrial pollution hazards in the local community as a means of student motivation in ecology.

8:30 am STS-2 Solvent Extraction and Ion Exchange in the Nuclear Fuel Industry, WILLIAM L. MAC CREADY AND JOHN A. WETHINGTON, JR., Department of Nuclear Engineering Sciences, University of Florida, Gainesville, Florida. This paper is a teaching module containing information basic to the understanding of solvent extraction and ion exchange processes with respect to their use in the Nuclear Fuel industry, in particular the processing of uranium and plutonium. Topics discussed in the module are the water chemistry of uranium and plutonium, an overview of the principles of solvent extraction and ion exchange, the types of equipment used and how they operate, and a look at some of the industrial processes in the nuclear fuel industry. Solvent Extraction and ion exchange techniques are used in the concentration, purification, and reprocessing phases of the nuclear fuel cycle. Each of these phases are discussed through an example of an actual industrial process currently in use.

9:00 am STS-3 Audio Tape Transcripts - An Inexpensive Information Delivery System For Audio Tutorial Courses, CHARLES J. MOTT, St. Petersburg Junior College, Clearwater Fl. 33515.
A Brief history of the A-T program at St. Petersburg is presented. Results of ongoing experimentation with the system is discussed. The most recent modification provides written transcripts as an alternative to tapes. Results show that some students move faster through the objectives and show greater achievement when transcripts are used.

Benefits noted include marked decrease in cost for initial program development because fewer pieces of equipment are needed. Also, students with differing learning styles may be accommodated.

9:30 am STS-4 Differences in the Achievement of Women in a Self Paced Earth Science Course, CHARLES J. MOTT, St. Petersburg Junior College, Clearwater, Fl. 33515. The idea that roles imposed on women by social conditioning have an effect on the ability of those women to perform in independent study college classes was tested. An experiment was developed to test the hypothesis that women might show differences in achievement. Two study formats were compared with a lecture/demonstration approach: an audio tutorial, fixed calendar and an auto-paced format.
Although achievement for men and women were the same in the conventional and fixed calendar formats, men scored significantly higher in the auto-paced class. It is not certain whether social indoctrination was responsible for these results, but should be considered in development of independent study programs.

10:00 am Business Meeting of the Section

BREAK

10:30 am STS-5 Six-screen Panoramic Projections as a Teaching Tool, F. B. KUJAWA, Chemistry Dept., Florida Technological University, Box 25000, Orlando, Florida, 32816. Geology field trips can be much more adequately simulated by using 180° panoramic projections than by showing single slides. Long rock exposures, mountain ranges, canyons, craters, etc. can be viewed fairly close-up without restricting the view to such a narrow angle that overall perspective is effectively lost. Only such panoramas can preserve the breathtaking grandeur of the Great Smokies, Grand Canyon, Yosemite Valley, and the Grand Tetons. In addition, multiple-screens can be used to great advantage for comparisions, such as: successive stages of geologic processes, successive close-ups of rock outcrops, and photographic scenes with location maps on various scales.

11:00 am STS-6 Photochemical Isotope Separation Applied to Uranium, DAVID A. BRENNER, Department of Nuclear Engineering Sciences, University of Florida, Gainesville, Florida, 32611. We are preparing a series of teaching modules for nuclear engineering students on the reactor fuel cycle and have chosen to include a module dealing with the topic of photochemical isotope separation. Current textbooks in the typical nuclear engineering curriculum do not cover this topic. It appears that with the demand for enriched uranium rising and with the high cost of separative work, the photochemical separation process could provide a promising alternative at reduced cost. This process uses a tunable laser to selectively excite a single isotope and then, by some secondary process which favors the excited atom or molecule, separates the desired isotope. Selective excitation processes and secondary removal processes will be considered in detail.

11:30-1:00 pm LUNCH

1:00 pm Little Hall 101

Annual Business Meeting of the Academy

Patrick J. Gleason, President, presiding

1:30-3:15 pm Little Hall 101

GENERAL SESSION

7:30 pm Flagler Inn, BANQUET

SOCIAL SCIENCES SECTION

Friday 8:00 am Little Hall 223

Stuart I. Ritterman, University of South Florida, presiding

8:00 am SSS-1 Alternatives to the Oster and Heinrich[1] Mathematical Model of Majoring in *Bombus hypnorum* L. GERALYNN M. BRUNEAU, Student, Department of Biology, USF, Tampa, FL. 33620. The process of majoring in social insects refers to an individual within-species preference for the pollen and nectar of a given species of flower. To account for such majoring, Oster and Heinrich[1] proposed a mathematical model which, according to the authors "...indicates that the pure strategy of 'majoring' is always better than random foraging if the reward structure remains approximately constant through time."

The present paper explores alternative models to the one proposed by Oster and Heinrich.

[1]G. Oster and B. Heinrich, "Why Bumblebees Major? A Mathematical Model," in *Ecological Monographs*, 46 (1976) 129-133.

8:30 am SSS-2 The Application of a Closed Circuit TV Reading System for Improvement of Reading in Blind Adults, B. LAX, Exceptional Child Education, USF, Tampa, FL. 33620 and J.D. NEWMAN, Tampa, FL. A closed-circuit TV reading system was employed to test the reading speed of legally blind students. Subjects' reading speeds were expected to relate the power of the microscopic system to their I.Q.'s and educational levels and to their previous experience with low vision aides. Of twenty-one legally blind college students identified, 8 participated in this study. Results are discussed in terms of their clinical and academic implications.

9:00 am SSS-3 A Water Crop Doctrine for Water Allocation, C.E. PALMER, 307 Floral Drive, Tampa, FL. 33612. The allocation of water for private and corporate uses traditionally has been based on either the riparian or the appropriation doctrine. Both doctrines contain inflexabilities which are inconsistant with modern day water management requirements. Most of the Florida Peninsula has no inflow of water from outside the area and is totally dependent on local rainfall for water supplies. Several sub-areas of this portion of the peninsula can be similarly deliniated. Water management in some parts of Florida is currently based on a water crop concept, defined as percipitation minus evapotranspiration (P-Et). The water crop of individual property holdings, estimated at 13 inches per year, is an important basis for making water management decisions in this system. It is proposed that geographic variation in the water crop be recognized by determining values for local areas. In the proposed system, the water crop of an area would be allocated among three broad categories of use: property owners, common uses and the maintenance of natural systems.

9:30 am SSS-4 Applications of Computerized Speech Processing in Criminology. S. I. RITTERMAN, Dept. of Communicology, S. C. BLOCH, Physics Dept., and P. W. LYONS, Computer Research Center, USF, Tampa, FL. 33620. Advances in digital signal processing are discussed in the contexts of improvements in speech intelligibility in remote surveillance situations and assistance in speaker recognition[1]. We present results of an intelligibility enhancement experiment in which spectrum amplitude equalization is achieved by adaptive inverse digital filtering using the power spectrum (log-average spectrum) method.

[1] S. C. Bloch, P. W. Lyons, and S. I. Ritterman, "Enhancement of Speech

Intelligibility by Blind Deconvolution," in *Proceedings of the 1977 Carnahan Conference on Crime Countermeasures,* J. S. Jackson, Ed., Univ. of Kentucky, Lexington, KY, 1977.

10:00 am Business Meeting of the Section

BREAK

10:30 am SSS-5 An analysis of the Psychological Stress Evaluator as a Tool for Assessing Emotional States, D. H. VanDercar, J. Greaner, N. Hibler, C.D. Spielberger, Dept. of Psychology and S. C. Bloch, Dept. of Physics, University of South Florida, Tampa FL 33620. The Psychological Stress Evaluator (PSE) is an instrument which, according to the manufacturer "detects, measures, and graphically displays certain specific stress-related components of the human voice." Despite widespread publicity and use as a "lie-detector" few independent attempts have been made to validate this instrument. Two studies were conducted which experimentally manipulated stress through threat of shock and compared the data obtained with the PSE to changes in heart rate and a self-report measure of anxiety (State-Trait Anxiety Inventory). Results indicate that under certain conditions the PSE can reliably discriminate between high and low levels of stress.

11:00 am SSS-6 Correlates of Littering Behaviors and Attitudes. W.R. BROWN, Dept. of Sociology, FTU, Orlando, FL. 32816, Responses to a survey questionnaire administered under anonymous conditions to a quasi-random sample of 537 respondents of all ages in the Orlando, Florida area indicate the need to give more children, especially boys, responsibilities for caring for their own environment as a long range plan for combatting serious littering problems. Respondents who had carried greater responsibilities for cleaning and maintaining the home areas while growing up were subsequently bothered more by untidy situations; they also littered significantly less than those with fewer such responsibilities. Other facets of littering behaviors are discussed.

11:30-1:00 pm LUNCH

1:00 pm Little Hall
Annual Business Meeting of the Academy

Patrick J. Gleason, President, presiding

1:30-3:15 pm Little Hall 101
GENERAL SESSION

7:30 pm Flagler Inn, BANQUET

AMERICAN ASSOCIATION OF PHYSICS TEACHERS

Saturday, 10:15 am Little Hall 219

James Steven Browder, Jacksonville University, presiding

10:15 am APT-1 Diffracting X-rays with X-ray Film, JAY S. HUEBNER, Department of Natural Sciences, University of North Florida, Jacksonville, FL 32216, and TIM J. ALLEN, Science Department, Fletcher Senior High School, Neptune Beach, FL 32233. Introductory x-ray diffraction experiments require students to be familiar with 3 separate technologies, which are usually new to them. These technologies are x-ray generation, x-ray diffraction, and x-ray detection. We have found that x-ray film makes convenient x-ray diffraction targets and provides a useful demonstration of how photographic film detects x-rays. Individual AgBr crystals in the film accomplish x-ray detection by exposure and development converting the AgBr crystal into a Ag metal crystal. The Ag crystals absorb visible light, and thereby form the negative image. Unexposed AgBr crystals are rinsed away while "fixing" the film. Diffraction targets made from raw x-ray film, taken directly from the film box, produce AgBr powder diffraction patterns, while targets made from exposed, developed and fixed film produce Ag metal powder patterns.

10:30 am APT-2 Orbit Plotting Using Identical Iterative Steps, HERBERT W. JONES, Physics Department, Florida A & M University, Tallahassee, Florida 32307. A method similar to, and of the same order of approximation, as that in The Feymann Lectures on Physics has been developed which presents a more physical interpretation of motion. In this method the first step along the orbit follows the same procedure as the subsequent ones. Also, the velocity is calculated at each position, permitting a determination of energy. Briefly, the position is located after time $\Delta t/2$, assuming the initial velocity is maintained. Then the entire change in velocity $\Delta v = F\Delta t/m$ is calculated at this point. The particle then travels for time $\Delta t/2$ at this new velocity.

10:45 am APT-3 Homodyne Doppler Velocimetry -- An Undergraduate Experiment. HARRY E. BATES, FLORIDA TECHNOLOGICAL U. --Parallel explanations of homodyne Doppler velocimetry are discussed as well as an undergraduate experiment wherein this phenomenon in the microwave region of the electromagnetic spectrum is applied in the measurement of the constant acceleration of coupled masses. One mass is an air car with radar reflector attached and the other a drop weight.

11:00 am APT-4 Undergraduate Research Participation in Physics,* J. STEVE BROWDER, Department of Physics, Jacksonville University, Jacksonville, FL 32211. This paper presents an evaluation of an Undergraduate Research Participation (URP) Project carried on during the summer of 1976 at Jacksonville University. The value of the project to the student participants, the director and other science faculty members will be discussed. (The student participants are presenting the results of their research in a paper entitled "A Three Terminal Capacitance Method for Measuring the Dielectric Constant of Solids from Room Temperature to 77 K," at the Friday afternoon session of the Physics and Astronomy Section of the Florida Academy of Sciences Meeting.)

*Project supported by the National Science Foundation.

11:15 am APT-5 The Recent Chicago Meeting of AAPT. Stanley S. Ballard, University of Florida. Highlights are presented of the joint annual AAPT-APS meeting held in Chicago on February 7-10, 1977. Special attention is given to items of interest to members of the regional sections.

11:30 am Little Hall 219

Business Meeting of the American Association of Physics Teachers

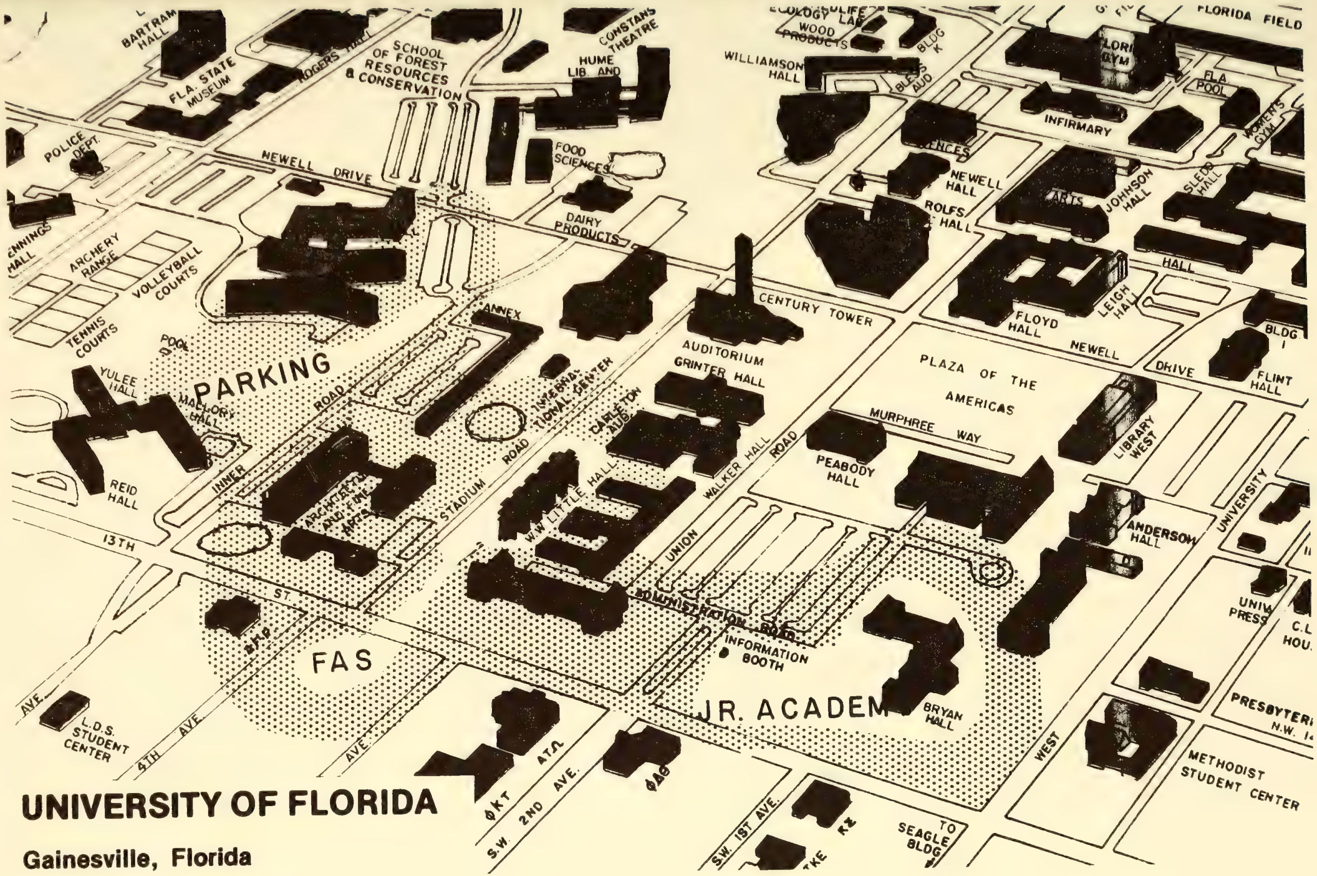
Alexander K. Dickison, Seminole Community College, presiding

NOTES

NOTES

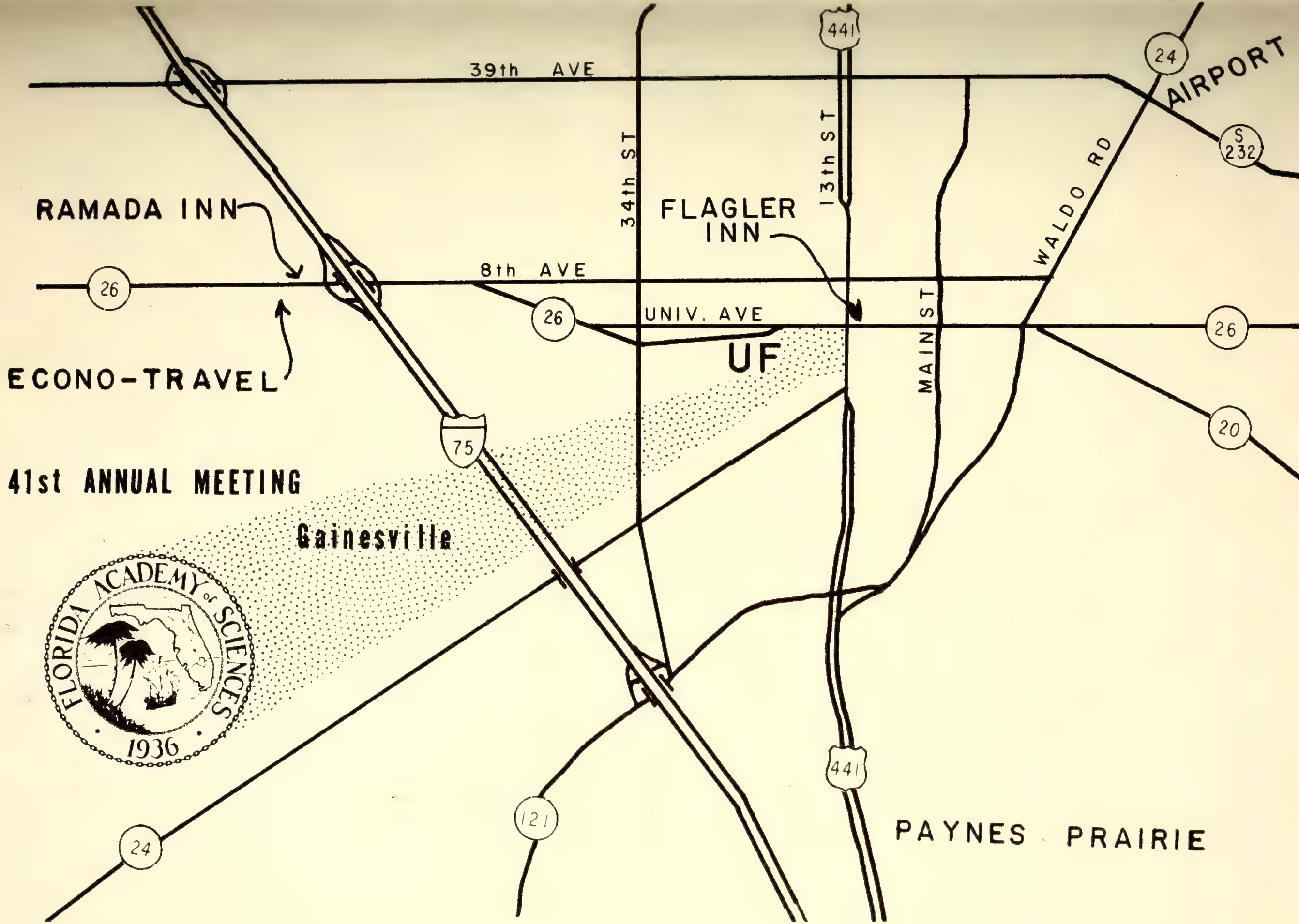
NOTES

NOTES

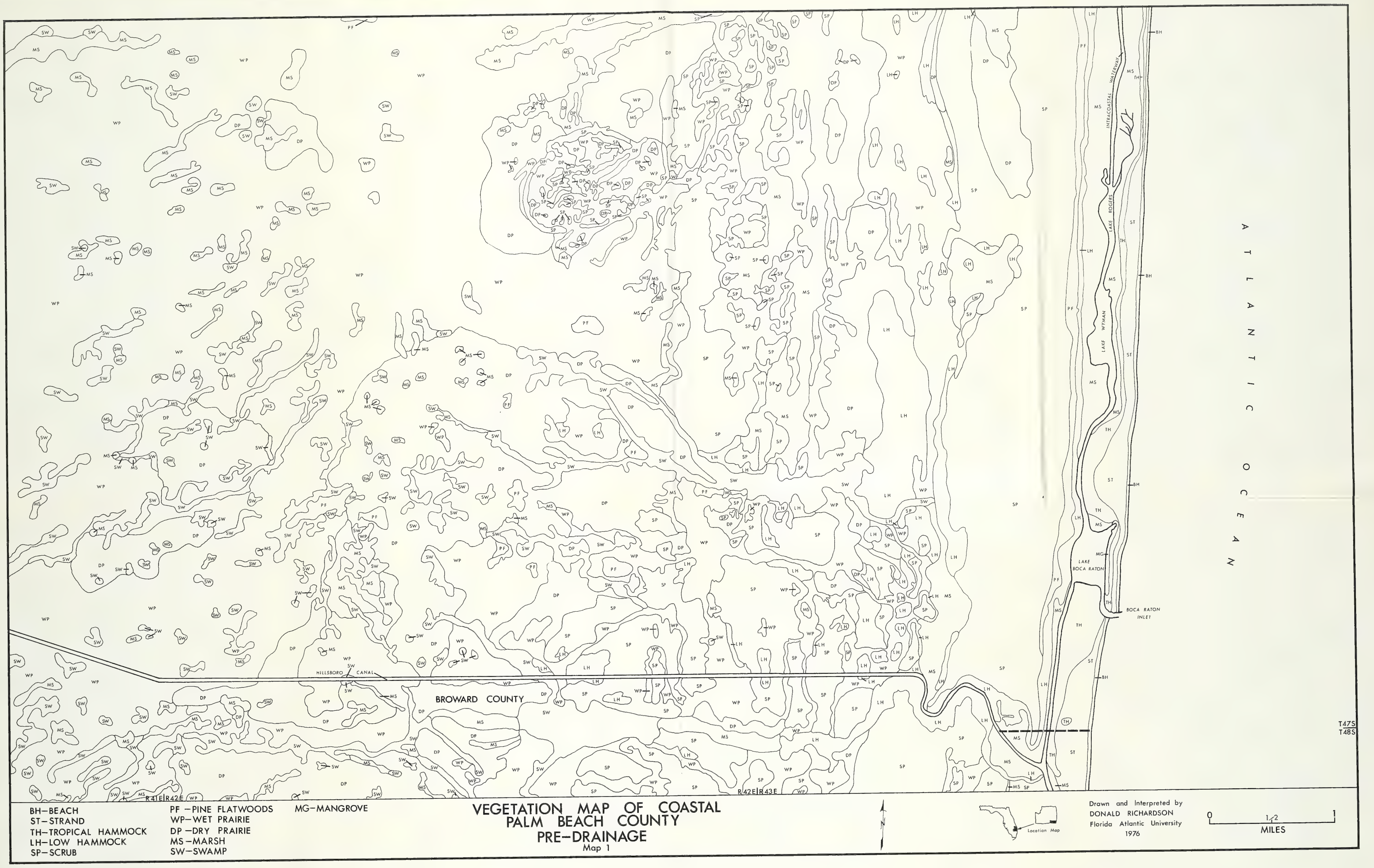


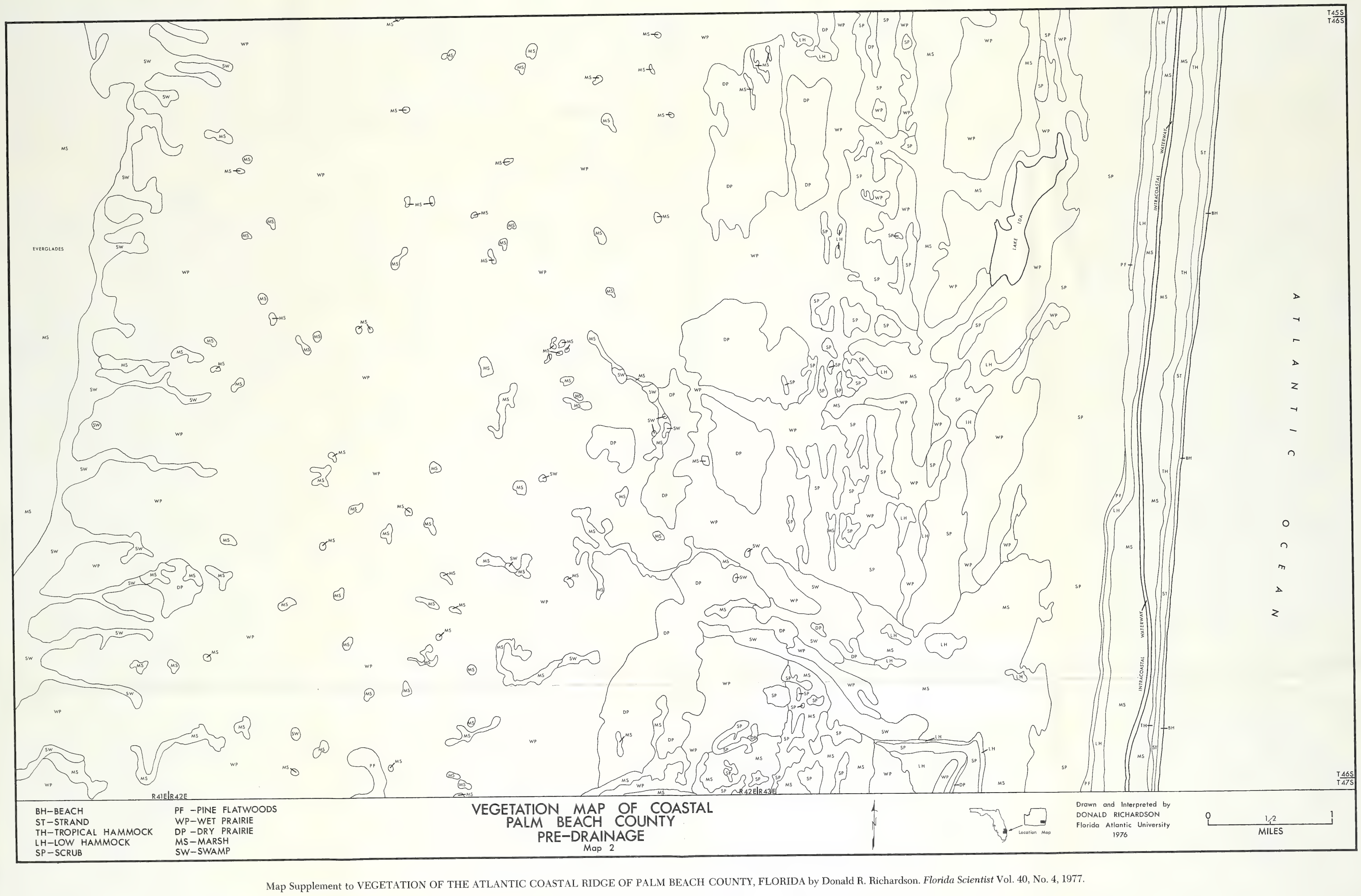
UNIVERSITY OF FLORIDA

Gainesville, Florida

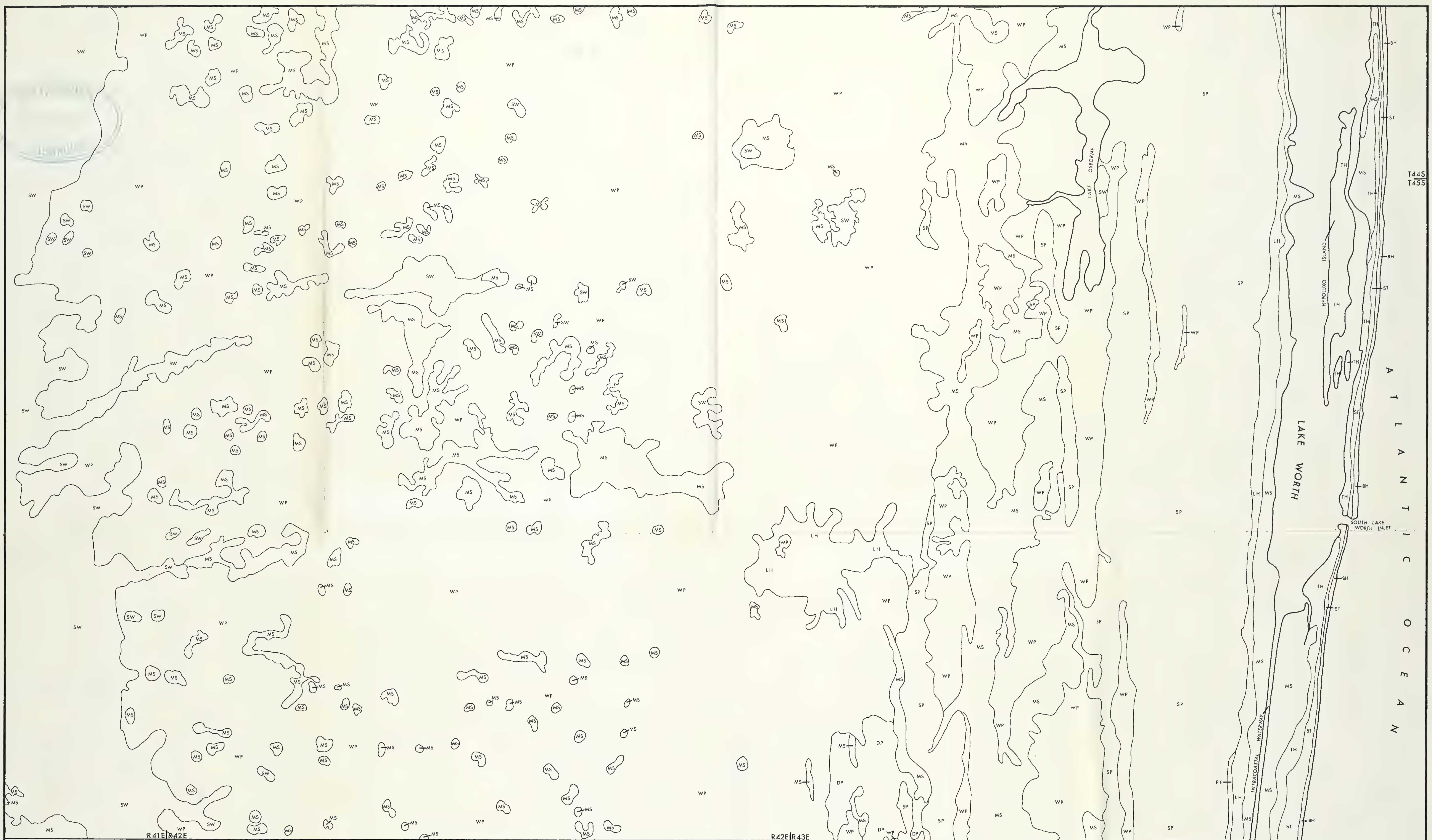

39th AVE
RAMADA INN
ECONO-TRAVEL
8th AVE
UNIV. AVE
34th ST
13th ST
FLAGLER INN
MAIN ST
WALDO RD
AIRPORT
UF
41st ANNUAL MEETING
Gainesville
FLORIDA ACADEMY of SCIENCES
1936
PAYNES PRAIRIE
441
24
26
75
121
20
S 232

Map 8 a(left) and b(right). Water level c





Map Supplement to VEGETATION OF THE ATLANTIC COASTAL RIDGE OF PALM BEACH COUNTY, FLORIDA by Donald R. Richardson. *Florida Scientist* Vol. 40, No. 4, 1977.



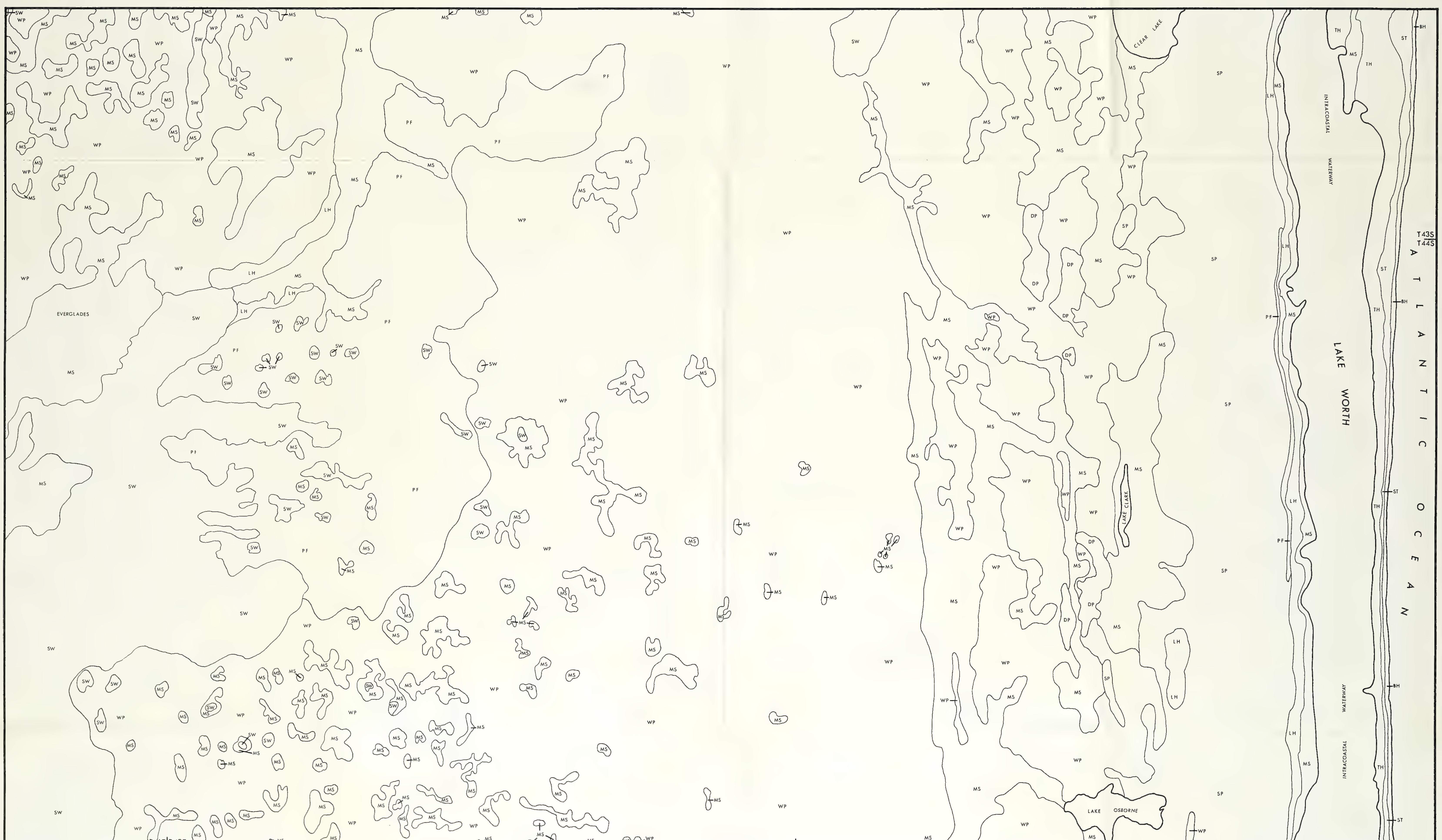
BH–BEACH
ST–STRAND
TH–TROPICAL HAMMOCK
LH–LOW HAMMOCK
SP–SCRUB
PF–PINE FLATWOODS
WP–WET PRAIRIE
DP–DRY PRAIRIE
MS–MARSH
SW–SWAMP

VEGETATION MAP OF COASTAL
PALM BEACH COUNTY
PRE-DRAINAGE
Map 3

Location Map

Drawn and Interpreted by
DONALD RICHARDSON
Florida Atlantic University
1976

0 1/2 1
MILES



BH–BEACH
ST–STRAND
TH–TROPICAL HAMMOCK
LH–LOW HAMMOCK
SP–SCRUB
PF–PINE FLATWOODS
WP–WET PRAIRIE
DP–DRY PRAIRIE
MS–MARSH
SW–SWAMP

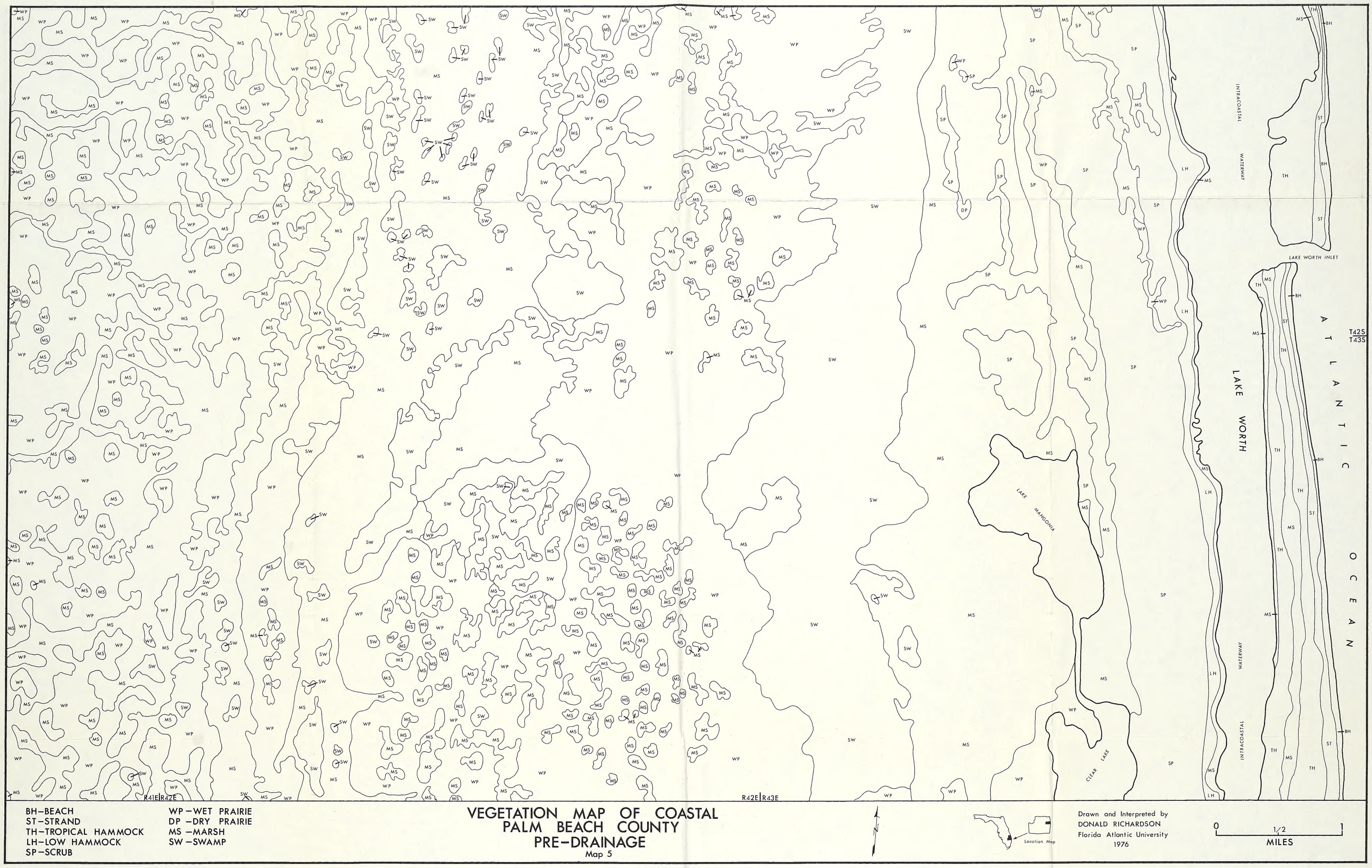
VEGETATION MAP OF COASTAL
PALM BEACH COUNTY
PRE-DRAINAGE
Map 4

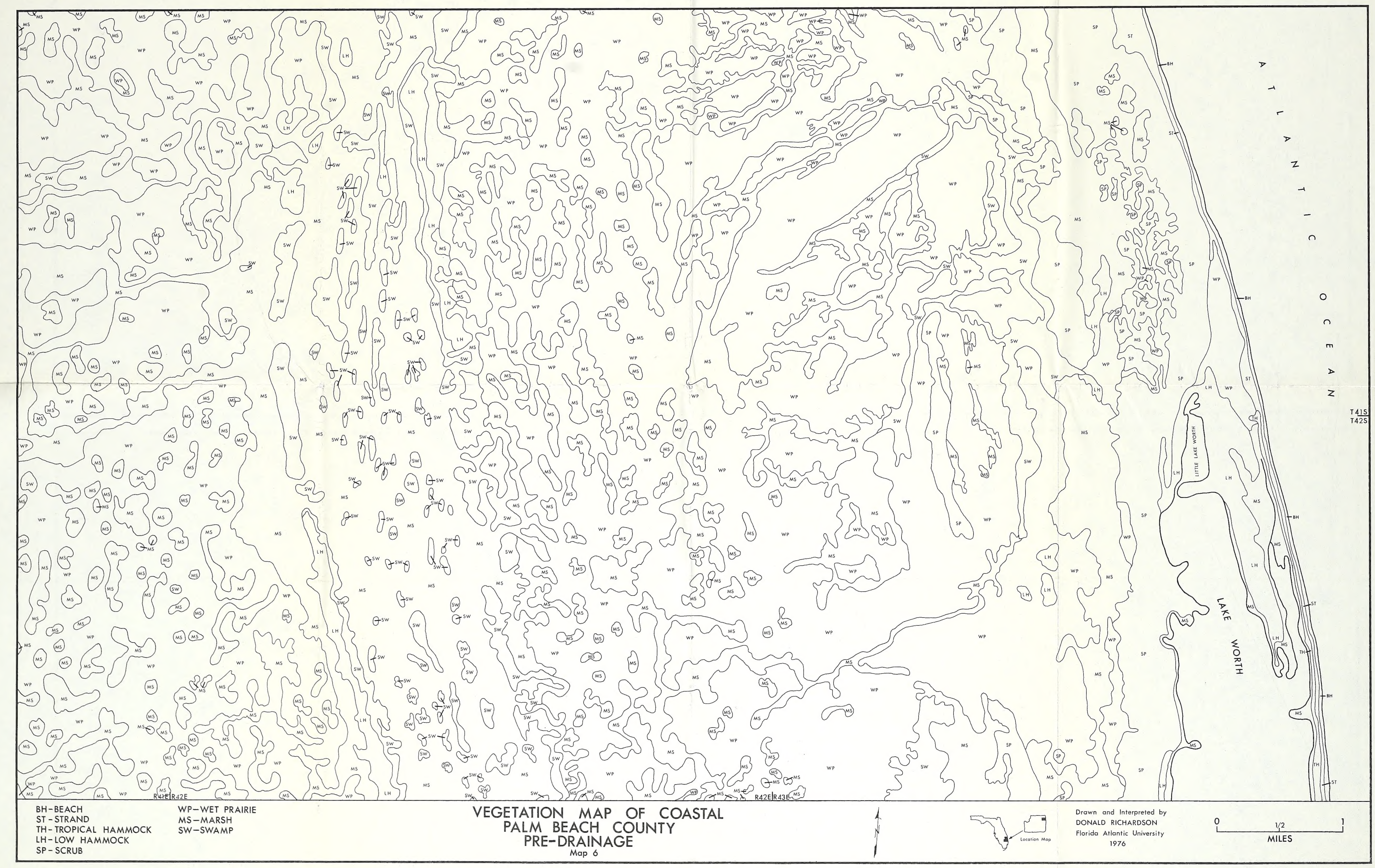
Location Map

Drawn and Interpreted by
DONALD RICHARDSON
Florida Atlantic University
1976

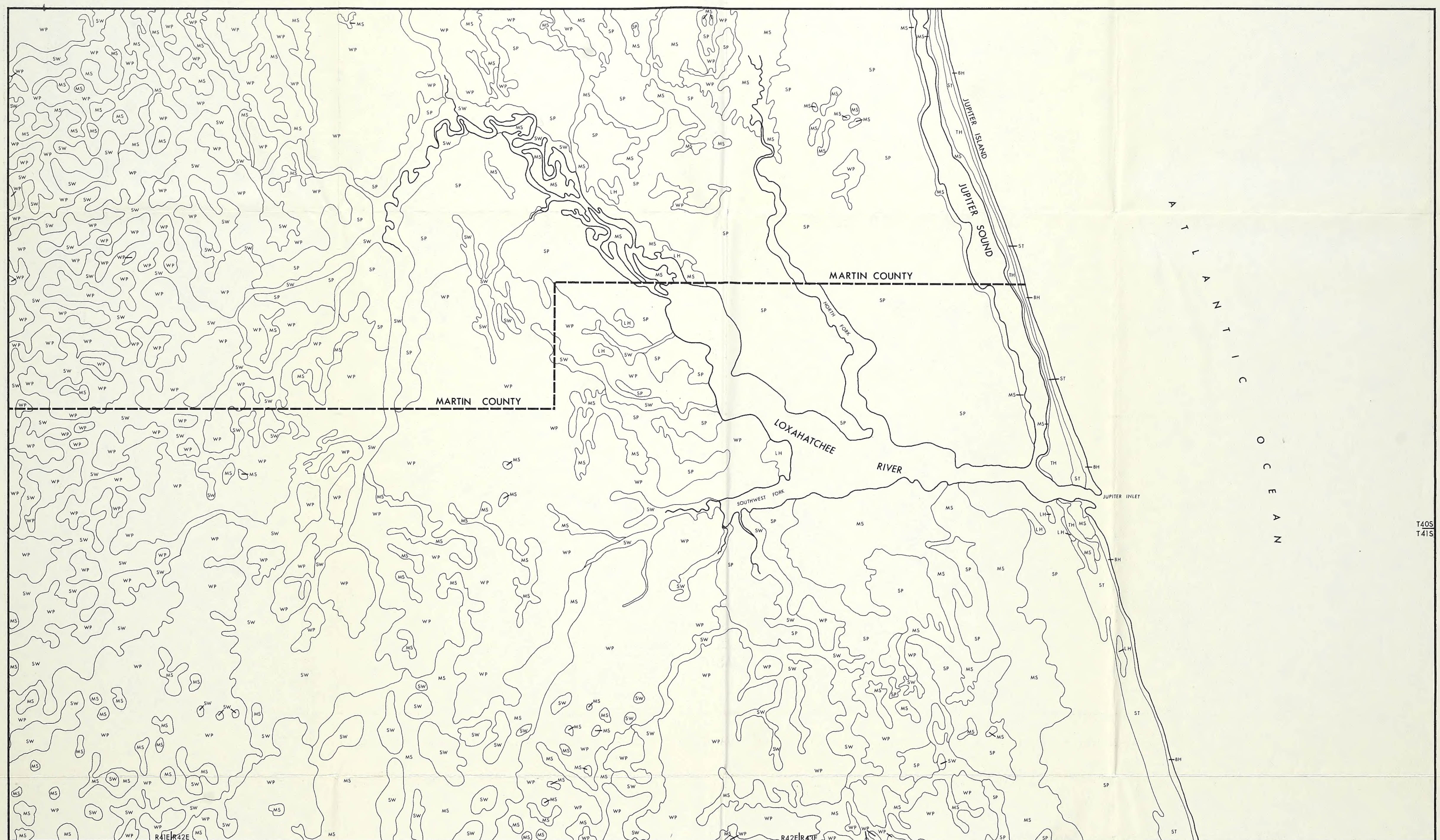
0 1/2 1
MILES

Map Supplement to VEGETATION OF THE ATLANTIC COASTAL RIDGE OF PALM BEACH COUNTY, FLORIDA by Donald R. Richardson. *Florida Scientist* Vol. 40, No. 4, 1977.





Map Supplement to VEGETATION OF THE ATLANTIC COASTAL RIDGE OF PALM BEACH COUNTY, FLORIDA by Donald R. Richardson. *Florida Scientist* Vol. 40, No. 4, 1977.

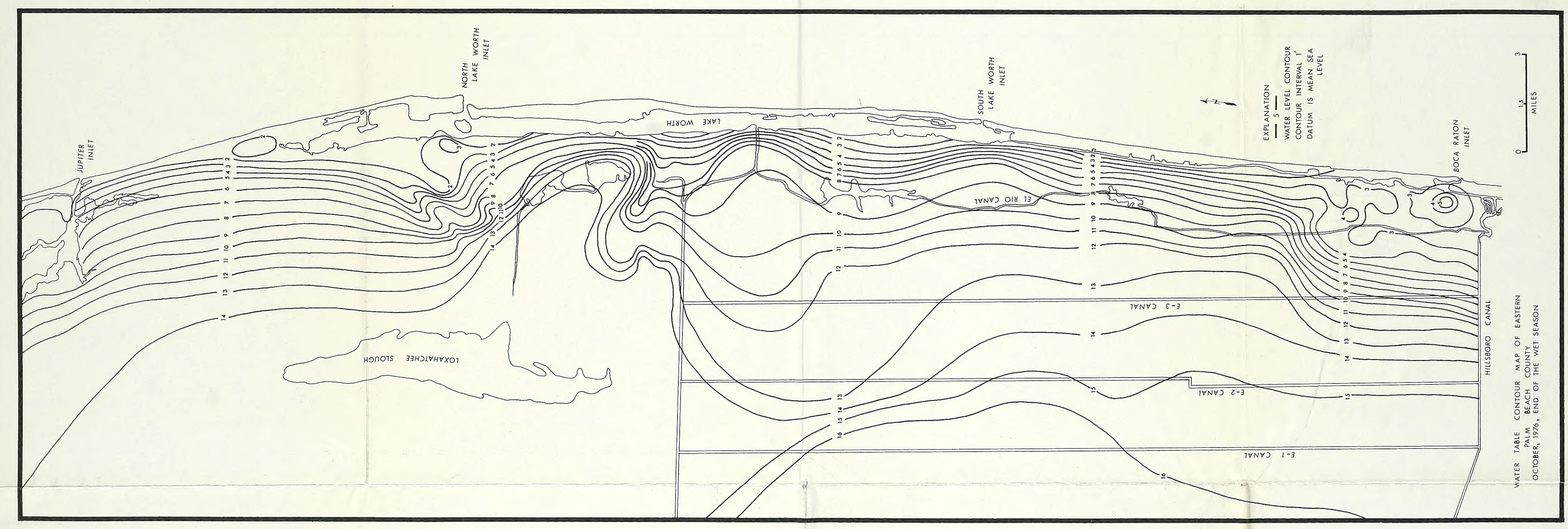


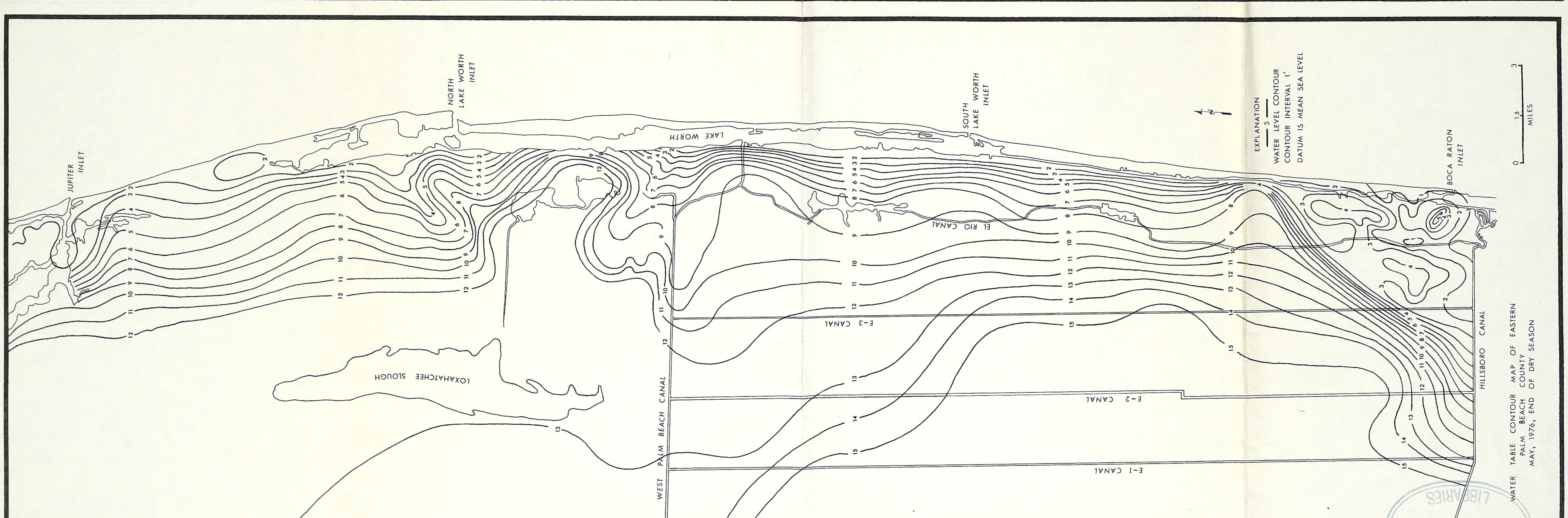
BH - BEACH
ST - STRAND
TH - TROPICAL HAMMOCK
LH - LOW HAMMOCK
SP - SCRUB
WP - WET PRAIRIE
MS - MARSH
SW - SWAMP

VEGETATION MAP OF COASTAL PALM BEACH COUNTY PRE-DRAINAGE
Map 7

Drawn and Interpreted by DONALD RICHARDSON Florida Atlantic University 1976

0 1/2 1 MILES





Map 8 a(left) and b(right). Water level contour maps, 1976.

Map Supplement to VEGETATION OF THE ATLANTIC COASTAL RIDGE OF PALM BEACH COUNTY, FLORIDA by Donald R. Richardson. *Florida Scientist* Vol. 40, No. 4, 1977.