QL
11
F6F63
NH

ISSN: 0098-4590

Florida Scientist

Volume 68 Spring, 2005 Number 2

CONTENTS

Eradication of a Reproducing Population of Convict Cichlids, *Cichlasoma nigrofasciatum* (Cichlidae) in North-Central Florida.. Jeffrey E. Hill and Charles E. Cichra 65

New Locality Record for *Anopheles grabhamii* (Diptera: Culicidae) in the Florida Keys ..... Lawrence J. Hribar 75

The Farm Index—A Proposed Addition to the SAFE Index ..... Dean F. Martin, Dawn Blankenship, and Barbara B. Martin 77

A Checklist of Birds of the Everglades Agricultural Area ..... Elise V. Pearlstine, Michelle L. Casler, and Frank J. Mazzotti 84

Implications of Water and Sediment Quality Distribution for Seagrass Restoration in West Bay of the St. Andrew Bay System ..... Jon M. Hemming, Michael Brim, and Robert B. Jarvis 97

Records and Observations for Some Diptera in the Florida Keys ..... Lawrence J. Hribar 109

Mosquito Lagoon Sea Turtle Cold Stun Event of January 2003, Kennedy Space Center/Merritt Island National Wildlife Refuge, Florida ..... J. A. Provancha, M. J. Mota, K. G. Holloway-Adkins, E. A. Reyier, R. H. Lowers, D. M. Scheidt, and M. Epstein 114

Population Status and Distribution of Spotted Bullhead *Ameiurus serracanthus* in North Florida Rivers ..... Richard L. Cailteux and Daniel A. Dobbins 122

Florida Endowment for the Sciences 130

Florida Academy of Sciences Medalists 131

SMITHSONIAN
JUN 02 2005
LIBRARIES

FLORIDA SCIENTIST

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

Copyright © by the Florida Academy of Sciences, Inc. 2005

Editor: Dr. Dean F. Martin Co-Editor: Mrs. Barbara B. Martin
Institute for Environmental Studies, Department of Chemistry, University of South Florida,
4202 East Fowler Avenue, Tampa, Florida 33620-5250
Phone: (813) 974-2374; e-mail: dmartin@chuma1.cas.usf.edu
Business Manager: Dr. Richard L. Turner
Department of Biological Sciences, Florida Institute of Technology,
150 West University Boulevard, Melbourne, Florida 32901-6975
Phone: (321) 674-8196, e-mail: rturner@fit.edu
http://www.floridaacademyofsciences.org

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. Direct subscription is available at $45.00 per calendar year.

Original articles containing new knowledge, or new interpretations 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 preparations of manuscripts are inside the back cover.

Officers for 2004–2005
FLORIDA ACADEMY OF SCIENCES
Founded 1936

President: Dr. Cherie Geiger
Department of Chemistry
University of Central Florida
Orlando, FL 32816

President-Elect: Dr. John Trefry
Department of Oceanography
Florida Institute of Technology
150 W. University Boulevard
Melbourne, FL 32901

Past-President: Barry Wharton
HDR Engineering, Inc.
2202 N. Westshore Boulevard
Suite 250
Tampa, FL 33607-5711

Secretary: Dr. Elizabeth Hays
Barry University
Miami Shores, FL 33161-6695

Treasurer: Mrs. Georgina Wharton
11709 North Dr.
Tampa, FL 33617

Executive Director: Edward A. Haddad
e-mail: floridaacademyofsciences@osc.org

Program Chair: Dr. Jeremy Montague
Department of Natural and Health Sciences
Barry University
Miami Shores, FL 33161

Published by The Florida Academy of Sciences, Inc.
Printing by Allen Press, Inc., Lawrence, Kansas

Florida Scientist

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

DEAN F. MARTIN, *Editor* BARBARA B. MARTIN, *Co-Editor*

Volume 68 Spring, 2005 Number 2

Biological Sciences

ERADICATION OF A REPRODUCING POPULATION OF CONVICT CICHLIDS, *CICHLASOMA NIGROFASCIATUM* (CICHLIDAE), IN NORTH-CENTRAL FLORIDA

JEFFREY E. HILL[(1)]* AND CHARLES E. CICHRA[(2)]*

[(1)]Tropical Aquaculture Laboratory, Department of Fisheries and Aquatic Sciences, University of Florida, 1408 24th Street SE, Ruskin, FL 33570;
[(2)]Department of Fisheries and Aquatic Sciences, University of Florida, 7922 NW 71st Street, Gainesville, FL 32653

ABSTRACT: *We report on the eradication of a reproducing population of nonindigenous convict cichlids,* Cichlasoma nigrofasciatum *(Cichlidae), from a closed basin on the University of Florida (UF) campus in Gainesville, Alachua County, Florida, in December 2001. The population had persisted for three or more years despite cold winter air temperatures owing to the thermal refuge afforded by a constant influx of warm water from UF cooling systems. A brief shutdown of the water flow allowed the use of rotenone to renovate the pond. Over 1000 convict cichlids were removed and data were collected from representative specimens. Relations of standard length, weight, and body depth to total length were estimated. Plant material dominated the stomach contents in frequency of occurrence, followed by unidentified organic material and amphipods. However, fish and plant material made up the greatest volume of stomach contents. Although it was winter, three of 14 females examined had apparently ripe eggs and there were nests and brood pits within the pond. Two other nonindigenous fish species were found—two black pacus,* Colossoma macropomum *(Characidae), and an oscar,* Astronotus ocellatus *(Cichlidae). Also collected were native yellow bullhead,* Ameiurus natalis *(Ictaluridae), eastern mosquitofish,* Gambusia holbrooki *(Poeciliidae), and sailfin molly,* Poecilia latipinna *(Poeciliidae).*

Key Words: Convict cichlid, *Cichlasoma nigrofasciatum*, nonindigenous, introduced, fish, renovation, rotenone

A REPRODUCING population of the nonindigenous convict cichlid, *Cichlasoma nigrofasciatum* (Cichlidae), was eradicated in December 2001 from Alachua County in north-central Florida. This was the only confirmed reproducing population in Florida. Fuller and co-workers (1999) reported that convict cichlids were

* e-mail addresses—Hill: jehill@ifas.ufl.edu; Cichra: fish@ifas.ufl.edu

"established locally" in Florida, referring to this Alachua County population. Later, Hill (2002) listed this population as "formerly reproducing" in Florida to reflect its new status (i.e., eradicated). An older record of a reproducing population of convict cichlids in a rock pit in Miami-Dade County (Rivas, 1965) is unconfirmed (Fuller et al., 1999).

Convict cichlids are native to Pacific slope drainages from Guatemala to Costa Rica and Atlantic slope drainages from Honduras to Panama in Central America, a distribution from about 7–15° N latitude (Conkel, 1993). Within this range, convict cichlids occupy rocky habitats in small streams, shallows of larger streams and rivers, and along lake shores (Konings, 1989; Conkel, 1993). This small, distinctive cichlid species (see Konings, 1989; Page and Burr, 1991; Conkel, 1993; Axelrod et al., 1997 for photos or illustrations) attains a maximum total length (TL) of about 140 mm. Convict cichlids are sexually dimorphic—females are smaller (up to 90 mm TL), have somewhat shorter dorsal and anal fins, and possess a more colorful abdomen (Konings, 1989). This species is omnivorous, consuming a wide variety of invertebrates, algae, and detritus (Konings, 1989). It is considered a cavity-nesting species, with nest sites typically located in natural or excavated holes (Lavery, 1991; Wisenden, 1995). Nevertheless, convict cichlids will construct shallow depressions on the substrate if suitable cavity sites are unavailable (J. E. Hill, pers. obs.). Both male and female parents aggressively guard the eggs, yolk-sac larvae, and free-swimming fry. The adults dig small brood pits to hold fry overnight (Konings, 1989; authors, pers. obs). Being hardy, easy to breed in captivity, and behaviorally interesting, convict cichlids are popular aquarium and research fishes.

In a review of fish introductions in the United States, Fuller and co-workers (1999) mentioned difficulties in compiling documentation of many species records, including detailed locality data, reproductive status, and other pertinent information. The scattered and often anecdotal nature of information on nonindigenous fishes hampers review and research efforts to better understand patterns and processes of species introductions. The purpose of this paper is to document the site and history of the convict cichlid introduction, the renovation of the system, and biological data from the introduced population.

METHODS—*Site description*—The introduced convict cichlid population was confined to a small sinkhole pond (i.e., Green Pond; 29.38° N, 82.22° W) and outlet stream within a highly modified, closed basin on the main campus of the University of Florida (UF), Gainesville, Alachua County, Florida (Fig. 1). Green Pond is about 0.22 ha with a mean depth of 1.6 m and a maximum depth of 2.8 m. The outlet stream is about 2–3 m in width and flows about 100 m before entering a culvert pipe. The culvert opens out into a surface stream several hundred meters downstream of Green Pond that later empties into Hume Pond (about 0.4 ha). Hume Pond overflows through a short outlet stream into a broadleaf marsh associated with Lake Alice (about 30 ha). Lake Alice does not have a surface outlet.

Green Pond is located near the center of the main university campus and is adjacent to the J. Wayne Reitz Union building. The northern half of the pond was ringed by a corrugated steel retention wall topped by a walkway. The remainder of the pond and the outlet stream was surrounded by hardwood hammock. The substrate was sand, limestone gravel, leaf litter, and detritus. A few limestone rocks, branches, and some trash objects were found in the pond. Aquatic macrophytes were absent except for a few clumps of wild taro, *Colocasia esculenta*, along the pond margin and on a small island. Some overhanging terrestrial vegetation also was present.

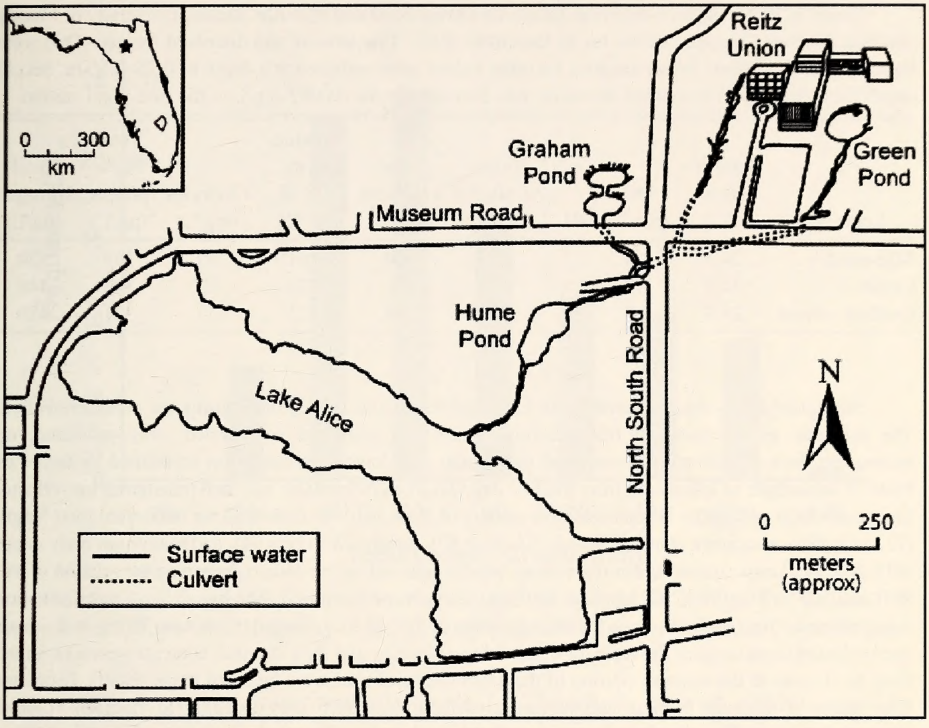

FIG. 1. Map of the Hume Pond portion of the Lake Alice drainage, University of Florida (UF) campus, Alachua County, Florida, including Green Pond. The star in the inset map indicates the UF campus in Gainesville.

Renovation—A survey to determine the extent of the spread of convict cichlids through the system and a site assessment to determine pond volume and characteristics was completed on 20 December 2001. The presence of convict cichlids was obvious given their active nature and conspicuous vertical stripes, as well as their highly visible nests and brood pits scattered over the substrate. Convict cichlids were found only in Green Pond and in the outlet stream immediately below Green Pond. No convict cichlids were observed in the outlet stream downstream of the culvert pipe, in Hume Pond, or in other sections of the Hume Pond drainage (e.g., Graham Pond). Water samples were collected at a depth of 0.25–0.50 m from three areas—mid-pond, near the outlet stream, and in the stream. Triplicate sample analyses for pH, total alkalinity, total hardness, conductivity, chlorides, total phosphorus, and total nitrogen were conducted according to standard methods (APHA, 1998). The un-ionized ammonia concentration was measured at the mid-pond station using a Hach® water chemistry colorimetric kit. Water temperature and dissolved oxygen were measured at the surface at each site with a YSI Model 58 DO/T meter.

The renovation was conducted by staff of the Department of Fisheries and Aquatic Sciences, UF, with assistance of personnel from the Florida Fish and Wildlife Conservation Commission (FWC) and the Florida Museum of Natural History (UF-FLMNH). The inflowing water was shut off and the pond dropped to its outlet level by 28 December 2001. On that day, > 3.0 ppm of 5% emulsified rotenone was applied to the pond and remaining pools of the outlet stream. An attempt was made to collect all observed fish and series of specimens were preserved in formalin for study and deposition with the Florida Museum of Natural History (UF 119600) as voucher specimens. Fish pickups continued over the following three days. An additional fish pickup was conducted on the fifth day post-application. No live convict cichlids were subsequently observed. On 2 January 2002, 4.5 kg of potassium permanganate ($KMnO_4$) was applied to the pond to detoxify the rotenone. Also, potassium permanganate was used at the downstream mouth of the culvert to detoxify any residual rotenone in the outlet stream when water flow to the pond was restored.

TABLE 1. Water physico-chemical values for Green Pond and its outlet stream, University of Florida campus, Alachua County, Florida, on 20 December 2001. Temperature and dissolved oxygen (DO) were measured at the surface. Water samples for other values were collected at a depth of 0.25–0.50 m. Secchi depth exceeded 1 m. Un-ionized ammonia was estimated to be 0.0082 mg/L at the mid-pond station.

Location	Temperature (°C)	DO (mg/L)	pH	Total Alkalinity (mg/L)	Total Hardness (mg/L)	Conductivity (μS @ 25°C)	Chlorides (mg/L)	Total Phosphorus (μg/L)	Total Nitrogen (μg/L)
Mid-pond	24.3	1.4	7.5	170	204	484	30	339	520
Outlet	24.5	1.8	7.6	155	200	478	32	342	440
Outflow stream	24.4	3.7	7.6	172	204	477	33	327	470

Biological data—An estimated 1000–1500 convict cichlids were killed during the pond renovation. The first day pickup included 654 individuals, but fish were not enumerated, only estimated, on subsequent days. Additionally, some dead individuals may have been missed or consumed by turtles or birds. A subsample of specimens from the first day was fixed in formalin and then transferred into ethanol for preservation and study. A representative sample of these fish was measured for maximum total length (TL; N = 186), maximum standard length (SL; N = 50), weight (WT; N = 94), and maximum body depth (BD; N = 94). Least-squares linear regressions were conducted on the data to determine the relation of SL, WT, and BD to TL (PROC GLM; SAS Institute, Cary, North Carolina). The $\log_{10}$– $\log_{10}$ transformation was performed prior to the analysis for the regression of WT on TL to linearize the data. Thirty individuals were selected to encompass the range of observed total lengths and their stomach contents were examined. Only food items in the stomach portion of the gastrointestinal tract were included in the results. Estimates were made of stomach fullness and percent contribution of each prey category to stomach volume. Stomach fullness values ranged from 1 to 4, with 1 being empty, 2 having some food but less than 25% of the estimated stomach capacity, 3 having 25–75% of stomach capacity filled, and 4 having > 75% of estimated stomach capacity. Egg numbers for three females were made by direct counts of apparently ripe (i.e., large) ova. Five large ova from each female (total eggs = 15) were selected and measured for maximum length and width using a calibrated micrometer on a dissecting microscope.

RESULTS AND DISCUSSION—Convict cichlids apparently were present at the site at least by 1997 (based on a personal communication reported in Fuller et al., 1999), with museum specimens available from 1998 (UF 110742 and 119548). Therefore, the population survived the winter of 2000–2001, one of the colder winters of recent record. Indeed, massive die-offs of nonindigenous blue tilapia, *Oreochromis aureus* (Cichlidae), occurred in the Lake Alice portion of the system during the winter of 2000–2001 (authors, pers. obs.). Blue tilapia had been a major component of the Lake Alice fish assemblage for many years, yet intensive sampling with boat electrofishing and experimental gillnets in the spring of 2001 yielded only a single, moribund individual (authors, unpubl. data). On many occasions since 1999 we have visited Green Pond and from the shore viewed fishes near the retaining wall and mouth of the outlet stream. Based on these casual observations, it was evident that the population size of convict cichlids fluctuated widely over time.

Green Pond receives nearly 4000 L/min of well water from cooling systems of the UF campus (Day, 2001). The warm temperature of the water and its high flow rate through the pond provided a thermal refuge for the convict cichlids and prevented total winter kills of this tropical species. Nevertheless, the inflowing water was low in dissolved oxygen to the point of hypoxia, and the pond and outlet stream

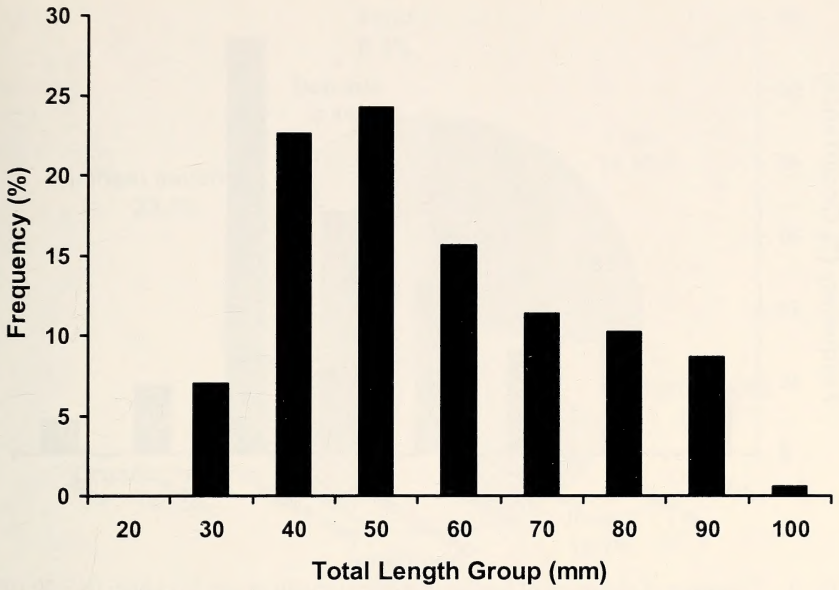

FIG. 2. Total length frequency for convict cichlids (N = 186; 33–101 mm TL) collected by rotenone from Green Pond, University of Florida campus, Alachua County, Florida, in December 2001.

were also low oxygen environments (Table 1). Therefore, convict cichlids must be relatively tolerant of low dissolved oxygen concentrations. Physico-chemical measurements are provided in Table 1.

It was hoped that the cold winter of 2000–2001 would eliminate the population, but the warm inflow of water allowed survival of sufficient individuals to repopulate the pond and outlet stream. Failing a winter kill, the active options for eradication were few. Stocking native largemouth bass, *Micropterus salmoides* (Centrarchidae), as a predator was rejected based on low dissolved oxygen in the pond. Other considered methods of removal also were discarded as ineffective (e.g., trapping). Rotenone is the usual method of pond renovation, but its use in flowing water systems is not allowed in Florida. In the winter of 2001–2002, the impediment to the use of rotenone (i.e., the constant water inflow into Green Pond) was removed when the cooling system for the Reitz Union was shut down during the Christmas break. This allowed the renovation of both the pond and its outlet stream to proceed during a brief window.

Convict cichlids of a wide range of lengths were collected (Fig. 2). The relationship of WT and TL for this population was:

$$\text{Log}_{10}\text{WT} = 3.03\ \text{Log}_{10}\quad \text{TL} - 4.718 \qquad (1)$$

($r^2 = 0.985$; N = 94; 33–101 mm TL). The conversion from TL to SL was:

$$\text{SL} = 0.768\quad \text{TL} + 1.167 \qquad (2)$$

($r^2 = 0.996$; N = 50; 35–101 mm TL).

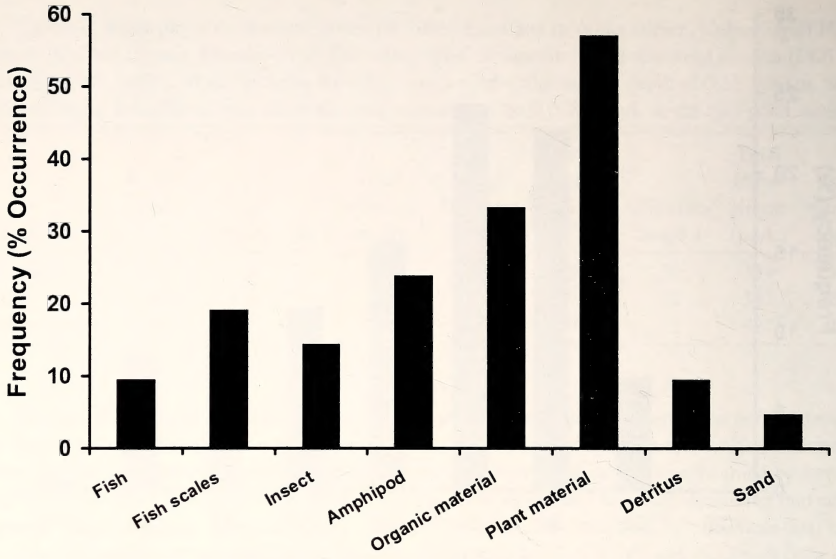

FIG. 3. Frequency of occurrence of food categories in stomachs of convict cichlids (N = 30; 38–95 mm TL) collected by rotenone from Green Pond, University of Florida campus, Alachua County, Florida, in December 2001.

Morphological vulnerability to predation may be estimated using prey body depth (Lawrence, 1958; Hambright, 1991). The relation of BD to TL for convict cichlids in this population was:

$$BD = 0.383 \quad TL - 2.744 \tag{3}$$

($r^2 = 0.967$; N = 94; 33–101 mm TL). Using the relation of gape width (GW) to TL for largemouth bass from Hill (1998) (i.e., GW = 0.135 TL − 4.084), all convict cichlids collected from this population would be vulnerable to predation by largemouth bass of about 300 mm TL and larger.

Convict cichlids in Green Pond consumed a variety of food types (Fig. 3). Eight (about 27%) of the 30 fish examined had empty stomachs and were excluded from the analysis. Most individuals had relatively small volumes of stomach contents. The median stomach fullness value was 2 and only five fish had estimates exceeding this value. Plant material dominated in frequency of occurrence, followed by organic material and amphipods (Fig. 3). However, fish was the dominant category by volume, followed closely by plant material (Fig. 4). Fish found in the stomachs were eastern mosquitofish, *Gambusia holbrooki* (Poeciliidae), and larval convict cichlids.

The range of food items for convict cichlids in this introduced population was broadly similar to food items reported for their native range, with diets mainly differing in relative proportions. For example, Bussing (1993) considered convict cichlids to be insectivores, reporting that at least 50% of their diet by volume consisted of aquatic insects. Nevertheless, insects made up only about 13% of the stomach contents by volume in Green Pond. Costa Rican populations contained

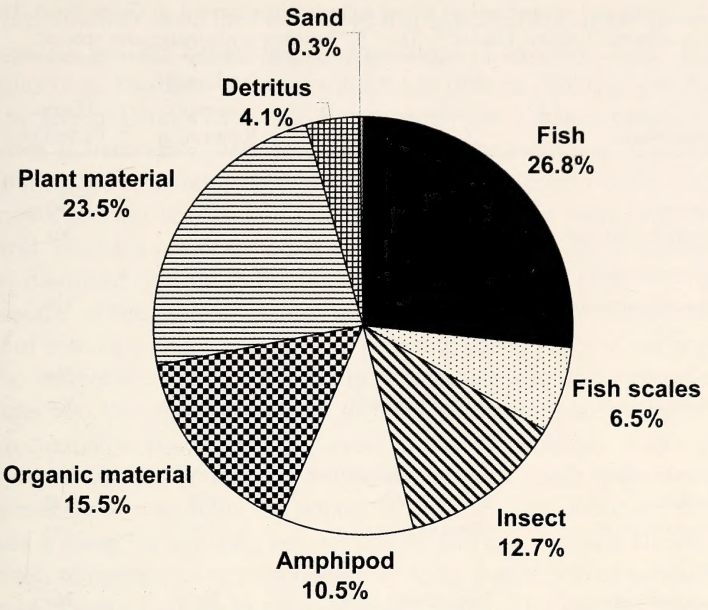

FIG. 4. Percent contribution of food categories by volume to the stomach contents of convict cichlids (N = 30; 38–95 mm TL) collected by rotenone from Green Pond, University of Florida campus, Alachua County, Florida, in December 2001.

relatively high volumes of plant material compared to the present study (i.e., 70% in Burcham, 1988; > 50% in Wootton and Oemke, 1992; 24% in present study). Moreover, Green Pond convict cichlids consumed a far higher percentage by volume of fish than found in other studies (> 26% in Green Pond versus 5–8% in Central American field studies; Burcham, 1988; Bussing 1993). However, the convict cichlids used in our diet analysis came from a rotenone collection and fish may not be a common prey item. For example, predatory fish may eat unusual amounts of small fishes that are stunned by rotenone (Bettoli and Maceina, 1996). Nevertheless, convict cichlids in tanks will consume fish, larval fish, and fish eggs (J. E. Hill, pers. obs.).

Although the pond assessment and renovation occurred in winter (i.e., December 2001), there was evidence of recent reproductive behavior, including brood pits in the substrate. Indeed, three females of 14 examined had large, apparently ripe ova. The egg counts for the females were 132 (65 mm TL; 5.07 g), 146 (66 mm TL; 4.82 g), and 576 (95 mm TL; 16.72 g). In comparison, in a laboratory study using tank-raised convict cichlids, Townshend and Wootton (1984) reported a mean fecundity of 523 eggs (range 172–692) for 15 females of 5.13 g mean weight (± 0.62). Because they further demonstrated that fecundity in convict cichlids is related to food availability (Townshend and Wootton, 1984), these data suggest that egg production of females in Green Pond, at least in winter, was food limited. This suggestion is supported by the low stomach fullness values and relatively high volumes of plant material, detritus, and sand in the stomachs

TABLE 2. Native and nonindigenous fishes collected or observed in Green Pond, University of Florida campus, Alachua County, Florida[a,b]. The "*" indicates a nonindigenous species.

Scientific Name	Common Name	Collected during Renovation	Historic Collection	Sight Record Only[c]
Cyprinidae				
*Carassius auratus**	Goldfish	No	No	Yes
*Ctenopharyngodon idella**	Grass carp	No	No	Yes
Characidae (Serrasalmidae)				
*Colossoma macropomum**	Black pacu	Yes	Yes	No
Ictaluridae				
Ameiurus natalis	Yellow bullhead	Yes	No	No
Ameiurus nebulosus	Brown bullhead	No	Yes	No
Poeciliidae				
Gambusia holbrooki	Eastern mosquitofish	Yes	Yes	No
Poecilia latipinna	Sailfin molly	Yes	Yes	No
*Xiphophorus variatus**	Variatus platy	No	Yes	No
Centrarchidae				
Micropterus salmoides	Largemouth bass	No	No	Yes
Cichlidae				
*Astronotus ocellatus**	Oscar	Yes	Yes	No
*Cichlasoma citrinellum**	Midas cichlid	No	Yes	No
*Cichlasoma nigrofasciatum**	Convict cichlid	Yes	Yes	No

[a] Other nonindigenous fish are known from the University of Florida campus in Gainesville, Florida. Species reproducing include blue tilapia (*Oreochromis aureus*) and Jack Dempsey cichlid (*Cichlasoma octofasciatum*). Common carp (i.e., koi) (*Cyprinus carpio*) (Robins, 2002), black pacu (C. E. Cichra, unpubl. data), and armored suckermouth catfish (unknown species; Loricariidae) (C. E. Cichra, unpubl. data) have been collected, but are not reproducing.

[b] Seven bowfins (*Amia calva*) collected from Lake Alice were stocked into Green Pond on 17 January 2002 as predators to consume convict cichlids that may have survived the rotenone treatment and as a biological resistance to any future releases of nonindigenous fish into the pond.

[c] (Robins, 2002; authors, pers. obs.).

(about 28%) of specimens from Green Pond. The eggs were oval and the average size for 15 eggs (five from each female) was 1.54 (± 0.096) mm long × 1.22 (± 0.095) mm wide (mean ± 1 standard deviation). This is similar to the mean length of 1.70 mm for convict cichlid eggs documented in a laboratory study (Townshend and Wootton, 1984). Although females (in aquaria?) reportedly reach only 90 mm TL (Konings, 1989), the largest confirmed female from the Green Pond population was 95 mm TL. In contrast, no females larger than 76 mm TL (based on SL conversions in the present study) were reported from Lake Jiloá, Nicaragua, (McKaye, 1986) or a Costa Rican stream (Wisenden, 1994).

No internal or external parasites or symptoms of disease were noted for any convict cichlid collected in Green Pond. However, detailed necropsies and microscopic evaluations were not conducted.

Probably due to its isolated nature, small basin size, and harsh environment, relatively few native fishes are recorded from the pond (Table 2). Yellow bullhead, *Ameiurus natalis* (Ictaluridae), eastern mosquitofish, and sailfin molly, *Poecilia*

latipinna (Poeciliidae), were the only native fish collected during the renovation. All of these species possess behavioral or physiological adaptations for low oxygen environments (e.g., Kushlan, 1974). Exotic fishes besides convict cichlids also have occurred in Green Pond (Table 2). For example, two black pacus, *Colossoma macropomum* (Characidae), and an oscar, *Astronotus ocellatus* (Cichlidae), were collected during the renovation. Grass carp, *Ctenopharyngodon idella* (Cyprinidae), have been stocked into Green Pond under FWC permit at least twice for aquatic weed control, but have not persisted as expected of this long-lived species, possibly due to low dissolved oxygen in the pond.

The source of the convict cichlid introduction is unknown. Nevertheless, the popularity of convict cichlids as aquarium fishes, the occurrence of the population in an easily accessible site within a university setting, and a prior history of exotic fish introductions into this water body lead to the speculation that this is an aquarium release. An alternative possibility is a release of research animals. Although either is plausible, it is unlikely that the true source will ever be confirmed.

The presence of a reproducing population of convict cichlids on the UF main campus was a cause for concern, but not alarm. The site was in a closed basin and the cool water temperatures of surrounding systems during winter precluded further expansion of convict cichlids in north-central Florida. The primary concerns were the putative source of the introduced population (i.e., "students dumping their tanks between semesters") and the message of tacit consent by the university to this and other fish introductions into campus waters. For example, exotic fishes have been introduced into the Lake Alice basin and isolated ponds on the UF campus for at least 35 years, including blue tilapia in Lake Alice and Jack Dempsey, *Cichlasoma octofasciatum* (Cichlidae), in another stream within the basin (Jennings, 1986; Table 2). This history may reflect a lack of education concerning the illegality of releasing nonindigenous fishes in Florida (FAC, 2003; Florida Statutes, 2003) and the possible adverse consequences that introduced fishes can have for aquatic systems (reviewed in Taylor et al., 1984).

Acknowledgments—We gratefully acknowledge the close cooperation and assistance of the FWC, particularly E. Moyer, P. Shafland, J. Krummrich, R. Wattendorf, R. Hujik, E. Nagid, and J. Rowe. P. Day and C. Hogan provided information on flow rates, timing of flow shut down, and water pathways across campus. Thanks go to J. Sowards, T. Glancy, and W. Cooper (UF) and to R. Robins, S. Gardieff, and F. Barreto (UF-FLMNH) for assistance in the pond renovation, to R. Robins for providing information on exotic fish records from Green Pond, and K. Jacoby for preparing the map. M. Hoyer, R. Robins, and C. Watson provided helpful suggestions for improving the manuscript.

LITERATURE CITED

APHA (American Public Health Association). 1998. Standard Methods for the Examination of Water and Wastewater, 20th edition. American Public Health Association, Washington, D.C.

Axelrod, H., W. E. Burgess, N. Pronek, and J. G. Walls. 1997. Atlas of Freshwater Aquarium Fishes, 9th edition. TFH Publications, Inc., Neptune City, NJ.

Bettoli, P. W. and M. J. Maceina. 1996. Sampling with toxicants. Pp. 303–333. *In*: Murphy, B. R. and D. W. Willis (eds.). Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, MD.

Burcham, J. 1988. Fish communities and environmental characteristics of two lowland streams in Costa Rica. Rev. Biol. Trop. 36:273–285.

Bussing, W. A. 1993. Fish communities and environmental characteristics of a tropical rain forest river in Costa Rica. Rev. Biol. Trop. 41:791–809.

Conkel, D. 1993. Cichlids of North and Central America. TFH Publications, Inc., Neptune City, NJ.

Day, P. 2001. Reitz Union Facilities Coordinator, Univ. of Florida, Gainesville, FL, Pers. Commun.

FAC. 2003. Florida Administrative Code, 68A-23.008. http://fac.dos.state.fl.us. (accessed Dec. 2003).

Florida Statutes. 2003. Florida Statute 372.26. http://flsenate.gov/statutes. (accessed Dec. 2003).

Fuller, P. L., L. G. Nico, and J. D. Williams. 1999. Nonindigenous Fishes Introduced into Inland Waters of the United States. American Fisheries Soc., Spec. Publ. 27, Bethesda, MD.

Hambright, K. D. 1991. Experimental analysis of prey selection by largemouth bass: role of predator mouth width and prey body depth. TAFS 120:500–508.

Hill, J. E. 1998. Estimate of Gape Limitation on Forage Size for the Peacock Cichlid, *Cichla ocellaris*, an Exotic Fish Established in Florida. MS thesis. Univ. of Florida, Gainesville, FL.

———. 2002. Exotic fishes in Florida. Lakelines, North Amer. Lake Manage. Soc. 22(1):39–43.

Jennings, D. P. 1986. Characterization of a localized Jack Dempsey, *Cichlasoma octofasciatum*, population in Alachua County, Florida. Florida Scient. 49:255–259.

Konings, A. 1989. Cichlids from Central America. TFH Publications, Inc., Neptune City, NJ.

Kushlan, J. A. 1974. Effects of a natural fish kill on the water quality, plankton, and fish population of a pond in the Big Cypress Swamp, Florida. TAFS 103:235–243.

Lavery, R. J. 1991. Physical factors determining spawning site selection in a Central American hole nester, *Cichlasoma nigrofasciatum*. Environ. Biol. Fish. 31:203–206.

Lawrence, J. M. 1958. Estimated sizes of various forage fishes largemouth bass can swallow. Proceedings SEAGFC 11:220–225.

McKaye, K. R. 1986. Mate choice and size assortative pairing by the cichlid fishes of Lake Jiloá, Nicaragua. J. Fish Biol. 29 (Suppl. A):135–150.

Page, L. M. and B. M. Burr. 1991. A Field Guide to Freshwater Fishes of North America North of Mexico. The Peterson Field Guide Series volume 42. Houghton Mifflin Co., Boston, MA.

Rivas, L. R. 1965. Florida fresh water fishes and conservation. Quart. J. of the Florida Acad. of Sci. 28:255–258.

Robins, R. 2002. Florida Museum of Natural History, Gainesville, FL. Pers. Commun.

Taylor, J. N., W. R. Courtenay, Jr., and J. A. McCann. 1984. Known impacts of exotic fishes in the continental United States. Pp. 322–373. *In*: Courtenay, Jr. W. R. and J. R. Stauffer, Jr. (eds.). Distribution, Biology, and Management of Exotic Fishes. Johns Hopkins University Press, Baltimore, MD.

Townshend, T. J. and R. J. Wootton. 1984. Effects of food supply on the reproduction of convict cichlid, *Cichlasoma nigrofasciatum*. J. Fish. Biol. 24:91–104.

Wisenden, B. D. 1994. Factors affecting reproductive success in free-ranging convict cichlids (*Cichlasoma nigrofasciatum*). Can. J. Zool. 72:2177–2185.

Wisenden, B. D. 1995. Reproductive behaviour of free-ranging convict cichlids, *Cichlasoma nigrofasciatum*. Environ. Biol. Fish. 43:121–134.

Wootton, J. T. and M. P. Oemke. 1992. Latitudinal differences in fish community trophic structure, and the role of fish herbivory in a Costa Rican stream. Environ. Biol. Fish. 35:311–319.

Florida Scient. 68(2): 65–74. 2005
Accepted: September 1, 2004

NEW LOCALITY RECORD FOR *ANOPHELES GRABHAMII* (DIPTERA: CULICIDAE) IN THE FLORIDA KEYS

LAWRENCE J. HRIBAR

Florida Keys Mosquito Control District, 506 106th Street, Marathon, Florida 33050
and
Research Associate, Florida State Collection of Arthropods, Gainesville, FL 32614

ABSTRACT: *A new locality record for* Anopheles grabhamii *(Diptera: Culicidae) is reported from No Name Key, Florida. Twenty adult female specimens were collected from May 2003 to January 2004. This species is sympatric with* Anopheles albimanus *in the Florida Keys and appears to be more abundant in the cooler parts of the year.*

Key Words: Mosquito, Culicidae, Florida Keys

THE FLORIDA Keys are islands that lie east, south, and southwest of the southernmost tip of the Florida peninsula within Dade and Monroe Counties. The Florida Keys Mosquito Control District conducts mosquito control operations on the larger inhabited islands within Monroe County. A large part of these operations is surveillance for larval and adult mosquitoes both in natural areas and in domestic situations (i.e., in neighborhoods). Larval surveillance includes fieldwork in salt marshes and mangrove areas, examination of artificial and natural containers near houses, inspection of sewage treatment plants, and monitoring mosquito larval development in storm water catch basins. Adult surveillance is conducted primarily through use of Dry Ice-baited light traps.

Darsie and coworkers (2002) added *Anopheles grabhamii* Theobald (Diptera: Culicidae) to the fauna of the United States based on the collection of a single female in a dry ice-baited light trap on Big Pine Key. They remarked that additional collections would be necessary to determine if this species had successfully colonized the Florida Keys. Twenty additional specimens of this species have been collected in a dry ice-baited ABC light trap (American Biophysics Company, Jamestown, Rhode Island) on No Name Key. The trap site is located near the coast and near a large flooded quarry. Dominant vegetation consists of Australian pine, sea grape, mangroves, and exotic grasses (Hribar, 2002). A large stand of saltwort is adjacent to the trap site. The sides of the quarry are bereft of emergent aquatic vegetation, although buttonwood, mangrove, and sea grape grow to the water's edge.

One female *An. grabhamii* was collected on 6 May 2003, three additional female specimens were collected on 30 June 2003, another female was collected on 3 September 2003, two females were collected on 20 October 2003, four females were collected on 4 November 2003, one female on 24 November 2003, and 9 females on 26 January 2004. The female collected in May was placed in the

collection of the Florida Keys Mosquito Control District. Three of the females collected on 4 November, and the female collected on 24 November, were deposited in the Peabody Museum of Natural History, Yale University, New Haven, CT (accession numbers 208585, 208587, 208589, 208599). The other specimens were sacrificed for a study of mosquito-borne viruses in the Florida Keys. To date neither adult males nor larvae of this species have been collected in the Florida Keys. *Anopheles grabhamii* is sympatric with *An. albimanus* in the Greater Antilles (Darsie et al., 2002). This sympatry extends to the Florida Keys, where *An. albimanus* is known from No Name Key (Hribar, 2002) and Big Pine Key (Pritchard et al., 1947), among other islands. According to Earle (1936), *An. grabhamii* is more common during the cool season; this could explain the collection of more specimens during January. *Anopheles grabhamii* is believed to be of only minor importance in the transmission of human disease (Darsie et al., 2002).

LITERATURE CITED

Darsie, R. F., Jr., J. J. Vlach, and E. M. Fussell. 2002. New addition to the mosquito fauna of United States, *Anopheles grabhamii* (Diptera: Culicidae). J. Med. Entomol. 39:430–431.

Earle, W. C. 1936. *Anopheles grabhamii* (Theobald), a possible vector of malaria. Bol. Asoc. Med. Puerto Rico 28:228–232.

Hribar, L. J. 2002. Mosquito (Diptera: Culicidae) collections in the Florida Keys, Monroe County, Florida, USA. Studia Dipterol. 9:679–691.

Pritchard, A. E., E. L. Seabrook, and M. W. Provost. 1947. The possible endemicity of *Anopheles albimanus* in Florida. Mosq. News 6:183–184.

Florida Scient. 68(2): 75–76. 2005
Accepted: May 21, 2004

THE FARM INDEX—A PROPOSED ADDITION TO THE SAFE INDEX

Dean F. Martin, Dawn Blankenship, and Barbara B. Martin

Institute for Environmental Studies, Department of Chemistry, University of South Florida, 4202 East Fowler Avenue, Tampa, FL 33620-5205

Abstract: *The SAFE (Strategic Assessment of Florida's Environment) index is an environmental measurement system that covers five areas, i.e., air quality, surface water quality, groundwater quality, water quantity and use, and natural resource protection. For each area, indices have been developed that encompass that area. It appears that another area may help reflect the impact of Florida's expanding population, i.e., the Farm Index. Florida's expanding population must be housed in some way, and it would appear that this is done at the expense of farm land given up for development. Total farm acreage in Florida was obtained from statistical sources and presented in chronological order. The index was calculated as before with 1969 taken as a base year (1969 value = 100). A major problem was obtaining consistent data because the definition of "farm" changed several times over the years.*

Key Words: SAFE project, indices, citrus, farm definition

The SAFE Project was initiated by the Florida former Department of Environmental Regulation [renamed the Department of Environmental Protection (DEP)] as a means of measuring the status of the state's environmental values. The DEP mission statement directed them to "Protect, conserve and restore the air, water, and natural resources of the state" (Bergquist, 1988). Members of the USF Institute for Environmental Studies, in cooperation with Dr. C. David Cooper, P.E., University of Central Florida assumed the responsibility. Dr. Cooper's group developed the indices for air quality, and members of the Institute developed indices for four other areas (surface water quality, groundwater quality, water quantity and use, and natural resource protection), and the results were presented in a report (Martin et al., 1989) and as a summary (Martin and Martin, 1992).

The SAFE Project was planned to provide a baseline of current environmental quality as well as a continuing system of documenting the direction and change in intensity of environmental quality in Florida. Some additional background information (Ott, 1978) may be useful. By definition, an index is a number derived from a formula used to characterize data. Typically, an index is a combination of parameters in a meaningful grouping that will provide a useful insight.

We believed that an index should satisfy five criteria: It should be (1) numerically documentable; (2) available or derivable from contemporary data sources; (3) available at least on an annual basis; (4) demonstrably a valid basis of the parameter it describes; and (5) it should be a direct reflection of an environmental value or concern (Martin and Martin, 1992).

TABLE 1. Summary of Florida farm acreage and population data as a function of time and comparison with the Farm Index (Anon., 1997)

Year	No. Farms	Acreage	Farm Index	Florida Population
1930	58,966	5,026,617	35.8	1,468,211
1935	72,857	6,048,406	43.1	
1940	62,248	8,337,708	59.4	1,897,414
1945	61,159	13,083,501	93.2	
1950	56,921	16,527,536	117.8	2,771,305
1954	57,543	18,161,675	129.4	4,790,300**
1959	45,100	15,236,521	108.6	
1960				4,951,560
1964	40,542	15,411,181	109.8	5,654,000**
1969	35,586	14,031,998	100	6,641,000
1970				6,789,443
1974	32,466	13,199,365	94.1	8,099,000**
1978	36,109	13,016,288	92.8	9,156,700**
1980				9,746,324
1982	36,352	12,814,216	91.3	10,375,300
1986				11,657,800
1987	36,556	11,194,090	79,8	12,000,200**
1990				12,938,000
1992	35,204	10,766,077	76.7	13,424,400**
1996	40,000	10,300,000	73.4	14,185,403**
2000				15,982,400

* Farm Index = $(\text{acreage})_{\text{year}}/(\text{acreage})_{1969}$.

** Florida Population data from National census data or estimates in pertinent annual issues of *Florida Statistical Abstracts;* 1996 data based on a USDA estimate.

It seemed evident to us that population growth could have a pronounced impact on the environment, and that there should be additional Indices that address that issue. The population increase should have been accompanied by an increase in housing, and this in turn may have been accompanied by a subsequent change in land use, i.e., from farming. Thus, it seemed reasonable to review the change in Florida population prior to 1970 and subsequently to develop a *Farm Index,* which would be based on the change of available farm land using 1970 as the index year to be consistent with other indices that were developed earlier.

METHODS—*Sources*—Data were obtained from standard sources, including the *Florida Statistical Abstracts* (*cf.* Shoemyen, 1987), a consideration of population trends by Smith (1989), *Florida Agricultural Facts* (Anon, 1997) and *Economic Leaflets* (Bucca, 1997).

Data treatment—Pertinent data are provided in Table 1 arranged in chronological order. Year 1970 was taken as the base year because it appears the major population change in Florida started in the 1970s (Smith, 1989).

RESULTS AND DISCUSSION—*Calculation of the Farm Index*—The farm index is defined as being equal to $(\text{acreage})_{\text{year}}/(\text{acreage})_{1969}$. The value for 1969 was selected instead of the value for 1970 because the 1970 data appear to be flawed. A closer examination indicates a flaw in the survey method used to collect the data, and it appears that some farms (and the corresponding acreage) were counted twice and

that other mistakes may have been made in the survey for this particular year. Thus, 1969 seems to be a better choice, though probably 1971 could have been as good a choice. As noted earlier, 1970 was the year arbitrarily selected as a base for the indices previously proposed (Martin and Martin, 1992) because this seemed to be the start of a really significant period of population growth. For example for the period 1970-80, the proportion of growth due to net migration was 92%, and was 89% for the period 1980-86 (Bucca, 1987).

A basic problem was the definition of a farm. For example, the Agricultural Stabilization and Conservation Service (ASCS) defined a farm "as a place producing agricultural products for commercial sale" (Shoemyen, 1987). [The ASCS definition of 1983 was given in the *Florida Statistical Abstract* (1985).]

In other years, estimates were based on the input from county agents. In the 1950 and 1954 census, a farm was defined as a place of three or more acres, provided the sale of agricultural products amounted to $150 or more, according to another issue of the *Florida Statistical Abstract* (1971). Later, the Bureau of Census appeared to define a farm as "any agricultural operation that sells at least $1,000 worth of products a year"(Anon., 1997).

The disagreement between definitions could be notable and required a decision to be made. In the early 1980s, for example, the number of farms and farm acres was either 36,109 and about 12 million acres (Table 1) or was 57,096 and 34,660,480 acres. We elected to use the data from a single source (Anon., 1997), and the results are reported in Table 1.

We recognize that the variation in definitions could limit the effectiveness of the Farm Index, but we also believe that it is possible to compensate for changes in definition by "indexing", i.e., using the ratio of definitions. For example, determining a multiplier ratio, e.g., $(\text{total farm acreage})_2/(\text{total farm acreage})_1$ where the subscripts refer to the two different definitions and where the values would be selected for the adjacent years for the two definitions. Related to this problem, of course, is the uncertainty of purpose, i.e., when investors have bought farm land as an investment for ultimate conversion to building sites. As we note elsewhere this is a known practice, but it may be a non-issue because the land is being used for farming and it is being taxed at that rate, but the Farm Index is clearly subject to revision.

We also recognize that farming practices may change, and this may prevent loss of land to development. For example, freezes in Hernando County discouraged citrus farmers from replanting, and the citrus mutual closed at one point. But the area turned out to be well placed for raising blueberries, and this turned out to be an excellent, highly competitive crop. Thus, the Farm Index might not show the decrease that one would expect from the freeze-discouragement-sale-for-development sequence as noted in Pinellas County (vide infra).

Population factors are significant, but the changes in farming practices are significant as well in affecting the value of the Farm Index.

Land-grant college needs—The impact of the land-grant college program (Morrill Act of 1862 with subsequent modifications) has been considerable, but hard to document specifically. An example of the impact is cited by Fribourg (2003): in

the 1850s, a typical American farmer could just barely manage to feed his close family, but 150 years later, his descendent, with the considerable aid of capital investments and alteration of society, can feed his immediate family and 150 additional persons (Fribourg, 2003). Or another example: American farmers produced two billion bushels of corn on 90 million acres in the 1920s but nine billion bushels on 70 million acres in the 1990s (Fribourg, 2003).

Comparative property values—The value of farm land varies considerably, but one factor to judge its worth is taxable value. In Hillsborough County, for example, the taxable value per acre for work farms or alligator farms was $850 (Cridlin, 2003). The taxable value per acre for other applications ranges from $1000 for strawberry farms, to $1,200 for citrus nurseries, to $2,000 (grapefruit groves 36 or more years old), and $2850 (orange groves 36 or more years old) (Cridlin, 2003). These factors need to be considered in noting the change in the Farm Index, especially with respect to the number and total acreage associated with citrus production.

Citrus groves—Currently, Florida leads the nation in citrus production (Anon., 2004), and the orange crop alone is expected to fill 303 million 90-pound boxes. Clearly the impact of citrus is a major one in volume and economics. The impact was calculated to be $13 billion for fruits and vegetables (Regional Impact, 2004).

Unfortunately, a partial validation of the Farm Index is to be found in the history of orange groves (cf. Klinkenberg, 2004). Spaniards brought citrus trees to the state (when it was La Florida) in the sixteenth century and planted them near St. Augustine. There was a slow migration of the trees southward that accelerated after the terrible freeze of 1985 that destroyed the citrus industry in north Florida.

Pinellas County (second smallest) was favored for groves in the early twentieth century because it was undeveloped and because favorable breezes thwarted freezes. Ample rainfall, cool nights and sandy soil were also attractive features of the County. Much of St. Petersburg was covered with groves that went over a 15-block area. The groves tended to be along the waterfront where they were accessible to shipping and railroads. Groves also extended northward and were found in the Clearwater and Largo areas. In the 1950s "hundreds of family groves sprawled across 17,000 acres between Tarpon Springs and St. Petersburg" (Klinkenberg, 2004).

Susbequently, citrus farmers in Pinellas County sold their groves to developers, and for a considerable enhancement of their investment (Gross, 2002). For example the Polaski grove (five acres) in the Palm Harbor area was purchased in 1929 for $200 by Frank Wall Polaski. His sons were paid $244,000 for this land in 2000. They were of retirement age, their parents had died, and they were faced with the drought of 2000. The total parcels of land came to 22.5 acres along Belcher Road and the five owners were paid $2.5 million. It was suggested that the new subdivision when complete would have 95 lots and be valued at about $25 million.

The remaining citrus grove in Pinellas County, owned (in 2004) by Mr. Al Repetto (Klinkenberg, 2004), was 37 acres with more than 3,000 trees in what is now Seminole. It was developed in 1946, and was the lone holdout in the county.

Other citrus-raising counties have noted a decrease in acreage associated with citrus raising (Squires, 2002). Florida Agricultural Statistics Service had provided a biennial survey of citrus land, and a statewide decline is noted for several reasons. These include drought, diseases, lower citrus prices, lighter replanting than formerly, cheap foreign fruit, and in some counties development pressures. In Pasco County, as was true in Pinellas, developers were willing to pay more for the land than the groves produce. Thus from 2000 to 2004, Pasco County had a 4% drop in citrus acreage, i.e., down to 10,467 acres (Squires, 2002).

To place the issue in context (Squires, 2002), in the University of South Florida service area, Polk County was the top grower with 100,202 acres devoted to commercial citrus acreage, followed by Hillsborough (23,734 commercial acres), then Pasco (10,467), Citrus County (147 acres), and Pinellas (38). The total for the state was 797,303 acres of citrus (Squires, 2002) as of January 2002, a two-year decrease of 4%.

There is a significant investment in citrus, not only for the land but for the corporation investment in juice production. Given that investment, the industry is likely to remain in place, particularly given some protection from the effects of cheap imported citrus.

The impact of farmland, including citrus groves, is truly significant, apart from the value of the products, and the jobs that farming provides. The acreage provides green space, wildlife refuge and wildlife corridors, and rainfall recharge areas. And these are significant considerations.

Economic pressures—The economic pressures that caused owners or their heirs to sell citrus farms in Pinellas County are not unique to that county or to citrus farmers.

The same pressures have been felt in Hillsborough County by the Mormon church (Church of Jesus Christ of Latter-day Saints), which was the third largest owner of agricultural land in that county (Zink, 2004). Some 5,500 acres (out of 8,500 acres) of Deseret Farms were sold for housing development. This was anticipated and was a deliberate investment when the church started purchasing land about 25 years ago. The investment is sound because it generates income and appreciates substantially in high growth areas (Zink, 2004).

The investment of the church in state farmland elsewhere is also significant (Zink, 2004). For example, 15 years ago, the farmland mentioned would have sold for $15 million according to the farm manager's estimate; today it is probably worth $110 million to developers as sites for homes and commercial buildings (Zink, 2004).

Florida farm impacts—A significant portion of the state is devoted to agriculture. The total land area of Florida is almost 54,000 square miles, and of this about 16,000 square miles (29.6%) is devoted to agricultural and forestry land (Anon, 2004).

The loss of land associated with curtailment of citrus production is evident from Table 2, and the decrease in defined farm land is noticeable from the value of the Farm Index given in Table 1. Citrus land may be especially vulnerable because

TABLE 2. Commercial citrus groves (in acres) for selected years, 1966-2000*

Year	Acres	Relative Size
1966	858,082	91.1
1968	931,249	98.9
1970	941,471	100
1972	878,019	93.3
1974	864,098	91.8
1976	852,369	90.5
1978	831,235	88.3
1980	845,283	89.8
1982	847,856	90.1
1984	761,365	80.9
1986	624,492	66.3
1988	697,929	74.1
1990	732,767	77.8
1992	791,290	84.0
1994	853,742	90.7
1996	857,687	91.1
1998	845,260	89.8
2000	832,275	88.4

* Calculation of relative size based on 1970 = 100% using data from annual issues of *Florida Statistical Abstract.*

climatic impacts have led to shifting in citrus areas to the south since the 1980s. In addition, the qualities that favor citrus farms (climate and sandy, well-drained soil) can be those that favor good housing. There is a view that building homes in poorly drained areas can lead to an elevated moisture content in slab-on-grade homes and resulting microbial growth (Moon, 2004). Also, as noted above anecdotally, it appears that economic pressures favor the conversion of farm land into home building sites.

We believe that the farm-to-home sequence can have an adverse effect on the environment, if for no other reason that an increased use of fertilizer. The economic reasons for applying fertilizer to citrus and other agricultural lands are dictated by nutritional demands, of course, but they are also governed by economic restrictions that can vanish when the land is used for housing and surrounded by grass. In Florida, as elsewhere, growing grass is not energetically favorable, and expansive lawns tend to call for extensive use of fertilizer. The mitigating effect, however may well be that housing is increasingly compressed and that even expensive homes may be built much closer together than would have been the practice in 1969, the base year for the Farm Index.

ACKNOWLEDGMENT—We are grateful for the helpful assistance of Mrs. Cheryl McCoy, Associate Librarian, Tampa Campus Library. We are grateful to Dr. Joseph J. Krzanowski, who served as consulting editor.

LITERATURE CITED

ANON. 1997. Florida Agricultural Facts. Florida Department of Agricultural and Consumer Services, Tallahassee, FL.

Anon. 2004. Show of strength. Impact 20(1):4–7.

Bergquist, G. 1988. The strategic assessment of Florida's Environment. A white paper prepared by the Department of Environmental Regulation for the Commission of the Future of Florida's Environment. Florida Department of Regulation, Tallahassee, FL.

Bucca, J. K. 1987. 1980-1986 More people moved in than out of every Florida county. Economic Leaflets (Bureau of economic and business research, University of Florida, Gainesville, FL vol. 46 (6): 1-4.

Cridlin, J. 2003. Quality of life index, Dec. 29 St. Petersburg Times. as obtained from Hillsborough County Property Appraiser.

Fribourg, H. A. 2003. Land-Grant Colleges need new grants. Chronicle of High. Educ. Dec 12, p. B20.

Gross, Ed. 2002. Citrus grove to make way for home series. St. Petersburg Times. December 27. p. 3

Klinkenberg, J. 2004. Al Repetto and his 37 acres of fruit are all that remain of a once-thriving industry in a county that raises subdivisions not citrus. St. Petersburg Times. February 1. p. 1E.

Martin, D. F. and C. D. Cooper with M. C. Flynn. B. B. Martin, C. D. Norris, and L. B. Worrell. 1989. Strategic Assessment of Florida's Environment (SAFE). Part I: Environmental Status and Conditions Report. Part II: Environmental Measurement System. Final Report Submitted to Florida Department of Environmental Regulation, Tallahassee, FL.

——— and B. B. Martin. 1992. The SAFE Project: An environmental assessment prototype. J. Environ. Sci. Health A27(4):955–966.

Moon, R. E. 2004. HSA Engineers and Scientists, 4019 East Fowler Avenue, Tampa, FL 33617, Pers. comm.

Ott, W. R. 1978. Environmental Indices: Theory and Practice, Ann Arbor Science, Ann Arbor, MI.

Regional Impact. 2004. Regional impacts of Florida's agricultural and natural resources industries. http://economicimpact.ifas.ufl.edu.

Shoemyen, A. H. (ed) 1987. 1987 Florida Statistical Abstract, 21st ed. Bureau of Economic and Business Research, University of Florida, University Presses of Florida, Gainesville, FL. Pp 227-228.

Squires, C. 2002. Citrus groves fading away in Pasco, state. St. Petersburg Times, September 18, P. 3.

Smith, S. K. 1989. Population and growth in Florida and its counties, 1980-1988. Econ. Leaflet 48(2): 1-4 (a publication of Bureau of Economic and Business Research, University of Florida, Gainesville).

Zink, J. 2004. Mormon farmland may soon sprout subdivisions. St. Petersburg Times. February 3. pp 1B, 7B.

Florida Scient. 68(2): 77–83. 2005
Accepted: September 10, 2005

A CHECKLIST OF BIRDS OF THE EVERGLADES AGRICULTURAL AREA

ELISE V. PEARLSTINE, MICHELLE L. CASLER, AND FRANK J. MAZZOTTI[1]

University of Florida, IFAS, Ft. Lauderdale Research and Education Center, 3205 College Ave, Davie, FL 33314
[1]University of Florida, Department of Wildlife Ecology, Ft. Lauderdale Research and Education Center, 3205 College Ave. Davie, FL 33314

ABSTRACT: *We studied bird habitat affinity and abundance in the Everglades Agricultural Area (EAA). The EAA is comprised of approximately 280,000 ha of lands dedicated primarily to sugarcane. Rice is grown on less than 10% of the area. We completed four years of study in rice fields and two years of surveys in sugarcane fields between 1998 and 2004. We observed 138 species with individuals being more abundant in rice fields. Twenty species were observed breeding in the area and 22 other species were potentially breeding. We saw all species of wading birds that occur regularly in south Florida, nearly all species of raptors and many bird species of open habitats. Waterbirds in general were the best represented group and these included three species of breeding ducks. Sugarcane fields and associated edge habitat supported a number of upland and other birds. Forest and woodland birds were poorly represented in the EAA due to the sparse distribution of trees. Because of its size and the nature of agriculture in the EAA, a large and diverse group of birds use this habitat for dispersal, migratory and breeding habitat.*

Key Words: agriculture, birds, bird checklist, Everglades Agricultural Area, sugarcane, rice.

THE Everglades Agricultural Area (EAA) is a 280,000 ha area of farmlands in south Florida on the southeast side of Lake Okeechobee. The EAA is primarily devoted to the production of sugarcane but supports other crops as well. South Florida has been the site of intensive environmental study as a major restoration effort is underway in the greater Everglades ecosystem including the Everglades, Lake Okeechobee and the Kissimmee River. The EAA, however, has been rarely studied as a landscape and little is known of the occurrence, habitat use and life history needs of birds that inhabit this area.

Sugarcane (*Saccharum sp.*) provides "grassland' habitat but supports few wildlife species by itself. Edges and ditches in sugarcane tend to be brushy and provide habitat for some wildlife species. Sugarcane is grown year round and is harvested in late fall and winter providing a changing landscape of fallow fields, young sugarcane and tall, dense plants. Rice (*Oryza sativa*) has been grown in the EAA since the 1950s but only since 1977 has it been grown in any appreciable amount (Lodge and Clark, 1996). Rice is grown through the spring and summer and is flooded throughout the growing season. This aquatic habitat provides an opportunity for invertebrates and fish to colonize and reproduce in the flooded fields.

At harvest, a final drawdown serves to concentrate aquatic animals in the ditches and is analogous to periodic drydowns in natural Everglades habitat. Sod farms, vegetable farms, seasonally flooded and fallow fields are other types of agricultural fields found in the EAA. Larger ditches and canals tend to be permanently flooded and provide habitat for some aquatic species but the steep banks and scarce vegetation limit use of these ditches.

The few studies of birds in the EAA have documented the use of flooded fields by 59 species of wading birds, ducks, rails, shorebirds, gulls and other species (Sykes and Hunter, 1978), Fulvous Whistling-ducks (*Dendrocygna bicolor*) (Turnbull et al., 1989a) and use of rice fields by waterbirds (Townsend, 2000). A summary report of birds in the EAA provides a list of 68 species of birds (Lodge and Clark, 1996).

The EAA exists within a matrix of natural habitat and highly urbanized areas in Broward, Glades, Hendry and Palm Beach counties. Natural areas and wildlife refuges provide habitat for a variety of south Florida wildlife species. In comparison, urban and suburban areas are generally considered to be low in biological diversity and tend to exhibit high numbers of exotic species (Blair, 1996).

METHODS—*Study area*—Historically, south Florida was dominated by the greater Everglades ecosystem. From Lake Okeechobee southward, water flowed across a wide landscape of marshes, sloughs, tree islands, and mangrove swamps into Florida Bay (Porter and Porter, 2002). Vast expanses of sawgrass (*Cladium jamaicense*) marsh, over thousands of years, produced a layer of rich peat soil more than 3.7 meters deep in places (Snyder and Davidson, 1994). Before the turn of the 20th century, drainage of the northern part of the Everglades commenced with production of a system of canals and dikes in the vicinity of Lake Okeechobee. By the mid-20th century, the EAA was established (Light and Dineen, 1994). The agricultural fields are organized around a grid system of unpaved roads, permanent canals and shallow ditches that provide varying degrees of irrigation and drainage. This system of fields and canals produces a patchwork of agricultural crops with edge habitat consisting of shrubs (usually non-native species) and sparse trees along canal and ditch edges.

As part of a three-year project to characterize wildlife habitat use in the EAA, we conducted bird surveys in rice and sugarcane fields along with driving surveys. We included fallow fields or fallow flooded fields during their temporary occurrences within the EAA. We also used data from a previous two-year study using the same methods (Townsend, 2000).

Rice—We chose rice fields with differences in management and construction such as edge vegetation, dike or berm construction and canal and ditch layout. Road accessibility also affected the study areas chosen. Each rice field consisted of 8 to 10 units separated by ditches. Ditches and internal units were chosen randomly within each larger rice field. The study began just before the rice fields were flooded and ended as they were drained for harvest. Surveys of fallow and fallow flooded fields followed the same protocol as for rice fields. Each field was surveyed every two weeks. Survey sites were distributed throughout the EAA. Bird surveys were conducted during mid-morning when birds were actively foraging. The observation area included one rice field unit and the ditches, dikes and canals directly associated with it. One edge of a field unit was walked and birds were counted for ten minutes. All birds seen or heard in the field were noted. For each species we recorded the number of individuals observed, age, sex, plumage, location in the field and activity.

Sugarcane—Seven sugarcane fields were chosen with different ownership and management and based on accessibility. We chose roads that were driveable but had low traffic volume. A road transect was determined with four to six stopping points that included stops at ditches within the fields. Bird surveys began within an hour after sunrise. Point counts were conducted for 5 minutes at each point. We collected the same data as in rice surveys.

Raptor surveys—We conducted roadside raptor surveys along SR 27 from the southern border of Palm Beach County to Belle Glade just south of Lake Okeechobee. Location was plotted using a GPS for each raptor observed and specific habitat data recorded. Observations on the roadside survey represent the majority of raptor sightings but we also included those seen during our surveys of rice and sugarcane fields. Owls were generally sighted during our dawn and dusk surveys in sugarcane fields.

Abundance calculations—For all observations relative bird abundance was calculated based on number of sightings and bird species were placed into categories abundant, common, uncommon, rare and accidental. Birds were classified as breeding if pre-fledgling young were seen. Burrowing owls (*Athene cunicularia*) and both species of night-herons were seen in family groups and were classified as breeding.

To determine the suite of species and relative abundances expected in south Florida, we used *Birdlife of Florida* (Stevenson and Anderson, 1994), checklists of birds from two natural areas, Everglades National Park (ENP) (Robertson et al., 1984) and Arthur R. Marshall Loxahatchee National Wildlife Refuge (LOX) (US Fish and Wildlife Service, 1994), and a checklist of birds from Palm Beach County (Hope, 2003). We also used *Florida Bird Species: An annotated list* (Robertson and Woolfenden, 1992) for reference. We compared relative abundances based on a nominal scale ranging from accidental to abundant that was slightly different for each area (Table 1). We expected to observe those species that were common and abundant as well as a large number of rare species as well. We did not expect to see any of the accidental or casual species. We also used the Florida Breeding Bird Atlas (Florida Fish and Wildlife Conservation Commission, 2003) to determine breeding locations and to designate a species as resident, migrant or disperser. Residents included those species that are present year round whether or not they breed. Migrants are species that are not present in south Florida for most of the year and occur only during migration in the spring and fall or during the winter. Dispersers are south Florida species that breed nearby and use the EAA as habitat after the completion of breeding. In the EAA, assignment to groups such as wading bird, forest bird, and songbird were loosely based on classifications in Elphick and co-workers (2001).

Results—We observed 138 species of birds in the various habitats of the EAA (Table 1). We observed 20 species breeding in the area with 22 others suspected of breeding. The most abundant species were those associated with water. These included wading birds such as herons and egrets, larids such as gulls, terns, and others, waterfowl, marsh specialists, and shore birds. Birds of open areas and generalists were also common as were raptors. Upland landbirds were seen least often.

To determine relative abundance of dispersers, migrants and resident birds, we graphed average monthly counts (Fig. 1). We saw an increase in abundance in May with highest counts in June through October. The increase in June probably represents dispersing young and post-breeding adults from surrounding areas as they leave nesting areas in search of other foraging sites and was especially apparent in rice fields. The high numbers continue through the summer as rice is being grown and fallow flooded fields are present. The peak in September may represent migrants but also may reflect the end of rice harvesting activities. High numbers in October are likely due to migratory birds, especially waterfowl.

Discussion—Rice fields provide important habitat for herons and egrets worldwide (Hafner and Fasola, 1997; Fasola and Ruiz, 1996; Kushlan and Hafner, 2000; Maeda 2001). Due to wetland loss, in some places they may be significant in maintaining some species of wading birds. Yet they are not analogous to natural freshwater marshes and cannot be considered an appropriate substitute (Tourenq et al., 2001). Herons, egrets and storks are associated with rice fields worldwide and

TABLE 1. Birds observed in the EAA with relative abundance and habitat compared with birds from other south Florida habitats. 1 = ENP, 2 = LOX, 3 = Palm Beach County, 4 = Stevenson and Anderson 1994. For abundance data, no = not present, * = accidental, r = rare, u = uncommon, f = fairly common, c = common, a = abundant, o = occasional, # = breeding in area. For habitat, R = rice, F = fallow field, FF = fallow-flooded, S = sugarcane, AG = general agricultural habitat, ALL = all habitats, - means no specific habitat could be assigned. P = probable breeder and Y = year round resident.

Name	Abundance EAA	Habitat EAA	Abundance Other
Black-bellied Whistling-Duck# *Dendrocygna autumnalis*	u	R, FF	1: no, 2: no, 3: u#, 4: becoming established
Fulvous Whistling-Duck# *D. bicolor*	c	R, FF	1: u, 2: u-c, 3: u-c#, 4: r-u
Snow Goose *Chen caerulescens*	*	F	1: *, 2: *, 3: *, 4: irregular
Gadwall *Anas strepera*	r	R	1: r, 2: o, 3: u, 4: r-u
American Wigeon *A. americana*	r	—	1: c, 2: u, 3: c, 4: r-a
Mottled Duck# *A. fulvigula*	a	R, FF	1: c#, 2: a#, 3: c, 4: u-f
Blue-winged Teal *A. discors*	c	—	1: c, 2: a/o, 3: c, 4: f-a
Northern Shoveler *A. clypeata*	r	—	1: c, 2: u, 3: u, 4: u-f
Green-winged Teal *A. crecca*	r	—	1: u, 2: c, 3: c, 4: r-a
Ring-necked Duck *Aythya collaris*	r	FF	1: c, 2: a, 3: c, 4: r-f
Ruddy Duck[Y] *Oxyura jamaicensis*	r	FF	1: u, 2: r, 3: u: 4: r-f
Wild Turkey[P] *Meleagris gallopavo*	r	AG	1: r#, 2: *, 3: r#, 4: o-u
Northern Bobwhite# *Colinus virginianus*	r	AG	1: c#, 2: u#, 3: c#, 4: r-c
Pied-billed Grebe# *Podilymbus podiceps*	c	FF, R	1: c#, 2: c#, 3: c#, 4: r-c
American White Pelican[Y] *Pelecanus erythrorhynchos*	r	FF, R	1: c, 2: r, 3: c, 4: r
Brown Pelican[Y] *P. occidentalis*	r	AG	1: c#, 2: *, 3: c, 4: coastal
Double-crested Cormorant[P] *Phalacrocorax auritus*	c	ALL	1: c#, 2: u#, 3: c#, 4: c-a
Anhinga[P] *Anhinga anhinga*	c	FF, canal	1: c#, 2: a#, 3: c#, 4: r-a
American Bittern *Botaurus lentiginosus*	r	—	1: u/r/c, 2: u, 3: u, 4: *-r
Least Bittern# *Ixobrychus exilis*	c	R, C	1: u#, 2: u#, 3: u-c#, 4: o-f
Great Blue Heron (blue morph)[Y] *Ardea herodias*	c	ALL	1: c#, 2: a#, 3: c#, 4: c

TABLE 1. Continued.

Name	Abundance EAA	Habitat EAA	Abundance Other
Great Blue Heron (white morph)[Y] *A. herodias*	*	FF	1: c#, 2: no, 3: no, 4: regular Keys and Lake Okeechobee
Great Egret[Y] *A. alba*	a	ALL	1: c#, 2: a#, 3: c#, 4: f-a
Snowy Egret[Y] *Egretta thula*	a	ALL	1: c#, 2: c#, 3: c#, 4: f-a locally
Little Blue Heron[P] *E. caerulea*	a	R, F, FF	1: c#, 2: a#, 3: c#, 4: f-c
Tricolored Heron[P] *E. tricolor*	a	R, F, FF	1: c#, 2: c#, 3: c#, 4: f-a
Reddish Egret *E. rufescens*	r	—	1: u#, 2: no, 3: u, 4: only coastal
Cattle Egret[P] *Bubulcus ibis*	a	ALL	1: c#, 2 Y: a#, 3: c#, 4: c-a
Green Heron# *Butorides virescens*	a	ALL	1: c#, 2: a#, 3: c#, 4: f-c locally
Black-crowned Night-Heron# *Nycticorax nycticorax*	c	R, F, FF	1: c#2: c#, 3: c#, 4: r, u, c locally
Yellow-crowned Night-Heron# *N. violacea*	c	ALL	1: u#, 2: u#, 3: c#, 4: c
White Ibis[Y] *Eudocimus albus*	a	R, F, FF	1: c#, 2: c#, 3: c#, 4: a
Glossy Ibis[Y] *Plegadis falcinellus*	a	R, F, FF	1: u#, 2: c/u#, 3: c#, 4: *-a locally
Roseate Spoonbill[Y] *Platalea ajaja*	c	R, FF	1: c#, 2: o, 3: c-a, 4: r-c
Wood Stork[Y] *Mycteria americana*	a	R, FF	1: u/r#, 2: c/u#, 3: c#, 4: f-c
Black Vulture[Y] *Coragyps atratus*	a	ALL	1: c#, 2: a#, 3: u-c#, 4: f-a
Turkey Vulture[Y] *Cathartes aura*	a	ALL	1: c#, 2: a#, 3: c#, 4: c-a
Osprey[Y] *Pandion haliaetus*	c	FF	1: c#, 2: c#, 3: c#, 4: r-f
Swallow-tailed Kite *Elanoides forficatus*	u	ALL	1: c#, 2: u/r, 3: u#, 4: u-f
Bald Eagle[P] *Haliaeetus leucocephalus*	r	ALL	1: c#, 2: o/r, 3: u#, 4: r-u
Northern Harrier *Circus cyaneus*	c	ALL	1: u/c, 2: c, 3: c, 4: u-f
Sharp-shinned Hawk *Accipiter striatus*	r	ALL	1: u, 2: c, 3: u, 4: r-u
Cooper's Hawk[Y] *A. cooperii*	r	ALL	1: r, 2: o, 3: c#, 4: r-u
Red-shouldered Hawk[P] *Buteo lineatus*	c	ALL	1: c#, 2: a#, 3: c#, 4: f-c
Broad-winged Hawk *B. platypterus*	r	ALL	1: u, 2: o, 3: r, 4: r
Short-tailed Hawk *B. brachyurus*	r	ALL	1: u/r#, 2: o, 3: u, 4: locally present

TABLE 1. Continued.

Name	Abundance EAA	Habitat EAA	Abundance Other
Red-tailed Hawk[Y]	c	ALL	1: u#, 2: u,
B. jamaicensis			3: c#, 4: r-u
			more abundant in winter
Crested Caracara[Y]	r	S	1: *, 2: *, 3: *, 4: r,
Caracara cheriway			locally present
American Kestrel	c	ALL	1: c, 2: c, 3: c, 4: r-u
Falco sparverius			
Merlin	r	ALL	1: u, 2: u Y, 3: u, 4: r-u
F. columbarius			
Peregrine Falcon	r	ALL	1: u, 2: r, 3: u-c, 4: r-c locally
F. peregrinus			
King Rail#	c	S, R, FF	1: c#, 2: c#, 3: u#, 4: very r-u
Rallus elegans			
Sora	r	—	1: c, 2: u, 3: c, 4: very r-f
Porzana carolina			
Purple Gallinule#	c	AG	1: c#, 2: c#, 3: c#, 4: very r-f
Porphyrio martinica			
Common Moorhen#	a	ALL	1: c#, 2: a#, 3: c#, 4: r-a
Gallinula chloropus			
American Coot	c	FF	1: c#, 2: a#, 3: r-c#: 4: f-a
Fulica americana			
Limpkin	r	R, F	1: c#, 2: c#, 3: c#, 4: local
Aramus guarauna			
Sandhill Crane#	r	F	1: r#, 2: c#, 3: u#, 4: very r - f
Grus canadensis			
Black-bellied Plover[Y]	c	FF, AG	1: c/r, 2: u, 3: r-c, 4: c in migration
Pluvialis squatarola			
Semipalmated Plover	u	R, F, FF	1: c, 2: c, 3: c-u, 4: f-c
Charadrius semipalmatus			
Killdeer#	a	ALL	1: c#, 2: c#, 3: c#, 4: f-c
C. vociferous			
Black-necked Stilt#	a	ALL	1: u/r#, 2: c#, 3: c#, 4: c-a
Himantopus mexicanus			
American Avocet	r	FF	1: c, 2: o, 3: u, 4: c
Recurvirostra americana			
Greater Yellowlegs	c	R, F, FF	1: c, 2: c/u, 3: c, 4: u-f
Tringa melanoleuca			
Lesser Yellowlegs	c	R, FF	1: c, 2: u-c, 3: u-c, 4: r-c locally
T. flavipes			
Solitary Sandpiper	c	R, FF	1: r-u, 2: r-u, 3: r-u, 4: very r-u
T. solitaria			
Willet	r	FF	1: c, 2: r, 3: r, 4: r-c
Catoptrophorus semipalmatus			
Spotted Sandpiper	r	F, FF	1: c, 2: u-c, 3: c, 4: u-f
Actitis macularius			
Upland Sandpiper	r	FF	1: *, 2: no, 3: r-u, 4: very r-r
Bartramia longicauda			
Ruddy Turnstone	r	FF	1: c, 2: no, 3: c, 4: very r-r
Arenaria interpres			

TABLE 1. Continued.

Name	Abundance EAA	Habitat EAA	Abundance Other
Semipalmated Sandpiper *Calidris pusilla*	c	R, F, FF	1: r-u, 2: c, 3: c, 4: r-a
Western Sandpiper *C. mauri*	u	FF	1: c, 2: c, 3: c, 4: r-a
Least Sandpiper *C. minutilla*	c	AG	1: c, 2: c-a, 3: c, 4: f-c
White-rumped Sandpiper *C. fuscicollis*	r	R, FF	1: r, 2: u, 3: r, 4: r-u
Pectoral Sandpiper *C. melanotos*	c	FF	1: c, 2: u, 3: u-c, 4: c-a
Stilt Sandpiper *C. himantopus*	r	FF	1: u, 2: u, 3: r-c, 4: very r-c
Ruff *Philomachus pugnax*	*	F	1: *, 2: no, 3: *, 4: casual
Short-billed Dowitcher *Limnodromus griseus*	r	FF	1: c, 2: o-c, 3: u-c, 4: r inland
Long-billed Dowitcher *L. scolopaceus*	r	FF	1: u, 2: no, 3: u-c, 4: u
Wilson's Snipe *Gallinago delicata*	r	—	1: u, 2: c, 3: c, 4: r-u
Wilson's Phalarope *Phalaropus tricolor*	r	FF	1: *, 2: no, 3: u, 4: r
Laughing Gull[Y] *Larus atricilla*	c	S, FF	1: c#, 2: u, 3: u-c, 4: very r - f
Ring-billed Gull *L. delawarensis*	r	FF	1: c, 2: u, 3: *summer –c, 4: a winter
Herring Gull *L. argentatus*	r	FF	1: c, 2: o, 3: c, 4: very r-f
Gull-billed Tern[Y] *Sterna nilotica*	u	FF	1: u, 2: r/o, 3: r-u, 4: f, breeds near L. Okeechobee
Caspian Tern *S. caspia*	r	FF	1: c, 2: u, 3: u, 4: r-f
Royal Tern[Y] *S. maxima*	r	FF	1: c, 2: no, 3: c, 4: c-a
Sandwich Tern *S. sandvicensis*	r	FF	1: u, 2: no, 3: u, 4: very r-f
Common Tern *S. hirundo*	r	FF	1: u, 2: no, 3: r, 4: r
Forster's Tern *S. forsteri*	r	FF	1: c, 2: o, 3: c, 4: r
Least Tern *S. antillarum*	c	R, FF	1: c#, 2: u, 3: u-c #, 4: u-a
Black Tern *Chlidonias niger*	c	FF	1: u, 2: u, 3: u, 4: a in fall
Black Skimmer[Y] *Rynchops niger*	r	FF	1: c, 2: no, 3: u-c, 4: abundance varies
Rock Pigeon[Y] *Columba livia*	c	ALL	1: *, 2: no, 3: c, 4: present

TABLE 1. Continued.

Name	Abundance EAA	Habitat EAA	Abundance Other
Eurasian Collared-Dove[Y] *Streptopelia decaocto*	r	AG	1: no, 2: no, 3: c#, 4: increasing
Mourning Dove[P] *Zenaida macroura*	c	ALL	1: c, 2: a#, 3: c#, 4: c-a
Common Ground-Dove[P] *Columbina passerina*	c	ALL	1: u#, 2: c#, 3: u#, 4: c-a
Smooth-billed Ani[P] *Crotophaga ani*	u	—	1: u#, 2: c#, 3: u#, 4: fc
Barn Owl# *Tyto alba*	c	F, S	1: u#, 2: u#, 3: u#, 4: r
Burrowing Owl# *Athene cunicularia*	r	S	1: r, 2: *, 3: u#, 4: variable
Barred Owl[P] *Strix varia*	r	AG	1: c#, 2: o#, 3: u#, 4: r-c
Short-eared Owl *Asio flammeus*	*	S	1: r, 2: r, 3: no, 4: very rare
Common Nighthawk# *Chordeiles minor*	c	ALL	1: c#, 2: c#, 3: c#, 4: variable
Belted Kingfisher *Ceryle alcyon*	c	R, AG	1: c, 2: c-a, 3: c, 4: u-f
Red-bellied Woodpecker[P] *Melanerpes carolinus*	r	AG	1: c#, 2: a#, 3: c#, 4: c
Pileated Woodpecker *Dryocopus pileatus*	r	AG	1: c#, 2: c#, 3: c#, 4: r
Eastern Phoebe *Sayornis phoebe*	r	S	1: c, 2: a/c, 3: c, 4: f
Vermilion Flycatcher *Pyrocephalus rubinus*	r	S	1: *, 2: no, 3: *, 4: r
Great Crested Flycatcher[P] *Myiarchus crinitus*	r	FF	1: c#, 2: c/r#, 3: u-c#, 4: r-u
Eastern Kingbird[P] *Tyrannus tyrannus*	r	S	1: c#, 2: a/u#, 3: u#, 4: f
Gray Kingbird[P] *T. dominicensis*	r	AG	1: c#, 2: r/u, 3: c#, 4: f
Loggerhead Shrike[P] *Lanius ludovicianus*	r	F, S	1: u#, 2: c#, 3: c#, 4: r-c
Blue Jay *Cyanocitta cristata*	c	ALL	1: c#. 2: c#, 3: c#, 4: u-f
American Crow *Corvus brachyrhynchos*	r	AG	1: c#, 2: no, 3: no, 4: f
Fish Crow *C. ossifragus*	r	AG	1: *, 2: c, 3: c, 4: f-c
Tree Swallow *Tachycineta bicolor*	c	F	1: c, 2: a, 3: c#, 4: a
Northern Rough-winged Swallow[P] *Stelgidopteryx serripennis*	c	F, FF	1: u, 2: c, 3: c#, 4: irregular
Bank Swallow *Riparia riparia*	u	F, FF, S	1: u, 2: u, 3: u, 4: r-f

TABLE 1. Continued.

Name	Abundance EAA	Habitat EAA	Abundance Other
Barn Swallow *Hirundo rustica*	a	ALL	1: c/u#, 2: a, 3: r-c, 4: locally common
Carolina Wren[Y] *Thryothorus ludovicianus*	r	AG	1: c#, 2: c#, 3: c#, 4: c
Sedge Wren *Cistothorus platensis*	r	R	1: u, 2: r, 3: u, 4: r-o
Blue-gray Gnatcatcher *Polioptila caerulea*	r	AG	1: c, 2: a, 3: u-c#, 4: c winter, u-r summer
American Robin *Turdus migratorius*	r	AG	1: r/c, 2: u-a, 3: c, 4: r-a
Gray Catbird *Dumetella carolinensis*	u	AG	1: c, 2: a, 3: c, 4: c
Northern Mockingbird[P] *Mimus polyglottos*	c	S, AG	1: c#, 2: a, 3: c#, 4: c-a
Yellow-rumped Warbler *Dendroica coronata*	u	S	1: r-c, 2: a, 3: c, 4: a
Prairie Warbler *D. discolor*	r	AG	1: c#, 2: u-a, 3: r-c#, 4: u-c
Palm Warbler *D. palmarum*	c	ALL	1: c, 2: a, 3: c, 4: f-c
Swainson's Warbler *Limnothlypis swainsonii*	r	S	1: r, 2: r, 3: r-u, 4: r
Common Yellowthroat# *Geothlypis trichas*	a	ALL	1: c#, 2: a#, 3: c#, f-c
Eastern Towhee *Pipilo erythrophthalmus*	r	S	1: c#, 2: c, 3: c#, 4: u-c
Savannah Sparrow *Passerculus sandwichensis*	c	ALL	1: c, 2: a/c, 3: c, 4: f
Grasshopper Sparrow *Ammodramus savannarum*	r	—	1: u, 2: u, 3: u, 4: r
Lincoln's Sparrow *Melospiza lincolnii*	r	—	1: r-u, 2: *, 3: r, 4: r
Northern Cardinal[P] *Cardinalis cardinalis*	c	F	1: c#, 2: a#, 3: c#, 4: a
Red-winged Blackbird[P] *Agelaius phoeniceus*	a	ALL	1: c#, 2: a#, 3: c#, 4: c-a
Eastern Meadowlark[P] *Sturnella magna*	c	ALL	1: c#, 2: u#, 3: u#, 4: c-a
Boat-tailed Grackle[P] *Quiscalus major*	a	ALL	1: c#, 2: a#, 3: c#, 4: a

have been studied in Japan, France and California (Maeda, 2001; Tourenq et al., 2001; Elphick, 2000). Flooded fallow fields also provide habitat for waterbirds and may provide important supplemental habitat to rice fields (Sykes and Hunter, 1978; Fujioka et al., 2001). Nearly all birds documented from ENP and LOX that are associated with marsh and shallow water habitat, excluding rare or accidental

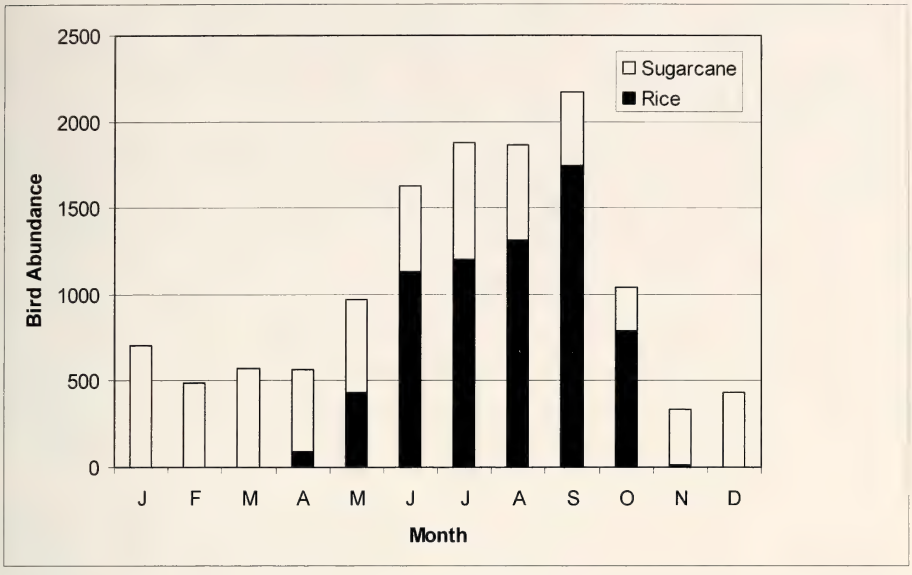

FIG. 1. Total bird abundance by month in agricultural fields in the EAA. Total numbers were determined from counts in each field type and averaged by the number of different individual fields. Sugarcane surveys were conducted year-round while rice surveys were only conducted from March through November when rice fields were present.

occurrences, were seen in the EAA. Our lack of observations for some species of rails was probably due to their secretive habits.

Fulvous Whistling-ducks and Black-bellied Whistling-ducks (*Dendrocygna autumnalis*) were both present in the EAA and are known to utilize agricultural habitat (Sykes and Hunter, 1978; Turnbull et al., 1989a). Fulvous Whistling-ducks are rare in ENP and uncommon or common depending on season in LOX yet are common and found to be breeding in the rice fields in the EAA. Black-bellied Whistling ducks were not listed as present in either natural area. However, Black-bellied Whistling ducks have only recently become established in south Florida (Stevenson and Anderson, 1994). They were regularly seen in the EAA throughout the spring and early summer flying over the rice fields and are probably breeding in the area. Mottled Ducks (*Anas fulvigula*) were common or abundant and known to breed in all three areas. Other duck species likely breed elsewhere and utilize these habitats during migration and winter.

All species of wading birds present in south Florida were found in the EAA and were counted in rice fields, fallow-flooded fields and adjacent to the canals and ditches. Wood Storks, herons, egrets, ibis and spoonbills were generally observed after the start of rice cultivation in April and increased in numbers as the rice grew. Highest numbers were observed in relationship to drawdowns either of canals and ditches for maintenance or as rice began to be harvested. At this time fish were concentrated in the ditches. Fallow-flooded fields also provided foraging habitat, especially for shorebirds during migration in the late summer and early fall. Rafts of

American White Pelicans (*Pelecanus erythrorhynchos*) were seen on several occasions utilizing flooded fallow fields for foraging and roosting. Large numbers of waterbirds were associated with post-breeding dispersal or migratory individuals; few species were observed to breed in the area (Table 1).

The most common south Florida raptor species were all seen during our surveys. No diurnal raptors were observed to nest in the area although the Red-shouldered Hawk (*Buteo lineatus*) probably breeds in the EAA. There is an extensive nest box program for Barn Owls (*Tyto alba*) in the sugarcane fields and they were frequently observed in all types of agricultural areas. We saw one family group of Burrowing Owls (*Athene cunicularia*), and Barred Owls (*Strix varia*) were observed in trees associated with sugarcane fields near natural areas. Although we didn't see it, the White-tailed Kite (*Elanus leucurus*) is increasing in abundance in south Florida (Pranty and McMillian, 1997) and is known to breed at the southern boundary of Palm Beach County (Florida Fish and Wildlife Conservation Commission, 2003) and should therefore be observed in the area.

Upland birds were not seen in large numbers or were absent (Table 1). This reflects the low density of trees and brush in the EAA. When present, trees are distributed around houses and buildings. Brush is generally controlled through mowing or herbicide, especially in the vicinity of sugarcane fields. In the natural Everglades system, large tree islands may support hardwood hammocks, providing forested habitats. Smaller tree islands support bay or willow heads that may be brushy or wooded. Smaller tree islands in the Everglades such as bayheads and willowheads support a suite of bird species with the Red-winged Blackbird (*Agelaius phoeniceus*), Common Yellowthroat (*Geothlypis trichas*) and White-eyed Vireo (*Vireo griseus*) dominating the communities (Gawlik and Rocque 1998). We observed Red-winged Blackbirds and Common Yellowthroats in abundance in sugarcane and rice (Red-winged Blackbirds only) but no White-eyed Vireos.

Exotic species observed included the Eurasian Collared Dove (*Streptopelia decaocto*) and Rock Pigeon (*Columba livia*). The dove species are either escaped or introduced exotic species that are established in south Florida. We did not observe European Starlings (*Sturnus vulgaris*), or House Sparrows (*Passer domesticus*); however, they may be present in urban and suburban areas. There were also none of the exotic tropical species that tend to occur in suburban and urban areas such as the psittacines. We did not see some native species common to agriculture such as the Brown-headed Cowbird (*Molothrus ater*) and the Common Grackle (*Quiscalus quiscula*). Both species are present in the area but may prefer more urban habitat and were simply not observed during our surveys.

The EAA provides primary, dispersal or migratory habitat for wetland and open upland bird species. Some species are drawn to specific agricultural habitats such as rice fields, sugarcane, flooded fields or canals/ditches. Waterbirds were present in abundance throughout the rice cultivation period. Other species such as the Cattle Egret, Red-winged Blackbirds and Boat-tailed Grackles (*Quiscalus major*) respond to general agricultural practices. Large numbers of these species appear as rice and sugarcane are harvested. The Common Yellowthroat is particularly abundant in sugarcane throughout the year and reproduces extensively in these fields. Other

species may be selecting open and herbaceous areas associated with the edge habitat near fields, buildings and canals or ditches.

The EAA is a significant landscape in south Florida by virtue of size alone. Although agriculture is not considered to be optimum or even functioning habitat for most bird species; agroecosystems are part of the world and will continue to be so (Vandermeer, 1997). Much is unknown about the potential for support of healthy populations of wildlife in the EAA. Pesticides and other chemicals are currently used in the area and have been used in the past with unknown effects on both resident and migratory birds. A study of Fulvous Whistling-Ducks found sub-lethal quantities of pesticides in individuals in the EAA (Turnbull et al., 1989b) and pesticides are found in the water around sugarcane fields (Gross, 2003). We hope that future studies will help to elucidate the role of south Florida agriculture in the larger natural system and provide information to the public and managers on how to improve its function in the south Florida landscape.

Acknowledgments—We thank the Everglades Agricultural Area Environmental Protection District for funding this project. We have also received invaluable assistance from the growers and managers of sugarcane and rice in the EAA including Charles Wilson, Modesto Ulloa, Raoul Perdomo, Gerald Wilson, Stuart Stein, Orvelle Wright, and various managers and workers we see every day. We would also like to thank Mary Kelly, Anna Liner and Sara Townsend for assisting in data gathering. This research was supported by the Florida Agricultural Experiment Station, and approved for publication as Journal Series R-10385.

LITERATURE CITED

Blair, R. B. 1996. Land use and avian species diversity along an urban gradient. Ecol. Apps. 6:506–519.

Elphick, C. S. 2000. Functional equivalency between rice fields and seminatural wetland habitats. Cons. Biol. 14(1):181–191.

———, J. B. Dunning, Jr., and D. A. Sibley. 2001. The Sibley Guide to Bird Life and Behavior. Alfred A. Knopf, New York, NY.

Fasola, M. and X. Ruiz. 1996. The value of rice fields as substitutes for natural wetlands for waterbirds in the Mediterranean Region. Colon. Waterbirds 19:122–128.

Florida Fish and Wildlife Conservation Commission. 2003, January 6. Florida's breeding bird atlas: A collaborative study of Florida's birdlife. http://www.wildflorida.org/bba/ (Date accessed 1/14/2004).

Fujioka, M., J. W. Armacost, Jr., H. Yoshida, and T. Maeda. 2001. Value of fallow farmlands as summer habitats for waterbirds in a Japanese rural area. Ecol. Res. 16:555–567.

Gawlik, D. E. and D. A. Rocque. 1998. Avian communities in bayheads, willowheads and sawgrass marshes of the central everglades. Wilson Bull. 110:45–56.

Gross, T. S. 2003. Atrazine exposure and the occurrence of reproductive abnormalities in field caught *Bufo marinus* from south Florida. Greater Everglades Ecosystem Restoration Conference, From Kissimmee to the Keys, April 13–18, 2003. Palm Harbor, FL.

Hafner, H. and M. Fasola. 1997. Long-term monitoring and conservation of herons in France and Italy. Colon. Waterbirds 20:298–305.

Hope, B. 2003. Palm Beach County Checklist of Birds. Audubon Society of the Everglades, West Palm Beach, Fl.

Kushlan, J. A. and H. Hafner (eds.). 2000. Heron Conservation. Academic Press, San Diego, CA.

Light, S. S. and J. W. Dineen. 1994. Water control in the Everglades: A historical perspective. Pp. 47–84. *In:* Davis, S. M. and J. C. Ogden (eds.). Everglades: The Ecosystem and Its Restoration. St. Lucie Press, Delray Beach, FL.

Lodge, T. E. and M. R. Clark. 1996. Wildlife of the Everglades Agricultural Area. Unpublished report by Law Engineering and Environmental Services, Inc., Miami Lakes, FL.

Maeda, T. 2001. Patterns of bird abundance and habitat use in rice fields of the Kanto Plain, central Japan. Ecol. Res. 16:569–585.

Porter, J. W. and K. G. Porter. 2002. Introduction: The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An Ecosystem Sourcebook. Pp. 1–16. *In*: Porter, J. W. and K.G. Porter (eds.). The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An Ecosystem Sourcebook, CRC Press, Boca Raton, FL.

Pranty, B. and M. A. McMillian. 1997. Status of the White-tailed Kite in northern and central Florida. Florida Field Naturalist 25:117–127.

Robertson, W. B., Jr., O. L. Bass, Jr., and M. Britten. 1984. Birds of the Everglades National Park. Published by Florida National Parks and Monuments Association. Updated June 1997. http://www.nps.gov/ever/eco/birds.htm.

——— and G. E. Woolfenden. 1992. Florida Bird Species: An annotated list. Special Publication No. 6. Florida Ornithological Society, Gainesville, FL.

Snyder, G. H. and J. M. Davidson. 1994. Everglades Agriculture: Past, present and future. Pp. 85–115. *In*: Davis, S. M. and J. C. Ogden (eds.). Everglades: The Ecosystem and Its Restoration. St. Lucie Press, FL.

Stevenson, H. M. and B. H. Anderson. 1994. Birdlife of Florida. University Press of Florida, Gainesville, FL.

Sykes, P. W., Jr. and G. S. Hunter 1978. Bird use of flooded agricultural fields during summer and early fall and some recommendations for management. Florida Field Natur. 6:36–43.

Tourenq, C., R. E. Bennetts, H. Kowalski, E. Vialet, J-L. Lucchesi, Y. Kayser, and P. Isenmann. 2001. Are ricefields a good alternative to natural marshes for waterbird communities in the Camargue, southern France? Biol. Cons. 100:335–343.

Townsend, S. E. 2000. Waterbirds in Rice Fields of the Everglades Agricultural Area. Master's Thesis, University of Florida, Gainesville, FL.

Turnbull, R. E., F. A. Johnson, and D. H. Brakhage. 1989a. Status, distribution, and foods of fulvous whistling-ducks in South Florida. J. Wildl. Manage. 53:1046–10.

——— F. A. Johnson, M. A. Hernandez, W. B. Wheeler, and J. P. Toth. 1989b. Pesticide residues in Fulvous Whistling-Ducks from south Florida. J. Wildl. Manage. 53:1052–1057.

U.S. Fish and Wildlife Service. 1994. Birds of Arthur R. Marshall Loxahatchee National Wildlife Refuge. U.S. Fish and Wildlife Service. Unpaginated. Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/othrdata/chekbird/r4/loxahatc.htm (Version 22May98). Jamestown, ND

Vandermeer, J. 1997. The Agroecosystem: A Need for the Conservation Biologist's Lens. Cons. Biol. 11:591–592.

Florida Scient. 68(2): 84–96. 2005
Accepted: September 29, 2004

IMPLICATIONS OF WATER AND SEDIMENT QUALITY DISTRIBUTION FOR SEAGRASS RESTORATION IN WEST BAY OF THE ST. ANDREW BAY SYSTEM.

Jon M. Hemming, Michael S. Brim, and Robert B. Jarvis

United States Fish and Wildlife Service, Panama City Field Office,
1601 Balboa Avenue, Panama City, FL 32405.

Abstract: *Seagrass losses have been reported for the area of St. Andrew Bay known as West Bay, in Bay County, Florida. Utilizing both field density observations and aerial photography extrapolation for 1953, 1964, 1980, and 1992 images, estimated seagrass losses from West Bay have been reported by the U.S. Geological Survey to be over 1,000 acres or approximately 50%. Noteworthy anthropogenic events altering the condition of West Bay during this time period have included: 1) U.S. Army Corps of Engineers' (USCOE) construction of the Gulf Intracoastal Waterway (GIWW) between Choctawhatchee Bay and West Bay in 1938; 2) the creation of wetland drainage canals for both transportation and silvicultural purposes around the 1960s; 3) the 1970 implementation of an aquacultural endeavor, and 4) the 1971 introduction of a wastewater effluent to southern West Bay from a municipal sewage treatment plant. In an effort to better understand the cause of seagrass losses for the purpose of designing restoration efforts, a water and sediment quality survey was conducted. Suspected sediment contamination (potentially resulting from extensive use of antifouling coatings for nets and equipment during the aquacultural enterprise) was not confirmed with sediment sampling and analyses for metals and organotin compounds. Water column surveys revealed important differences in turbidity (NTU), water clarity (Secchi depth), and salinity (ppt). However, small differences in dissolved oxygen (mg/L), pH (SU), chlorophyll a (μg/L), and temperature (EC) were not thought as important to seagrass loss or restoration efforts. Differences in water quality appeared to be heavily dependent on depth, wind direction, recent precipitation, tidal flow, and proximity to points of allochthonous inputs such as the GIWW, wetland drainage canals, stormwater runoff, and a wastewater effluent outfall.*

Key Words: seagrass atrophy, seagrass restoration, water quality, sediment quality

St. Andrew Bay is located in northwest Florida and is composed of a number of lobes or smaller bays including North Bay, East Bay, West Bay, and Lower St. Andrew Bay. The major freshwater inflow source is Econfina Creek, a relatively small tributary. The low volume of freshwater input has been credited with minimal sediment loading (Brim, 1998). The minimum sediment loading has historically resulted in low turbidity and allows the waters in the bay to remain relatively clear, thereby sustaining the growth of some 6,200 acres of submerged vegetation (Brim, 1998). The dominant seagrass species is turtle grass (*Thalassia testudinum*), but there are also extensive beds of shoal grass (*Halodule wrightii*) and manatee grass (*Syringodium filiforme*) (McNulty et al., 1972). Average salinities are high and often exceed 30 parts per thousand (ppt) (Brim, 1998). All of these characteristics create a coastal habitat that supports an unusually high diversity of marine species (Keppner, 1996). Information supporting the importance and uniqueness of this

system can be found in the more thorough descriptions of the St. Andrew Bay system reported by Brim (1998) and Keppner and Keppner (2001).

West Bay, the least developed area in the St. Andrew Bay system, has had little historic freshwater inflow creating an estuarine habitat with moderate to high salinity. Seagrass beds are numerous, and the south shore of West Bay provides the most extensive salt marsh area in this system (Brim, 1998; Keppner and Keppner, 2001). However, large seagrass losses have been recently reported for West Bay by the U.S. Geological Survey (USGS), particularly in the southern portions. The majority of losses appear to have occurred after 1964 and continued losses have been verified past the early 1990s. Utilizing both field density observations and aerial photography extrapolation, USGS estimated seagrass losses from southern West Bay have been proposed to be nearly 2,000 acres.

Natural processes occurring in the West Bay area were accompanied by noteworthy anthropogenic events that may have participated in altering the system's ability to sustain seagrass beds. The first change in the bay system was the U.S. Army Corps of Engineers' (USCOE) construction of the Gulf Intracoastal Waterway (GIWW) connection between the oligohaline eastern portion of Choctawhatchee Bay and northwest West Bay in 1938. Another occurrence was the 1970 implementation of an aquacultural endeavor involving isolating the southern half of West Bay proper, as well as large sections of the tidal marsh along its shoreline. A third event was the 1971 introduction of a waste effluent to the southern end of West Bay from a municipal sewage treatment plant for residents of Panama City Beach, Florida. An additional large-scale change to the watershed stemmed from the creation of extensive drainage canals to drain wetland areas on the north and west shores sometime around the 1960s. Locations of various anthropogenic alterations are shown in Figure 1.

The influence of water quality on seagrass success has been well documented, especially the importance of water clarity (Buzzelli et al., 1998; Fonseca et al., 1998; Livingston et al., 1998) and high salinity (Fonseca et al., 1998; Livingston et al., 1998; Hanisak, 2002), however, numerous indirect factors and conditions have also been implicated as stressors (Fonseca et al., 1998; Pergent et al., 1999; Prange and Dennison, 2000; Jones et al., 2001; Macinnis-Ng and Ralph, 2002; Barwick and Maher, 2003). In an effort to better understand the current state of West Bay and to evaluate the potential for successful seagrass restoration efforts, a water quality survey was conducted under various environmental settings. Sediment samples were also taken to determine if metals contamination from antifouling coatings was present.

METHODS—*Water column sampling*—Water quality in West Bay and the adjacent GIWW was monitored using a YSI Model 6600 multiparameter data logger. The instrument included a rapid-pulse dissolved oxygen probe, conductivity/temperature probe, fluorescence-derived chlorophyll probe, nephlometric turbidity probe, pH probe and calculated salinity and total dissolved solids. Readings were taken at a depth of 1 meter. The data were recorded to a YSI 650 Multiparameter Display System. Secchi disk measures were also taken at each site as a measure of water clarity. Secchi depth calculations were based on averaging readings taken while lowering and raising the disk. Sampling conditions and exact sites varied by season, recent precipitation, and winds and were conducted during 3 incoming tides and 3 outgoing tides.

Statistical analyses on water quality data were performed using JMP version 5.01 (SAS Institute Inc, 2002). Statistically significant differences were accepted at $\alpha = 0.05$. Analyses were conducted on

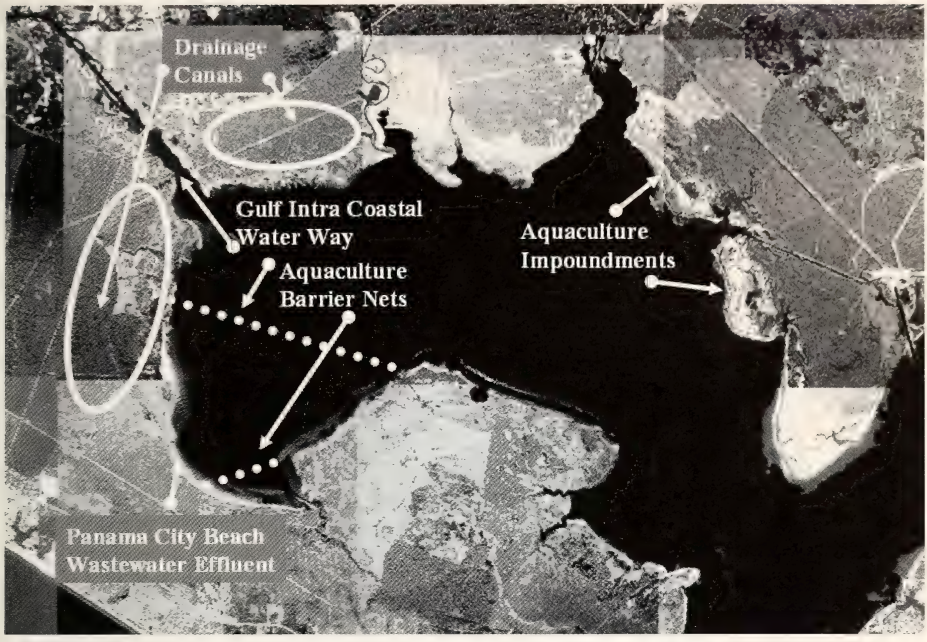

FIG. 1. Locations of various anthropogenic alterations relative to West Bay.

replicate sampling at a 4 to 10-second interval performed from 5 to 10 minutes at each site. Data were analyzed with parametric Analysis of Variance when assumptions of normality and homogeneity were met. The Tukey-Kramer Honest Significant Difference (HSD) multiple comparison tests (MCT) was used when differences were found. When parametric assumptions were not met, the non-parametric Kruskal-Wallis analysis was used with a ranked Tukey-Kramer HSD MCT when differences were found.

Data were also evaluated for ecological significance (limiting factor determination) to the recovery of seagrasses in West Bay. Semi-quantitative risk estimations were applied to the data collected during each sampling period to elucidate areas less suited to restoration. The semi-quantitative assessment was based on literature-derived threshold values for various water quality parameters (Barwick and Maher, 2003; Buzzelli et al., 1998; Fonseca et al., 1998; Hanisak, 2002; Jones et al., 2001; Macinnis and Ralph, 2002; Livingston et al., 1998; Pergent et al., 1999; Prange and Dennison, 2000).

Sediment Sampling—Sediment samples were collected from 10 sites in West Bay. Sediment samples were composite samples consisting of three ~200 ml subsamples taken from the center of three separate ponar grabs collected with a standard ponar 316 stainless steel grab. Depth of sediment samples collected depended on the type of sediment at each station (maximum depth in silt ~10 cm). Samples collected in the field were immediately put into laboratory-certified, chemically-cleaned, 1-L amber glass jars with Teflon-lined lids and placed on ice in coolers. Samples were temporarily stored at the Panama City Field Office (PCFO) in freezers at –5° C until shipment to analytical laboratories within 72 hours. Sediment samples were analyzed for metals and organic tin compounds to examine the extent to which the aquacultural net treatment may have impacted the bay sediments. Analyses for organotins were carried out by Geochemical and Environmental Research Group, Texas A&M Research Foundation, 833 Graham Road, College Station, TX 77845. Analyses for inorganic metals were performed by Trace Element Research Laboratory, VAPH/CVM Highway 60, VMA Bldg, Room 107, College Station, TX 77843-4458. Sediment analytical results were compared to the Effects Range Low (ERL) and Effects Range Median (ERM) criteria of Long and co-workers (1995) to estimate risk to living resources from exposure to contaminated sediments.

RESULTS AND DISCUSSION—Water quality is a well known determining factor in seagrass losses (Gallegos and Kenworthy, 1996; Fonseca et al., 1998; Livingston et al., 1998; Wang et al., 1999; Jones et al., 2001; Hanisak, 2002). Further, some have speculated that knowledge of water quality could allow for developing optimal seagrass restoration plans or even forecasting seagrass distributions (Johansson, 1995; Fourqurean et al., 2003). This water quality survey was conducted to provide guidance for seagrass restoration efforts in West Bay. Results are discussed below by tidal condition and sampling date. The results represent discrete sampling times and therefore should not be interpreted to represent all conditions that the West Bay system experiences.

Water column sampling—Incoming tide, January 28th 2003—As would be expected during January, the water temperatures were seasonally cool (below 14 degrees C). These cool water temperatures allowed high dissolved oxygen concentrations (12–15 mg/L) at all sites as a consequence of supersaturation (113–146%). Hydrogen ion concentrations (pH) were neutral (7.39–8.25), but did differ between sites in the open bay (8.03–8.25) and GIWW sites (7.39–7.78). These differences in pH likely reflected the differences in salinity between the open bay (20.26–26.65 ppt) and GIWW (11.05–18.26 ppt) due to the distinct water chemistries of each. However, there was one outlier in West Bay with lower salinity. The possible trend in salinity and pH contrasting the open bay from the GIWW on incoming tide was reinforced by differences in turbidity levels (0.57–3.73 NTU open bay, 5.70–11.0 NTU GIWW) and chlorophyll concentrations (1.50–6.10 µg/L open bay, 4.37–6.43 µg/L GIWW). Variable turbidity was also observed within the GIWW during a chance event that allowed measures immediately before (5.8 NTU) and after (11.0 NTU) the passage of a tug boat pushing two fully loaded fuel barges, thereby demonstrating re-suspension of bottom sediments with GIWW use. However, the turbidity returned to the original level within 15 to 20 minutes after tug boat passage.

A site in southern West Bay also had salinity (18.41 ppt) that was also somewhat lower than other bay sites (20.26–26.65 ppt). The more subtle salinity difference at this site suggested another source of freshwater input, potentially the Panama City Beach municipal wastewater effluent outfall, a forestry drainage ditch, or the tidal creek subwatershed to the southeast of the site that drains a subdivision and golf course area. The low tide, at a time of year when tides are especially low, may have emphasized the contribution of the input. However, no concomitant difference in pH, turbidity, or chlorophyll concentration was noted as was for the GIWW.

The influence of the incoming tide in all likelihood affected the distribution of these water quality parameters. Currents flowing from West Bay into the GIWW westward were qualitatively observed during sampling. The resulting water chemistry of samples showed differences between waters of the open bay and those in, and at the mouth of, the GIWW. The degree of mixing between waters in the open bay and the GIWW was unclear; however, it seems probable that waters from the more saline West Bay had mixed with the more brackish GIWW to some undefined extent. The true differences in water chemistry between these waters is likely to be more clear with sampling further west in the GIWW and in West Bay on outgoing tides that would bring waters from the GIWW eastward.

Incoming tide, March 27th 2003—Weather conditions around the time of this sampling were dissimilar from the January sampling in many ways. Water temperatures were warmer (21.3–23.1 degrees C), heavy rains had preceded sampling, and southeast winds drove moderate waves that broke on the western shore of West Bay. As a result of the heavy precipitation over the past few weeks, salinity was lower overall ranging from 10.8 to 13.2 ppt, with the exception of the uppermost site in the GIWW that had a mean salinity of 9.6 ppt. pH was similar at all sites (7.34–8.1). The highest pH measure coincided with the highest dissolved oxygen measure (10.1 mg/L). Dissolved oxygen at this site was higher than other bay sites (7.9–8.5 mg/L) and considerably higher than GIWW sites (5.8–6.9 mg/L), indicating two possible areas of allochthonous (external from the bay) water introduction. The higher dissolved oxygen and pH site was located in southern West Bay between the Panama City Beach municipal wastewater effluent outfall and the unnamed tidal creek (described above) reemphasizing the probability of input in this area of the bay. Albeit, inputs from northern West Bay again resulted in far lower salinity measures even on incoming tide.

Chlorophyll-a concentrations (8.6–13.0 μg/L) were higher in March as would be expected by the warming temperatures, longer days, and nutrients being introduced via the frequent precipitation. The influence of chlorophyll on turbidity was negligible at these concentrations as was evident by the highest chlorophyll concentrations being (13.0 μ/L) measured at the same site the lowest turbidity measures (1.4 NTU) were observed. Turbidity in the open bay was largely related to depth, wind speed and direction, and wave energy, as was most clearly demonstrated by the westward transect performed from the open bay to the western shore. Turbidity was inversely proportional to depth (Non-parametric Spearman Rho, $p < 0.0001$, $r = -0.6798$). Turbidity in the GIWW was consistently higher (10.6–13.8 NTU) than depth (>10 feet) would have indicated when compared to the open bay sites.

Lower salinity and dissolved oxygen concentrations combined with higher turbidity (when normalized by depth) again indicated a different water quality (somewhat lower based on dissolved oxygen) in the GIWW. This is particularly noteworthy when considering the short distance up the GIWW that was sampled and the potential for more extreme differences further away from West Bay. Conversely, higher dissolved oxygen and slightly higher pH may have again illustrated another aqueous introduction from the wastewater outfall and/or tidal creek in southern West Bay. However, the magnitudes of the indicated inputs in southern West Bay were apparently smaller when compared to those from the northern shore of West Bay and the GIWW. Additionally, the contribution of the numerous drainage canals on the western and northern shores demonstrates that draining of these extensive areas cannot be discounted as insignificant inputs.

Outgoing tide, May 14th 2003—The first sampling on an outgoing tide was performed during a month with very little precipitation and warm temperatures. The calm winds produced only light chop on the warmer waters (26.2–29.0°C). Water temperatures progressively warmed with daylight hours to the highest measured.

The lack of wind and rain allowed for the isolated observation of the influence that a third major factor, the outgoing tide, had on West Bay water quality.

Despite the warmer water temperatures, dissolved oxygen concentrations were 6.9–13.1 mg/L. Two of the three readings below 7.5 mg/L were taken in the GIWW (6.9 and 7.5 mg/L) and the third was taken at the mouth of Burnt Mill Creek (7.0 mg/L). Nevertheless, all dissolved oxygen concentrations measured were adequate to support both flora and fauna. pH ranged from 7.4 to 8.6 for all sites. Again the lower pH readings were interconnected with decreased salinity. Salinity differences were large between sites in the open bay (16–23.4 ppt) and sites in the GIWW (10.3 and 6.9 ppt). To elaborate, the salinity decreased with distance into the GIWW; and open bay salinities were 16.2–18.7 on the western shore, 20.5–22.8 ppt in the central bay, and above 23.0 ppt in the eastern bay (except for one site in the southeast near North Bay, 22.7 ppt). The salinity trend was similar to possible trends in turbidity and chlorophyll concentration. Turbidity was highest (6–10 NTU) in the GIWW and in shallow areas (<3 feet) near the western shore. Turbidity was also somewhat higher (3–6 NTUs) in the central bay where salinities were intermediate, but were lower (0–3 NTU) in the more saline eastern bay. To a lesser extent, chlorophyll concentrations were higher (4–8 μg/L) in the GIWW and along the western shore than in the eastern bay (0–4 μ/L).

This survey, conducted during an outgoing tide, provided useful information about the movement of water from different possible inputs into West Bay. The water quality differences observed during the previous incoming tides changed in distribution with outgoing tides. This assumption was made because the influences of precipitation and wind driven waves were not present during this sampling. Water quality distribution revealed that less saline, more turbid waters had higher chlorophyll concentrations, presumably originating in the GIWW, and extending westward into West Bay. A possible intermediate mixing zone separated this area from the more saline and less turbid waters of eastern West Bay. These observations support the hypothesis that large allochthonous contributions are coming into West Bay via the northern shore and progressing south and west into the bay. However, the western and northern shores may also be the source of significant stormwater input via drainage canals that would have similar effects on water quality in that area of the bay.

No indication of significant allochthonous contributions was observed connected to the wastewater outfall or tidal creek on this sampling date. The earlier observations were of subtle differences in water quality and these may have been masked by the larger differences introduced from other sources on this outgoing tide.

Outgoing tide, June 12th 2003—Temperatures were slightly warmer and very consistent (29.3–30.9 degrees C) among sites on the second outgoing tide sampling of West Bay. The weather was quite different compared to the first outgoing tide sampling. Two varied factors thought to be of large importance to the water quality of West Bay included the strong southeast winds and the heavy rains preceding the sampling. All three driving factors (tidal movement, wind/waves, and precipitation) contributed to some undefined degree to the water quality conditions of West Bay on this sampling date.

Salinity measurements showed a similar pattern to the May outgoing tide sampling in that open bay sites salinities (23.2–25.4 ppt) were higher than those associated with the GIWW (17.3–18.86 ppt) or near the mouth of Burnt Mill Creek (19.3 and 20.3 ppt). Western bay sites did not have lower salinity measures than open bay sites during this sampling as they did in the prior outgoing tide sampling. However, turbidity NTUs and chlorophyll concentrations were higher in both the GIWW and on the western shore of West Bay. Turbidity was highest in (and at the mouth of) the GIWW (9.0–14.3 NTU), intermediate around the western shore (4.3, 5.0 and 8.3 NTU), and lowest in the central and eastern bay (0.9–2.3 NTU). Chlorophyll concentrations were similar between the sites associated with the GIWW (4.4–6.7 NTU) and those along the western shore (4.5–5.9 NTU), but were all somewhat higher than central bay (2.5–3.2 NTU) and eastern bay (2.5–3.1 NTU) sites. Dissolved oxygen concentrations (6.3–8.2 mg/L) were not thought to have been limiting at any site and the overall pH range was small (7.8–8.2 SU) during this sampling.

It is noteworthy that the site that showed the highest turbidity and chlorophyll concentration, but the lowest dissolved oxygen and pH, among western shore sites was located just north of the wastewater outfall, transportation drainage ditch, and tidal creek on the southwestern West Bay shore. Turbidity was measured to be almost twice as high as locations to either side of this site despite salinity being of the highest recorded this date. It is difficult to speculate on a possible allochthonous source that would very locally increase turbidity, but not decrease salinity. The observation could have been dismissed as inherent variability if this area had not differed slightly in water quality during both the January and March incoming tide surveys.

Taken as a whole, the causes of the various water quality conditions may have been numerous, but it is likely the tidal circulation, recent precipitation, and wind-driven wave energy played key roles. The pattern of turbidity, chlorophyll, and (to a lesser extent) salinity resembled that exhibited by the outgoing tide in May. The water movement appeared to be from the GIWW down the west shore of West Bay. However, the pattern was also similar to the incoming tide in March with the strong southeast wind and waves breaking on the northern and western shores. In both cases, heavy precipitation preceded the sampling and may have thereby increased the turbidity via large episodic inputs to the system as was evident from the ubiquitous presence of tannin stained water during all surveys that followed heavy rains. The pattern of decreasing turbidity eastward in the bay was consistent for both this and the March incoming tide sampling. However, in March the precipitation inputs were reflected in very low salinities (<15 ppt) bay-wide, despite the more saline waters coming into West Bay as a result of the incoming tide. This was not the case for this outgoing tide sample because salinities of the western shore sites (24.9–25.4 ppt) were similar to central (23.6–24.4 ppt) and eastern bay (23.2–23.6 ppt) sites, despite lower salinities in the GIWW (17.9 and 18.9 ppt) and near the mouth of Burnt Mill Creek (19.3 and 20.3 ppt).

Notwithstanding, the drainage canals on the western and northern shores could again have contributed significantly to the water quality conditions observed. In particular, the decreased salinity near the northern West Bay area may be a strong indication of this possibility. The influence of each driving factor cannot be separated

in field evaluations, despite optimistic efforts to catch various combinations. Data must be interpreted with consideration of all environmental contributions and conditions.

Outgoing tide, June 26th 2003—This final water quality survey was the most geographically extensive and was performed two days after heavy rains. The wind was moderate to light, variable and from the south, and at times, west. The tide was outgoing and moved the waters of the GIWW into both West Bay and Choctawhatchee Bay simultaneously. The assumption that Choctawhatchee Bay waters travel down the GIWW on outgoing tides toward, and into, West Bay was observed not to be accurate in all situations. Water temperatures remained warm (28.1–31.3 degrees C) as seen in the previous survey and did not differ considerably from site to site.

The heavy rains again stained the entire bay with tannic acids via stormwater runoff. This nonpoint source storm runoff also had a large influence on salinity, as it had in earlier surveys, reducing it below 15 ppt at all but one eastern bay site (18.22 ppt). However, this was the first occasion when salinity variation within the GIWW and Choctawhatchee Bay was observed. Salinities below 4 ppt were recorded in Choctawhatchee Bay and central GIWW, although sites between Choctawhatchee Bay and the central GIWW had salinities between 4 and 8 ppt, as did sites nearing West Bay. There was an apparent higher salinity portion of the GIWW caught between the oligohaline Choctawhatchee Bay and the similar salinity of the central GIWW. Sites in the central GIWW (0–4 ppt) and Choctawhatchee Bay (0–4 ppt) had lower salinities than sites in the western GIWW between them (4–8 ppt). The eastern GIWW (0–4 ppt) was again much less saline than West Bay with its trend of increasing salinity southward and eastward (16–20 ppt).

This observation may suggest large freshwater inputs entering the GIWW between the two bays. Observations were made of consistently flowing stormwater drains and groundwater seepage from the cliff banks of the central portion of the GIWW likely contributed to some undefined extent. Although the low saline conditions frequently found in Choctawhatchee Bay would provide a convenient explanation for the trend observed from the GIWW to West Bay, this scenario would not account for the observations made during this survey. Taken together, the salinity variation and the observed tidal flow divergence supports a partial rejection of the hypothesis stating that freshwater flows almost exclusively from Choctawhatchee Bay to West Bay via the GIWW on outgoing tides thereby altering the water chemistry of West Bay.

The salinity distribution pattern was again similar to both turbidity and chlorophyll concentrations. Turbidity was highest in the GIWW (6–22 NTU), but an area of lower turbidity (5.8 NTU) was found to coincide with the unexpected increased salinity in the western GIWW. Turbidity was again found to decrease with distance southeastward and turbidity readings at southern and eastern sites were low (0–3 NTU). Although overall chlorophyll concentrations were markedly higher on this date, chlorophyll concentrations were highest on either end of the GIWW (12–22 μg/L) when compared to the central GIWW (9–11 μg/L) or the majority of West Bay (8–12 μg/L). The most southeasterly sites again had the lowest chlorophyll readings (5–7 μg/L).

Dissolved oxygen concentrations were lower overall during this sampling. The decline likely resulted from a combination of warm water temperatures and the chemical and biological oxygen demand resulting from the material carried by the recent rains. Dissolved oxygen ranged from 5.6 to 7.2 mg/L in most areas, with the exception of the GIWW (3.8–4.8 µg/L) and one anomalous site in the eastern open areas of West Bay (4.8 µg/L). Measured pH varied little among sites, but did appear to differ slightly when comparing the Choctawhatchee Bay and GIWW sites (6.5–6.9) to open West Bay sites (7.0–7.8). The pH differences again reflected the noted differences in salinity distribution as proposed for earlier survey data.

Sediment sampling—Sediment contamination from the historic shrimp aquaculture operation (extensive chemical treatment of 36,000 feet of confinement nets) was proposed as a possible contributing cause for the seagrass losses. Organic tins and inorganic metals were analyzed for because of their reported extensive use to minimize the growth of organisms that foul marine structures (Thouvenin et al., 2002; Thomason et al., 2002; Voulvoulis et al., 2002; Valkirs et al., 2003). Additionally, high concentrations of copper (26,510 ppm or 2.7%) and organotin (0.2%), common components with arsenic and other metals in antifouling paints, had been previously found at the net-treatment site adjacent to a dipping vat (Michael Brim, 2001). Seagrass susceptibility to metal toxicity is well known (Ralph and Burchett, 1998; Prange and Dennison, 2000, Macinnis-Ng and Ralph, 2002; Barwick and Maher, 2003), as are the implications for wildlife resulting from organic metals (organotins) used in antifouling treatments (Nicolaidou and Nott, 1998; Kajiwara et al., 2000; Tanabe, 2002; Gagne et al., 2003; Siah et al., 2003). This survey revealed no sediment contamination with metals or organic metals originating from antifouling paints or coatings. It should be noted, however, that net treatment took place between 1970 and 1975, some 28 years ago.

Sediment analyses showed no organotin compounds (monobutyltin, dibutyltin, tributyltin, and tetrabutyltin) above the detection limits of each analysis (<0.005 mg/L or <5 parts per billion). Similarly, inorganic metal concentrations were not dissimilar to background levels in St. Andrew Bay or other area bays (Brim, 1998; Brim et al., 2000). No metals exceeded sediment quality guidelines provided for estuarine sediments (Long et al., 1995). Additionally, no metal concentrations were suspect upon normalization by sediment iron or aluminum concentration (a method used to look for sites that are unusual in their metal ratios, Morel and Gschwend, 1987).

Sediment analytical results suggested that metal concentrations (organic or inorganic) were not limiting to the growth of seagrasses at the time of sampling. Although the data represent composite samples taken throughout the bay on only one occasion, the persistent nature of metals in sediments and the agreement with previous bay-wide sample data support the analytical results.

The analytical data do not exclude the possibility that the extensive loss of seagrasses from southern West Bay resulted from metals contamination that no longer is present, or resulted from contaminants for which no analyses were performed. The data also do not account for the physical and mechanical or hydrologic alterations resulting from the aquacultural endeavor. Significant insult may have

been imposed on the seagrasses by the physical and mechanical action of repetitive net trawling across the seagrass beds for shrimp harvest. The data also do not account for the stresses that may have been imposed via flow restrictions and other hydrologic alterations caused by activities such as the net barricades that isolated the entire southern bay.

Conclusions—The hydrologic condition of this coastal aquatic system is complex and involves numerous factors. Natural phenomena such as the tides, winds and waves, and precipitation had easily recognized effects. However, it was apparent that the water quality of the West Bay system is under substantial influence by factors that have been anthropogenically introduced. Notwithstanding, this survey represents only five days and existing conditions and cannot be taken to explain or illustrate in full the complex and dynamic nature of this system, but rather, may demonstrate noteworthy differences in water quality, contributions of natural factors, possible influences of human derived changes, and identification of nonpoint source inputs at unexpected locations.

If conditions observed during this survey reflect typical water quality conditions in West Bay, then water quality could be limiting seagrass recovery and growth. Salinity and water clarity stresses may be sufficient to prevent successful seagrass establishment. Water quality trends appear to be driven predominantly by tides, precipitation and wind-driven waves. These driving factors controlled the distribution of considerable inputs to West Bay that resulted in areas of distinct water quality. Large contributions entering northern West Bay apparently originated in the Gulf Intracoastal Water Way (GIWW) and were characterized by lower salinity, water clarity, pH, and dissolved oxygen than in the south and eastern areas of West Bay. The source of freshwater entering the GIWW was likely from multiple places, and at least included contributions from Choctawhatchee River via Choctawhatchee Bay, groundwater seepage into the GIWW, direct rainfall, and stormwater drains discharging into the GIWW. Another more subtle input to West Bay seemingly existed in southern West Bay in the area of the Panama City Beach municipal wastewater effluent outfall and a tidal creek sub-watershed that drains a subdivision and golf course area. Wetland drainage canals on the western and northern shores of West Bay are also the source of probable input, but these were not easily distinguished from the larger contributions to these areas.

It was not possible to clearly define the timing of events that surrounded the extensive loss of seagrasses from West Bay, particularly in the southwestern bay. It is also unclear if water quality led to the decline, or if seagrasses declined for other reasons, and subsequently their absence led to increased turbidity and other water quality differences in West Bay. It is quite possible that mechanical stresses imposed on the southwest bay as a result of the aquacultural endeavor in the 1970s, physically removed the seagrasses from the southwestern bay. Increases in turbidity may have followed due to the loss of the ecological function of the seagrasses that naturally enhance water clarity via nutrient utilization and particulate filtration. Therefore, it is plausible that water quality limitations to seagrass regrowth may have resulted from the initial loss of seagrasses. Compounding these challenges to

seagrass re-establishment were numerous anthropogenic alterations that may have significantly increased external inputs to the bay.

Taken together, water quality conditions in West Bay, particularly in areas where seagrasses have been lost, were different than in areas with healthy seagrass beds. Lower salinity and high turbidity and chlorophyll concentrations were different most often between areas. Considerable evidence suggests that the source of these changes to water quality resulted directly from anthropogenic changes to the West Bay watershed.

Further investigation into the extent of water quality differences in West Bay and their distribution pattern will be required to appropriately design a restoration plan. However, the data indicate that current sediment contamination with metals from antifouling paint from a historic shrimp aquaculture operation can be ruled out as a limiting factor. A more concentrated focus is recommended for water quality distribution in West Bay with particular emphasis on salinity, water clarity (turbidity, chlorophyll concentration, and color), pH and dissolved oxygen. Additional parameters should include those that will help to identify sources of allochthonous (external) inputs to the bay such as nutrients, oxygen demand, traceable isotopes and bacteria.

LITERATURE CITED

Barwick, M. and W. Maher. 2003. Biotransference and biomagnification of selenium copper, cadmium, zinc, arsenic and lead in a temperate seagrass ecosystem from Lake Macquarie Estuary, NSW, Australia. Mar. Environ. Res. 56(4):471–502.

Brim, M. S. 1998. Environmental contaminants evaluation of St. Andrew Bay, Florida. Publication No. PCFO-EC-98-01. U.S. Fish and Wildlife Service, Panama City Field Office, Panama City, Florida.

———, D. Bateman, and R. Jarvis. 2000. Environmental contaminants evaluation of St. Joseph Bay, Florida. Publication No. PCFO-EC-00-01. U.S. Fish and Wildlife Service, Panama City Field Office, Panama City, Florida.

Buzelli, C. P., R. L. Wetzwl, and M. B. Meyers. 1998. Dynamic simulation of littoral zone habitats in lower Chesapeake Bay. II. Seagrass habitat primary production and water quality relationships. Estuaries 21:673–689.

Fonseca M. S., W. J. Kenworthy, and G. W. Thayer. 1998. Guidelines for the conservation and restoration of seagrasses in the United States and adjacent waters. Decision Analysis Series No. 12. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Coastal Ocean Program, Washington D.C.

Fourqurean, J. W., J. N. Boyer, M. J. Durako, L. N. Hefty, and B. J. Peterson, 2003. Forecasting responses of seagrass distributions to changing water quality using monitoring data. Ecol. Applic. 13(2)474–489.

Gagne F., C. Blaise, J. Pellerin, E. Pelletier, M. Douville, S. Gauthier-Clerc, and L. Viglino. 2003. Sex alteration in soft-shell clams (*Mya arenaria*) in an intertidal zone of the Saint Lawrence River (Quebec, Canada). Comp. Biochem. Physiol., Part C 134(2):189–198.

Gallegos, C. L. and W. J. Kenworthy. 1996. Seagrass depth imits in the Indian River Lagoon: Application of an optical water quality model. Estuar. Coast. Shelf Sci. 42(3):267–288.

Hanisak, M. D. 2002. Impacts of reduced salinity on seagrasses in Indian River Lagoon. J. Phycol. 38: 15–16.

Johansson, J. O. 1995. Recovery of water quality and submerged seagrass in Tampa Bay, Florida. Florida Scient. 58(2):197–204.

Jones, A. B., M. J. O'Donohue, J. Udy, and W. C. Dennison. 2001. Assessing ecological impacts of shrimp and sewage effluent: Biological indicators with standard water quality analyses. Estuar. Coast. Shelf Sci. 52(1):91–109.

Kajiwara, N., S. Niimi, M. Watanabe, Y. Ito, S. Takahashi, S. Tanabe, L. S. Khuraskin, and N. Miyazaki. 2002. Organochlorine and organotin compounds in Caspian seals (*Phoca caspica*) collected during an unusual mortality event in the Caspian Sea in 2000. Environ. Poll. 117(3):391–402.

Keppner, E. J. 1996. An inventory of the biological resources reported from the St. Andrew Bay Estuarine System, Bay County, Florida. BEST 0001. Bay Environmental Study Team for St. Andrew Bay. Panama City, Bay County, Florida.

——— and L. Keppner. 2001. The St. Andrew Bay Ecosystem, Our Environment: A Revision of "A look to the future." BEST 0004. Bay Environmental Study Team for St. Andrew Bay. Panama City, Bay County, Florida.

Livingston, R. J., S. E. McGlynn, and X. Niu. 1998. Factors controlling seagrass growth in a gulf coastal system: Water and sediment quality and light. Aquat. Bot. 60(2):135–159.

Long, E. R., D. MacDonald, S. Smith, and F. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environ. Manage. 19(1):81–97.

Macinnis-NG C. M. O. and P. J. Ralph. 2002. Towards a more ecologically relevant assessment of the impact of heavy metals on the photosynthesis of the seagrass, *Zostera capricorni*. Marine Poll. Bull. 45(1):100–106.

McNulty, J. K., W. N. Lindall, Jr., and J. E. Sykes. 1972. Cooperative Gulf of Mexico estuarine inventory and study, Florida: Phase I, Area description. NOAA Technical Report NMFS Circ-368, U.S. Department of Commerce. Live Oak, FL.

Morel, F. M. M. and P. M. Gschwend. 1987, The role of colloids in the partitioning of solutes in natural waters. Pp. 405–422. *In*: Stumm, W., ed., Aquatic Surface Chemistry, Wiley-Interscience, New York, NY.

Nicolaidou, A. and J. A. Nott. 1998. Metals in sediment, seagrass and gastropods near a nickel smelter in Greece: Possible interactions. Marine Poll. Bull. 36(5):360–365.

Pergent, G., S. Mendez, C. Pergent-Martini, and V. Pasqualini. 1999. Preliminary data on the impact of fish farming facilities on *Posidonia oceanica* meadows in the Mediterranean. Ocean. Acta 22(1):95–107.

Prange, J. A. and W. C. Dennison. 2000. Physiological responses of five seagrass species to trace metals. Marine Poll. Bull. 41(7):327–336.

Ralph, P. J. and M. D. Burchett. 1998. Photosynthetic response of *Halophila ovalis* to heavy metal stress. Environ. Poll. 103(1):91–101.

Siah, A., J. Pellerin, J. Amiard, E. Pelletier, and L. Viglino. 2003. Delayed gametogenesis and progesterone levels in soft-shell clams (*Mya arenaria*) in relation to in situ contamination to organotins and heavy metals in the St. Lawrence River (Canada). Comp. Biochem. Physiol., Part C 135(2):145–156.

Tanaba, S. 2002. Contamination and toxic effects of persistent endocrine disrupters in marine mammals and birds. Marine Poll. Bull. 45(1):69–77.

Thomason, J. C., J. M. Hills, and P. O. Thomason. 2002. Field-based behavioural bioassays for testing the efficacy of antifouling coatings. Biofouling 18(4)285–292.

Thouvenin, M., J. J. Peron, C. Charreteur, P. Guerin, J. Langlois, and K. Vallee-Rehel. 2002. A study of the biocide release from antifouling paints. Prog. Organ. Coatings 44(2):75–83.

Valkirs, A. O., P. F. Seligman, E. Haslbeck, and J. S. Caso. 2003. Measurement of copper release rates from antifouling paint under laboratory and in situ conditions: implications for loading estimation to marine water bodies. Marine Poll. Bull. 46(6):763–779.

Voulvoulis, N., M. D. Scrimshaw, and J. N. Lester. 2002. Comparative environmental assessment of biocides used in antifouling paints. Chemosphere 47(7):789–795.

Wang, P. F., J. Martin, and G. Morrison. 1999. Water quality and eutrophication in Tampa Bay, Florida. Estuar. Coast. Shelf Sci. 49:1–20.

Florida Scient. 68(2): 97–108. 2005
Accepted: September 29, 2004

RECORDS AND OBSERVATIONS FOR SOME DIPTERA IN THE FLORIDA KEYS

Lawrence J. Hribar

Florida Keys MCD, 506 106th Street, Marathon, Florida 33040
and
Research Associate, Florida State Collection of Arthropods, Gainesville, Florida 32614

Abstract: *Distribution records for gall midges, shore flies, and crane flies in the Florida Keys are presented. The distribution of the black mangrove gall-making midge,* Meunieriella avicenniae, *in the Florida Keys is reported, as are some notes on the adult morphology. The presence of the kleptoparasite* Didactylomyia longimana *in the Florida Keys is noted. The shore fly,* Brachydeutera neotropica, *was found breeding in a sewage treatment plant in Marathon, Vaca Key, Florida. The crane flies* Limonia brevivena, L. domestica, *and* L. floridana *are reported from the Florida Keys.*

Key Words: Cecidomyiidae, Ephydridae, Tipulidae

The Florida Keys Mosquito Control District conducts mosquito control operations on the larger inhabited islands within Monroe County, Florida. An important part of these operations is surveillance for larval and adult mosquitoes in natural areas and in domestic situations (i.e., near homes and businesses). Among larval surveillance activities are examination of artificial and natural containers near houses, inspection of sewage treatment plants, and monitoring mosquito larval development in storm water catch basins. Adult surveillance is conducted primarily through use of dry ice-baited light traps. During these surveillance activities opportunities often arise for making observations or collection records for other species not usually of interest to mosquito control programs. Herein are reported locality records and other data for some species of flies seen during 2003 and 2004 in the Florida Keys.

Diptera: Cecidomyiidae—One specimen of *Didactylomyia longimana* Felt was collected in a light trap on Long Key, 11 May 2004. The specimen was deposited into the Florida State Collection of Arthropods (accession number E2004-6420-601). This is a free-living species kleptoparasitic on spiders (Sivinski and Stowe, 1980). Previous Florida records were from Alachua County, Florida (Sivinski and Stowe, 1980). This species is Holarctic in distribution (Gagné, 1981). Five Nearctic species of *Didactylomyia* have been described, distinguished principally by the male genitalia (Felt, 1915 [1916]; 1919). Three of these have been synonymized with *D. longimana* and a fourth species has been transferred to another genus (Thompson, 2004).

Meunieriella avicenniae (Cook) is a gall-making midge on black mangrove, *Avicennia germinans* (L.). Gagné and Etienne (1996) described the larva, pupa, and

adult of this midge, which had previously been known only from the description of its gall (Cook, 1909). Records from the United States are given only as Florida, with no localities mentioned (Gagné, 1989; 1994). The presence of this midge in the Florida Keys was detected by identification of its characteristic leaf galls on Big Pine Key, Grassy Key, and Long Key. It is likely that this species occurs throughout the Florida Keys. Other records from Florida include Dade, Lee, and Pinellas Counties (Steck, 2004). Two adult midges reared from galls were consistent with the description of Gagné and Etienne (1996). One pupa was dissected from a leaf gall. Voucher specimens were deposited into the Florida State Collection of Arthropods (accession numbers E2004-6421-601, E2004-6421-602, E2004-6422-601). Some interesting coloration was noted on these two midges. The abdomens and trochanters of all legs were bright orange. This color was due to some pigment or substance in the fat body, although it was not removed during clearing with acetic acid nor when the midges were mounted on slides in Euparal medium. The coloration eventually faded after some weeks. The scutum of each fly was light brown with three long brown spots, one central and two lateral, giving the appearance of two light brown stripes.

The Cecidomyiidae are a poorly studied family of flies in North America. Over 1,000 species are known from North America, but there are many undescribed species, and collection records for most species are few, such that their true distribution is unknown. Many species form galls on plants, whereas others are free-living and are predacious, parasitic, phytophagous, or mycetophagous; some are of economic importance (Gagné, 1981). One species has been introduced into the United States as a biological control agent (Pecora et al., 1991).

Diptera: Ephydridae—Immature stages of a shore fly, *Brachydeutera neotropica* Wirth, were collected from a sewage treatment plant in the City of Marathon, Vaca Key, Monroe County, Florida, along with a large quantity of larvae of the southern house mosquito, *Culex quinquefasciatus* Say. Collection data–FL, Monroe Co., Vaca Key, Marathon: April 21, 2004, sewage treatment plant: 1 puparium, B. Dillon, coll.; April 28, 2004, sewage treatment plant, 4 puparia, 2 larvae, B. Dillon, coll. Five adult specimens were reared from puparia. These adults and their associated exuviae, along with one unassociated set of exuviae and one larva, were deposited into the Florida State Collection of Arthropods, Gainesville (accession number E2004-3955-601).

Ephydridae, or shore flies, are a large family with 425 species in 68 genera known from the Nearctic region (Wirth et al., 1987). Wirth (1965), writing for the catalog of North American Diptera, listed only one species, *B. argentata* (Walker) from the USA. However, Wirth (1964) revised the genus based on male genitalia and reported three species from the continental USA: *B. argentata* (Walker), mainly northeastern but with records from Florida and Louisiana; *B. sturtevanti* Wirth, from the southwestern USA; and *B. neotropica* Wirth, mainly Neotropical but with records from North Carolina, Louisiana, Texas, and Florida. Mathis and Winkler (2003) report the distributions of these species as Nearctic (*B. argentata*) or Nearctic and Neotropical (*B. neotropica* and *B. sturtevanti*). The distributions of *B. argentata* and *B. neotropica* overlap in Florida (Mathis, 1983). One Oriental species, *B. longipes*

Hendel, has been reported from Maryland, Georgia, and North Carolina (Mathis and Steiner, 1986). This species is the most widespread *Brachydeutera* species in Asia (Mathis and Ghorpadé, 1985). Johannsen (1935) illustrated the puparium of what was then called *B. argentata*. Keiper and Walton (2000) presented keys to the immature stages of *B. argentata*, *B. sturtevanti*, and *B. neotropica*. Larval cephalopharyngeal skeletons and puparia of specimens collected in Marathon, Florida, were consistent with descriptions of Lizarralde de Grosso (1972) and Keiper and Walton (2000), confirming identity of species. (The larval cephalopharyngeal skeleton remains within the puparium.) Larvae of both *B. neotropica* and *B. sturtevanti* have a "window" in the ventral cornu of the cephalopharyngeal skeleton; this window is lacking in *B. argentata* (Keiper and Walton 2000). The size, shape, and position of the window were consistent with the illustrations of Lizarralde de Grosso (1972), who illustrated the larvae of *B. neotropica*.

Whereas Lizarralde de Grosso collected *B. neotropica* larvae in bodies of water ("cuerpos de agua", presumably ponds) in the Parque Pereyra Iraola in Argentina, the larvae collected in Marathon, Florida, were taken from a sewage treatment plant. Mathis and Steiner (1986) summarized the biology of *B. longipes*; in India this species is used as an indicator of water pollution, since it is a common inhabitant of raw sewage and septic tanks, where it coexists and competes with larvae of the mosquito *Cx. quinquefasciatus*. Considering that *B. neotropica* was taken in the same larval habitat along with the same mosquito species, it is likely that the larval biologies of *B. longipes* and *B. neotropica* are similar.

Diptera: Tipulidae—Crane flies were collected from light traps placed on Long Key, Grassy Key, Vaca Key, No Name Key, and Big Pine Key, from January to May 2004. Two species, *Limonia* (*Dicranomyia*) *brevivena* (Osten Sacken) and *Limonia* (*Dicranomyia*) *floridana* (Osten Sacken), were collected sporadically from most islands but consistently from No Name Key. The trap site on No Name Key is adjacent to a large stand of saltwort, *Batis maritima* L. Large numbers of *L. floridana* were collected from Big Pine Key, again near *B. maritima*. Most specimens were collected from January to March. Two specimens of *Limonia* (*Rhipidia*) *domestica* (Osten Sacken) were collected inside a house on Vaca Key. Voucher specimens of all three species have been deposited into the Carnegie Museum of Natural History, Pittsburgh.

Limonia is the largest genus in the order Diptera, with almost 2,000 species included (Alexander, 1965). Larvae occur in decaying plant matter (Alexander and Byers, 1981). *Limonia floridana* has been reported from Florida, Maryland, Virginia, and South Carolina. It is virtually a marine species, associated with plant communities near marine environments (Alexander, 1965; Rogers, 1932). *Limonia brevivena* is a widespread species, occurring from Oregon to Newfoundland and south to Florida (Alexander, 1965). Previous records from Florida include Hillsborough and Orange Counties (Steck, 2004). There does not seem to have been a lot of work done on the crane flies in the Florida Keys, although the tipulid fauna of northern Florida has been studied in detail (Rogers, 1933), and the fauna of the Caribbean has been studied (e.g., Alexander, 1939, 1964; Gelhaus et al., 1993).

ACKNOWLEDGMENTS—C.W. Young, Carnegie Museum of Natural History, identified the voucher specimens of Tipulidae.

LITERATURE CITED

ALEXANDER, C. P. 1939. New or little-known species of the West Indian Tipulidae (Diptera) IV. J. Agric. Univ. Puerto Rico 23:91–130.

———. 1964. The crane-flies of Jamaica (Diptera, Tipulidae). Bull. Inst. Jamaica Sci. Ser. 14:1–68.

———. 1965. Family Tipulidae. Pp. 16–90. *In*: STONE, A., C. W. SABROSKY, W. W. WIRTH, R. H. FOOTE, AND J. R. COULSON (eds.). A Catalog of the Diptera of America North of Mexico. USDA Agric. Handb. No. 276. 1696 pp.

——— AND G. W. BYERS. 1981. Tipulidae. Pp. 152–190. *In*: MCALPINE, J. F., B. V. PETERSON, G. E. SHEWELL, H. J. TESKEY, J. R. VOCKEROTH, AND D. M. WOOD, (eds.). Manual of Nearctic Diptera, Vol. 1. Agric. Canada Monog. No. 27:1–674.

COOK, M. T. 1909. Some insect galls of Cuba. Est. Cent. Agron. Cuba 2:143–146.

FELT, E. P. 1915 [1916]. 30th report of the State Entomologist on injurious and other insects of the State of New York, 1914. New York State Mus. Bull. 180:5–336.

———. 1919. New gall midges or Itonididae from the Adirondacks. J. New York Entomol. Soc. 27: 277–292.

GAGNÉ, R. J. 1981. Cecidomyiidae. Pp. 257–292. *In*: MCALPINE, J. F., B. V. PETERSON, G. E. SHEWELL, H. J. TESKEY, J. R. VOCKEROTH, AND D. M. WOOD (eds.). Manual of Nearctic Diptera, Vol. 1. Agric. Canada Monog. No. 27:1–674.

———. 1989. The Plant-Feeding Gall Midges of the North America. Cornell Univ. Press, Ithaca, NY. 356 pp.

———. 1994. The Gall Midges of the Neotropical Region. Cornell Univ. Press, Ithaca, NY. 352 pp.

——— AND J. ETIENNE. 1996. *Meunieriella avicenniae* (Cook) (Diptera: Cecidomyiidae) the leaf gall maker of black mangrove in the American tropics. Proc. Entomol. Soc. Washington 98:527–532.

GELHAUS, J. K., E. C. MASTELLER, AND K. M. BUZBY. 1993. Emergence composition and phenology of Tipulidae (Diptera) from a tropical rainforest stream at El Verde, Puerto Rico. J. Kansas Entomol. Soc. 66:160–166.

JOHANNSEN, O. A. 1935. Aquatic Diptera. Part II. Orthorhappha-Brachycera and Cyclorhappha. Cornell Univ. Agric. Exper. Sta. Mem. No. 177. 62 pp.

KEIPER, J. B. AND W. E. WALTON. 2000. Biology and immature stages of *Brachydeutera sturtevanti* (Diptera: Ephydridae), a hyponeustic generalist. Ann. Entomol. Soc. Amer. 93:468–475.

LIZARRALDE DE GROSSO, M. S. 1972. Notas sobre Ephydridae Argentinos. I. (Diptera) Descripción de las larvas y pupas de *Scatella notabilis* Creson y *Brachydeutera neotropica* Wirth. Rev. Soc. Entomol. Argentina 34:79–84.

MATHIS, W. M. 1983. Notes on *Brachydeutera* Loew (Diptera: Ephydridae) from North America. Entomol. News 94:177–180.

——— AND K. D. GHORPADÉ. 1985. Studies of Parydrinae (Diptera: Ephydridae), I: a review of the genus *Brachydeutera* Loew from the Oriental, Australian, and Oceanian regions. Smithsonian Contrib. Zool. No. 406. 25 pp.

——— AND W. E. STEINER, JR. 1986. An adventive species of *Brachydeutera* Loew in North America (Diptera: Ephydridae). J. New York Entomol. Soc. 94:56–61.

——— AND I. S. WINKLER. 2003. A review of the Neotropical species of *Brachydeutera* Loew (Diptera: Ephydridae). Proc. Entomol. Soc. Washington 105:407–424.

PECORA, P., R. W. PEMBERTON, M. STAZI, AND G. R. JOHNSON. 1991. Host specificity of *Spurgia esulae* Gagné (Diptera: Cecidomyiidae), a gall midge introduced into the United States for control of leafy spurge (*Euphorbia esula* L. "complex"). Environ. Entomol. 20:282–287.

ROGERS, J. S. 1932. On the biology of *Limonia* (*Dicranomyia*) *floridana* (Osten Sacken). Florida Entomol. 15:65–70.

———. 1933. The ecological distribution of the crane flies of northern Florida. Ecol. Monog. 3:2–74.

SIVINKSI, J. AND M. STOWE. 1980. A kleptoparasitic cecidomyiid and other flies associated with spiders. Psyche 87:337–348.

Steck, G. J. 2004. Gainesville, FL. Pers. Comm.

Thompson, F. C. 2004. The Biosystematic Database of World Diptera. http://www.sel.barc.usda.gov/Diptera/biosys.htm (Accessed 12 September 2004).

Wirth, W. W. 1964. A revision of the shore flies of the genus *Brachydeutera* Loew (Diptera: Ephydridae). Ann. Entomol. Soc. Amer. 57:3–12.

———. 1965. Family Ephydridae. Pp. 734–759. *In*: Stone, A., C. W. Sabrosky, W. W. Wirth, R. H. Foote, and J. R. Coulson (eds.). A Catalog of the Diptera of America North of Mexico. USDA Agric. Handb. No. 276. 1696 pp.

———, W. N. Mathis, and J. R. Vockeroth. 1987. Ephydridae. Pp. 1027–1047. *In*: McAlpine, J. F., B. V. Peterson, G. E. Shewell, H. J. Teskey, J. R. Vockeroth, and D. M. Wood (eds.). Manual of Nearctic Diptera, Vol. 2. Agric. Canada Monogr. No. 28:657–1332.

Florida Scient. 68(2): 109–113. 2005
Accepted: October 1, 2004

MOSQUITO LAGOON SEA TURTLE COLD STUN EVENT OF JANUARY 2003, KENNEDY SPACE CENTER/MERRITT ISLAND NATIONAL WILDLIFE REFUGE, FLORIDA

J. A. Provancha[1], M. J. Mota[1], K. G. Holloway-Adkins[1], E. A. Reyier[1], R. H. Lowers[1], D. M. Scheidt[1] and M. Epstein[2]

[1]Dynamac Corporation, Dyn-2 Kennedy Space Center, FL, 32899
[2]Merritt Island National Wildlife Refuge, Titusville, FL 32782

Abstract: *In January 2003, east-central Florida lagoon water temperatures plunged quickly to 5°C. Twenty-nine* Chelonia mydas *(green turtles) became cold stunned and were found in a comatose-like state in Mosquito Lagoon, Brevard County. The turtles were retrieved from the water, and taken to a facility at the Merritt Island National Wildlife Refuge to warm and protect them from the elements. Researchers recorded retrieval times and locations for each animal. The turtles were examined, photographed and measured. Fifteen of the turtles were afflicted with fibropapillomatosis (FP) disease. The disease manifests as tumors normally on the eyes and fleshy parts of the body. The condition of each individual was documented including the location and size of FP tumors. Ten turtles were transported to a rehabilitation facility due to their advanced stage of FP or their overall health condition; five of these died in transport, at the facility, or their extremely poor condition warranted euthanization. Five days later, the remaining* C. mydas *were released in Mosquito Lagoon when water temperatures reached 23°C. The details of this and previously documented cold stun events in Florida are discussed. Keywords: sea turtles, cold-stun, fibropapillomatosis.*

Key Words: green turtle, *Chelonia mydas*, fibropapillomatosis, cold stun, Mosquito Lagoon, acoustic tags.

Cold stun events have historically impacted tropical and subtropical species found in the temperate/subtropical transition zone along Florida's east-central coast (Mendonca and Ehrhart, 1982; Provancha et al., 1986) (Fig.1). Sea turtle cold stun events, particularly in Mosquito Lagoon, were documented in 1894, 1977, 1978, 1981, 1985, 1986, and 1989 (Mendonca and Ehrhart, 1982; Witherington and Ehrhart, 1989; Schroeder et al., 1990). This lagoon is within the jurisdiction of the Kennedy Space Center (KSC), the Merritt Island Wildlife Refuge (MINWR) and the Canaveral National Seashore (CNS). Observations of previous incidents indicate that when water temperatures dropped abruptly below 10°C in a short period of time (24 to 48 hours) sea turtles' metabolic processes became compromised and turtles became lethargic and incapacitated (Schroeder et al., 1990). During these cold stun events turtles were found floating at the surface of the water in a comatose-like state; leaving them additionally susceptible to boat strikes and predation. Marine turtles are federally protected under the Endangered Species Act of 1973; *Chelonia mydas*, green turtles, are currently listed as endangered and *Caretta caretta*, loggerhead turtles, are listed as a threatened species. Large cold stun events can result in hundreds

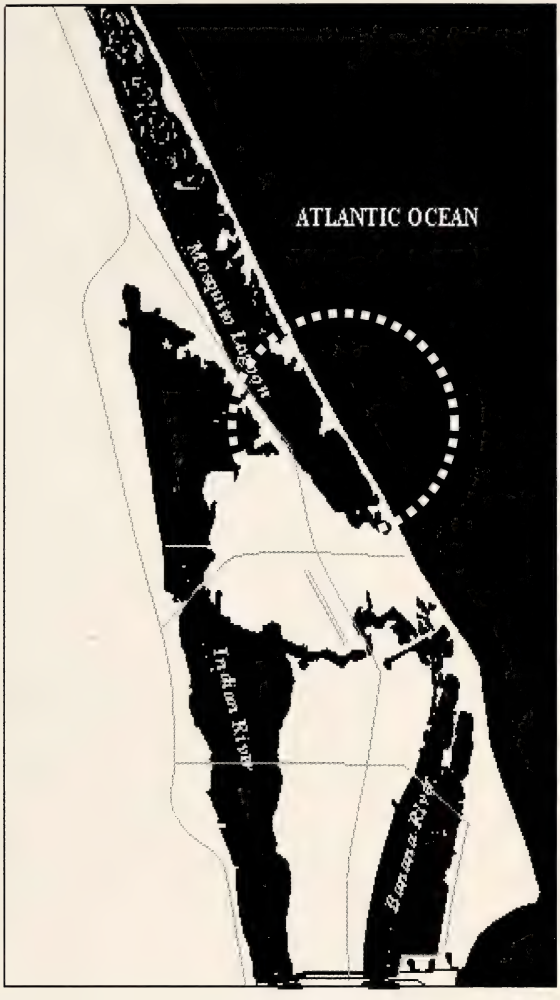

FIG. 1. Diagram of the Northern Indian River Lagoon Complex including Mosquito and North Indian River, the eastern barrier island (Canaveral National Seashore), and Merritt Island National Wildlife Refuge. Mosquito Lagoon and the eastern barrier island adjacent to the Atlantic Ocean are located in the upper right portion of the map. The circle represents the zone in which turtles were found.

of turtles stranding. In the past, researchers observed birds pecking at the eyes and soft skin of immobile, cold stunned turtles, hence the necessity to intervene during a cold stun event or the turtles can die from continued exposure to cold or be blinded by scavenging birds.

Since the 1970s, biologists have gained more experience and knowledge about weather patterns that predict a potential cold stun event (Gilmore et al., 1978). Sudden large drops in water temperature preceded by mild, moderate water temperatures have been the best indicator thus far. Biologists at KSC have monitored water temperatures and cold fronts to predict potential cold stun events since 1981 as part

of NASA's Ecological Program. Since 1994, KSC biologists have conducted a general assessment of the Mosquito Lagoon population of sea turtles outside of cold fronts by periodically capturing them using tanglenets. Assuming a sea turtle cold stunning event was likely to occur in the future, a protocol for responding to such an event in Mosquito Lagoon was jointly drafted by MINWR and KSC in January 2001 with concurrence from the US Fish and Wildlife Service, the Florida Fish and Wildlife Conservation Commission (FWC) and the National Marine Fisheries Service. The plan is updated annually and lists contact personnel, monitoring strategies, required equipment and animal care. In Florida, sea turtle biologists communicate and combine efforts during cold stun events. Invaluable data are collected and turtles are provided with temporary protection against predation and further injury. Several marine animal rehabilitation facilities provide support by accepting turtles in need of extended care. The largest recorded cold stun event in Mosquito Lagoon occurred in 1989 (Schroeder et al., 1990) and not until January of 2003 did another significant event occur, and herein we describe our observations.

Methods—We received water temperature data from the USGS continuous monitoring station (#02248380) located at the Haulover Canal Bridge just east of the Mosquito Lagoon and collected data from our NASA HydroLab station situated at the culvert opening at Banana Creek approximately 10 kilometers south of Mosquito Lagoon. Water temperature samples were also taken by hand during boat surveys using a Yellow Springs Instruments meter.

We conducted boat and aerial surveys to determine extent of the predicted event and aid in the rescue of cold stunned animals. Aerial surveys were flown at 500' altitude in a SeaHawk twin prop airplane. Searches were conducted from an airboat and two open fishermen-style boats. Personnel wading into the lagoon from the shoreline also retrieved turtles. Time and location of retrieved turtles were documented. Turtles were protected from the wind and transported to an indoor workshop at MINWR. There they were further protected from the elements, warmed, and assessed.

A layer of petroleum jelly was applied to the soft tissue of the turtles to prevent further dehydration and increase thermal protection. Turtles with tumors (fibropapillomatosis, or FP) were separated from non-tumored turtles. Each turtle was temporarily marked on the carapace with a water-resistant label (Sharpie pen) to identify them until more permanent tagging was approved. The status of each individual was documented using a cursory system based on the overall condition of the animal and extent of FP disease. Turtles were evaluated as good, fair or poor. FWC biologists were updated by telephone on status of the event and they coordinated the transportation of turtles in poor condition to appropriate rehabilitation centers.

Turtles were photographed, measured and most were tagged. Straight length (SL) measurements were taken using forestry calipers and curved measures were taken using a cloth measuring tape. Turtles were tagged with inconel tags in the second scale of the distal edge of the right and left front flippers. A passive integrated transponder (PIT) tag was inserted above the second scale of the right front flipper. Biopsy samples for genetics were collected from fair and good condition turtles and tumor maps were drawn for turtles with FP. An acoustic tag (Vemco model VR16, approximately 9 cm in length $\times$ 1 cm in diameter) was applied to the posterior costals of the carapace of a few turtles using a low heat hardener and resin system.

When water temperatures were considered warm enough (at or above 17°C) boats were used to transport and release turtles into the central and southern portions of Mosquito Lagoon. Basic statistics were performed using Microsoft Excel.

Results—During the winter of 2003, water temperatures averaged 15°C for several weeks but plunged to 5°C within a few short hours on January 23rd. Temperatures remained below 8°C for the 36 hours following (Fig. 2). On 24 January, snowflakes were observed falling on KSC and Cape Canaveral for a few

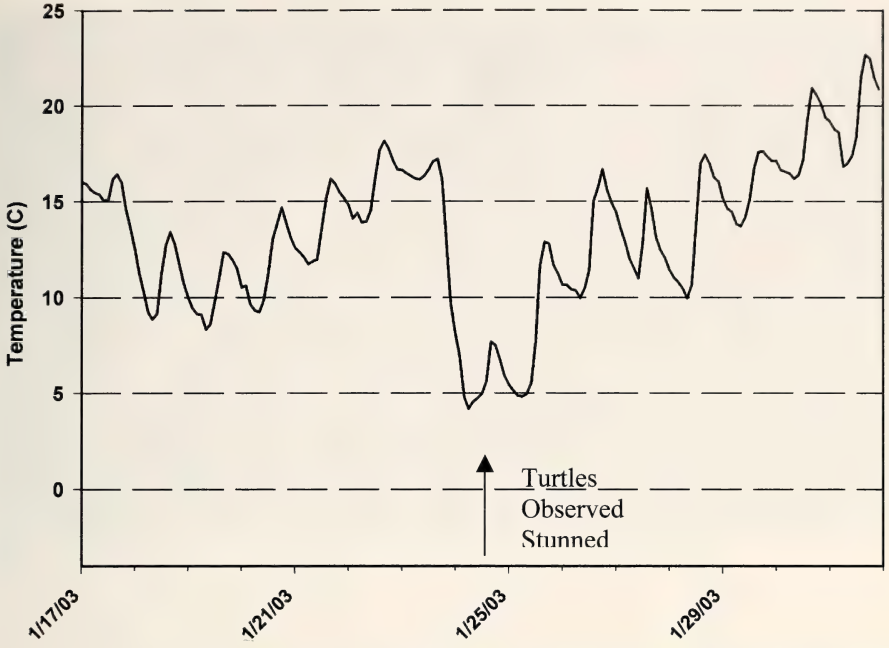

FIG. 2. Water temperatures collected in Banana Creek just south of Mosquito Lagoon for the time period surrounding the observation of cold stunned sea turtles.

moments during the daylight hours of mid-morning. Falling snow at KSC has only been recorded three times; 2003, 1989, and 1977 (U.S. Air Force Eastern Test Range, Weather Database). Conditions for a cold stun event were evident to the sea turtle team and consequently an aerial survey was conducted on 25 January at 0830h to search for stunned turtles and boat surveys were planned. No turtles were seen during the flight. Boats searched for cold-stunned turtles along the shorelines of Mosquito Lagoon and were the first to locate stranded turtles. By 1230h, 15 juvenile, cold-stunned green turtles (*C. mydas*) had been retrieved. Additional boat support was provided in the afternoon and 12 more *C. mydas* were recovered by 1600h. Water temperatures rose and averaged 9.6°C during the afternoon search. The afternoon boat crews observed some turtles that were capable of escaping when approached. On the morning of January 26th, only one cold-stunned *C. mydas* was sighted and retrieved for protection and support. All of the turtles were found along the shore or shallow flats of the southern end of the lagoon, south of Haulover Canal, Figure 3.

The turtles' size distribution based on SCL ranged from 28.8 cm to 71.1 cm (SCL) with a mean of 47.1 cm. Fifteen turtles (53%) had FP tumors and 12 of those had health condition scores of poor (n = 8) or fair (n = 4). The non-FP turtles were all in good condition with the exception of one; considered to be in only fair condition. Ultimately, 10 turtles (35%) were transported to rehabilitation facilities. The Sea Turtle Hospital in Marathon Key, Florida received seven *C. mydas* with advanced stages of FP and the Clearwater Aquarium on the west coast of Florida received three turtles.

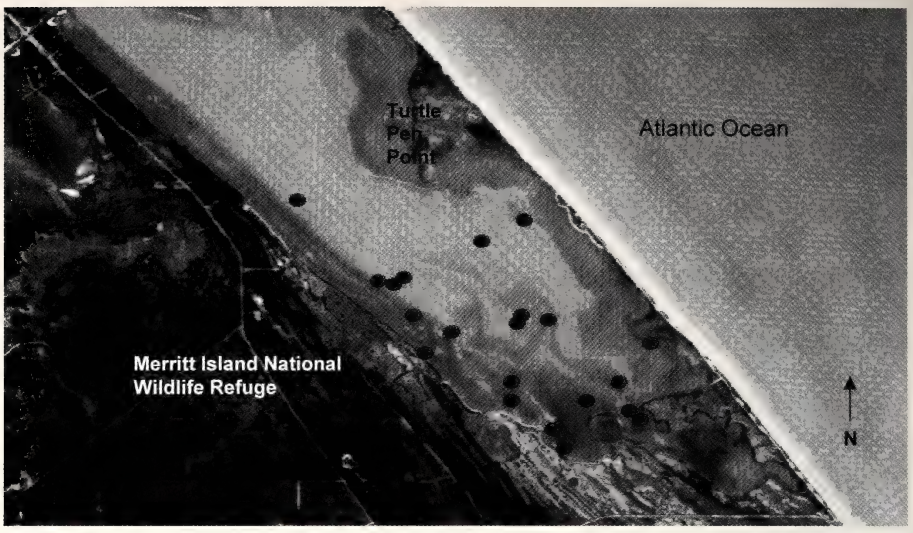

FIG. 3. Location of juvenile *C. mydas* found stranded in Mosquito Lagoon during the cold stun event in January, 2003.

Three of the rescued turtles were previously tagged. Two of these were originally tagged by us in October, 2000 in Mosquito Lagoon. The third tagged turtle was tagged by us in August of 2001. All three of these tagged turtles were in the group of poor condition turtles and were transported for rehabilitation. One of the turtles we tagged in 2000 died twelve days later in the rehabilitation center.

The 18 remaining "good" condition turtles (64%) were monitored daily at the MINWR facility and released in central and southern Mosquito Lagoon on January 30th, 2003 when the water temperatures climbed to 23°C. The largest of these (71cm SCL) was fitted with a satellite transmitter prior to release by University of Central Florida to track its potential migration out of the estuary. All of the turtles exhibited vigor and good swimming patterns within minutes of their return to the lagoon. None of these animals have been recaptured or reported stranded as of August 2004.

As for the ten turtles at the rehabilitation facilities, five died or were euthanized by veterinarians due to their extreme conditions. Two turtles remain in captivity at the time of this writing. Finally, the three turtles cared for at the Clearwater Aquarium received surgeries to remove their tumors and were maintained until April 26, 2004 when they were returned to KSC. We fitted each with an acoustic tag and released them into the lagoon that same day. As of August 2004, the three continue to transmit signals from Mosquito Lagoon between Turtle Pen Point (28° 40′ 04″ N; 80° 48′ 28″ W) to just south of Oak Hill (28° 51′ 04″ N; 80° 48′ 28″ W).

DISCUSSION—Cold stun events are a natural occurrence and have periodically affected populations of marine turtles. The threatened or endangered status of these species has encouraged intervention during events that could be detrimental to

regionally or locally significant assemblages. These events also offer an opportunity to document cold-tolerance strategies and thresholds of marine turtles, and lend more insight into the local population structure and characteristics.

The most recent significant sea turtle cold stun event in Mosquito Lagoon occurred December 1989 and resulted in the largest recorded event in east-central Florida (Schroeder et al., 1990). There were 246 *C. mydas* and 10 *C. caretta* recovered in Mosquito Lagoon and adjacent waters of northern Indian River Lagoon over a six-day period. Approximately 27% of the turtles were found dead or moribund. This large concentration of affected turtles was attributed to the extreme, and perhaps more importantly, the sudden cold temperatures that followed unseasonably mild weather (Schroeder et al., 1990).

During a cold period in December 1995, water temperatures fell to 8°C. Anticipating a fish and sea turtle cold stun event, KSC biologists conducted aerial and boat surveys in nearby lagoon waters. Aerial surveys over Mosquito Lagoon and the northern Indian River revealed several turtles lying motionless (until disturbed) on the mud/sand bottom in the vicinity of Tiger Shoals and Shiloh's eastside. Cooling trends preceding this cold snap may have allowed an adjustment period where turtles could either acclimate or emigrate and no stunning event was observed.

For three days in January 2001, water temperatures in the lagoon fell to 4–9°C. Several fish-kill events were recorded and one cold-stunned green turtle (30.8 cm SCL) was located on 1 January. Another larger turtle (67.2 cm SCL) was rescued on 10 January (Provancha, pers. observ.). (During this same winter, the largest recorded cold stun event in the United States occurred in St. Joe Bay in northwest Florida. Four hundred stranded sea turtles, primarily greens, were recovered after water temperatures dropped to 6°C (McMichael et al., 2004). In January 2003, during the same time frame of our observations in Mosquito Lagoon, a cold stun event in northwest Florida occurred involving 43 turtles. (McMichael et al., 2004).

The size distribution of the cold stunned turtles from Mosquito Lagoon in 2003 is found in Figure 4, with a range of 28 to 71 cm SCL and is similar to our data from ongoing turtle research in this lagoon for net-captured green turtles (Provancha et al., 1998). These range in size from 31.5 to 83.4 cm SCL with a mean of 51.3 cm. The first group of *C. mydas* rescued tended to be smaller, were found in the early part of the day, and had a mean SCL of 43.5 cm. These first turtles also tended to be found in the more extreme shallows. The mean SCL of *C. mydas* retrieved later during the event (afternoon) was 52.1 cm. This limited temporal observation may indicate that the larger turtles possess higher resistance to cold than smaller turtles. There is no evident size difference between FP and non-FP turtles from our netting data. The same is true for this cold stun event with the exception of the smallest size class; those with SCL of less than 30 cm. Those smaller turtles were all non-FP turtles. This smaller size-class is similar to the average size-class of *C. mydas* captured at the Port Canaveral Trident Basin (28° 24′ 57″ N; 80° 35′ 46″ W) where no cases of FP have been documented since the onset of the study in 1993 (L. M. Ehrhart, 2003).

One of the *C. mydas*, originally captured and tagged in October 2000 in Mosquito Lagoon, had FP on both capture occasions. In October 2000 that turtle had

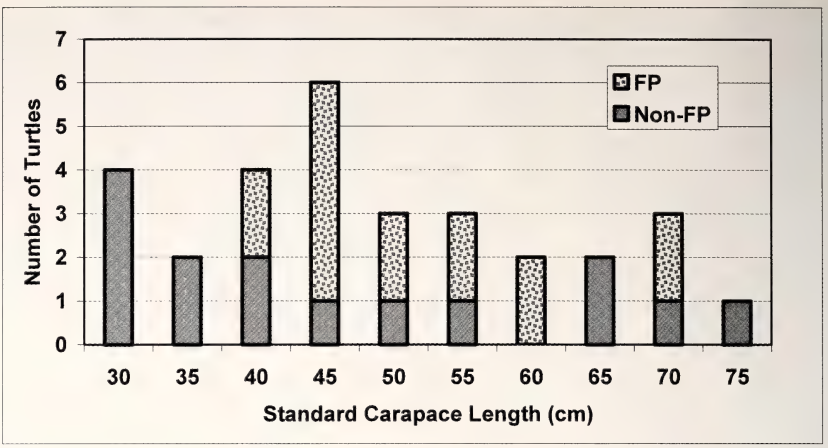

FIG. 4. Distribution of the carapace lengths (SCL, cm) for Green Turtles with fibropapilloma tumors (FP) and those without tumors during the cold stun event in Mosquito Lagoon, January 2003. Solid bars represent non-FP turtles and patterned bars represent those with FP.

several one cm diameter-sized tumors. When it was retrieved during the January 2003 cold stun, tumors in the inguinal region had increased to 10 cm diameter and larger. Over the 28 months since its initial capture, the SCL increased from 44.4 to 52.3 cm. As noted above, it survived at the rehabilitation center for only 12 days.

In summary, the January 2003 event was the first significant cold stun of sea turtles in Mosquito Lagoon since 1989 and resulted in a mortality rate of 17%. The formation of the response team, with protocols prepared in advance, was a valuable asset in terms of coordination and timeliness of rescues.

ACKNOWLEDGMENTS—All field activities and funding were supported by NASA Kennedy Space Center Ecological Program, NAS10-02001, under NMFS permit #1214 and Florida permit #114. We thank Kelly Gorman/NASA for her continuous support. We gratefully acknowledge assistance from the NASA helicopter crew for aerial survey support, the Merritt Island National Wildlife Refuge staff under Ron Hight for logistical, field and facility support (airboats, heaters and facility space for turtles). Assistance and coordination support was provided by Dean Bagley (UCF), Ed DeMaye (FWCC), L.M. Ehrhart (UCF), Allen Foley (FWCC), Barbara Schroeder (NMFS), Karrie Singel (FWCC) and Blair Witherington (FMRI). Special thanks go to Dr. Bill Knott (NASA) for his support for sea turtle work on KSC since 1981.

LITERATURE CITED

EHRHART, L. M. 2003. University of Central Florida, Orlando, Pers. Commun.

GILMORE, R. G., L. H. BULLOCK, AND F. H. BERRY. 1978. Hypothermal mortality in marine fishes of south-central Florida January 1977. Northeast Gulf Sci. 2:77–97.

MENDONCA, M. T. AND L. M. EHRHART. 1982. Activity, population size and structure of immature *Chelonia mydas* and *Caretta caretta* in Mosquito Lagoon, Florida. Copeia 1:161–167.

MCMICHAEL, E., R. R. CARTHY, AND J. A. SEMINOFF. 2004. Population ecology of juvenile sea turtles in the northeastern Gulf of Mexico. *In press*: Proceedings of the 23rd Annual Sea Turtle Symposium. Kuala, Lumpur, Malaysia, March 2003.

Provancha, J., R. Lowers, D. Scheidt, M. Mota, and M. Corsello. 1998. Relative abundance and distribution of marine turtles inhabiting Mosquito Lagoon, Florida, USA. Pp.78–79. *In*: Epperly, S.P. and J. Braun, (compilers), Proceedings of the 17th Annual Sea Turtle Symposium. U.S. Dep. Commer. NOAA Tech. Memo. NMFS-SEFSC-415.

Provancha, M. J, P. A. Schmalzer, and C. R. Hall. 1986. Effects of the December 1983 and January 1985 freezing air temperatures on select aquatic poikilotherms and plant species of Merritt Island, Florida. Florida Scient. 49(4):199–212.

Schroeder, B. A., L. M. Ehrhart, J. L. Guseman, R. D. Owen, and W. E. Redfoot. 1990. Cold stunning of marine turtles in the Indian River Lagoon system, Florida, December 1989. Pp. 67–69, *In:* Richardson, T. H., J. I. Richardson, and M. Donnelly (compilers). Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Tech. Mem. NMFS-SEFC-278.

Witherington, B. E. and L. M. Ehrhart. 1989. Hypothermic stunning and mortality of marine turtles in the Indian River lagoon system, Florida, Copeia 3:696.

Florida Scient. 68(2): 114–121. 2005
Accepted: October 5, 2004

POPULATION STATUS AND DISTRIBUTION OF SPOTTED BULLHEAD *AMEIURUS SERRACANTHUS* IN NORTH FLORIDA RIVERS

Richard L. Cailteux and Daniel A. Dobbins

Florida Fish and Wildlife Conservation Commission 5300
High Bridge Rd., Quincy, FL 32351

Abstract: *Spotted bullhead* Ameiurus serracanthus *were collected from the Suwannee, Ochlockonee, Apalachicola, Choctawhatchee, and Yellow rivers. No spotted bullhead were collected from either the Escambia or St. Marys rivers. The highest mean relative abundance of spotted bullhead was observed in the Suwannee River (1.72 fish/minute) compared to the Yellow River where only five individuals were collected in four years of sampling. The Apalachicola River exhibited a very low relative abundance of spotted bullhead (<0.04 fish/minute) probably due at least in part to the range extension of flathead catfish* Pylodictis olivaris *more than 20 years ago. Although the flathead catfish has been in the Ochlockonee (at least 11 years) and the Choctawhatchee (at least two years) rivers, relative abundance of spotted bullhead continues to be high (>0.5 fish/minute) in most years. Between 13% (Suwannee River) and 23% (Choctawhatchee River) of all spotted bullhead collected were greater than 23 cm, total length, the previously assumed maximum size. Two spotted bullheads collected from the Suwannee (335 mm; 646g) and the Ochlockonee (338 mm; 588 g) rivers are the largest reported specimens collected to date.*

Key Words: Spotted bullhead, *Ameiurus serracanthus*, north Florida rivers

A paucity of information exists on populations of spotted bullhead *Ameiurus serracanthus*. This lack of information is probably due to in part to a historical inability to effectively sample this species. This native species was described by Yerger and Relyea (1968) and may have been misidentified as flat bullhead *Ameiurus platycephalus* by Carr (1937) and Crittenden (1957), and grouped as *Ictalurus* sp. by Hellier (1967) although he knew this was a new species being described by Yerger and Relyea (1968). It is not sought after as a commercial species due to its small size, although this species has been reportedly caught by commercial fishermen in slat baskets in the Apalachicola River (Yerger and Relyea, 1968).

Yerger and Relyea (1968) provided minimal life history information in their description of this riverine species. They reported the Florida distribution of the species within the Suwannee, Ochlockonee and Apalachicola river drainages with unverified reports of this species occurring in the Choctawhatchee River. They also reported the maximum size to be approximately 23 cm. Lee and others (1980) also show records of this species in the St. Marks River and the Econfina Creek (St. Andrews Bay drainage). The recent introductions and migration of flathead catfish *Pylodictis olivaris* into several Florida rivers (Cailteux et al., 2003) may have dramatic repercussions for small riverine species such as the spotted bullhead. Guier

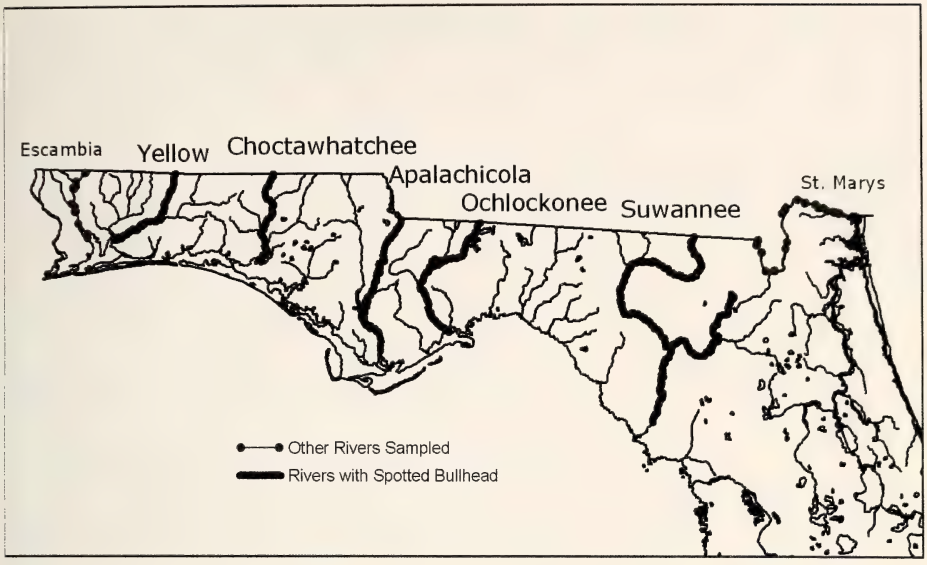

FIG. 1. Distribution of rivers sampled and ones in which spotted bullhead were collected.

and co-workers (1981) reported declines in bullhead *Ictalurus* sp. populations following the introduction of flathead catfish into North Carolina rivers, including *I. platycephalus*, a species similar to the spotted bullhead. Also, Thomas (1993) reported major declines in angler harvest of bullheads in the Altamaha River, Georgia concurrent with the expansion of flathead catfish within that system. Range extension and increases in abundance of flathead catfish, a top predator, may drastically impact the abundance of spotted bullhead in Florida rivers.

The ability to effectively sample a species is vital to the study of life history parameters. The introduction of low pulse rate electrofishing units for collecting catfish species (Hale et al., 1984; Quinn, 1986; Gilliland, 1987) coupled with modifications of pulse rates in commercially-available electrofishers, has made electrofishing an efficient sampling gear for ictalurid species (Vokoun and Rabeni, 1999).

Increased sampling efficiency for ictalurid species now provides the opportunity to easily collect spotted bullhead and ascertain their distribution. The objective of this study was to determine the population status and distribution of spotted bullhead in north Florida rivers using low-pulse DC electrofishing gear.

STUDY AREA—Catfish species were sampled from seven major north Florida rivers: Escambia, Yellow, Choctawhatchee, Apalachicola, Ochlockonee, Suwannee, and St. Marys (Fig. 1). Physical characteristics of those rivers are reported in Table 1.

METHODS—Low pulse rate (30 pulses per second) electrofishing was used to collect all catfish species from north Florida rivers during summer months. A Smith Root GPP 5.0 or 7.5® electrofishing unit provided low-pulse DC current to two Wisconsin rings set on booms in front of the boat as the anode, with the aluminum boat as the cathode. Fixed location, variable-timed transects were established on all

TABLE 1. Description of study rivers (modified from Bass and Cox, 1985).

River	Total length/Florida length (km)	Drainage Area (km^2)	Average flow (m^3/sec)
Apalachicola	805/161	51,800	702.4
Choctawhatchee	280/201	12,033	204.8
Escambia	148/87	10,878	180.7
Ochlockonee	257/180	5,957	45.7
St. Mary's	193/161	3,885	19.3
Suwannee	394/333	25,641	304.7
Yellow	148/98	3,626	33.6

rivers to collect catfish. All catfish were measured for total length (mm) and a sub-sample of each species were weighed (g) and live released into the river. Catch-per-unit-effort (CPUE; fish/minute) estimates were generated.

Total lengths and weights of spotted bullhead were logarithmically transformed before developing length-weight regressions for all rivers studied. CPUE was logarithmically transformed and analysis of variance was used to test differences between years using Tukey's comparison of means. An analysis of covariance was used to test differences between length-weight regressions from three rivers: Choctawhatchee, Ochlockonee, and Suwannee.

RESULTS—*Choctawhatchee River*—Numerically, spotted bullhead accounted for 62% (2001) to 88% (1997) of all ictalurids collected by electrofishing from the Choctawhatchee River during the study (Table 2). Of all the rivers sampled, the Choctawhatchee River had the highest percentage of spotted bullhead greater than 23 cm (23%; Fig. 2). The modal peak was 19 cm for all samples combined.

The mean CPUE estimate for 2003 (1.71 fish/minute) was significantly higher ($P < 0.05$) than every year except 1998 (1.55 fish/minute). The mean CPUE estimate for 2001 was significantly lower ($P < 0.05$) than any other year.

Ochlockonee River—Spotted bullhead comprised 40% (2000) to 72% (1998) of all ictalurids collected by electrofishing from the Ochlockonee River. This species accounted for the highest relative abundance of all catfish collected from this river in all years except 2000. For all samples combined, a modal peak occurred at 19 cm (Figure 2). Twenty percent of all spotted bullhead collected from the Ochlockonee River were greater than 23 cm. The largest fish by length recorded during this study was collected from the Ochlockonee River (338 mm; 588 g.). Mean CPUE estimates for 2003 (1.47 fish/minute) were significantly higher ($P < 0.05$) than every other year from this river (Table 2).

Suwannee River—Of all the Florida rivers sampled, the Suwannee River has the highest average relative abundance of spotted bullhead (Table 2; 0.96 to 3.03 fish/minute). This species accounted for 79% (2002) to 88% (2003) of all ictalurids collected by low-pulse DC electrofishing in the Suwannee River. A modal peak occurred at 14 cm, which was the lowest modal peak of any river sampled (Figure 2). Of the three rivers with high relative abundance of spotted bullhead (>0.5 fish/minute), the Suwannee River had the lowest percentage of fish greater than 23 cm

TABLE 2. Mean electrofishing catch-per-unit-effort (fish/minute (S.E.)) of catfish species from North Florida Rivers, 1996-2003. NC = Not Collected.

River	Year	#transects	Spotted bullhead	Channel catfish	White catfish	Flathead catfish	Blue catfish	Yellow bullhead	Total catfish
Apalachicola	1998	15	0.04 (0.02)	1.32 (0.30)	NC	1.89 (0.14)	0.00 (0.00)	0.00 (0.00)	3.26 (0.37)
	1999	14	NC	1.54 (0.25)	NC	1.43 (0.10)	NC	NC	2.98 (0.27)
	2000	17	0.02 (0.01)	0.88 (0.16)	NC	1.09 (0.09)	0.02 (0.01)	NC	2.00 (0.21)
	2001	16	0.01 (0.00)	0.31 (0.09)	NC	1.10 (0.15)	NC	NC	1.42 (0.17)
	2002	19	0.04 (0.01)	0.72 (0.16)	0.00 (0.00)	1.04 (0.13)	0.01 (0.01)	0.00 (0.00)	1.82 (0.25)
	2003	20	0.05 (0.02)	1.45 (0.16)	0.00 (0.00)	1.43 (0.13)	0.09 (0.03)	0.01 (0.00)	3.03 (0.19)
Choctawhatchee	1997	18	1.11 (0.17)	0.04 (0.01)	0.10 (0.04)	NC	NC	0.01 (0.01)	1.26 (0.18)
	1998	23	1.55 (0.33)	0.13 (0.03)	0.15 (0.04)	NC	NC	0.01 (0.01)	1.84 (0.34)
	1999	22	0.80 (0.20)	0.08 (0.02)	0.10 (0.03)	NC	NC	0.02 (0.01)	0.99 (0.22)
	2001	24	0.08 (0.03)	0.04 (0.01)	0.04 (0.01)	NC	NC	NC	0.13 (0.02)
	2002	24	0.76 (0.16)	0.13 (0.02)	0.09 (0.02)	0.02 (0.01)	0.01 (0.00)	NC	1.00 (0.18)
	2003	24	1.71 (0.24)	0.08 (0.02)	0.14 (0.03)	0.02 (0.01)	NC	NC	1.95 (0.24)
Escambia	1996	31	NC	0.32 (0.06)	NC	0.46 (0.06)	0.01 (0.01)	NC	0.79 (0.11)
	1997	27	NC	0.13 (0.06)	NC	0.18 (0.05)	0.00 (0.00)	NC	0.31 (0.09)
	1998	30	NC	0.20 (0.04)	NC	0.35 (0.06)	0.00 (0.00)	NC	0.55 (0.08)
	2001	29	NC	0.16 (0.03)	NC	0.27 (0.05)	0.00 (0.00)	NC	0.43 (0.07)
Ochlockonee	1996	29	0.86 (0.14)	0.26 (0.07)	0.23 (0.05)	0.00 (0.00)	NC	0.02 (0.01)	1.38 (0.18)
	1997	26	0.81 (0.16)	0.43 (0.13)	0.14 (0.05)	0.00 (0.00)	NC	0.02 (0.01)	1.24 (0.22)
	1998	23	0.43 (0.08)	0.08 (0.02)	0.06 (0.02)	0.01 (0.01)	NC	0.01 (0.01)	0.60 (0.09)
	2000	21	0.30 (0.06)	0.39 (0.07)	0.06 (0.02)	0.00 (0.00)	NC	NC	0.75 (0.10)
	2001	18	0.24 (0.08)	0.07 (0.02)	0.10 (0.05)	NC	NC	NC	0.41 (0.12)
	2002	34	0.39 (0.07)	0.21 (0.10)	0.20 (0.06)	0.04 (0.01)	NC	0.01 (0.00)	0.84 (0.15)
	2003	29	1.47 (0.23)	0.32 (0.06)	0.30 (0.05)	0.02 (0.01)	NC	0.02 (0.01)	2.12 (0.25)
St. Mary's	2003	29	NC	0.65 (0.13)	1.35 (0.19)	NC	NC	0.05 (0.01)	2.05 (0.28)
Suwannee	2001	45	1.10 (0.12)	0.01 (0.00)	0.14 (0.03)	NC	NC	0.01 (0.01)	1.26 (0.12)
	2002	35	0.96 (0.14)	0.11 (0.03)	0.15 (0.06)	NC	NC	NC	1.22 (0.18)
	2003	42	3.03 (0.34)	0.13 (0.03)	0.23 (0.04)	NC	NC	0.07 (0.04)	3.46 (0.35)
Yellow	1999	15	NC	0.11 (0.04)	0.00 (0.00)	0.04 (0.02)	0.00 (0.00)	0.08 (0.02)	0.23 (0.05)
	2001	7	NC	0.01 (0.00)	NC	0.03 (0.01)	NC	0.04 (0.01)	0.08 (0.02)
	2002	13	0.00 (0.00)	0.24 (0.03)	NC	0.11 (0.04)	0.00 (0.00)	0.03 (0.03)	0.38 (0.04)
	2003	8	NC	0.11 (0.02)	NC	0.23 (0.07)	NC	0.28 (0.05)	0.61 (0.06)

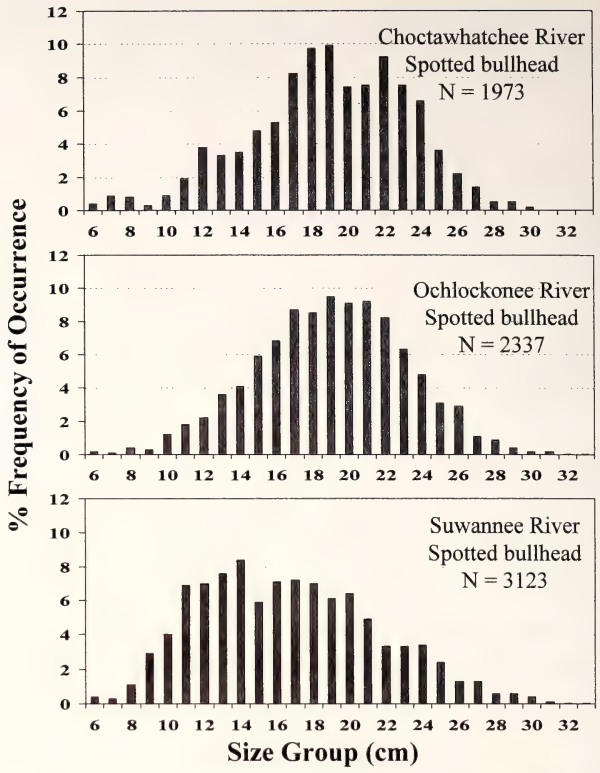

FIG. 2. Length frequencies of spotted bullhead collected by electrofishing, Choctawhatchee, Ochlockonee, and Suwannee rivers.

(13%), although the largest fish by weight (335 mm; 646 g) was collected from this river.

Mean CPUE estimates for 2003 (3.03 fish/minute) was significantly higher ($P < 0.05$) than either 2001 or 2002 from this river and was the highest mean CPUE collected from any river in this study. The Suwannee River was the eastern-most Florida river in which spotted bullhead were collected.

Apalachicola River—Spotted bullhead comprised zero to two percent of all ictalurids collected from the Apalachicola River from 1998 to 2003. Catch rates of spotted bullhead in the Apalachicola River were the lowest (not collected (1999) to 0.05 fish/minute (2003)) of any of the rivers in which more than one individual was collected (Table 2).

Other north Florida rivers—Only five spotted bullhead were collected from the Yellow River in four years of sampling. This probably indicates the western-most distribution of this species in Florida. Spotted bullhead were not collected in four years of sampling the Escambia River (west of the Yellow River; Figure 1) nor in one year of sampling the St. Marys River (east of the Suwannee River).

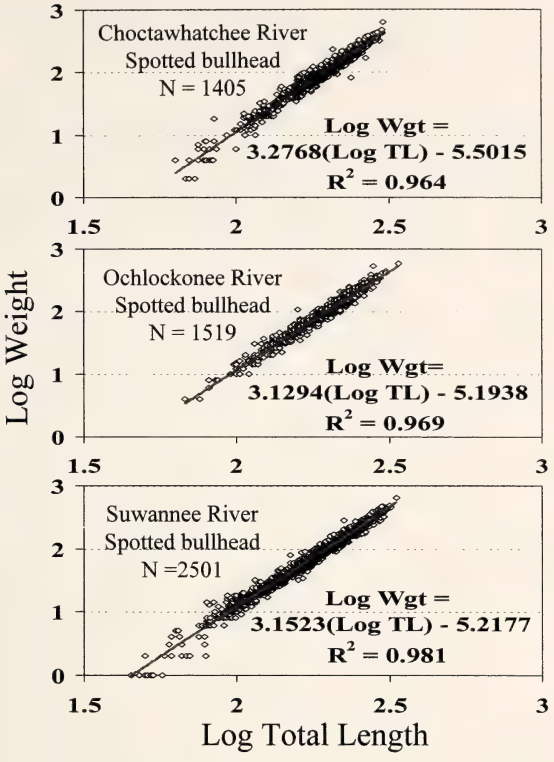

FIG. 3. Length-weight regressions for spotted bullhead, Choctawhatchee, Ochlockonee, and Suwannee rivers.

Length-weight relationships—The length-weight relationship of spotted bullhead collected from three Florida rivers are described by the following equations (Fig. 3; Eqn 1–3):
Choctawhatchee River:

$$\text{Log Wgt} = 3.2768\ (\text{Log TL}) - 5.5015; \quad (r^2 = 0.964). \tag{1}$$

Ochlockonee River:

$$\text{Log Wgt} = 3.1294\ (\text{Log TL}) - 5.1938; \quad (r^2 = 0.969). \tag{2}$$

Suwannee River:

$$\text{Log Wgt} = 3.1523\ (\text{Log TL}) - 5.2177; \quad (r^2 = 0.981). \tag{2}$$

The slopes of the regression equations of the Ochlockonee and Suwannee populations were similar ($P = 0.0959$), however, the equation from the Choctawhatchee River was significantly different than either the Ochlockonee ($P < 0.0001$) or the Suwannee ($P < 0.0001$) river equations. This equates to spotted

bullhead from the Choctawhatchee River growing at an increased rate in weight versus a given length than in either of the other two rivers

Discussion—Spotted bullhead are the dominant ictalurid in three of the five rivers in which they occur in Florida, the Choctawhatchee, Ochlockonee and Suwannee. Occurrence of this species in the Apalachicola and Yellow rivers is rare. Anecdotal evidence supports that spotted bullhead were probably much more prevalent in the Apalachicola River in the past, but abundance may have declined in part to the increase in abundance of flathead catfish.

Flathead catfish were introduced upstream in the Flint River, Georgia (a tributary of the Apalachicola River) in the early 1950s (Quinn, 1986) and have been collected from the Apalachicola River since at least 1982 (Mesing, 2004). Since that time, this species has become established in the Apalachicola River and occurs in high relative abundance (1.04 to 1.89 fish/minute; Table 2). Dobbins and co-workers (1999) found 35 to 58 flathead catfish (>380 mm TL) per river kilometer in the Apalachicola River. Although no spotted bullhead CPUE data exists prior to the flathead catfish introduction, greater population numbers probably existed (Mesing, 2004). The spotted bullhead's small size coupled with the piscivorous appetite of the flathead catfish may have resulted in a significant population decline.

Flathead catfish were first documented in the Choctawhatchee River in 2002 (Cailteux et al., 2003), but in very low relative abundance (Table 2; 0.02 fish/minute). If flathead catfish abundance increases over time, spotted bullhead numbers may decline. No flathead catfish have been collected from the Suwannee River, to date. Introduction of this voracious predator may be detrimental to the abundance of spotted bullhead in this system. Low numbers of flathead catfish have been collected from the Ochlockonee River since 1992 (Table 2; 0.00 to 0.04 fish/minute). Although spotted bullhead CPUE data do not exist prior to flathead catfish introduction, overall population density does not appear to have decreased since 1996. Flathead catfish have been established in the Yellow River (0.03 to 0.23 fish/minute) and Escambia River (0.18 to 0.46 fish/minute) for an undetermined time frame. However, no flathead catfish were collected from the St. Marys River in 2003.

Conclusions—In Florida, spotted bullheads presently range from the Yellow River to the Suwannee River. Of the rivers sampled, the highest relative abundance of spotted bullhead presently occurs in the Suwannee River. With recent, unauthorized introductions of flathead catfish into the Ochlockonee and Choctawhatchee rivers, spotted bullhead numbers may decline in the future to levels that presently exist in the Apalachicola River.

Smaller rivers (within and just out of the current range of spotted bullhead described in this study) need to be sampled in order to provide a complete understanding of the potential distribution and status of this species. Basic life history parameters need to be studied to fully understand the scope and importance of this species to Florida river ecosystems. Although the complete extirpation of spotted bullhead from waters in which flathead catfish occur is probably unlikely,

their ability to drastically deplete this species will impact rivers where flathead catfish are introduced.

Acknowledgments—We are grateful to the many FWC biologists that helped with sampling catfish on all of the rivers sampled. We thank T. Hoehn for his assistance in map generation and Ms. D. Schroeder for help with manuscript preparation. We thank G. Bass, F. Cross, S. Hardin, C. Mesing, W. Porak, L. Snyder, and A. Strickland for helpful criticism of earlier drafts of this manuscript.

LITERATURE CITED

Bass, D. G. and D. T. Cox. 1985. River habitat and fishery resources of Florida. Pp. 121–187 *In*: Seaman, W., Jr., (ed.), Florida Aquatic Habitat and Fisheries Resources. Florida Chapter of American Fisheries Society, Kissimmee, FL.

Cailteux, R. L., D. A. Dobbins, and R. S. Land. 2003. Apalachicola/Ochlockonee River Investigations. Annual Report. Florida Fish and Wildl. Cons. Comm. Tallahassee, FL.

Carr, A. F., Jr. 1937. A key to the fresh water fishes of Florida. Proc. Florida Acad. Scien. 1:73–86.

Crittenden, E. 1957. A pre-impoundment fishery study of North Bay and associated waters, Bay County, Florida. Proc. Ann. Conf. Southeastern Assoc. Game and Fish Comm. 11:211–219.

Dobbins, D. A., R. L. Cailteux, and J. J. Nordhaus. 1999. Flathead catfish abundance and movement in the Apalachicola River, Florida. Pp. 199–202 *In*: Irwin, E. R., W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon, (eds.), Catfish 2000: Proc. Intern. Ictalurid Symp. American Fisheries Society, Symposium 24. Bethesda, MD.

Gilliland, E. 1987. Telephone, microelectronic and generator powered electrofishing gear for collecting flathead catfish. Proc. Ann. Conf. Southeastern Assoc. Fish Wildl. Agencies 41:221–229.

Guier, C. R., L. E. Nichols, and R. T. Rachels. 1981. Biological investigations of flathead catfish in the Cape Fear River. Proc. Ann. Conf. Southeastern Assoc. Fish Wildl. Agencies 35:607–621.

Hale, M. M., J. E. Crumpton, and D. J. Renfro. 1984. An inexpensive low voltage electrofishing device for collecting catfish. Proc. Ann. Conf. Southeastern Assoc. Fish Wildl. Agencies 38:342–345.

Hellier, T. R., Jr. 1967. The fishes of the Sante Fe River system. Bull. Florida State Museum 2:1–46.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980. Atlas of North American Freshwater Fishes. North Carolina St. Mus. Nat. Hist. Raleigh, NC. 854 pp.

Mesing, C. 2004. Florida Fish and Wildlife Conservation Commission, pers. comm.

Quinn, S. P. 1986. Effectiveness of an electrofishing system for collecting flathead catfish. Proc. Ann. Conf. Southeastern Assoc. Fish Wildl. Agencies 40:85–91.

Thomas, M. E. 1993. Monitoring the effects of introduced flathead catfish on the sport fish populations in the Altamaha River, Georgia. Proc. Ann. Conf. Southeastern Assoc. Fish Wildl. Agencies 47: 531–538.

Vokoun, J. C. and C. F. Rabeni. 1999. Catfish sampling in rivers and streams: A review of strategies, gears and methods. Pp. 271–286. *In*: Irwin, E. R., W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr., and T. Coon (eds.), Catfish 2000: Proc. Intern. Ictalurid Symp. American Fisheries Society, Symposium 24. Bethesda, MD.

Yerger, R. W. and K. Relyea. 1968. The flat-headed bullheads (Pisces: Ictaluridae) of the southeastern United States and a new species of *Ictalurus* from the Gulf Coast. Copeia 1968:361–384.

Florida Scient. 68(2): 122–129. 2005
Accepted: October 5, 2004

The Florida Endowment for the Sciences

The Florida Academy of Sciences was founded in 1936 with the purpose of advancing the sciences in Florida through educational programs and public outreach. Although the Academy serves as an important means of communicating scientific research conducted by State agencies, as well as by the State University System, it receives no State assistance. Thus, it exists independently by means of membership dues, sale of its publications, occasional gifts or grants, and modest registration fees at meetings.

Over the years the Academy has built up an Endowment Fund designed to provide the necessary financial stability for its activities. The assets of this endowment fund now total over $115,000, and the Trustees of the Fund wish to encourage the membership to keep the Endowment Fund in mind as they make charitable donations.

The Academy is recognized by the IRS as a non-profit scientific and educational organization. Your gifts to the Endowment Fund are removed from the amount subject to Federal Income Tax when you itemize deductions on your personal income tax return. This can result in substantial tax savings.

In addition to making gifts by check, you may also make gifts of other investments. When you do so, you take advantage of their appreciated value. These can include stocks, bonds, mutual funds, insurance policies, real estate, paintings, unwanted jewelry, rare books, etc. You may also want to remember the Endowment Fund in your will.

Cash donations should be sent as checks made out to Wachovia Securities, with "For Florida Academy of Sciences" down at the bottom, and mailed to Dr. Donald W. Lovejoy at Palm Beach Atlantic University, P. O. Box 24708, West Palm Beach, FL 33416. The Academy will provide you with a receipt to be filed with your Federal Income Tax return. For gifts other than cash, please contact Don at 561-803-2275 or by email at **Donald_Lovejoy@capba.edu**

Florida Academy of Sciences Medalists

1963	Dr. Archie Carr	University of Florida	Biology
1964	Dr. Werner A. Baum	University of Miami	Meteorology
1965	Dr. Alex G. Smith	University of Florida	Astronomy
1966	Dr. Karl Dittmer	Florida State University	Chemistry
1967	Dr. Alfred H. Lawton	University of South Florida	Medicine
1968	Dr. Sidney Fox	University of Miami	Biochemistry
1969	Dr. F. G. Walton Smith	University of Miami	Marine Science
1970	Dr. Pierce Brodkorb	University of Florida	Zoology
1971	Dr. Maurice A. Barton	Mound Park Foundation	Medicine-Teaching
1972	Dr. Lloyd M. Biedler	Florida State University	Physiology-Biophysics
1973	Dr. Ruth S. Breen	Florida State University	Botany
1974	Dr. E. T. York, Jr.	University of Florida	Agriculture
1975	Dr. Alex E. S. Green	University of Florida	Physics
1976	Dr. Robert N. Ginsburg	University of Miami	Geology
1977	Dr. Michael Kasha	Florida State University	Molecular Biophysics
1978	Dr. John Edward Davies	University of Miami	Public Health
1979	Dr. Stanley S. Ballard	University of Florida	Optics
1980	Dr. Thomas D. Carr	University of Florida	Astronomy
1981	Dr. Harold J. Humm	University of South Florida	Marine Biology
1982	Dr. George B. Butler	University of Florida	Chemistry
1983	Dr. Karen Steidinger	Florida Dept. Natural Resources	Biology
1984	Dr. Yngve Ohrne	University of Florida	Chemistry
1985	Dr. William Sears	Florida Atlantic University	Anthropology
1986	Dr. E. Dwight Adams	University of Florida	Physics
1987	Dr. Larry Hench	University of Florida	Engineering
1988	Dr. Gene C. Ness	University of South Florida	Biochemistry
1989	Dr. Frank Bradshaw Wood	University of Florida	Astronomy
1990	Dr. Martin Uman	University of Florida	Electrical Eng'n
1991	Dr. Frank Millero	University of Miami	Oceanography
1992	Dr. Gregory Choppin	Florida State University	Chemistry
1993	Dr. D. O. Shah	University of Florida	Chemical Eng'n
1994	Mrs. Barbara B. Martin	University of South Florida	Chemistry
	Dr. Dean F. Martin	University of South Florida	Chemistry
1995	Dr. James N. Layne	Archbold Biological Station	Zoology

1996	Dr. Leslie Sue Lieberman	University of Florida	Anthropology
1997	Dr. George R. Newkome	University of South Florida	Chemistry
1998	Dr. Joseph J. Krzanowski	University of South Florida	Pharmacology
1999	Dr. Abraham Kandel	University of South Florida	Computer Science
2000	Richard F. Lockey, M.D.	University of South Florida	Medicine
2001	Dr. Clinton J. Dawes	University of South Florida	Biology
2002	Dr. John Trefry	Florida Technological Univ	Oceanography
2003	Dr. Christian Clausen	University of Central Florida	Chemistry
2004	Dr. Jerald T. Milanich	University of Florida	Anthropology
2005	Dr. Thomas L. Crisman	University of Florida	Ecology

INSTRUCTION TO AUTHORS

This information is available at two web sites:

(1) **IES site**: http://www.cas.usf.edu (click on "Centers and Institutes", then select "Institute for Environmental Studies", then select "Florida Scientist").

(2) **FAS site**: http://www.floridaacademyofsciences.org (select "Florida Scientist").

It is possible to search for papers and abstracts of papers for the past six years: Go the FAS site (above), select "Allen Press". When the link is complete, select "Advanced Search" and follow the directions.

The Florida Academy of Sciences Web page, indicated above, allows interested persons to join the Florida Academy of Sciences and pay dues.

FLORIDA ACADEMY OF SCIENCES

CORPORATE MEMBER

Tierra Verde Consulting, Inc.

INSTITUTIONAL MEMBERS

Archbold Biological Station
Army Corps of Engineers Technical Library, Jacksonville
Disney's Animal Kingdom
Duke University
Florida Community College at Jacksonville
Florida Fish and Wildlife Conservation Commission (Panama City)
FFWCC (Ocala)
FFWCC (Olustee)
FFWCC (Lakeland)
FFWCC (West Palm Beach)
FFWCC (Tallahassee)
FFWCC (Gainesville)
Florida Marine Research Institute
Hillsborough Community College
NIOZ-Netherlands Institute for Sea Research
Science Library, University of Chicago
South Florida Water Management District
University of North Florida
University of Washington
US EPA Library
Virginia Institute of Marine Science
Virginia Polytechnic University
WDI Florida

Membership applications, subscriptions, renewals, and changes of address should be addressed to the Executive Secretary, Florida Academy of Sciences, Orlando Science Center, 777 East Princeton St., Orlando, FL 32803. Phone: (407) 514-2079

Send purchase orders, payments for reprints and publication charges, orders for back issues and other journal business matters to the Business Manager, Dr. Richard L. Turner, Department of Biological Sciences, FIT, 150 W. University Blvd., Melbourne, FL 32901-6975 [(321) 674-8196; e-mail rturner@fit.edu].

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. Prices quoted include domestic postage. Some issues may not be available. All are $20 per volume or $5 per issue, except for symposium issues.

PROCEEDINGS OF THE FLORIDA ACADEMY OF SCIENCES (1936–1944)
Volumes 1–7

QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES (1945–1972)
Volumes 8–35

FLORIDA SCIENTIST (1973–)

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)

Anthropology—Academy Symposium
FLORIDA SCIENTIST 43(3)—$7.50

Shark Biology—Academy Symposium
FLORIDA SCIENTIST 45(1)—$8.00

Future of the Indian River System—Academy Symposium
FLORIDA SCIENTIST 46(3/4)—$15.00

Second Indian River Research Symposium—Academy Symposium
FLORIDA SCIENTIST 53(3)—$15.00

Human Impacts on the Environment of Tampa Bay—Academy Symposium
FLORIDA SCIENTIST 58(2)—$15.00

Please send payment with order. If required, an invoice will be sent on purchases over $20 from a recognized institution. Please include Florida sales tax if shipped to a Florida address, unless a copy of a valid Florida Consumer's Sales Tax Certificate is enclosed.

SMITHSONIAN INSTITUTION LIBRARIES

3 9088 01140 4415