TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

Volume 53
Numbers 1–2
March 1992

Official Publication of the Academy

The Kentucky Academy of Science

Founded 8 May 1914

All manuscripts and correspondence concerning manuscripts should be addressed to the Editor. Authors must be members of the Academy.

The TRANSACTIONS are indexed in the Science Citation Index. Coden TKASAT. ISSN No. 0023-0081.

Membership in the Academy is open to interested persons upon nomination, payment of dues, and election. Application forms for membership may be obtained from the Secretary. The TRANSACTIONS are sent free to all members in good standing.

Annual dues are $25.00 for Active Members; $10.00 for Student Members; $35.00 for Family; $350.00 for Life Members. Subscription rates for nonmembers are: domestic, $45.00; foreign $50.00; back issues are $30.00 per volume.

The TRANSACTIONS are issued semiannually in March and September. Four numbers comprise a volume.

Correspondence concerning memberships or subscriptions should be addressed to the Secretary. Exchanges and correspondence relating to exchanges should be addressed to the Librarian, University of Louisville, Louisville, Kentucky 40292, the exchange agent for the Academy.

THIS PUBLICATION IS PRINTED ON ACID-FREE PAPER.

EDUCATIONAL AFFILIATES

Fellow

University of Kentucky

Sustaining Member

Eastern Kentucky University
Morehead State University
Murray State University
Northern Kentucky University
University of Louisville
Western Kentucky University

Members

Bellarmine College
Cumberland College
Georgetown College

Associate Members

Berea College
Brescia College
Campbellsville College
Centre College
Kentucky State University
Kentucky Wesleyan College
Midway College
Spalding University
Sue Bennett College
Thomas More College
Translvania University
Union College

INDUSTRIAL AFFILIATES

Associate Patron

Ashland Oil, Inc.

Fellow

Brown and Williamson Tobacco Corporation

Sustaining Member

Air Products & Chemicals, Inc.

Members

All-Rite Pest Control
Alltech Biotechnology Center
Chemical & Industrial Engineering, Inc.
Corhart Refractories Corporation
Databeam Corporation
First Security Banks
Gaf Chemicals Corporation
The Humana Foundation Inc.
International Business Machines Corporation
Litton Industrial Automation
MPD, Inc.
United Catalysts Inc.
Westvaco

Associate Members

Group Financial Partners, Inc.
Procter & Gamble Mfg. Co.
Wood Hudson Cancer Research Lab., Inc.

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

March 1992
Volume 53
Numbers 1–2

Trans. Ky. Acad. Sci., 53(1–2), 1992, 1–4

Intermediate Host Sex and Cysticercoid Age: Effect on Size of Adults of the Tapeworm, *Hymenolepis diminuta* (Cyclophyllidea)

Ron Rosen

Department of Biology, Berea College, Berea, Kentucky 40404

Abstract

This study determined the effect of mealworm (*Tenebrio molitor*) sex on the rate of *Hymenolepis diminuta* cysticercoid development and infectivity at 25.5°C and subsequent size of the adult worm developing from these larvae. In addition, the effect of cysticercoid age on the size of adult worms was also assessed. A significant difference in the frequency of cysticercoid developmental stages between male and female beetles was apparent on day 8 postinfection (PI). At this time, all male beetles possessed cysticercoid infrapopulations in which less than 20% of the larvae had withdrawn scoleces. By contrast, 50% of the female beetles had larvae infrapopulations in which more than 20% of the worms possessed withdrawn scoleces, indicating a faster rate of development. No host sex-related differences in the rate of cysticercoid development, infectivity or scolex width were detected by day 10 PI indicating the transient nature of this phenomenon. Eleven-day-old, prepatent adult *H. diminuta*, which developed from 15-day old cysticercoids obtained from male vs. female beetles and 12- vs. 27-day old cysticercoids, did not vary significantly in their dry weights. Therefore, the effect of intermediate host sex on cysticercoid condition and differences in cysticercoid age do not affect the size obtained by adults of the tapeworm, *H. diminuta*.

Introduction

Sex of the intermediate host is rarely recorded in studies dealing with the metacestode of *Hymenolepis diminuta* (1). Susceptibility of male and female beetles to this parasite has been evaluated by several workers (2, 3, 4, 5), but only Soltice et al. (6) assessed the effect of intermediate host sex on the rate of *H. diminuta* development. They found that *H. diminuta* developed more rapidly in females of the beetles, *Tribolium confusum* and *Tribolium castaneum*, but it was unclear as to the physiological basis for this difference. Hurd and Arme (7, 8, 9) have reported differences in some metabolic changes between infected male and female mealworms, *Tenebrio molitor*, but no study has compared rates of cysticercoid development between the sexes in this host species.

Beetle sex may not only affect the rate of cysticercoid differentiation, but may have a carry-over effect on adult worm size in the definitive host. Several studies have suggested such a link between tapeworm size in one stage of the life cycle and larval "condition" in the previous host in the Orders Proteocephalata (10) and Pseudophyllidea (11, 12, 13), but only Mueller (14) provided adequate quantitative evidence for this phenomenon when he found that larger plerocercoids were obtained from older procercoids of the pseudophyllidean tapeworm, *Spirometra mansonoides*.

This study was initiated to further assess the importance of intermediate host sex and larval age on the size of adult tapeworms using the cyclophyllidean, *H. diminuta*, as a model system. The specific objectives of this study were to determine the effect of: (1) sex of *T. molitor* on the rate of cysticercoid development, infectivity and, thus, subsequent adult worm size and (2) cysticercoid age on the ensuing size of *H. diminuta* in the definitive host.

MATERIALS AND METHODS

Pupae of *T. molitor* were sexed according to the techniques of Bhattacharya *et al.* (15). The sexes were maintained separately at 25.5°C for the duration of the experiments. This eliminated possible effects mating and oviposition might have on cysticercoid development. Following emergence, adults were placed in bran (Wingold Baker's Bran, Bay State Milling Co., Winona, MN) from 1–6 days and then starved for 3 days. Eggs of *H. diminuta* (Rice Strain) were obtained from a single Sprague-Dawley rat with a single worm infection to minimize genetic variation. Beetles were between 4–9 days postemergence when they were exposed to a mixture of apple pulp and *H. diminuta* eggs for 24 hours. It was assumed that male and female beetles ingested eggs at a similar rate during this exposure period. Following exposure to eggs, beetles were placed in bran and maintained in the dark.

Seventy male and 65 female *T. molitor* were dissected between days 6–10 postinfection (PI) to evaluate the effect of host sex on the rate of cysticercoid development. Cysticercoids from each beetle were stored in buffered formalin and later staged with a compound microscope using slightly modified criteria adopted from Voge and Heyneman (16). The major features used to classify each stage were as follows: (1) stage II—body spherical or pear-shaped; (2) stage III—tripartite body; scolex not withdrawn into cyst and; (3) stages IV/V—scolex withdrawn into cyst. In addition, 23 male and 21 female beetles were dissected on day 10 PI to evaluate the effect of host sex on scolex width of 10 randomly selected stage V cysticercoids from each beetle. (It should be noted that the scolex represents the only tissue which ultimately establishes itself in the definitive host in the case of *H. diminuta.*) Measurements were made with a compound microscope using an ocular micrometer and are reported in μm.

As a preliminary experiment had established that day 12 PI was the earliest time for 100% infectivity of cysticercoids at 25.5°C, an experiment was conducted at day 10 PI to assess early infectivity of cysticercoids from male vs. female beetles. Seven and 9, one-month old Sprague-Dawley rats were infected with 10 day PI cysticercoids obtained from female and male beetles, respectively. Fifteen one-month old male Sprague-Dawley rats were infected with 15-day old cysticercoids from male beetles, and 15 additional male rats with larvae from female beetles to assess possible differences in adult worm size resulting from cysticercoid condition due to differences in intermediate host sex. Eighteen (9 male and 9 female) and 20 (10 male and 10 female) two-month old Sprague-Dawley rats were infected with 12- and 27-day old cysticercoids, respectively, to evaluate the effect of larval age on adult worm size. In all experiments, rats were infected by gastric intubation with 4 randomly selected cysticercoids each to avoid the well documented crowding effect (17). In the experiment assessing cysticercoid age, rats were infected with equal numbers of larvae from male and female beetles at each time period. Rats were killed by a blow to the head on day 11 PI. Prepatent adult worms were flushed from the intestine with saline, cleaned free of debris, placed on metal planchets and dried for 24 hours at 95°C. Percent worm recovery was recorded and an average dry weight was calculated for worms from each individual rat.

A 2×3 chi-square contingency test was used to compare frequencies of cysticercoid developmental stages between male and female beetles on days 6, 8 and 10 PI. Intensity of infection is reported but not considered in these comparisons since Voge and Heyneman (16) indicated that the crowding effect on *H. diminuta* in its intermediate host is directed against the thickness of the sheaths enveloping the scolex, but not against this parasite's rate of development. A 2×2 chi-square contingency test was used to compare the infectivity of day 10 PI cysticercoids taken from male vs. female beetles. A Student's t test was used to test for differences in: (1) scolex width of stage V cysticercoids recovered from male vs. female beetles and (2) dry weights of adult worms. A probability of $P < 0.05$ was considered significant for all tests.

TABLE 1. Frequencies of developmental stages (II, III and IV/V) of *Hymenolepis diminuta* cysticercoids in adult male and female *Tenebrio molitor* at days 6, 8 and 10 postinfection and 25.5°C.

	Female beetles				Male beetles			
	N (#)[1]	% II	% III	% IV and V	N (#)	% II	% III	% IV and V
Day 6	799 (23)	100.0	0	0	1,406 (23)	99.5	0.5	0
Day 8	2,074 (20)	6.5	73.6	19.9	1,611 (24)	11.2	82.1	6.7
Day 10	1,817 (22)	0.8	4.6	94.6	2,761 (23)	0.4	3.8	95.8

[1] N (#) = number of cysticercoids assessed (number of beetle hosts).

RESULTS

A total of 10,468 (mean intensity of infection = 77.5 ± 71.5; range = 1–400) cysticercoids were staged from the infections of *T. molitor*. The data on cysticercoid development are presented in Table 1. There was a significant difference in the proportions of cysticercoid stages between male and female beetles on day 8 PI (χ^2 = 143.95; df = 2). More cysticercoids had withdrawn scoleces in female beetles than in males at this time. Comparison of the data by individual hosts on day 8 PI revealed that none of the cysticercoid infrapopulations from the 24 male beetles evaluated had more than 20% stage IV/V metacestodes. By contrast, 50% (10/20) of the female beetles had cysticercoid infrapopulations in which more than 20% of the worms had withdrawn scoleces at this time. No host sex-related differences in the rate of cysticercoid development were detected at days 6 or 10 PI.

A total of 433 stage V cysticercoids (mean intensity of infection = 104.0 ± 92.1; range = 7–400) were assessed to determine possible differences in the scolex width of larvae due to beetle sex. No significant difference was observed in the scolex width between male (0.096 ± 0.009) vs. female (0.097 ± 0.008) beetles at day 10 PI (T = 1.219; df = 431). No significant difference in the infectivity of day 10 PI cysticercoids taken from male (adult worm recovery = 27.8%, 10/36) vs. female (adult worm recovery = 14.3%, 4/28) beetles was noted (χ^2 = 1.678; df = 1). Adult worms, grown from 15-day old cysticercoids taken from male vs. female beetles, did not show a significant difference in dry weight (T = 1.423, df = 28; Table 2). Similarly, adult worms grown from 12- vs. 27-day old cysticercoids did not vary significantly in their weights (T = 0.563, df = 36; Table 2).

TABLE 2. Mean dry weights ± SD of 11-day old prepatent adults of *Hymenolepis diminuta* grown from: (1) 15-day old cysticercoids from male vs. female *Tenebrio molitor* and (2) 12- vs. 27-day old cysticercoids. Infected beetles were held at 25.5°C during cysticercoid development.

Variable	Number of adult worms recovered	Dry weight (mg) mean ± SD[1]
Beetle sex		
Female	60	29.3 ± 5.36
Male	55	26.2 ± 6.78
Cysticercoid age		
12 Days	62	34.8 ± 8.00
27 Days	75	36.1 ± 6.19

[1] Mean ± SD = 3–4 worms were recovered from each rat. The average dry weight of worms from an individual rat was determined, and these were used to obtain an overall mean dry weight for worms recovered from all rats in a treatment.

DISCUSSION

The developmental rate of *H. diminuta* in female *T. molitor* was more rapid than in males by day 8 PI. Hurd and Arme (9) suggested that more metabolites may be available in the hemolymph of infected female *T. molitor* as a result of reduced vitellogen synthesis. This developmental advantage imparted to cysticercoids developing in "nutrient-rich" females is apparently transient since no difference was encountered in either: (1) cysticercoid development, infectivity or scolex width between male and female beetles by day 10 PI or (2) the size of 11 day adult worms grown from 15-day old cysticercoids taken from male vs. female *T. molitor*.

Differences have been documented in the cyst walls (18) and excystation times (19) of young vs. old infective cysticercoids of *H. diminuta*. However, the cyst wall tissue is lost during the excystment of the parasite in the definitive host and would therefore not be a likely factor contributing to adult worm size. Only the small scolex of *H. diminuta*, which ceases growth after the larva reaches maturity within the beetle (16), contains tissue which will become part of the adult worm. Thus, it was not surprising that adult worm size was unaffected by cysticercoid age. Similarly, Goodchild and Harrison (20) were unable to detect differences in the early (i.e., 48 hours PI) growth of *H. diminuta* in rats developing from young vs. old cysticercoids. By contrast, the majority of procercoid tissue, with the exception of the cercomer in *S. mansonoides*, is incorporated into the next stage in the life cycle so that factors affecting procercoid growth in the cyclopid host may be reflected in plerocercoid size as described by Mueller (14). These findings support the conclusion that the amount and type of cestode tissue transferred into the next host in the life cycle dictate the importance of larval "condition" with regard to tapeworm size in subsequent hosts.

ACKNOWLEDGMENTS

This investigation was supported by a fellowship to R. Rosen from the Appalachian College Program with funds granted by the Mabel Pew Myrin Trust. Facilities for this study were provided by Dr. Gary L. Uglem, School of Biological Sciences, The University of Kentucky.

LITERATURE CITED

1. Ubelaker, J. E. 1980. Structure and ultrastructure of the larvae and metacestodes of *Hymenolepis diminuta*. Pp. 59–156. In H. P. Arai (ed.) Biology of the tapeworm *Hymenolepis diminuta*. Academic Press, New York.

2. Kelly R. J., D. M. O'Brien, and F. F. Katz. 1967. The incidence of burden of *Hymenolepis diminuta* cysticercoids as a function of the age of the intermediate host *Tribolium confusum*. J. N.Y. Entomol. Soc. 75:19–23.

3. Mankau, S. K. 1977. Sex as a factor in the infection of *Tribolium* spp. by *Hymenolepis diminuta*. Environ. Entomol. 6:233–236.

4. Rau, M. E. 1979. The frequency distribution of *Hymenolepis diminuta* cysticercoids in natural, sympatric populations of *Tenebrio molitor* and *T. obscurus*. Int. J. Parasitol. 9:85–87.

5. Keymer, A. 1982. The dynamics of infection of *Tribolium confusum* by *Hymenolepis diminuta*: the influence of exposure time and host density. Parasitology 84: 157–166.

6. Soltice, G. E., H. P. Arai, and E. Sheinberg. 1971. Host-parasite interactions of *Tribolium confusum* and *Tribolium castaneum* with *Hymenolepis diminuta*. Can. J. Zool. 49:265–273.

7. Hurd, H. and C. Arme. 1984. *Tenebrio molitor* (Coleoptera): effect of metacestodes of *Hymenolepis diminuta* (Cestoda) on hemolymph amino acids. Parasitology 89:245–252.

8. Hurd, H. and C. Arme. 1984. Pathophysiology of *Hymenolepis diminuta* infections in *Tenebrio molitor*: effect of parasitism on hemolymph proteins. Parasitology 89:253–262.

9. Hurd, H. and C. Arme. 1986. *Hymenolepis diminuta*: influence of metacestodes on synthesis and secretion of fat body protein and its ovarian sequestration in the intermediate host, *Tenebrio molitor*. Parasitology 93:111–120.

10. Wagner, E. D. 1954. The life history of *Proteocephalus tumidocollus* Wagner, 1953, (Cestoda), in rainbow trout. J. Parasitol. 40:489–498.

11. Archer, D. M. and C. A. Hopkins. 1958. Studies on cestode metabolism; III. Growth pattern of *Diphyllobothrium* sp. in a definitive host. Exp. Parasitol. 7:125–144.

12. Rosen, R. and T. A. Dick. 1984. Growth and migration of plerocercoids of *Triaenophorus crassus* Forel and pathology in experimentally infected whitefish, *Coregonus clupeaformis* (Mitchill). Can. J. Zool. 62:203–211.

13. Kuperman, B. I. 1973. Tapeworms of the genus *Triaenophorus*, parasites of fishes. Nauka Publishers, Leningrad. (English translation by Amerind Publishing, Co. Pvt. Ltd., New Delhi, 1981, for the United States Department of the Interior and the National Science Foundation, Washington, D.C.).

14. Mueller, J. F. 1966. The laboratory propagation of *Spirometra mansonoides* (Mueller, 1935) as an experimental tool. VII. Improved techniques and additional notes on the biology of the cestode. J. Parasitol. 52:437–443.

15. Bhattacharya, A. K., J. J. Ameel, and G. P. Waldbauer. 1970. A method for sexing living pupal and adult yellow mealworms. Ann. Entomol. Soc. Amer. 63B:1783.

16. Voge, M. and D. Heyneman. 1957. Development of *Hymenolepis nana* and *Hymenolepis diminuta* (Cestoda: Hymenolepididae) in the intermediate host *Tribolium confusum*. Univ. Calif. Publ. Zool. 59:549–580.

17. Roberts, L. S. 1961. The influence of population density on patterns and physiology of growth in *Hymenolepis diminuta* (Cestoda: Cyclophyllidea) in the definitive host. Exp. Parasitol. 11:332–371.

18. Richards, K. S. and C. Arme. 1984. An ultrastructural analysis of cyst wall development in the metacestode of *Hymenolepis diminuta* (Cestoda). Parasitology 89:536–566.

19. Rothman, A. H. 1959. Studies on the excystment of tapeworms. Exp. Parasitol. 8:336–364.

20. Goodchild, C. G. and D. L. Harrison. 1961. The growth of the rat tapeworm, *Hymenolepis diminuta*, during the first five days in the final host. J. Parasitol. 47:819–829.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 5–8

A Preliminary Survey of the Small Mammals on the Fort Knox (Meade, Hardin and Bullitt counties), Kentucky, U.S. Army Facility

JENNIFER MCGEHEE MARSH, RICHARD K. KESSLER, AND ROBERT A. MATTINGLY, JR.
Biology Department, University of Louisville, Louisville, Kentucky 40292

ABSTRACT

A small mammal survey was conducted on the Ft. Knox, KY, military reservation. One hundred forty-six specimens (11 species) were trapped and preserved. The white-footed mouse (*Peromyscus leucopus*) was the most abundant species caught, followed by the prairie deer mouse (*Peromyscus maniculatus bairdii*), prairie vole (*Microtus ochrogaster*), short-tailed shrew (*Blarina brevicauda*), golden mouse (*Ochrotomys nutalli*), eastern chipmunk (*Tamias striatus*), pine vole (*Microtus pinetorum*), house mouse (*Mus musculus*), eastern cottontail (*Sylvilagus floridanus*), southern bog lemming (*Synaptomys cooperi*), and eastern harvest mouse (*Reithrodontomys humulis*).

INTRODUCTION

The U.S. Army is responsible for managing almost 5 million hectares (19,000 square miles) of land in the continental United States. According to the Army (1), this is not adequate to meet their training mission because the area necessary to train a division in the use of modern weapon systems is roughly 10 times the area that was needed in the 1940s. Because of the increased use of training lands, there has been a general deterioration in the condition of the U.S. Army's natural resources (2, 3). As a result, the Secretary of Defense has charged the military to be a leader in environmental compliance and natural resource management (4).

In the spring of 1984, an independent expert review panel was convened by the U.S. Army to evaluate the natural resource management programs on selected military installations and to make recommendations for improving these programs. Twenty four recommendations were developed, including "... the requirement that new or more adequate natural resource inventories be completed on all military installations ..." (5).

The U.S. Army Construction Engineering Resource Laboratory (USACERL) was enlisted to develop the recommended natural resource inventory and monitoring program, using standard methods for data collection, analyses, and reporting so that information would be comparable among installations and could be compiled Army-wide. This Land Condition Trend Analysis (LCTA) program has the support of the Assistant Secretary of the Army (6), the National Military Fish and Wildlife Association (7) and the Defense Natural Resource Council (8).

A Wildlife Inventory and Monitoring System (WIMS) was designed by the U.S. Army Corps of Engineers to integrate with existing LCTA technology and to provide the U.S. Army with an integrated, low cost system for assessing the status of installation wildlife. Three year-long WIMS have already been implemented at Ft. Hood (TX), Ft. Sill (OK), Ft. Chaffee (AR), White Sands Missile Range (NM), Dugway Proving Ground (UT), Pinon Canyon Maneuver Site (CO) and Orchard Training Area (ID). Ft. Knox (KY) is one of the sites that has been selected for a WIMS during the summers of 1991, 1992 and 1993. This paper reports the results of the first (1991) summer's survey.

Fort Knox is a U.S. Army installation that encompasses 101,000 acres in Meade, Hardin and Bullitt counties, Kentucky. It lies southeast of the Ohio River and is split by the Salt and Rolling Fork rivers. The military reservation includes a cantonment (residential) area, artillery and grenade ranges and impact areas, and tank training tracks. Most of the land is rugged and hilly with steep slopes gullied by intermittent streams and is heavily wooded with secondary growth timber. There is a large area of knobs topography, conical, flat-topped hills with broad valley floors, developed on shale and sandstone bedrock. There are rolling uplands along the Salt and Rolling Fork rivers, dominated by a sandstone substratum. The open range area, covered with sparse, scrub growth, has a clay soil. Sinkholes are prevalent where the installation edges a karst region (9).

MATERIALS AND METHODS

It was decided that by using permanent plots, it would be possible to return to the same location year after year, providing a statistical foundation for determining trends in resource conditions. The standard size of the LCTA plots is 100 m × 6 m with a 100-m line transect forming the central, longitudinal axis. There is one core plot per 200 ha (500 acres) of land, with a maximum of 200 core plots per installation. In order to ensure objectivity in the placement of the plots, an automated site selection process was developed. The procedure used incorporated SPOT (Système Probatoire pour l'Observation de la Terre) satellite imagery, digital soil surveys and the Geographic Resource Analysis Support System (GRASS) geographical information system. The 140 core plots surveyed for this study were allocated through a stratified random process (5).

The small mammal census was taken by setting out 2 rows of 20 museum special traps and 5 rat traps parallel to the longitudinal axis of each LCTA plot. A total of 40 museum special traps and 10 rat traps were placed about 7.5 m and 30 m apart, respectively. The traps were baited with rolled oats and peanut butter and run for 2 nights for a total of 100 trap nights per plot. Traps were set late in the afternoon of the first day, checked early the next morning, reset during the late afternoon of the second day and checked and collected the following morning. Captures for each site and day were placed in separate Ziploc® bags, labeled and frozen. Trapping began on May 15 and ended on June 15, 1991. Specimens were identified by their morphological characteristics and the enamel patterns on the occlusive surfaces of the cheek teeth as described by Barbour and Davis (10). All specimens have been preserved and are on deposit in the collections of the University of Louisville.

RESULTS

Eleven species were collected with a total of 144 specimens. In the following list, all measurements are in centimeters with averages given first, followed by the extremes given in parentheses. Information about the habitats of each animal is from Barbour and Davis (10).

1. *Peromyscus leucopus* (Rafinesque). White-footed Mouse. This was the most abundant mammal in the inventory. It was found at all elevations and all habitats except weedfields not bordered by trees or shrubs, areas which were occupied by the prairie deer mouse, *P. maniculatus bairdii*. Measurements of the 96 specimens are weight 21.38 g (36.7–9.1); total length 15.07 (17.9–7.1); tail length 6.88 (10.7–2.1); foot length 1.83 (2.2–1.1); pinna length 1.38 (1.9–1.1).

2. *Peromyscus maniculatus bairdii* (Hoy and Kennicott). Prairie Deer Mouse. These mice occupy open weedfields, grasslands and agricultural land. Measurements of the 11 specimens are weight 13.7 g (21.1–7.4); total length 12.33 (17.6–9.7); tail length 5.11 (8.1–4.4); foot length 1.55 (2.1–1.3); pinna length 1.16 (1.8–0.7).

3. *Ochrotomys nutalli* (Harlan). Golden Mouse. This animal inhabits greenbrier thickets, pine and cedar saplings and honeysuckle, blackberry and grape vines. Measurements of the 8 specimens caught are weight 17.5 g (28.8–10.72); total length 14.87 (16.9–12.4); tail length 6.97 (7.9–5.9); foot length 1.69 (1.8–1.5); pinna length 1.43 (1.8–1.1).

4. *Mus musculus* Linnaeus. House Mouse. In addition to living wherever humans do, the house mouse lives in brushland and weedfields, away from deep woods. Measurements of the 2 caught are weight 10.5 g (14.2–6.8); total length 8.1 (11.3–4.9); tail length 3.9 (5.1–2.7); foot length 1.75 (1.9–1.6); pinna length 1.55 (1.6–1.5).

5. *Reithrodontomys humulis* (Audubon and Bachman). Eastern Harvest Mouse. With a statewide distribution, living in tall, dense weeds, this mouse is uncommon and requires persistent trapping. Only 1 animal was caught and its measurements are weight 12.1 g; total length 13.2; tail length 7.2; foot length 1.7; pinna length 0.9.

6. *Synaptomys cooperi* (Baird). Southern Bog Lemming. These mice are fairly common in Kentucky and live in colonies in dense stands of bluegrass which contain brush, rock or shrubs. They will live in habitats too small to support meadow or prairie voles. One animal was caught and its measurements are weight

38.2 g; total length 12.4; tail length 1.5; foot length 1.7; pinna length 0.8.

7. *Microtus ochrogaster* (Wagner). Prairie Vole. This vole is abundant in Kentucky except for the southeastern mountains. Its favored habitat is upland pasture grasses but it will also occupy lowland cattail swamps. During dry years the species becomes scarce. Ten specimens were trapped and their measurements are weight 33.03 g (42.2–30.1); total length 13.37 (14.2–12.5); tail length 3.21 (3.7–2.5); foot length 1.58 (1.8–1.4); pinna length 0.97 (1.3–0.7).

8. *Microtus pinetorum* (LeConte). Pine Vole. This species is found in all habitats, anywhere there is adequate cover and food supply. Only 2 specimens were caught and their measurements are weight 20.25 g (21.6–18.9); total length 10.8 (11.4–10.2); tail length 2.2 (2.8–1.6); foot length 2.15 (2.8–1.5); pinna length 1.05 (1.1–1.0).

9. *Blarina brevicauda* (Say). Short-tailed Shrew. Perhaps the most abundant mammal in Kentucky (10), the short-tailed shrew lives anywhere there is good vegetative cover and eats insects and slugs that are pests to farmers. Measurements of the 9 specimens are weight 13.32 g (14.8–10.5); total length 10.32 (10.8–9.8); tail length 1.97 (2.4–1.6); foot length 1.31 (1.7–1.1).

10. *Tamias striatus* (Linnaeus). Eastern Chipmunk. This striped squirrel is common in woodlands, parks, cemeteries and gardens. They prefer varied habitats which include rock walls, cliffs, woodpiles and hedgerows. Three chipmunks were trapped and their measurements are weight 106.9 g (139.9–71.1); total length 22.47 (25.3–17.4); tail length 9.77 (11.1–8.1); foot length 3.37 (3.4–3.3); pinna length 1.23 (1.3–1.1).

11. *Sylvilagus floridanus* (Allen). Eastern Cottontail. This is the most common rabbit in Kentucky. It occupies a variety of habitats including lawns, parks, upland thickets, brush, farmland, deep woods and lowland swamps. One rabbit was taken and its measurements are weight 100.8 g; total length 16.0; tail length 3.7; foot length 3.6.

DISCUSSION

Several factors could have contributed to the paucity of species taken. Trapping during the summer, with an abundance of food already available, could have lessened interest in our peanut butter-and-oats bait. In addition, formicids and cockroaches (Blattoidea) were a nuisance, eating the bait, and in some cases, the soft tissue of the trapped animals.

Another source of bias in the study could have been created by using only snap traps, which limited the size and type of animal caught. However, state law prohibits trapping game animals, so to produce a more exhaustive count of all animals on the facility, secondary evidence (scats, prints, burrows, nests) would have to be recorded.

The site selection process also had a built-in drawback. A computer was used to choose the study sites in an effort to ensure random selection and for the most part, a diverse range of habitats were targeted. Unfortunately, inappropriate areas were also selected (soccer field, rocky cliff face) and no animals were caught at these sites.

Two final problems encountered with this survey were a function of trapping on a military installation which has restricted areas. There were times when the investigators were not allowed back into an area on the second day of trapping because 'maneuvers' were scheduled for the area. There was also night fire practice over or close to areas where traps had been set, which we suspect would discourage all but the most intrepid animal from foraging. These issues will need to be addressed before the 1992 trapping begins.

ACKNOWLEDGMENTS

This study was funded by the U.S. Army Corps of Engineers Construction Engineering Resource Laboratory, Champaign, Illinois.

LITERATURE CITED

1. Department of the Army. 1978. Training land. Circular 25-1. Washington, D.C.

2. Schaeffer, D. J., W. R. Lower, S. Kapila, A. F. Yanders, R. Wang, and E. W. Novak. 1986. Preliminary study of the effects of military obscurant smokes on flora and fauna during field and laboratory exposures. U.S. Army Construction Eng. Res. Lab. Tech. Rept. N-86/22:1–84.

3. Goran, W. D., L. L. Radke, and W. D. Severinghaus. 1983. An overview of the ecological effects of tracked vehicles on major U.S. Army installations. U.S. Army Construction Eng. Res. Lab. Tech. Rept. N-142:1–75.

4. Cheney, R. 1989. Memorandum for Secretaries of the Military Departments. Subject: environmental management policy. October 10. Washington, D.C.

5. Diersing, V. E., R. B. Shaw, D. J. Tazik, R. J. Brozka, and S. D. Warren. 1991. U.S. Army land condition trend analysis field methods.

6. Shannon, J. W. 1987. Memorandum for Director of the Army Staff. Subject: land management—action memorandum. August 18. Washington, D.C.

7. National Military Fish and Wildlife Association. 1988. Resolution 2—military land inventory and monitoring. Fish and Wildlife News 5(2).

8. Ramsey, C. 1989. Memorandum for Deputy Director, Defense Research and Engineering. Subject: training area management technology. March 1. Washington, D.C.

9. McGrain, P. and J. C. Currens. 1978. Topography of Kentucky. University of Kentucky, Kentucky Geological Survey, Series 10, Special Publications 25:1–76.

10. Barbour, R. W. and W. H. Davis. 1974. Mammals of Kentucky. University Press of Kentucky, Lexington.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 9–14

The Combinatorial Game "Chomp"

Charles H. Franke

Department of Mathematics, Statistics and Computer Science, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

In their comprehensive treatment of Combinatorial Games, Winning Ways for Your Mathematical Plays, Berlekamp, Conway, and Guy considered the game "Chomp" and presented some winning positions for the 2-dimensional game. In this paper, a method of representing positions, moves, and strategies, and an algorithm to determine a winning strategy are given. Winning first moves for special cases of 2- and 3-dimensional chomp are given.

Introduction

The game "Chomp" is defined for a given positive integer N by the following rules. Define S to be the set of all positive divisors of N. At each turn, a player names an element of S. The number named, and all of its multiples, are removed from S. The player who names "1" loses. For example, if N = 6, then S = {1, 2, 3, 6}. If the first player names "2" then S is reduced to {1, 3}, and the second player can name "3" and win. If the first player starts with "6" then the first player can win by reducing S to {1} on his second move. Chomp, for a given N, will be denoted by C(N). If N has the prime decomposition $N = p^i \cdot q^j \cdots r^k$, then C(N) is clearly independent of the particular primes p, q, . . . , r, and C(N) will be called "the game (i, j, . . . , k)." When the game is represented in this form, it will be assumed that the exponents form a non-increasing sequence.

Chomp is a combinatorial game in the sense of (1). In general, the terminology of (1) will be used. In particular, the first player will be called white, the second player blue; a $\mathcal{P}$ position is one in which the previous player wins, and an $\mathcal{N}$ position is one in which the next player wins.

The 2-dimensional game, (i, j), has a natural geometric interpretation with the set S represented as a rectangle. For the game (5, 2), S is:

1	p	p^2	p^3	p^4	p^5
q	qp	qp^2	qp^3	qp^4	qp^5
q^2	q^2p	q^2p^2	q^2p^3	q^2p^4	q^2p^5

The first move determines a sub-rectangle whose upper left vertex is the number chosen. The result of the move is to excise that rectangle from S. Subsequent moves have similar interpretations.

It is noted that white always has a winning strategy, and some winning positions for 2-dimensional Chomp are given in (1). During the Short Course in Combinatorial Games at the American Mathematical Society 1990 Summer Meeting, Richard K. Guy suggested extending these results and analyzing 3-dimensional Chomp. (2).

Summary

A non-constructive proof that white has a winning strategy for C(N) if N ≠ 1 is given. A means of representing winning strategies for 2-dimensional Chomp is defined, and the results of (1) are extended. The method is extended to 3-dimensional Chomp and the winning first moves for (i, j, k) when i + j + k < 9 are given. Next, an algorithm to determine a winning strategy for any N is presented and discussed. The final section contains some questions and conjectures concerning Chomp.

The Existence Theorem

If one considers C(N) for small values of N, then it is not immediately clear that white has a decisive advantage, and it is surprising that it is so easy to prove that white always has a winning first move.

Theorem. If N ≠ 1, then white has a winning strategy for C(N).

Proof. Assume not. Then, for any initial move X by white there is a move by blue which defeats X; call it f(X). Then, independent of white's second move, blue wins the game that starts with white playing N and blue playing f(N). In particular, blue wins the game that starts N - f(N) - f(f(N)), and this sequence of moves results in an $\mathcal{N}$ position. Since f(N) is a divisor of N, the position of the game after the sequence N - f(N) is the same as the position after just the initial move f(N). Therefore, the position after N - f(N) - f(f(N)) is identical to that of the game that begins with f(N) - f(f(N)), which is a $\mathcal{P}$ position. This contradiction completes the proof.

The existence proof is of little practical value in determining the winning first move. The proof shows, in effect, that if one tests each move $K < N$ and finds a move f(K) that defeats it, then one knows that N is a winning move, since one already has a list of the moves that will defeat blue's possible responses to N. The theorem does, however, rule out powers of primes as winning first moves.

Corollary. If $N = p^j$ is a power of a prime, then the only winning first move for C(N) is p. If N has more than one prime divisor, then the winning first move is not a power of a prime.

Proof. Assume that $N = p^tM$ where (p, M) = 1 and p^s is a winning first move. After the move p^s the game becomes $C(p^{s-1}M)$. Since the next player has no winning strategy, s = M = 1. Conversely, p is clearly the winning move for $C(p^t)$, $t > 0$.

TWO-DIMENSIONAL CHOMP

A *shape* A for the game (i, j) is a non-increasing sequence (a(0), . . . , a(j)) of integers $0 \leq a(k) \leq i + 1$. The geometric representation of 2-dimensional Chomp given above defines a 1-to-1 correspondence between shapes and positions which can be reached in the game. The initial position is I = (i + 1, . . . , i + 1) and the final position is 0 = (0, . . . , 0). An *admissible transformation* of a shape B = (b(0), . . . , b(j)) is a shape C = (c(0), . . . , c(j)) $\neq$ 0 for which there is an integer s so that b(k) = c(k) for $k < s$, $b(s) > c(s)$, and c(k) = min{b(k), c(s)} for $k > s$. The shape C corresponds to the position in the game which follows from the position corresponding to B after the move $q^sp^{c(s)}$ is made.

A set T of shapes is *closed* if it satisfies (1) and (2) and *complete* if it also satisfies (3).

(1) (1, 0, . . . , 0) is in T and 0 is not in T.
(2) If A is in T and B is an admissible transformation of A, then there is a shape C in T which is an admissible transformation of B.
(3) T contains a shape which is an admissible transformation of the initial position I.

Example. For the game (3, 1), set T = {(4, 3), (3, 2), (2, 1), (1, 0)}. Then (4, 3) is an admissible transformation of the initial position (4, 4). The admissible transformations of elements of T are (3, 3), (2, 2), (1, 1), (4, 2), (4, 1), (4, 0), (3, 1), (3, 0), and (2, 0). There is an admissible transformation of each which is in T. Therefore, T is a complete set of shapes for (3, 1). The same argument shows that T = {(k, k − 1): $0 < k \leq i + 1$} is a complete set of shapes for (i, 1).

A complete set T of shapes for a game determines a complete strategy for white to win the game. White plays so that each move results in a shape in T. (3) guarantees that there is an initial move. (2) guarantees that white can respond to any move by blue, except the move 0, which is equivalent to blue resigning, by a move that will result in another position corresponding to a shape in T. Since each move by white results in a shape in T, and each move by either player reduces the sum of the components of the shape corresponding to the move, eventually white's move will result in the position corresponding to the shape (1, 0, . . . , 0).

The following is an algorithm to determine if a set of shapes is closed. If T has a few hundred shapes, then a program implementing this algorithm will execute in a few seconds.

Store the set to be tested in an array T[k].
(1) The outer loop is on k.
(2) The next level is on x and y. For each k, find each admissible transformation A[k, x, y] of T[k].
(3) The inner loop is on s and t. For each A[k, x, y], determine each admissible transformation B[k, x, y, s, t] of A[k, x, y]. When B is determined, search the array T for it. If it is found, then it is the shape in T which is a response to A[k, x, y]. Return to the next step of loop 2 and consider the next admissible transformation of T[k]. If such a B is not found for any (s, t), then T is not closed.

If one records the results of the algorithm for a complete set of shapes by listing each T[k] followed by each pair A[k, x, y] - B[k, x, y, s,

TABLE 1. Complete set of shapes to win (6, j) for j < 6. Winning initial moves are underlined.

<u>760000</u>	650000	540000	430000	320000	210000	100000	<u>774000</u>	752000
743000	642000	633000	553000	532000	422000	311000	221000	<u>773300</u>
755400	754300	753200	744200	732200	622200	552200	533200	521100
411100	331100	222100	741110	733110	<u>722220</u>	663330	643320	631110
622110	643320	511110	442220	421110	333220	332110	222210	<u>777744</u>
777611	777554	777543	777442	776665	776654	776642	776511	776443
776432	775532	775411	775333	755533	755332	754222	753311	744311
742222	733322	733211	732111	721111	611111	555311	555222	554211
531111	522111	441111	333111	332211	222221			

t], then one has a table which lists the moves necessary to win the game. This table is in a convenient but redundant form. One consults the entry T[k], corresponding to the current position of the game in the table. The A values represent all possible blue moves, and the corresponding B values the winning white responses. Particular pairs, A - B, may be repeated in several different entries, so this table is longer than necessary.

Table 1 gives a set of shapes which is sufficient to win any game (6, j) for 0 < j < 6. For (6, 5), the shapes are of length 5 + 1 = 6. For (6, j), one need only use the shapes whose final 5 − j positions contains 0's. Table 2 gives a sample of the entries in a table of responses.

A complete set of shapes for a particular game (i, j) can be considerably smaller than the list for all j; e.g., for (8, 5) there is a complete set of 21 shapes; a list containing all of these shapes and all responses takes 91 lines. For (8, 7), the smallest complete set found contains 407 shapes, and the list of shapes and all responses, as described above, requires about 63 pages (3,779 lines). A list of responses only, with duplicates omitted, for the 467 shapes found to win each (8, j) requires about 21 pages (1,266 lines).

The winning first moves for the game (i, j), 0 < j ≤ i ≤ 10, are in Table 3. In (1), 2-dimensional Chomp is described by the size of the initial rectangle, and winning moves by the size of the rectangle that must be removed. An entry of (a, b) for the game (i, j) in Table 3 corresponds to an entry of (i + 1 − a, j + 1 − b) for the game (i + 1, j + 1) in (1).

The author will provide a listing of a complete set of shapes, and a program which will generate the response table from the set of shapes, for any of the 2-dimensional games mentioned here or for the 3-dimensional games mentioned below.

THREE-DIMENSIONAL CHOMP

The set S for 3-dimensional Chomp has a natural geometric representation as a box, similar to the 2-dimensional representation as a rectangle. A shape for the game (i, j, k) can be obtained by using separate shapes for each value of the third component. For example, for (2, 2, 1), S can be written in the form.

$$\begin{array}{llllll} 1 & p & p^2 & r & rp & rp^2 \\ q & qp & qp^2 & rq & rqp & rqp^2 \\ q^2 & q^2p & q^2p^2 & rq^2 & rq^2p & rq^2p^2, \end{array}$$

with the initial position (3, 3, 3, 3, 3, 3).

In general, a shape for (i, j, k) is a sequence with 2 indices, A(x, y), 0 ≤ x ≤ j, 0 ≤ y ≤ k, and 0 ≤ A(x, y) ≤ i + 1. An admissible transformation of a shape B = (b(0, 0), . . . , b(j, 0), . . . , b(0, k), . . . , b(j, k)) is a shape C ≠ 0 for which there are integers s and t so that b(x, y) = c(x, y) if x < s or y < t, b(s, t) > c(s, t), and c(x, y) = min{b(x, y), c(s, t)} if x ≥ s and y ≥ t. With this definition of admissible transformation, all of the statements about complete sets of shapes carry over from 2-dimensional Chomp to 3-dimensional Chomp. Table 4 gives the winning first moves for i + j + k < 9.

There is a natural symmetry for 3-dimen-

TABLE 2. Winning Responses for the Game (6, 3).

(6, 3) initial position 7777, initial move 7733.
7732 - 7532, 7731 - 2221, 7730 - 7430, 7722 - 7322, 7711 - 3311, 7700 - 7600, 7633 - 7600, 7533 - 7532, 7433 - 7430, 7333 - 7322, 7222 - 6222, 7111 - 4111, 7000 - 1000, 6633 - 6222, 5533 - 5530, 4433 - 4111, 3333 - 3311, 2222 - 2221, 1111 - 1000.

TABLE 3. Winning first moves for game (i, j) $0 < j \leq i \leq 10$.

i	j = 1	2	3	4	5	6	7	8	9	10
1	(1, 1)									
2	(2, 1)	(1, 1)								
3	(3, 1)	(2, 1)	(1, 1)							
4	(4, 1)	(3, 2)	(2, 2)	(1, 1)						
5	(5, 1)	(3, 1)	(2, 1)	(3, 2)	(1, 1)					
6	(6, 1)	(4, 2)	(3, 2)	(2, 1)	(4, 4)*	(1, 1)				
7	(7, 1)	(4, 1)	(3, 1)	(6, 4)*	(3, 2)*	(2, 2)*	(1, 1)			
8	(8, 1)	(6, 2)	(7, 2)*	(5, 2)*	(2, 1)*	(3, 2)*	(6, 5)*	(1, 1)		
9	(9, 1)	(5, 1)	(5, 2)*	(3, 1)*	(4, 2)*	(2, 1)*	#	(7, 6)*	(1, 1)	
10	(10, 1)	(6, 1)	(4, 1)*	(9, 4)*	(10, 5)*	(6, 4)*	(5, 3)*	(3, 4)*	(2, 2)*	(1, 1)

If (a, b) is the ij entry, then $p^a q^b$ is the winning initial move for (i, j).
Values not in (1) are indicated by *.
Two values are known for (9, 7). They are (5, 4) and (8, 3).

sional Chomp when 2 of the exponents are equal. For example, 44434400, a shape in a complete set for (3, 3, 1), expresses the fact that the moves p^3q^3 and rq^2 are *paired* in the sense that if one is the initial move then the other is a move that defeats it. By symmetry, p^3q^3 and rp^2 are also paired. The shape that expresses that fact is 44432222. Symmetry in q and r is easily recognizable, since symmetric pairs correspond to matrix transposes; e.g., in the game (3, 2, 2), the shape (a, b, c; d, e, f; g, h, i) is symmetry to (a, d, g; b, e, h; c, f, i).

AN ALGORITHM TO FIND A COMPLETE SET OF SHAPES FOR ANY N

The definitions generalize directly. A *shape* for the game $(i_0, \ldots, i_t)$ is a finite sequence of integers $P(x_1, \ldots, x_t)$ defined for $0 \leq x_j \leq i_j$ and $0 \leq P(x_1, \ldots, x_t) \leq i_0 + 1$. $p^* \neq 0$ is an *admissible transformation* of P if there is a vector $y = (y_1, \ldots, y_t)$ so that $P^*(x) = P(x)$ if some $x_k < y_k$, $P^*(y) < P(y)$, and $P^*(x) = \min\{P(x), P^*(y)\}$ if each $x_k \geq y_k$.

While shapes can be used to represent positions and to find winning strategies for C(N) for any N, the representation is not always natural, nor is it likely that it is the most efficient representation for computational purposes. For example, if N is a product of 5 distinct primes, N = pqrst, then, by symmetry, there are only 5 different first moves. When one knows that p is paired with qrst and that pq is paired with rst, then the winning first move must be N. One would hope to be able to express a winning strategy in a more natural way than by sequences of 16 integers (the winning initial move corresponds to the shape consisting of 15 2's follows by a 1.

TABLE 4. Winning initial moves for (i, j, k), $i + j + k < 9$.

1, 1, 1	N	2, 2, 1	N	2, 2, 2	pqr
2, 1, 1	N	3, 2, 1	pq	3, 2, 2	N
3, 1, 1	N	4, 2, 1	qr	4, 2, 2	p^3qr
4, 1, 1	N	5, 2, 1	p^2q	3, 3, 2	p^2q^2
5, 1, 1	N	3, 3, 1	p^2q^2r		
6, 1, 1	N	4, 3, 1	N		

To obtain a complete set of shapes for any C(N), one can use the following algorithm.

(1) Let T be any closed set of shapes. (It is always possible to start with T = {(1, 0, . . . , 0)}. However, one would normally have solved lower-order games and have the solutions to those games available to use as an initial value of T. For example, to solve (3, 3, 2), one might start by combining complete sets of shapes for (3, 3, 1) and (3, 2, 2), adding 0's where necessary to obtain shapes of the proper form.)

(2) Start with P = I, the initial position for the game. This is a loop on the t variables $i_1, \ldots, i_t$.
  (a) Find the next admissible transformation P* of P.
  (b) Test each admissible transformation P** of P* to see if it is in T.
  (c) If some P** is in T, then go back to (a).

(3) Step (2) will end in one of two ways. If some P* is found for which no P** is in T then replace P by P* and go back to (2a). If for each P* there is a P** in T, then add

P to T. If P is an admissible transformation of I, then P is the winning first move. If not, go back to (2).

To illustrate the algorithm, consider the game (2, 1). Start with P = I = (3, 3) and T = {(1, 0)}. P has 5 admissible transformations, (3, 2), (3, 1), (3, 0), (2, 2), and (1, 1). The "lowest," (1, 1), has an admissible transformation (1, 0) in T. The next, (2, 2), does not. Set P = (2, 2). Two of P's 3 admissible transformations have admissible transformations in T; (2, 1) does not. Set P = (2, 1). Both of P's admissible transformations have (1, 0) as admissible transformations, so (2, 1) is added to T. Again set P = I. Now the 4 lowest transforms of P have transforms in T. Set P = (3, 2). The transforms of P are (3, 1), (3, 0), (2, 2), and (1, 1). They all have transforms in T, so (3, 2) is added to T. Now T = {(1, 0), (2, 1), (3, 2)} is complete and the game is solved.

To see that the algorithm always yields a solution to a game, notice that when P is replaced by P* the sum of the components decreases. Therefore, the process must terminate. When it terminates we have a shape P which can be added to T with T remaining closed. Since P is found by a sequence T, P_1, P_2, . . . , P_k = P where P_{k-1} was chosen as a shape with no admissible transformation in T, P is a new addition to T unless k = 1. Since there are a finite number of shapes, T remains closed at each step, and T grows at every step until a shape that is an admissible transformation of the initial position is reached, the algorithm determines a complete set of shapes.

An algorithm to find a solution to a finite game is not in itself remarkable, since an exhaustive search of the game tree is also such an algorithm. The value of the algorithm depends upon its performance. When the author first became interested in Chomp, an old program was modified, rather casually, to search the game tree and print the winning first move. It used only alpha-beta pruning and did not use symmetry. It gave a winning first move for a few games like (3, 1, 1) and (3, 2, 1) in a few seconds. When it did not solve (3, 2, 2) in a few minutes, it was put on a background queue where it would run at priority zero when the computer was not otherwise in use. The program used 92.5 hours of CPU time on a Vax 6000-410 and was not successful. The same game was solved easily in an afternoon using an interactive program which implemented the shape-finding algorithm. One could enter a shape and see its transforms, and which of its transforms have a transform in T. By choosing a transform which did not, and repeating the process, one could follow the algorithm down the game tree until a new $\mathcal{P}$ position was found, and then add it and its symmetric partner to T. Notice that one need not start applying the algorithm with the initial position. For any shape P, either P or one of P's transforms is a $\mathcal{P}$ position. Therefore, one can start with a simple shape and follow a short path to find a new $\mathcal{P}$ position. Also, one need not return to the starting position after finding a new $\mathcal{P}$ position. It is more efficient to back up a few steps on the path that was followed to the last shape added to T.

Although the number of possible initial moves in $(i_1, \ldots, i_t)$ is known to be the number of divisors of N, which is $(i_1 + 1)\cdots(i_t + 1)$, the branching factor of the game tree is not obvious. For example, (8, 3) has 36 initial moves, but the number of second moves is a function of the first move. By a direct count, the average number of second moves is 23.5. By comparison, (3, 2, 2) also has 36 initial moves, but the average number of second moves is 26. The propagation of this effect down the game tree accounts for the relative difficulty of 3-dimensional Chomp compared to 2-dimensional Chomp.

CONJECTURES AND QUESTIONS

(1) Frequently, more than 1 winning move is possible in a position, but the initial winning move is unique in all cases that have been studied except one. If one could find conditions under which the winning first move is unique, it would simplify the study of games with symmetry (e.g., in (3, 3, 2) there are 48 initial moves, but only 11 are symmetric in p and q).

(2) If N is a product of distinct primes, then it appears that the winning first move is N. To provide this conjecture, it would be sufficient to show that the winning initial move is unique.

(3) If M is a product of distinct primes and $N = M^k$, then it appears that M is the winning first move. This is known when M is the product of 2 primes and has been checked for other small values.

TABLE 5. Number of s(i) shapes in a known complete set, for all games (i, j) as a function of i.

i	I(i)	s(i)
1	1	1
2	6	3
3	12	7
4	20	15
5	30	26
6	42	77
7	56	104
8	72	467
9	90	1,373
10	110	1,324

I(i) is the number of initial moves in (i, i − 1). s(i) is the number of shapes in the complete set found for all of the (i, j), j < i.

(4) When one examines games (i, j) for small values, there appear to be many patterns; however, they do not always continue for larger values. The only classes of games for which the winning strategies are known in closed form are (i, i) and (i, 1). It would seem that complete strategies for some other general cases could be described.

(5) To measure the efficiency of the algorithm in solving Chomp, it would be interesting to have an estimate on the number of shapes in a complete set in terms of the number of initial moves for the game. Table 5 gives the number s(i) of shapes in a known complete set, for all games (i, j) as a function of i. It is unlikely that these sets are minimal, but it would be surprising if complete sets which are significantly smaller exist. It is interesting to note in Table 5 that s(10) < s(9). This is true, since the games (10, 9) and (10, 8) are "easy" in the sense that the winning initial moves remove a relatively large number of possible moves and prune the game tree sharply. Since it is frequently true that (i, k + 1) is "easier" than (i, k), the set of shapes that solve (i, j) for all j < i has been used to smooth the data. From this data it does not appear that s(i) will grow exponentially in I(i), the number of initial moves in the largest game.

ACKNOWLEDGMENT

The Academic Computing Center at Eastern Kentucky University provided the computing facilities used for this work.

LITERATURE CITED

1. Berlekamp, E., C. Conway, and R. Guy. 1982. Winning ways for your mathematical plays, Vol. 2. Academic Press, New York.

2. Guy, R. 1990. Unsolved problems in combinatorial games, combinatorial games lecture notes. American Mathematical Society, Providence, R.I.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 15–18

Internal Parasites in a Small Flock of Lambs and Ewes During the Periparturient Period in 1987 in Kentucky

EUGENE T. LYONS, SHARON C. TOLLIVER, J. HAROLD DRUDGE, AND SHELBY STAMPER

Department of Veterinary Science, Gluck Equine Research Center, University of Kentucky, Lexington, Kentucky 40546-0099

ABSTRACT

Epizootiology of internal parasites in ewes and lambs in a small flock in Kentucky was investigated during the periparturient period in 1987. Eggs per gram (EPG) counts in ewes (N = 7), which lambed between 17 March and 15 April, were determined weekly between 4 February and 19 August. Lambs (N = 10) from the flock were killed periodically (1 to 3 lambs per month) between 15 April and 19 August, at which time EPG and helminth counts were determined. EPG counts for the ewes gradually increased until early April after which, for about a month, they rapidly ascended and exhibited a diphasic peak during April and May before decreasing abruptly to low levels by late May and early June, and thereafter. For the lambs, EPG and helminth counts, in general, began to increase sharply in early June, reaching the highest numbers in July and August. The large increase in EPG counts and numbers of helminths in lambs began about 2 months after the peak period of EPG counts were found for ewes. Data are compared in this investigation with those from a similar study in 1986 in Kentucky.

INTRODUCTION

Periparturient increase in nematode eggs per gram of feces (EPG) of ewes allows build up on pastures of parasitic larvae (L_3) (1, 2). These larvae are the major source of infections of internal parasites in spring lambs. In 1986, research on the transmission of internal parasites in spring lambs in Kentucky and relationship to periparturient rise in EPG in ewes was published (3). The present investigation was undertaken to obtain additional data on transmission of internal parasites in spring lambs in Kentucky and to compare results in 1987 with similar research in 1986.

MATERIALS AND METHODS

Lambs and ewes in the present investigation were from the Field 21 flock, whose history was described previously (3). The flock in 1987 consisted of 16 ewes when the investigation was initiated, and 11 of them had lambs between 16 March and 7 June. Lambing of 7 ewes occurred between 17 March and 15 April and infections of gastrointestinal parasites in them were monitored by determining EPG counts once a week for the period 4 February through 19 August. Some (N = 10) of the lambs (testers) in the flock were euthanatized at periodic intervals (1 to 3 lambs per month) from 15 April through 19 August. At necropsy, data on worm eggs (EPG) (except for the lamb killed on 15 April) and helminths were recorded. Specific details on the tester lambs, relative to the dates of and age at necropsy, are summarized (Table 1).

At necropsy of the tester lambs, the abomasum, small intestine, cecum, and large intestine were examined for immature and adult helminths. Worm egg counts (EPG) on fecal samples and recovery and identification of internal parasites were done according to methods used previously (4).

RESULTS

Nematode EPG counts for the ewes (weekly) and lambs (at necropsy) are graphically shown (Fig. 1). The bulk of the eggs were trichostrongyle type.

For the ewes, EPG counts gradually increased until early April when a dramatic increase occurred, lasting for a period of about a month. However, during the month of highest EPG there was a decline in the middle of the period and an increase again. After late May, the EPG counts declined rapidly and soon returned essentially to prelambing values.

EPG counts at necropsy of the tester lambs were low for the 2 animals examined in May. For the 2 lambs killed in June, EPG increased to over 1,400 for 1 lamb. An unexplained low value EPG count was observed for the lamb examined on 1 July. Markedly higher EPG values (4,200 to 6,680) occurred in the remaining 4 lambs killed in July and August.

Worm-count data for the lambs at necropsy

TABLE 1. Data on species and numbers of helminths* recovered at necropsy of tester lambs (N = 10) in 1987.

	Lamb No. (date killed: age in days)									
Parasite species†	8746 (4/15:23)	8740 (5/13:58)	8742 (5/27:70)	8744 (6/3:74)	8750 (6/17:78)	8741 (7/1:107)	8745 (7/15:116)	8751 (7/29:120)	8752 (8/12:132)	8749 (8/19:140)
Haemonchus contortus (imm.)	0	73	80	40	40	80	380	140	2,320	1,260
Haemonchus contortus	0	0	200	220	460	420	1,660	3,300	10,580	5,320
Ostertagia spp. (imm.)	0	20	0	20	0	60	20	0	40	60
Ostertagia circumcincta ♂	0	60	140	34	20	140	140	60	100	80
Ostertagia trifurcata ♂	0	0	0	7	0	0	20	0	40	0
Ostertagia spp. ♀	0	33	80	67	73	100	280	120	260	60
Trichostrongylus spp. (imm.)	0	0	20	7	40	40	0	20	100	120
Trichostrongylus axei	0	0	0	0	27	40	20	40	240	340
Trichostrongylus colubriformis	0	0	20	20	60	180	340	460	1,760	1,480
Nematodirus spp. (imm.)	0	74	240	67	80	200	120	80	800	420
Nematodirus spathiger ♂	0	33	360	233	520	540	280	620	1,640	1,700
Nematodirus spp. ♀	0	60	320	280	600	880	360	760	1,900	2,400
Cooperia spp. (imm.)	0	0	0	0	0	0	20	20	140	0
Cooperia curticei	0	0	0	0	0	0	40	280	540	660
Strongyloides papillosus	7	7	0	0	0	0	0	20	0	40
Moniezia spp.	0	5	6	5	7	8	2	8	40	106
Trichuris spp. (imm.)§	0	20	120	27	40	20	0	40	20	0
Trichuris ovis	0	25	33	44	116	21	260	397	475	76
Oesophagostomum columbianum	0	0	0	0	0	0	0	0	4	1
All helminths	7	410	1,619	1,071	2,083	2,729	3,942	6,365	20,999	14,123

* All helminths are nematodes except for the flatworm, *Moniezia* spp.
† All nematodes are mature except where noted as immature (imm.); number of nematodes (mature) includes both ♂ and ♀ unless otherwise stated.
§ The immature category for *Trichuris* spp. is arbitrary and based only on being much smaller in size than the other specimens.

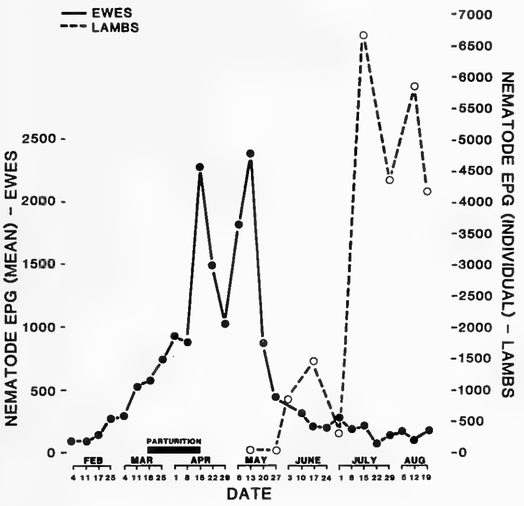


FIG. 1. Periparturient data on nematode eggs per gram of feces (EPG) in ewes (N = 7) (mean for weekly samples) and lambs (N = 9) (single EPG at necropsy) in 1987.

indicate a gradual increase from late May through early July (Table 1). From mid-July through the end of the investigation, worm counts increased more rapidly, with the highest numbers being found in lambs examined in August. The nematodes present in highest numbers were *Haemonchus contortus, Nematodirus spathiger*, and *Trichostrongylus colubriformis*. These 3 species increased in numbers throughout the investigation with the highest values being found in lambs examined in August. Worm counts and EPG counts had general correlation, although the EPG counts for the lamb examined on 1 July were much lower than would be expected according to worm-count data.

DISCUSSION

Worm and EPG counts in tester lambs began manifold increases at about 2 months (in mid-

TABLE 2. Data, including standard error of mean (SEM), on counts of eggs per gram (EPG) of feces for ewes at pre- and postparturition comparable periods in 1986* and 1987.

Parturition (week)	1986 Animals (N)	1986 EPG Avg.	1986 EPG Range	1986 EPG SEM	1987 Animals (N)	1987 EPG Avg.	1987 EPG Range	1987 EPG SEM
−5	1	160	—	±0	7	77	0–360	±49
−4	2	675	390–960	±288	7	74	10–220	±31
−3	5	278	50–490	±88	7	286	0–1,420	±196
−2	4	395	0–860	±227	6	408	10–1,510	±238
−1	8	326	40–1,270	±142	7	646	20–3,160	±431
0	4	188	20–500	±108	7	691	20–2,530	±354
1	11	245	0–990	±99	7	836	40–3,720	±500
2	6	773	90–2,390	±367	7	1,284	70–4,140	±595
3	8	408	10–800	±92	7	1,170	200–3,630	±470
4	6	1,020	80–2,970	±506	7	2,241	230–9,360	±1,242
5	8	824	200–2,590	±295	7	1,961	610–4,640	±555
6	6	908	10–2,420	±469	6	1,422	70–2,280	±327
7	8	1,644	120–4,520	±580	7	1,279	30–5,460	±741
8	7	1,514	0–5,060	±854	7	1,654	0–9,180	±1,294
9	7	1,923	480–7,680	±1,009	7	559	30–2,360	±324
10	6	1,120	20–2,740	±459	7	320	30–1,020	±138
11	7	1,754	50–5,270	±881	6	285	0–780	±126
12	4	1,905	80–4,300	±929	6	312	0–900	±147
13	6	1,320	80–3,790	±731	7	303	0–1,220	±170
14	4	805	40–1,840	±451	7	127	0–490	±71
15	7	834	30–5,500	±791	7	127	10–340	±55
16	5	152	0–630	±122	7	174	0–800	±109
17	6	15	0–60	±9	7	283	0–970	±137
18	5	10	0–20	±5	7	196	30–470	±73
19	5	28	0–120	±23	7	187	10–700	±105
20	1	10	—	±0	7	339	0–1,480	±226
21	1	20	—	±0	6	420	0–1,870	±314
22	1	0	—	±0	7	681	0–3,430	±496

N = number of ewes sampled.
Avg. = average.
* (3).

July) after the highest EPG of ewes that had lambed. The times for these related events were a month or so later than found in 1986 in the same breeding flock (3). This was probably due to the regulated breeding period of the ewes in the fall of 1986. Therefore, lambing of the ewes was somewhat later in starting, and occurred over a shorter period of time in 1987 than in 1986.

EPG-count data for the ewes in the present test were similar in pattern to those observed for 1986. Statistical comparison (SEM) for the data for the 2 years is recorded in Table 2. For the 1987 study, the transient decline in the middle of April is not readily explainable. Possibly, it was due to variability, accentuated because of the low number of test ewes. The epizootiological events in the present investigation provided a more definitive picture of periparturient worm egg production in ewes than in 1986 because of weekly (vs. biweekly) determination of EPG counts.

Likewise, the present research, using a small number of animals, provided further indication in Kentucky of ewes in the spring as an important source of nematode infections in the gastrointestinal tract of lambs (1, 2). Increased numbers of nematode eggs, voided by the lambing ewes during the periparturient period, contaminate the pastures and provide infective larvae for ingestion by grazing lambs.

ACKNOWLEDGMENTS

The investigation reported in this paper (No. 88-4-225) was made in connection with a project of the Kentucky Agricultural Experiment Station and is published with the approval of the director.

LITERATURE CITED

1. Michel, J. F. 1974. Arrested development of nematodes and some related phenomena. Adv. Parasit. 12:279–366.

2. Herd, R. P., R. H. Streitel, K. E. McClure, and C. F. Parker. 1983. Control of periparturient rise in worm egg counts of lambing ewes. J. Am. Vet. Med. Assoc. 182: 375–379.

3. Lyons, Eugene T., J. Harold Drudge, and Sharon C. Tolliver. 1987. Epizootiology of internal parasites in lambs and ewes during the periparturient period in Kentucky in 1986. Proc. Helm. Soc. Wash. 54:233–236.

4. Drudge, J. H. and J. Szanto. 1963. Controlled test of the anthelmintic activity of thiabendazole and an organic phosphate (CL 38,023) in lambs. Am. J. Vet. Res. 24:337–342.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 19–25

Observations on the Common Horse Bot (*Gasterophilus intestinalis*) (Diptera: Gasterophilidae): Incomplete Molting of a Second Instar Specimen

EUGENE T. LYONS, SHARON C. TOLLIVER, AND SHELBY STAMPER

Department of Veterinary Science, Gluck Equine Research Center, University of Kentucky, Lexington, Kentucky 40546-0099

ABSTRACT

Description and illustration are given of a specimen of the third instar of the common horse bot (*Gasterophilus intestinalis*) with the cast-off cuticle of the second instar attached at 2 places. It was recovered from the stomach of a dead 4-month-old horse along with 1 second instar *G. intestinalis* on 14 August 1991.

Horse bots are ubiquitous parasitic insects. There are 2 main species, the common horse bot (*Gasterophilus intestinalis*) and the throat bot (*Gasterophilus nasalis*), in equids in the U.S.A. Bots spend the bulk of their life span inside these animals as larvae (1st, 2nd, and 3rd instars). The primary location in equids is the stomach for the common bot and duodenum for the throat bot (1).

The life cycle is similar for all species of bots. Bot flies lay eggs on the hairs of equids (Fig. 1)—mainly on the forelegs for *G. intestinalis* and lower jaws for *G. nasalis*. After at least 1 week of incubation, 1st stage larvae hatch from the eggs in response to licking by the equid (*G. intestinalis*) (Fig. 2) or spontaneously (*G. nasalis*); shortly thereafter, they enter the mouth.

Larvae spend about 1 month in the tissues of the mouth undergoing development, and then are swallowed as 2nd instars (Fig. 2). The final molt to 3rd instars occurs after an additional month (Fig. 2). After a maximum of about 10 months in the equid, bot fly larvae pass as 3rd instars in the feces, pupate, and the adult flies emerge in a few weeks.

During an examination of the stomach of a dead 4-month-old horse (mixed lighthorse) suckling on 14 August 1991, two specimens of *G. intestinalis* were found. One was a 2nd instar. The other, a 3rd instar with the cuticle of the 2nd instar partially attached. The latter specimen is described because thousands of horse bots have been examined over several years by the present authors, but this type of occurrence has not been observed previously (E. T. Lyons, University of Kentucky, pers. comm.).

Morphological features of the present specimen are illustrated (Figs. 3, 4, and 5) and include the following: The cuticle of the 2nd instar is attached by structures (probably parts of the respiratory system) at 2 locations to the 3rd instar: (1) a few strands of tissue connect the spiracular plates of the 2nd instar cuticle to the area of 1 spiracular plate of the 3rd instar, and (2) a tubular structure is attached laterally to the 11th segment of the 2nd instar cuticle and last row of spines of the 3rd instar.

The cuticle of the 2nd instar is turned inside out except at the anterior end. There is a linear opening in the ventral midline, extending between segments 1 and 9 (through segments 2 and 8, inclusive). The cuticle is folded over on the edges of the opening. Between segment 1 and approximately the 3rd and 4th segments, the opening appears to be dorsal. However, in this area, the cuticle is not turned inside out. Apparently, the anterior end was reinverted with the normal side out during emergence of the 3rd instar; or, it never was turned inside out.

On the inside of the cuticle of the 2nd instar are several strands that are attached at one end; the other end is free. Exact nature of these remnants of the 2nd instar is uncertain, but it is likely that they are nonfunctional spiracular filaments (2). It has been suggested that the attachment of the internal tracheae to the nonfunctional spiracles is important to the process of the removal of the ecdysed 2nd instar tracheal system (2). The respiratory system of *G. intestinalis* first instars in metapneustic and second and third instars is amphipneustic (3).

The morphological details of the 2nd instar cuticle and its attachment to the 3rd instar

FIG. 1. *Gasterophilus intestinalis* from a horse: egg containing 1st instar and attached to a hair from the leg (20×).

FIG. 2. *Gasterophilus intestinalis* from a horse: 1st, 2nd, and 3rd instars (ventral side). Left to right—1st instar from an egg and from the mouth, 2nd instar from lesion around the teeth and from the stomach, and 3rd instar from the stomach (7.5×).

FIG. 3. Whole specimen of *Gasterophilus intestinalis*, 3rd instar (dorsal view) and cuticle of 2nd instar turned partially inside out (7.5×). Strands, probably part of the respiratory system, are evident (see arrow).

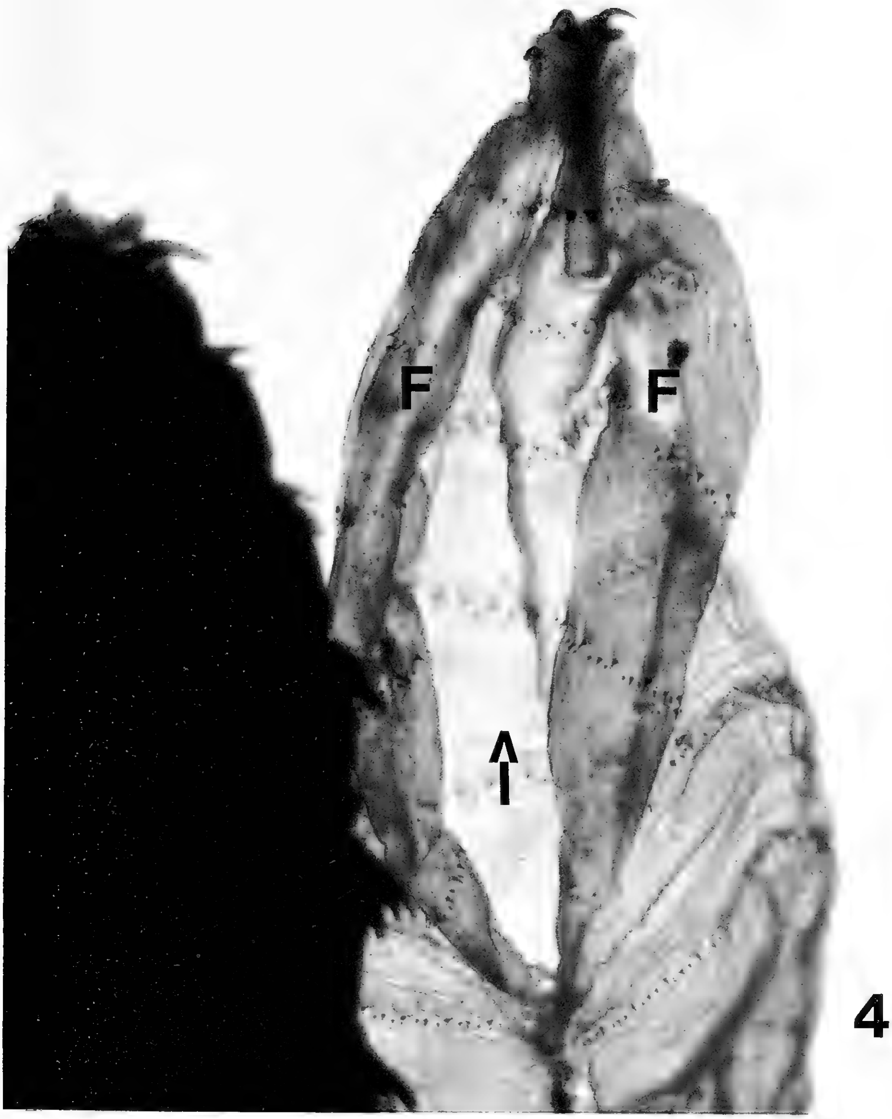


FIG. 4. Anterior end of *Gasterophilus intestinalis*, 3rd instar (partial) (dorsal view) and cuticle of 2nd instar (view is ventral except extreme anterior end is dorsal) (20×). The linear opening (arrow) of the 2nd instar cuticle where the 3rd instar emerged and the folds (F) are obvious.

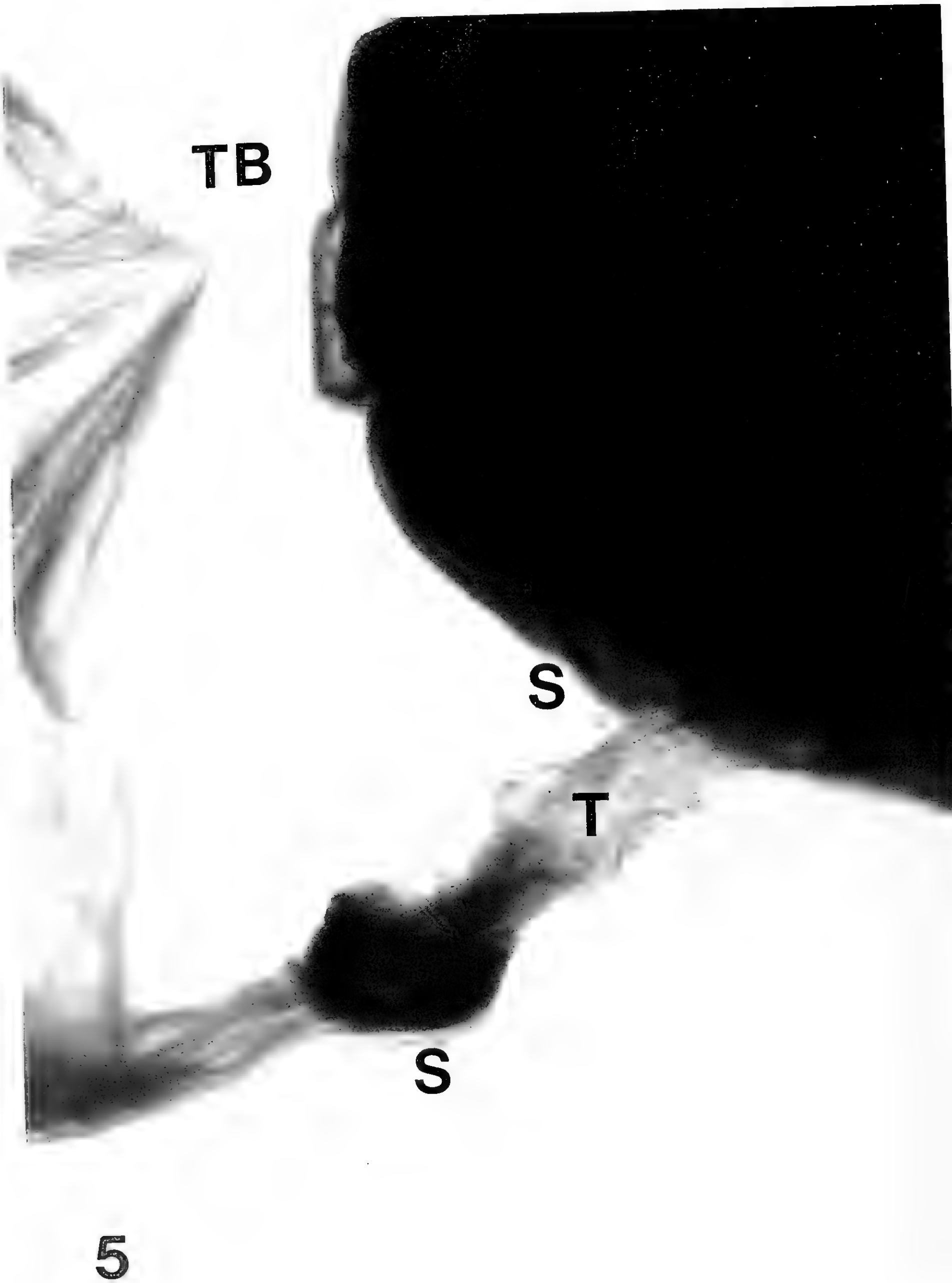


FIG. 5. Posterior ends (partial) of *Gasterophilus intestinalis*, 3rd instar (ventral view) and cuticle of 2nd instar (40×). Note: 2 attachment sites of cuticle of 2nd instar (left) to 3rd instar (right)—tags (T) of tissue connecting spiracles (S) of both instars and a tubular structure (TB).

have been described for the specimen *in situ*. It is unknown whether the 3rd instar was found just at the end of a normal ecdysis, or some abnormality existed so that separation of the 2nd instar cuticle would not have been completed even after a longer period of time.

The 3rd instar appeared normal. It is assumed that the manner of escape of this stage through the 2nd instar cuticle was typical. However, the failure to completely separate may be atypical.

ACKNOWLEDGMENTS

The investigation reported in this paper (No. 91-4-194) was made in connection with a project of the Kentucky Agricultural Experiment Station and is published with the approval of the director.

Appreciation is expressed to Dr. Douglas Dahlman, Department of Entomology, University of Kentucky, for his advice in writing the manuscript and evaluating the bot specimen.

LITERATURE CITED

1. Drudge, J. H. and E. T. Lyons. 1983. Bots. Pp. 283–286. In N. E. Robinson (ed.) Current therapy in equine medicine. W. B. Saunders Co., Philadelphia, Pennsylvania.
2. Hinton, H. E. 1947. On the reduction of functional spiracles in the aquatic larvae of the Holometabola, with notes on the moulting process of spiracles. Trans. Royal Entomol. Soc. London 98:449–473.
3. Klein, D. 1944. Respiratory systems and respiratory adaptations in larvae and pupae of Diptera. Parasitol. 36: 1–66.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 26–28

Bark Girdling by Herbivores as a Potential Biological Control of Black Locust (*Robinia pseudoacacia*) in Power-Line Corridors

James O. Luken, Steven W. Beiting, Scott K. Kareth, Robyn L. Kumler, Jun H. Liu, and Craig A. Seither

Department of Biological Sciences, Northern Kentucky University, Highland Heights, Kentucky 41099-0400

Abstract

Experimental plots were established in a Clermont County, Ohio power-line corridor to assess the effects of different herbicides on tree mortality, but a fortuitous influence on tree populations was observed. Herbivores, probably cottontail rabbits (*Sylvilagus floridanus*), girdled 36% of black locust (*Robinia pseudoacacia*) stems. Other tree and shrub species were avoided. On control plots (not sprayed with herbicides), 87% of black locust mortality was due to girdling. Encouraging high and persistent populations of herbivores in or adjacent to power-line corridors may be an efficient biological control of unwanted tree populations.

Introduction

Power-line corridors are common elements of urban, exurban, and rural landscapes (1). These linear openings exist solely to accommodate electric transmission lines and towers. Where corridors traverse forest patches, line managers constantly strive to inhibit or eliminate tree populations, because trees interfere with line function and maintenance. Herbicide spraying, mechanical mowing, and manual cutting have all been used in corridors to inhibit tree growth and forest regeneration (2, 3, 4).

Biological control of tree populations in power-line corridors is an alternative management approach. Most research in this area has centered on plant/plant competitive interactions (5, 6, 7, 8). Few have considered the possibility that plant/herbivore interactions could contribute to tree control.

In this paper, we present data on bark girdling of black locust (*Robinia pseudoacacia*) by herbivores. Efforts to augment this natural process could lead to more efficient and less environmentally damaging management techniques for vegetation in power-line corridors.

Methods

The study site was a power-line corridor in Clermont County, Ohio, near the Zimmer Power Plant. Vegetation in this corridor was last cut with a mechanical mowing machine during spring 1989. Regenerating plant communities that dominated this site in spring 1991 were characterized by the following woody species: black locust, sycamore (*Platanus occidentalis*), white ash (*Fraxinus americana*), redbud (*Cercis canadensis*), smooth sumac (*Rhus glabra*), sassafras (*Sassafras albidum*), black cherry (*Prunus serotina*), and spicebush (*Lindera benzoin*).

During spring 1990, vegetation in one-half of the corridor was recut at ground-level with a mechanical mowing machine. Fifty experimental plots (15.2 m × 15.2 m) were established, 25 in the recently cut area and 25 in the one-year-old vegetation. During August 1990, 4 different herbicides were applied to 40 of the plots. The remaining 10 plots were left as controls. At the time of herbicide application, it was noted that large numbers of black locust stems were girdled, but stem mortality was not yet evident.

In spring 1991, data were recorded for every woody plant stem found in the experimental plots. All stems were noted according to experimental plot number, species, stem diameter, whether the stem was alive or dead, and whether the stem was girdled or not. In October 1991, we collected bark tissue from black locust, redbud, and sycamore trees. This tissue was analyzed for total nitrogen using the microkjeldahl technique.

We compared the size-class distributions of girdled and ungirdled black locust stems with a Kolmogorov-Smirnov test. Differences in nitrogen content were detected on square root transformed data with a one-way analysis of variance. Specific differences among means were determined with Tukey's test.

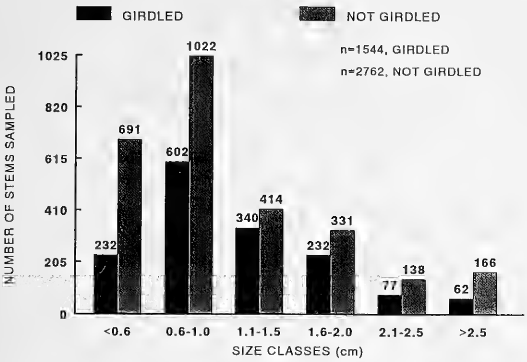


FIG. 1. Size-class distributions of black locust stems found in all plots of an herbicide efficacy experiment.

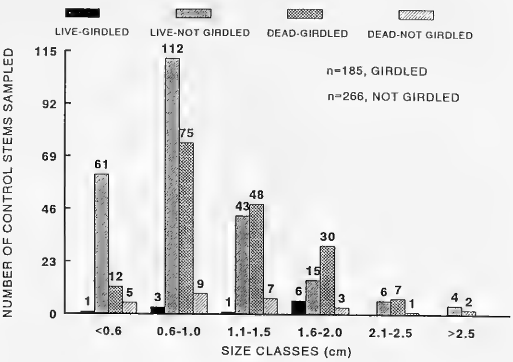


FIG. 2. Size-class distributions and physiological conditions of black locust stems found in control (unsprayed) plots of a herbicide efficacy experiment.

RESULTS

Of the 8 woody plant species found in the study sites, black locust was the only species showing evidence of bark girdling. Stems were typically girdled from the soil surface to 80 cm from the soil surface. Of the 4,306 black locust stems measured in all study plots, 36% were girdled. The size-class distribution of girdled stems was similar to that of ungirdled stems (Fig. 1). When these data were calculated as percentages of stems sampled, the distributions were not significantly ($P > 0.05$) different. Forty-one percent of black locust stems in control plots were girdled and 87% of black locust mortality was due to girdling (Fig. 2).

The nitrogen content of black locust bark was significantly ($P < 0.05$) higher than that of sycamore or redbud bark. Mean percentages $\pm$ standard error, $N = 3$ are as follows: sycamore 0.88 $\pm$ 0.13, redbud 1.04 $\pm$ 0.09, and black locust 2.75 $\pm$ 0.25.

DISCUSSION

The animal responsible for girdling black locust is unknown. However, because of the height and configuration of girdled zones on the stems (9), and because bark is a common component of the cottontail rabbit (*Sylvilagus floridanus*) diet (10), it is hypothesized that cottontail rabbits are responsible. Woodchucks (*Marmota monax*) and voles (*Microtus* spp.) might also be implicated, but the woodchuck diet does not commonly include bark (11), and girdled zones on stems were well beyond the reach of voles.

Bryant and Kuropat (12) maintained that browsing animals avoid plant tissues with high concentrations of secondary chemical constituents and do not select winter forage on the basis of proximal nutrient content. In contrast, other researchers have suggested that rabbits and hares do select woody tissue with the highest nitrogen (protein) content (13, 14). Black locust has nearly 3 times the amount of bark nitrogen than redbud or sycamore, but it is unknown if monospecific girdling is the result of this high nitrogen content or is due to the fact that other tree species have higher concentrations of secondary chemicals in the bark. Clearly, more research is needed in this area of plant/herbivore interaction because black locust bark is readily used as a food source but it is also toxic to livestock and humans due to the presence of a proteinaceous phytotoxin (15).

The fact that herbivores do selectively girdle black locust has implications for biological control. Black locust is the premier problem tree in power-line corridors, especially those with a history of repeated mowing (4). It is also considered a weed in nature reserves (16). By encouraging high and persistent populations of rabbits in or adjacent to power-line corridors, it is possible that management costs could be reduced. Such a biological control effort should be approached cautiously because rabbits are also implicated in damage to orchards and grainfields (9, 17).

ACKNOWLEDGMENTS

Financial support for this project was provided by Cincinnati Gas and Electric Company. We thank Dr. Debra Pearce for assistance with the nitrogen analyses.

LITERATURE CITED

1. Forman, R. T. T and M. Godron. 1986. Landscape ecology. John Wiley and Sons, New York.

2. Bramble, W. C. and W. R. Byrnes. 1983. Thirty years of research on development of plant cover on an electric transmission right-of-way. J. Arboric. 9:67–74.

3. Dreyer, G. D. and W. A. Niering. 1986. Evaluation of two herbicide techniques on electric transmission right-of-way: development of relatively stable shrublands. Environ. Manage. 10:113–118.

4. Luken, J. O., A. C. Hinton, and D. G. Baker. 1991. Assessment of frequent cutting as a plant-community management technique in power-line corridors. Environ. Manage. 15:381–388.

5. Niering, W. A. and R. H. Goodwin. 1974. Creation of relatively stable shrublands with herbicides: arresting succession on rights-of-way and pastureland. Ecology 55: 784–795.

6. Bramble, W. C., W. R. Byrnes, and R. J. Hutnik. 1990. Resistance of plant cover types to tree seedling invasion on an electric transmission right-of-way. J. Arboric. 16:130–135.

7. Pound, C. E., and F. E. Egler. 1953. Brush control in southeastern New York: Fifteen years of stable treeless communities. Ecology 34:63–73.

8. Luken, J. O. 1990. Directing ecological succession. Chapman and Hall, London.

9. Barnes, T. G. 1990. Managing rabbit and vole problems in Kentucky orchards. Univ. Ky. Coll. Ag. Rep. For-43, 5 pp.

10. Haugen, A. D. 1942. Life history studies of the cottontail rabbit in southwestern Michigan. Am. Midl. Nat. 28:204–244.

11. Grizzell, R. A. 1955. A study of the southern woodchuck, *Marmota monax monax*. Am. Midl. Nat. 53:257–293

12. Bryant, J. P. and P. J. Kuropat. 1980. Selection of winter forage by subarctic browsing vertebrates: the role of plant chemistry. Ann. Rev. Ecol. Syst. 11:261–285.

13. Miller, G. R. 1968. Evidence for selective feeding on fertilized plots by grouse, hares and rabbits. J. Wildl. Manage. 32:849–853.

14. Lindlöf, B., E. Lindström, and A. Pehrson. 1974. Nutrient content in relation to food preferred by mountain hare. J. Wildl. Manage. 38:875–879.

15. Hardin, J. W. 1961. Poisonous plants of North Carolina. Ag. Exp. Sta. North Carolina State Coll., Bull. No. 414.

16. Vegetation management manual. 1990. Illinois Nature Preserves Commission, Springfield, Illinois. Vol. 1. Nos. 2–27.

17. Anthony, R. B. and A. R. Fisher. 1977. Wildlife damage in orchards—a need for better management. Wildl. Soc. Bull. 5:107–112.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 29–38

Natural Plant Communities of Hopkins County, Kentucky

JULIAN CAMPBELL

The Nature Conservancy, Kentucky Field Office, 642 West Main Street, Lexington, Kentucky 40508

AND

JEFF GRUBBS

Division of Water, Kentucky Environmental Protection Agency,
18 Reilly Road, Ash Building, Frankfort, Kentucky 40601

ABSTRACT

A survey of Hopkins County was conducted in order to characterize the natural plant communities and to find the best remaining examples. This effort relied on aerial photographs, aerial reconnaissance, and field trips to selected sites. Vegetation patterns are interpreted in relation to Soil Conservation Service data. Species composition is outlined for each community, including reference to rare species. Some classification problems are discussed.

INTRODUCTION

This study is part of the ongoing effort by the Nature Conservancy and Kentucky State Nature Preserves Commission (KSNPC) to identify the best remaining examples of different natural ecosystems in the state. Variation in plant communities is receiving special attention. The inventory is progressing county by county, with the intent of completion in the next 5–10 years. The wetlands of Hopkins County are among the largest in the state; several have been studied previously by Harker et al. (1, 2). In the survey reported below, some of these wetlands were revisited, and uplands were also explored. The results indicate what plant communities exist in the county, and what sites deserve most urgent conservation action.

Human disturbance and destruction of natural vegetation in Hopkins County has increased greatly in the past few decades. Most of the flatter uplands have been farmed for over 100 years, but large bottomland areas remained forested until clearance and drainage accelerated after 1950. On the Pond and Green river bottoms, in particular, more than 10,000 acres (4,000 ha) were forested in the 1950s, but at least 75% has now been converted to cropland (see USGS Topographic Quadrangles and KSNPC aerial photographs). The other major disturbance is strip-mining for coal, which has removed over 10% of the natural soils (3), and has caused much sedimentation and pollution in the wetlands.

In addition to describing some of the best remaining natural areas in the county, this report discusses apparent ecological relationships, with special attention to wet and dry extremes, and possible seasonal fluctuations. Understanding the causes of variation in natural vegetation will help in developing a truly ecological (functional) classification, in selecting the best examples, and in implementing management for conservation.

The Study Area

Hopkins County lies entirely within the Shawnee Hills, in its strictest sense, which has also been called the "Western Coal Field" in Kentucky (4). The bedrock is all of Pennsylvanian age, consisting of shale, siltstone and sandstone with minor amounts of coal and limestone (USGS Geological Quadrangles). Overlying most of these gently rolling hills and broad valleys is a mantle of loess, i.e., calcareous silt blown in during glacial eras from large river valleys to the west. Probably due to this loess (3), most soils are only moderately acid (alfisols), in contrast to the Appalachian Plateau soils on similar bedrock (ultisols). The northern half of the county lies among less rugged hills, where uplands are mostly on Upper Pennsylvanian rocks, with less extensive sandstone. Loess deposits tend to be thicker in the north, and upland soils are mostly somewhat poorly drained (fragiudalfs) as opposed to well-drained (hapludalfs). There is also a

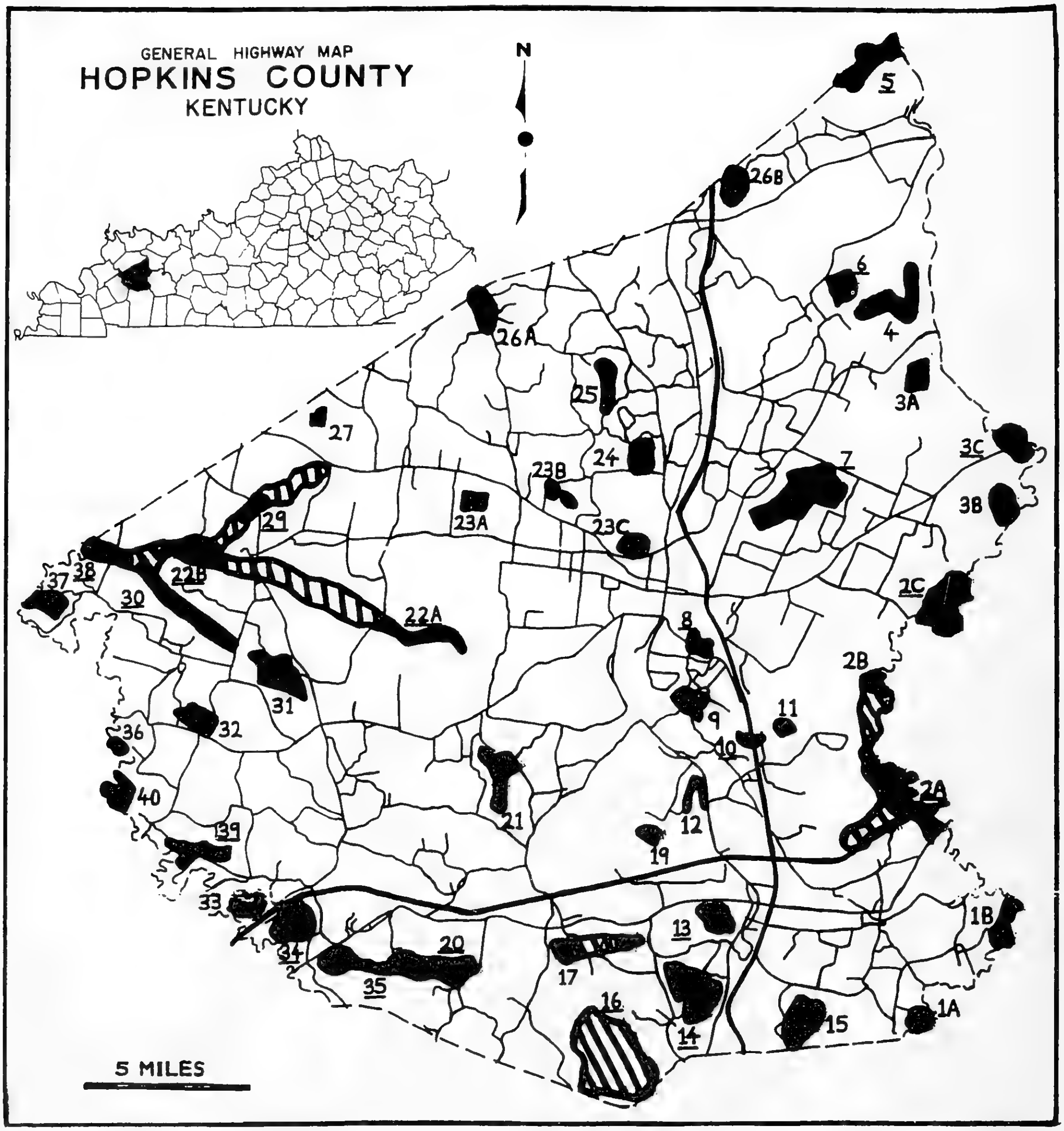


FIG. 1. Map of Hopkins County, Kentucky, showing roads (from 1990 Dept. of Transportation road map) and "potential natural areas" (PNAs) inspected during this study. The underlined numbers indicate PNAs that were checked on the ground in addition to aerial reconnaissance. Hatched areas do not have special natural quality other than their large acreage and potential importance for connecting better sites.

greater extent and variety of bottomland soils, covering huge terraces of the Green and Ohio rivers (3).

Early descriptions, and ecological inference, suggest that almost all of the county was forested before settlement, except, perhaps, the wettest and driest extremes (4, 5, 6, 7). Abundant trees included *Quercus alba*, *Q. velutina* and *Carya* spp. on drier sites; *Fagus grandifolia* and *Acer saccharum* on moister sites; bottomland *Quercus* spp., *Liquidambar styraciflua* and probably *A. rubrum* on wetter sites. Some trees typical of the Mississippian Embayment approach their northern limits here, e.g., *Q. pagoda*, *Q. michauxii*, *Carya illinoensis* and *C. aquatica*. The dominants of deep southern swamps—*Taxodium distichum* and *Nyssa aquatica*—are unknown from the county, though the former still occurs in McClean and Muhlenberg counties to the east. In the

UPLAND SOILS

no loess sewd
LITHIC DYSTROCHREPT
Ramsey lom
30-50 1-2 1-2

no loess wd
TYPIC DYSTROCHREPT
Steinsburg lom
20-30 2-3 1-2

thin loess wd/mwd
TYPIC FRAGIUDALF
Zanesville sil
2-20 5-8 1-2

thin loess mwd
GLOSSIC FRAGIUDALF
Sadler sil
2-6 5-8 1-2

no loess wd
VERTIC HAPLUDALF
Lenberg sil
12-30 2-3 1-2

thin loess wd
ULTIC HAPLUDALF
Wellston sil
6-20 3-5 1-2

thick loess mwd
GLOSSIC FRAGIUDALF
Grenada sil
2-6 5-10 1-2

thin loess wd
ULTIC HAPLUDALF
Frondorf sil
12-30 2-3 1-2

thick loess mwd
TYPIC FRAGIUDALF
Loring sil
2-12 5-10+ 1-2

thick loess spd
GLOSSIC FRAGIUDALF
Calloway sil
0-2 5-10+ 2-3

clay slack wd/mwd
TYPIC HAPLUDALF
Markland sic
6-12 6-12+ 2

mixed all. wd/mwd
TYPIC FRAGIUDALF
Otwell sil
2-6 >10 1-2

mixed all. spd
AERIC FRAGIUQUALF
Weinbach sil
0-2 >10 1-2

mixed all. wd
FLUV. DYSTROCHREPT
Cuba sil
0-2 >10 1-2

loess all. mwd
AQUIC UDIFLUVENT
Collins sil
0-2 >10 1-2

clay slack spd
AERIC OCHRAQUALF
McGary lom/sil
0-2 6-12+ 1-3

mixed all. mwd
FLUV. DYSTROCHREPT
Steff sil
0-2 >12 1-2

loess all. spd
AERIC FLUVAQUENT
Belknap sil
0-2 >12 1-2

clay slack pd
VERTIC HAPLAQUEPT
Karnak sil/sic
0-2 >12 3-4

mixed all. spd
AERIC FLUVAQUENT
Stendal sil
0-2 >12 1-3

loess all. pd
TYPIC FLUVAQUENT
Waverly sil
0-2 >12 1-2

mixed all. pd
TYPIC FLUVAQUENT
Bonnie sil
0-2 >12 1-2

LOWLAND SOILS

FIG. 2. Soil series of Hopkins County arranged according to natural gradients. All data are from Fehr et al. (3), and are condensed here in a way that enables overlays for individual characteristics to be readily generated. The terminology follows standard Soil Conservation Service usage. Terms and symbols in the four-line characterizations of each soil series are as follows: First line: *Left:* parent material; no loess = bedrock alone; thin loess = less than 1.2 m thick; thick loess = over 1.2 m thick; clay slack = clayey slack-water deposits; mixed all. = alluvium from bedrock and loess; loess all. = alluvium derived mostly from loess. *Right:* wd = well drained; sewd = somewhat excessively well drained; mwd = moderately well drained; spd = somewhat poorly drained; pd = poorly drained. Second line: Classification of National Cooperative Soil Survey. Third line: Soil series name, with typical A horizon texture: sil = silt loam; lom = loam; sic = silty clay loam. Fourth line: Left numbers = typical slope percent; Central numbers = typical depth to bedrock in feet; Right numbers = typical A horizon pH (unlimed): 1 = 4.5–5; 2 = 5–5.5; 3 = 5.5–6; 4 = 6–6.5.

absence of these 2 species, land that is too wet for closed hardwood forest is occupied by more or less open marshes, sloughs and ponds. These areas include some of the most extensive wetlands in the Shawnee Hills. The wetlands and adjacent forests have several rare plants, as detailed below, and these areas are also essential habitat for most rare animals known from the county or its immediate environs (8): fishes (cypress minnow, lake chubsucker, spotted sunfish, stargazing minnow); an amphibian (bird-voiced treefrog); reptiles (copperbelly watersnake, mudsnake—cottonmouth snake is also notable here at its range margin); and birds (American bittern, least bittern, great blue heron, pied-billed grebe). Most of these plants and animals are southern species, here near the northern edge of their Mississippi Valley ranges. No species currently listed or proposed for federal protection are known to reside in the county.

METHODS

About 40 "Potential Natural Areas" (PNAs) were identified by the senior author from aerial photographs taken in the summer of 1980 for the Kentucky State Nature Preserves Commission (Fig. 1). Compared to some other regions of the state, the threshold for "natural quality" was lowered substantially to select these 40 sites. This selection included the few areas that appeared to have forest of uniform commercial maturity, with trees ca. 75–100 years old (PNAs 6/10/29). However, most areas appeared to have younger forests, up to 30–60 years old, with only scattered older trees. Given this general immaturity, other sites were selected simply due to their having relatively large areas free from mining or recent logging. A particular effort was made to cover upland and bottomland about equally, and to include representative areas from all kinds of topography and soils (3).

On 19 June 1991, the 40 PNAs were inspected by the senior author by flying over the country in a small airplane (172 Cesna). This revealed any major disturbance or destruction of sites since 1980, and it allowed better assessment of tree sizes and other natural features in remaining sites. About 15 sites were finally selected for field visits, including sites with particularly mature forest, and maintaining topographic variety. These sites were visited in July 1991. Several of these sites, and some others, had been visited also by the second author during 1989. On the ground, notes were made on forest maturity and the most frequent species. Rare plant species were looked for, and vouched by collections deposited at the University of Kentucky. However, complete floristic lists were not attempted. Field notes of the senior author are deposited at the Kentucky State Nature Preserves office in Frankfort; those of the second author are available at his address. Field notes from KSNPC (1, 2) and other sources (especially Hal Bryan and R. Mohlenbrock, pers. comm., from PNA 2C) are also referred to below.

In order to examine the relationship of vegetation to soils, the USDA Soil Survey of Hopkins County (3) was analyzed in order to display the major gradients in soil conditions. Ecological features of each soil series were used to arrange them in a two-dimensional scheme that places similar soils close to each other (Fig. 2). On this scheme was then overlayed the pattern of forest types most frequently associated with each soil series (Fig. 3). All soil terminology below follows the above reference.

The term "old growth," as used in this report, refers to those few sites where most canopy trees exceed 75–100 years old, i.e., about 50–75 cm dbh (diameter at breast height) on bottomland or 40–60 cm dbh on uplands. "Maturing forest" refers to areas that appear to be in this transitional range of ages and sizes. Botanical nomenclature generally follows Fernald (9), though with a few changes used by Kartesz and Kartesz (10; see also 11).

Results: Notes on Community Types

Each community heading below is followed by the corresponding type code in Allard's (12) regional "Natural Community" classification (codes in parentheses are transitional or mixed types). Species lists in this section are not meant to be complete, but indicate only some of the more common, characteristic and rare species in each community type. Asterisks (*) indicate relatively rare species in Kentucky that have been listed by KSNPC (13), or may warrant consideration.

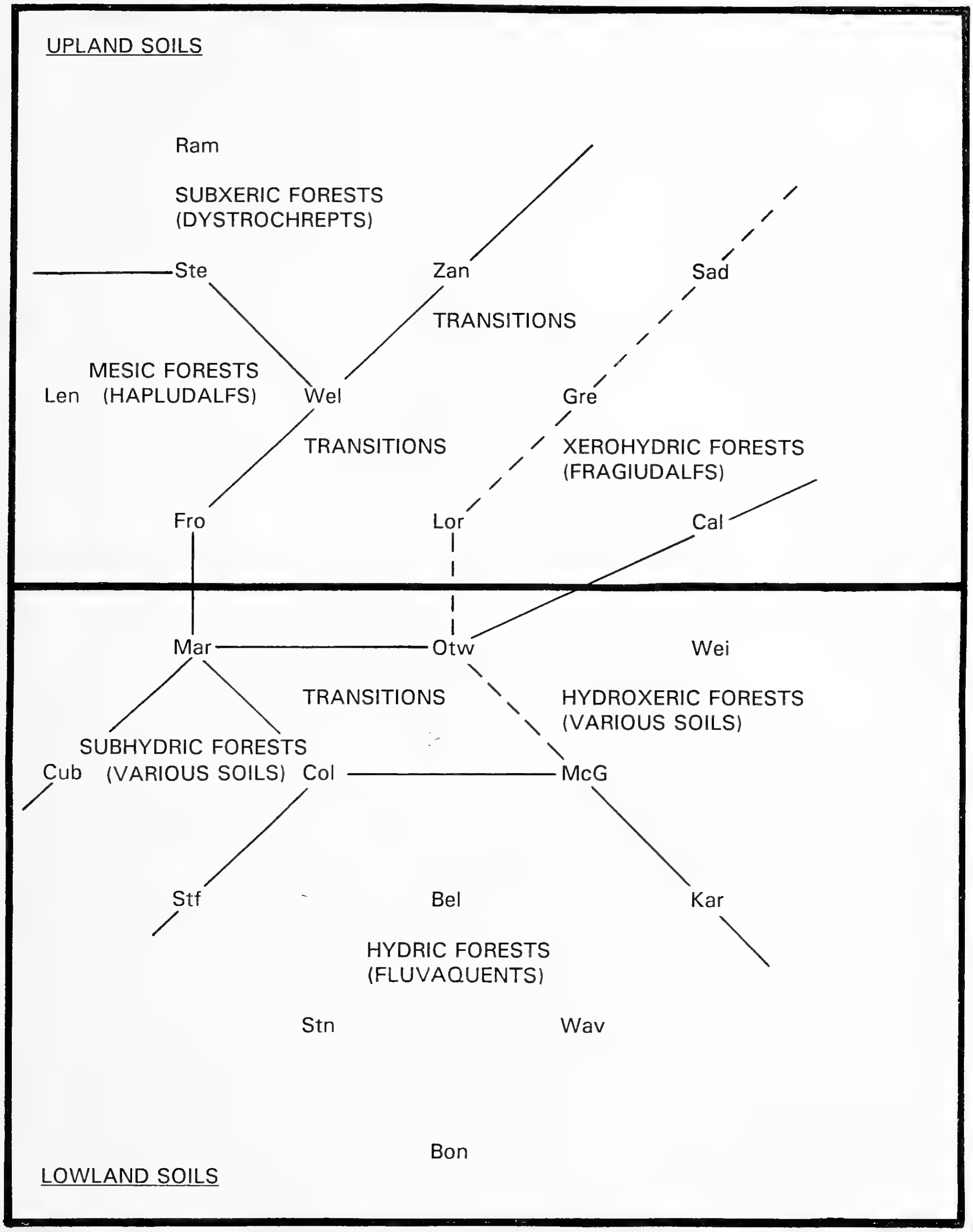


FIG. 3. Major forest types associated with each soil series. This is an overlay for Figure 2, with the same arrangement of soil series, abbreviated by their first three letters. Forest types and typical soil classes are shown in upper case. Forest types are based on data from the ca. 15 sites visited during this study. The most characteristic types are shown for each soil series; contacts and transitions are indicated by more than one type sharing a soil series.

Upland Communities

1. *Moist (mesic) forest:* IA5d(/e). This is typically located on well-drained soils that are relatively base-rich (hapludalfs), especially on lower slopes (6–30%) and on north or east aspects. Bedrock is at 2–5 ft (0.6–1.5 m) depth, and in some areas there is a thin loess cover. Common species include *Fagus grandifolia, Acer saccharum, Liriodendron tulipifera, Carpinus caroliniana, Asimina triloba* and *Lindera benzoin*. Also typical are *Quercus rubra, Juglans nigra, Fraxinus americana, Ulmus rubra* and *Morus rubra*. Ground vegetation includes *Polystichum acrostichoides, Podophyllum peltatum, Asarum canadense, Circaea canadensis, Mitchella repens, Galium triflorum, G. concinnum, Eupatorium rugosum, Polygonatum biflorum, Carex laxiflora* and *Brachyelytrum erectum*. The rare *Cimicifuga rubifolia**, *Hydrastis canadensis** and *Panax quinquefolius** have been found at an old-growth site in adjacent Caldwell County (1).

Best examples. No old-growth was found. Small 1–10 acre (0.4–4 ha) remnants of maturing forest occur on moister sites within some larger upland areas (e.g., PNAs 8/1/34/35).

2. *Moderately dry (subxeric) forest:* IA7i(/c/d). This is typically located on well- or somewhat excessively well-drained soils with relatively low base-status (dystrochrepts), especially on steeper slopes (20–50%) and on south or west aspects. Bedrock is at 1–2 ft (0.3–0.6 m) depth, and there is little or no loess. *Quercus alba* is frequent in this forest type, and may have been dominant before logging. In 1884, DeFriese (6) noted this species "all along the streams and the foot-hills and on low grounds generally. In many localities, even the hilltops are covered with it; but, generally speaking, it does not extend high up the hill-sides." Other species include *Q. velutina*, which increased greatly after logging (6), and lesser amounts of *Carya* spp. (especially *C. glabra*), *Acer rubrum, Nyssa sylvatica, Sassafras albidum, Cornus florida, Ostrya virginiana* and *Oxydendron arboreum*. *Quercus coccinea* and *Vaccinium arboreum* occur on more rocky ground, where the tree canopy is locally open. *Pinus virginiana* is locally abundant in younger stands, but it was apparently rare or absent before settlement (6, 7). In some transitions to moister forests (e.g., PNA 13), *Acer saccharum* dominates the understory, perhaps replacing the *Quercus* spp. in areas without fire or other disturbance. A different kind of transition was noted by DeFriese (6) as a "splendid belt of timbers" on relatively moist soil, corresponding to the Middle Pennsylvanian Carbondale Formation, with *Q. alba*, "*Q. heterophylla*" [*Q. pagoda*?], *Q. velutina, Carya* spp., *Liriodendron, Juglans nigra, Fraxinus americana* and *F. quadrangulata* [unvouched?]. Ground vegetation is generally sparse, except in disturbed areas with frequent *Rhus radicans* and the exotic *Lonicera japonica*. Typical species include *Porteranthus stipulatus, Desmodium nudiflorum, Ascyrum hypericoides, Aureolaria laevigata, Monarda bradburiana, Cunila origanoides, Houstonia tenuifolia, Galium circaezans, Solidago caesia, S. erecta, Aster undulatus, Helianthus microcephalus, Antennaria plantaginifolia, Carex digitalis, C. wildenovii, C.* Section *Montanae, Bromus purgans, Panicum commutatum* and *P. dichotomum*.

Best examples. There are 1,000s of forested acres that have not yet been mined, but few areas even approach old-growth status. A few areas are slightly more mature than average (PNAs 8/11/13), and a few are notable for their large contiguous acreage (PNAs 14/16).

3. *Dry-wet fluctuating (xerohydric) forest:* IA7c(/?). This appears to have been widespread, typically on gentler slopes (0–20%) with moderately well-drained soils containing a fragipan (fragiudalfs). Bedrock is at 5–10 ft (1.5–3 m) depth, and loess is present, often over 3 ft (1 m) deep. The forest is virtually all converted to farmland today. *Quercus stellata* (post oak) was the most typical tree; in 1884, DeFriese (6) noted that "post oak is plenty, covering all the hills through this part of Kentucky, and extending far down toward the foot-hills." Other characteristic species in modern remnants may include *Q. falcata, Q. marilandica, Carya tomentosa, Ulmus alatus, Corylus americana* and *Symphoricarpos occidentalis*. However, there is much mixture with other forest types. On the better drained land, now most intensively farmed, transitions to moister (mesic or subhydric) forest appear to have had much *Q. pagoda*, since trees up to 3–4 ft dbh (1 m) are frequently seen along roads and in

woodlots. Wetter sites appear to have had more *Acer rubrum*, *Liquidambar*, some *Q. palustris* and occasional *Q. imbricaria*.

Drier sites may have had sparse tree canopy. On Pennsylvanian shales in nearby Union County, R. Peter (in 5: vol. 2, p. 266; vol. 3, p. 402) noted "remarkable flat post oak glades." Judging from the few wooded remnants, adjacent rights-of-way and old fields, post oak forest in Hopkins County may indeed have been open in places. Some of the species in native grasslands are *Desmodium* spp., *Lespedeza* spp. (including *L. capitata**), *Strophostyles umbellata*, *Tephrosia virginiana*, *Crotonopsis elliptica**, *Monarda fistulosa*, *Hypericum denticulatum* var. *recognitum*, *Phlox pilosa*, *Pycnanthemum* spp., *Diodia teres*, *Galium pilosum*, *Liatris squarrosa*, *Helianthus* spp., *Eupatorium* spp., *Solidago nemoralis*, *Carex hirsutella*, *C. gravida*, *Danthonia spicata*, *Elymus glabriflorus*, *Panicum* spp. (including *P. longiligulatum**), *Andropogon scoparius*, *A. gerardii*, *Erianthus alopecurioides* and *Sorghastrum nutans*. Fires may well have promoted such species before settlement.

Best examples. There is virtually no native vegetation left on flatter ground with deeper loess (Loring-Grenada-Calloway soil association), other than highly disturbed, 1–10 acre (0.4–4 ha) remnants (e.g., uplands of PNAs 8/34 and woodlots SW of PNA 6). However, within more dissected areas, broad ridges capped by thin loess often have the characteristic *Quercus* spp. noted above, intermixed with typical subxeric forest (e.g., PNAs 8/14/16/35).

Bottomland Communities

These are all on alluvial soils with a depth to bedrock of at least 10 ft (4 m), or 6 ft (1.8 m) in slack-water areas. All of these communities can be intimately mixed with aquatic communities (see below).

4. *Moderately wet (subhydric) forest:* IIA8b(/6g). This transitional type occurs on more or less well-drained soils, on either: (a) mixed alluvium sufficiently high above the level of frequent saturation (fluventic dystrochrepts); or (b) more dissected areas near the front or back edges of broad slack-water floodplains (hapludalf and udifluvent soils). Common species include mesophytes like *Fagus* and *Liriodendron*, plus more hydrophytic species such as *Quercus michauxii*, *Q. pagoda*, *Liquidambar*, *Nyssa sylvatica* and *Acer rubrum* var. *trilobum*. Especially on slack-water deposits, other species include *Fraxinus pensylvanica*, *Ulmus americana*, *Celtis laevigata*, *Q. macrocarpa*, *Carya laciniosa* and occasional *C. illinoensis*. Rare trees that may be expected in the county or nearby include *Gleditsia aquatica** (vegetative collections suggest hybrids with *G. triacanthos*) and *Bumelia lanuginosa** (collected by L.R. Phillippe, pers. comm., from the small old-growth forest in adjacent McLean County). Ground vegetation includes *Boehmeria cylindrica*, *Polygonum virginianum*, *Parthenocissus quinquefolia*, *Rhus radicans*, *Eupatorium serotinum*, *Uvularia sessilifolia**, *Carex rosea*, *C. projecta*, *C. debilis*, *Poa autumnalis*, *Elymus virginicus*, *Panicum clandestinum* and *P. joorii**.

Best examples. Two areas of 5–20 acres (2–8 ha) approach old-growth (PNAs 10/34A). Another area (PNA 5B) has an unusual abundance of *Q. macrocarpa*, *Carya laciniosa* and Urticales (see Discussion).

5. *Wet (hydric) forest:* IIA6b(/d). This is extensive on more or less poorly drained soils of floodplains (especially fluvaquents). Common species include *Quercus palustris*, *Acer rubrum* var. *trilobum* and *Liquidambar*, with *Q. lyrata* on wetter sites and *Q. michauxii* on drier sites. *Quercus bicolor* and *Fraxinus pensylvanica* are frequent on slack-water deposits. Minor species on wetter sites include *F. tomentosa*, *Carya aquatica** and *Cornus stricta*. Ground vegetation includes *Onoclea sensibilis*, *Saururus cernuus*, *Boehmeria cylindrica*, *Impatiens capensis*, *Hypericum tubulosum*, *Cicuta maculata*, *Scutellaria lateriflorus*, *Lycopus virginicus*, *Galium obtusum*, *Bidens frondosa*, *Aster* spp. (*ontarionis*, *simplex*, *lateriflorus*, *vimeneus*), *Iris virginica*, *Commelina virginica*, *Carex crinita*, *C. louisianica*, *C. grayii*, *Leersia lenticularis*, *Glyceria striata*, *Cinna arundinacea* and *Muhlenbergia* cf. *bushii**. More acid soils at seeping slope bases may have had distinct vegetation, including *Stenanthium gramineum*, several ferns (*Osmunda* spp., *Thelypteris palustrus*, *Woodwardia areolata*, etc.) and mosses (*Sphagnum* spp.). The only good example known in the

region is in adjacent Caldwell County ("Dawson Springs Swamp"; 1), but these species have been found nearby in Hopkins County (Western PNA 35; M. Medley).

Best examples. There are no areas of old-growth. Maturing forest occurs in a few locations (e.g., parts of PNAs 2A/2C/22B/35). Extensive areas of less mature forest occur along the Pond River and the Tradewater River.

6. *Wet-dry fluctuating (hydroxeric) forest:* IIA6a(/5a/?). This is typical of soils that are more or less poorly drained, but which often dry out in the growing season. Extreme examples occur on the clayey slack-water deposits (with relatively base-rich ochraqualf and haplaquept soils). Less distinct examples also occur on these deposits and on old mixed alluvial terraces with fragipans (fragiudalfs). Perhaps the most characteristic tree of extreme hydroxeric conditions is *Quercus phellos*, which can be associated with *Q. lyrata* and other species of wetter forests, or with *Q. stellata*, *Carya ovata* and other species of drier forests. *Ilex decidua* is often frequent. Less extreme sites are transitional to wetter forest types with *Liquidambar*, *Q. palustris*, *Q. pagoda* and others, or to upland forest types with *Q. alba*, *C. tomentosa*, *Diospyros virginiana* and others. The highly varied ground vegetation includes *Rhus radicans*, *Baptisia leucantha** (collected by H. Bryan), *Amsonia tabernaemontanum* var. *gattingeri**, *Lycopus rubellus*, *Leersia virginica*, *Carex tribuloides*, *C. typhina*, *C. intumescens* and *Panicum longiligulatum**. Species in the *Quercus stellata* woods (PNA 5A) include *Lespedeza intermedia*, *Crotonopsis elliptica**, *Carex glaucodea*, *Eleocharis tenuis*, *Danthonia spicata* and *Panicum acuminatum* var. *fasciculatum*.

Best examples. There are no areas of old-growth. On slack-water deposits, areas with frequent *Quercus phellos* are well-represented along the outer floodplain limits of the lower Clear Creek watershed (especially PNA 38); DeFriese (5, p. 22) noted in 1884 that "On Clear Creek, a great deal of swamp laurel oak [*Q. phellos*] is found, often 26 inches [66 cm] in diameter". There are several less distinct examples, with little or no *Q. phellos* (e.g., PNA 6 and the large PNA 7). The *Q. stellata* forest on Pitman Creek (PNA 5A) is exceptional for its lack of typical hydric species. On the terraces with fragipans, strips of forest remain along Green and Pond rivers (e.g., PNA 3C).

Communities Associated with Bodies of Water

7. *Flowing water (rivers and streams):* IIA7b/f. More or less well-drained soil that, nevertheless, gets frequent flooding with fresh alluvium is typified by *Salix nigra*, *Platanus occidentalis*, *Betula nigra* (especially on more acid soil), *Acer negundo* (especially on more base-rich soil) and *A. saccharinum* (especially along larger streams and rivers). This zone generally grades into adjacent subhydric or hydric forest. A shrub zone of *Cornus obliqua* is often present next to the water. Ground vegetation includes *Boehmeria cylindrica*, *Laportea canadensis*, *Polygonum* spp., *Cryptotaenia canadensis*, *Ruellia strepens*, *Mimulus alatus*, *Aster ontarionis*, *Arundinaria gigantea*, *Chasmanthium latifolium*, *Leersia oryzoides*, *Elymus virginicus* and *Muhlenbergia frondosa*. Bars of gravel or sand are generally not well-developed.

Best examples. No particularly mature forest was found along rivers and streams, but these communities remain extensive.

8. *Stagnant water (marshes, sloughs, oxbows and ponds):* IIC1e/IID1d/IID6a/IID8a. In these situations, subhydric or hydric forest generally borders the water directly. Dead trees are frequent along the larger sloughs, as discussed further below. A zone of *Cephalanthus occidentalis* is generally present. Along the larger sloughs, this shrub is often mixed with *Populus heterophylla*, *Salix nigra*, *Forestiera acuminata* and *Styrax americana*. In deeper water, *Hibiscus militaris* is abundant. The herb layer includes *Polygonum hydropiperoides*, *Ludwigia* spp., *Diodia virginiana*, *Alisma subcordatum*, *Typha* spp., *Sparganium* spp., *Juncus effusus*, *Rhynchospora corniculata*, *Carex lupulina*, *Eleocharis quadrangulata*, *Phragmites australis*, *Panicum agrostoides* and *Echinochloa crus-gallii*. True aquatics include *Nuphar luteum*, *Nymphaea odorata*, *Ranunculus flabellaris*, *Ceratophyllum demersum*, *Didiplis diandra**, *Peltandra virginica**, *Limnobium spongia** and the liverwort, *Riccia fluitans* (sensu lato). Around one shallow pond polluted by red deposits from mine run-off,

*Decodon verticillatus** is dominant, with frequent *Cephalanthus, Itea virginica, Juncus acuminatus* and *Eleocharis obtusa*.

Best examples. There are several extensive marshy bottoms in the county, notably along Clear Creek (PNA 22) and its tributaries—Weir Creek (PNA 29) and Lick Creek (PNA 30). Relatively undisturbed examples of oxbows are Long Pond (in PNA 2A) and the oxbow just south of the mouth of Clear Creek (in PNA 38). Smaller ponds of various types occur in many areas, but their natural or artificial status is often uncertain. Though polluted, the Maple Swamp pond (in PNA 35) may have a natural origin and is notable for the *Decodon*.

Discussion

The Nature Conservancy is currently developing a "Natural Community" classification for the southeastern United States (12), including Kentucky (M. Evans, unpublished). The general correspondence of Hopkins County plant communities to this system is referenced above. However, some forest types on sites with much wet-dry fluctuation are not clearly matched in the regional classification, especially types on less well-drained uplands with fragipans, and on bottoms with high potential for seasonal drought. Also, there needs to be more analysis of soil chemical differences between communities at local and regional levels, which would help refine the correspondence.

A major component in the relationship between soil and vegetation indicated above (Figs. 1, 2) is that soils with potential for much moisture fluctuation have vegetation that is distinct from more constant dry, moist or wet conditions. This local pattern illustrates the independent gradients of dryness and wetness evident in the whole Central Hardwood Region (14). Such independence may be more pronounced on the Coastal Plain and Piedmont, though requiring deeper analysis than sometimes performed (15, 16, 17, 18). Expression of these trends is often limited by the almost complete agricultural conversion of flatter lands, where the most typical "xerohydric" vegetation is hypothesized to have existed before settlement. The search for good examples of natural vegetation on fragipan soils in these landscapes should become a priority. It is intriguing that upland areas most prone to a natural shift from forest to fire-prone, grassy, open woodland or barrens may have occurred on such sites. Despite the historical reference to "post oak glades" (4; see above), no definite remnants of such vegetation have been found within the Shawnee Hills, apart from some peripheral sites on Mississippian bedrock.

The natural condition of the Clear Creek wetland and other large marshy areas in Hopkins County remains uncertain. The frequent dead trees may indicate an increase in water levels during the past 10–30 years, caused by the concurrent increase in dam-building of the recovering beaver population (E. Young, Hopkins Co. Conservation Office, pers. comm.), and by sedimentation and pollution from stripmines. Studies of "greentree reservoirs" indicate that flooding in the growing season results in a shift from bottomland hardwoods to more water-tolerant plants (19), especially when the trees are less than 3 inches (7.5 cm) dbh (20). After such flooding, trees are stressed and killed by oxygen depletion, whereas flooding in the dormant season has little effect on tree growth (21).

The Hopkins County marshes have not been considered particularly good examples of natural communities (1, 2), though there are several rare plant and animal species. Their enigmatic treeless aspect could simply be due to a lack of natural migration from the Ohio River valley by the extremely flood-tolerant *Taxodium distichum* and *Nyssa aquatica*. However, *Taxodium* is said to have occurred formerly in several parts of the county, as evidenced by old stumps and knees, and may have been eliminated by logging (E. Young, pers. comm.). No relevant historical description has yet been found.

Differences in vegetation related to soil pH and fertility, as evident in regional comparisons (14), are less easily demonstrated within ares of relatively uniform soil parent material. Within Hopkins County, field notes suggest that some areas on the clayey slack-water deposits have forest composition typical of higher pH or fertility. These soils have an A horizon pH of up to 5.5–6.5, whereas all other soils in the county have a typical pH of 4.5–5.5. Trees of Hopkins County that are generally indicative of higher base-status (14), and which appear characteristic of these particular soils include *Carya laciniosa, Quercus macrocarpa, Q. bicolor, Q. shumardii, Gleditsia* spp., *Fraxinus* spp. and Ulmaceae. In composition, a few of these areas (e.g., PNA 5A) resemble the "savanna-woodlands" and swamps of the highly fertile Bluegrass stream bottoms, which often have a long grazing history (22, 23; and J. Campbell, unpublished data). More detailed study of soils will be needed to examine these relationships at the local level.

ACKNOWLEDGMENTS

Much work for this study was funded by a gift to The Nature Conservancy (Kentucky Chapter) by Dillman Rash, and was conducted with guidance from Jim Aldrich, Director of the Kentucky Office. Special thanks are due to Clarence Day (Aerial Recon, Lexington), who stretched his flying time to the limit for the aerial reconnaissance. Additional data and comments were provided by Hal Bryan, Marc Evans, Richard Hannan and Eddie Young.

LITERATURE CITED

1. Harker, D. F., R. R. Hannan, M. L. Warren, L. R. Phillippe, K. E. Camburn, R. S. Caldwell, S. M. Call, G. J. Fallo, and D. VanNorman. 1980. Western Kentucky Coal Field: preliminary investigations of natural features and cultural resources. Kentucky Nature Preserves Commission, Frankfort.

2. Harker, D. F., M. L. Warren, K. E. Camburn, and R. R. Cicerello. 1981. Aquatic biota and water quality survey of the Western Kentucky Coal Field. Kentucky Nature Preserves Commission, Frankfort.

3. Fehr, J. P., E. H. Jacobs, and H. T. Converse. 1977. Soil survey of Hopkins County, Kentucky. U.S.D.A., Soil Conservation Service.

4. Braun, E. L. 1950. Deciduous forests of eastern North America. Blakiston Company, Philadelphia, Pennsylvania.

5. Owen, D. D. 1987. Report on the Geological Survey of Kentucky. Kentucky Department of Geology and Forestry, Frankfort.

6. DeFriese, L. H. 1884. Report on the timbers of the Tradewater Region. Kentucky Geological Survey, Frankfort.

7. Barton, J. E. 1919. The amount of standing timber in Kentucky. Pp. 251–284. In The mineral and forest resources of Kentucky, Volume I, Series V. Kentucky Department of Geology and Forestry, Frankfort.

8. Kentucky State Nature Preserves Commission. 1991. Natural heritage database. KSNPC, Frankfort.

9. Fernald, M. E. 1950. Gray's manual of botany, 8th ed. (corrected printing 1970). D. Van Nostrand Company, New York.

10. Kartesz, J. T. and R. Kartesz. 1980. A synonymized checklist of the vascular flora of the United States, Canada and Greenland. University of North Carolina Press, Chapel Hill, North Carolina.

11. Mohlenbrock, R. H. 1985. The taxonomic status of *Panicum joorii* Vasey. Erigenia 5:45–51.

12. Allard, D. 1990. The southeastern regional ecological community classification, version 1.2. The Nature Conservancy, Southeastern Regional Office, Chapel Hill, North Carolina.

13. Kentucky State Nature Preserves Commission. 1991. Endangered, threatened and special concern plant and animal species of Kentucky. Frankfort, Kentucky. (See also: Trans. Kentucky Acad. Sci. 47:83–98).

14. Campbell, J. J. N. 1987. Gradients of tree species composition in the Central Hardwood Region. Pp. 325–346. In R. L. Hay, F. W. Woods, and H. DeSelm (eds.) Proc. Sixth Central Hardwood Forest Conf. University of Tennessee, Knoxville.

15. Christensen, N. L. 1988. Vegetation of the southeastern Coastal Plain. Pp. 350–363. In M. G. Barbour and W. D. Billings (eds.) North American terrestrial vegetation. Cambridge University Press.

16. Ware, S. 1988. Ordination of Quarterman and Keever's original Southern Mixed Hardwood Forest. Castanea 53:197–206.

17. Monk, C. D., D. W. Imm, R. L. Potter, and G. G. Parker. 1989. A classification of the deciduous forest of eastern North America. Vegetatio 80:167–181.

18. Monk, C. D., D. W. Imm, and R. L. Potter. 1990. Oak forests of eastern North America. Castanea 55:77–96.

19. Bedinger, M. S. 1979. Relation between forest species and flooding. In P. E. Greeson, J. R. Clark, and J. E. Clark (eds.) Wetland functions and values: the state of our understanding. American Water Resources Association, Minneapolis, Minnesota.

20. Hall, T. F. and G. E. Smith. 1955. Effects of flooding on woody plants in West Sandy Dewatering Project, Kentucky Reservoir. J. Forest. 53:281–285.

21. Mitchell, W. A. and C. J. Newling. 1986. Greentree Reservoirs. U.S. Army Corps of Engineers Wildlife Resource Management Manual. Technical Report EL-86-9, Section 5.5.3. Vicksburg, Massachusetts.

22. Bryant, W. S., M. E. Wharton, W. H. Martin, and J. B. Varner. 1980. The blue ash-oak savannah woodland, a remnant of presettlement vegetation in the Inner Bluegrass Region of Kentucky. Castanea 45:149–165.

23. Campbell, J. J. N. 1989. Historical evidence of forest composition in the Bluegrass Region of Kentucky. Pp. 231–246. In G. Rink and C. A. Budelsky (eds.) Proc. Seventh Central Hardwood Forest Conf. Southern Illinois Univ., Carbondale.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 39–45

Selection Methods for Simple Column PLA Folding

Bill Janeway and Patricia Costello

Department of Mathematics, Statistics and Computer Science, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

Simple column folding for programmable logic arrays (PLAs) consists of either input column folding or output column folding. Hatchel, Newton, and Sangiovanni-Vincentelli (1) developed a heuristic for optimal simple column folding for PLAs as the optimal solution is NP-complete. In their algorithm, a selection policy must be supplied to select the 2 columns/rows to try to combine next. This paper examines their recommended selection policy as well as several others. For non-sparse PLAs, none of the selection policies studied are statistically better than any of the others. However, it was found that in very sparse PLAs a selection criteria using the inverse of the personality density for live intervals is statistically better than several selection policies, including the one recommended by Hatchel, Newton, and Sangiovanni-Vincentelli.

Introduction

Integrated circuits have made it possible to put a large number of gates on a chip and to make gate interconnections on the chip as well. For each function or set of functions, the layout of the gates and interconnections on the chip has to be designed. The cost and time involved in the custom design of chips is high. Thus, it is an attractive option to develop a general purpose chip that can be readily adapted to specific functions. This is the reason for programmable logic arrays (PLAs). A PLA is an array of logic gates whose interconnections can be programmed to perform specific logical functions. A PLA is divided into 2 planes. One is the "**and**" plane and the other is the "**or**" plane. Figure 1 shows a PLA with five inputs and two outputs. A personality is a connection that is being used (represented by a dot in Fig. 1). Column **a** has a personality in row 1 and in row 3. The live interval of a column is the interval (measured in number of rows) from the top to the bottom personalities in the column. Hence, the length of the live interval for column **a** is 3. The output for **f** is the boolean function **ace** + **bd** (where the **and** operation is written as multiplication and the **or** operation is written as addition) and the output for **g** is the boolean function **bd** + **ae**. The sparseness of personalities in a PLA wastes components and leads to time degradation of circuits. PLA folding is a technique that constructs a physical PLA which minimizes the area of the chip by structural reorganization of the personalities of the PLA.

There are several types of PLA foldings. These include row and column folding and include the possibility of realizing more than two symbolic rows or columns within a given physical row or column. This paper discusses only simple column folding. Simple column folding consists of either input column (the **and** plane) folding or output column (the **or** plane) folding. In either case a physical column is divided into two parts so that two electrical input (output) signals can share the same physical column.

Hatchel, Newton, and Sangiovanni-Vincentelli (2) developed a heuristic for the optimal simple column folding problem. The optimal simple column folding problem is NP-complete. Their algorithm is an n^3 algorithm, where n is the number of columns, and provides a maximal solution but not necessarily a maximum solution. In using their algorithm, one must provide a selection policy to determine which 2 columns to try to combine next. In this paper, the primary objective is to study different selection policies to see if one is better than the others. Hatchel, Newton, and Sangiovanni-Vincentelli (2) recommended a selection policy based on the number of columns a column intersects (have a personality in the same row). For very sparse PLAs, a selection policy using the inverse of the personality density of the live interval is statistically better than their method as well as the other methods that were studied. However, for non-sparse PLAs all selection methods provided approximately the same results.

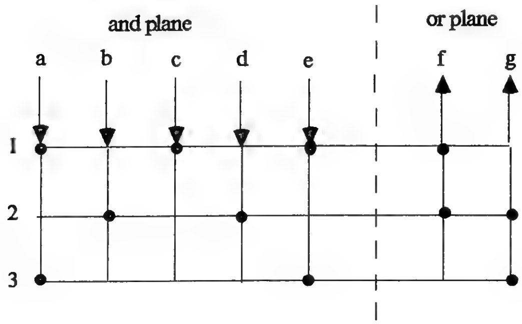


FIG. 1. A sample PLA.

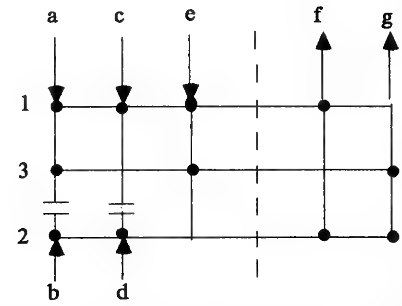


FIG. 3. PLA of Figure 1 folded with a row rearrangement.

SIMPLE COLUMN FOLDING

The density of a PLA is the number of personalities divided by the total number of connections (used and unused). The density for the PLA in Figure 1 is 11/21, or approximately 52%. Is it possible to decrease the area of the chip by improving the density so that the distance the signal will have to travel is decreased, thereby improving the performance of the PLA? Simple column folding combines 2 columns into 1 where the combined column is divided into 2 parts so that 2 electrical signals can share the same column. The personalities of the two signals in the column must not be intermixed but must be grouped on opposite sides of a "cut" to be located somewhere in the column with one signal routed from the top and the other from the bottom. Figure 2 shows the PLA from Figure 1 after a single column fold. The density of the PLA in Figure 2 is 11/18 which is approximately 61%. However, if row 2 and row 3 are swapped then the PLA can be folded into the PLA of Figure 3 which has density of approximately 73%. Hence, a simple column folding allows for a rearrangement of the rows in order to be able to find more pairs of columns that can be combined.

THE ALGORITHM

Only a brief summary of Hatchel, Newton, and Sangiovanni-Vincentelli's algorithm (2) is presented in this paper. In order to do this, a few definitions are needed. In a PLA, columns **u** and **v** are foldable if and only if they do not have personalities in the same row. If **u** and **v** are foldable with **u** occupying the rows above those of **v**, after folding, then ⟨**u**, **v**⟩ is an ordered folding pair. The fact that 2 columns must be disjoint to be folded is not the only constraint on folding. Folding columns **u** and **v** imposes a relation on the set of rows. The concept of an ordered folding pair being compatible with a set of ordered folding pairs is a bit more complicated. A set **B** of ordered folding pairs is an implementable folding set if there is a permutation on the rows such that

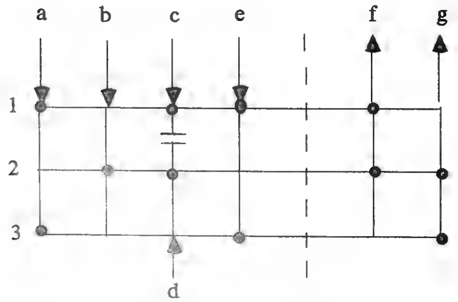


FIG. 2. PLA of Figure 1 folded without row rearrangement.

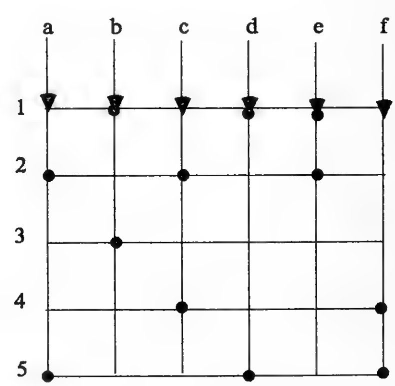


FIG. 4. A sample PLA plane.

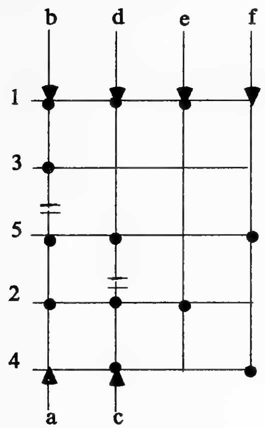


FIG. 5. PLA plane of Figure 4 after folding.

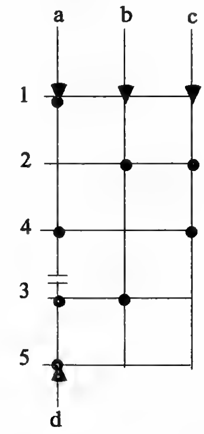


FIG. 7. A fold of the PLA plane in Figure 6.

for each ordered pair ⟨**u**, **v**⟩ in **B,** the rows in which **u** has a personality are above the rows in which **v** has a personality. As new ordered folding pairs are added to the implementable folding set, the relation on the rows obtained from the union of the relations imposed by each ordered folding pair must be checked. The transitive closure of this relation must be a partial ordering on the rows. If this is not a partial ordering on the rows, then it is not possible to find a permutation of the rows that will be compatible with the ordered folding pairs. To aid in this explanation, consider the example in Figure 4. The set {⟨**b**, **a**⟩, ⟨**d**, **c**⟩} is an implementable folding set. Figure 5 shows such an implementation. Now ⟨**f**, **e**⟩ is also an ordered folding pair. However, {⟨**b**, **a**⟩, ⟨**d**, **c**⟩, ⟨**f**, **e**⟩} is not an implementable folding set as ⟨**d**, **c**⟩ implies that row 1 must come before row 4 and ⟨**f**, **e**⟩ implies that row 4 must come before row 1. Similarly, {⟨**b**, **a**⟩, ⟨**d**, **c**⟩, ⟨**e**, **f**⟩} is not an implementable folding set.

The following is a brief version of Hatchel, Newton, and Sangiovanni-Vincentelli's (2) algorithm:

pre: A PLA plane whose set of columns is **V**

post: **F** is a maximal implementable folding set for the PLA plane (maximal in that there does not exist an implementable folding set **H** for the PLA with **F** a proper subset of **H**)

procedures: build1 and build2 will build a priority queue from a set based upon the selection method being used.

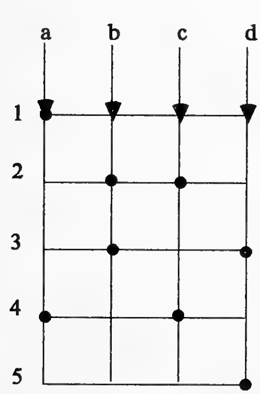


FIG. 6. A PLA plane.

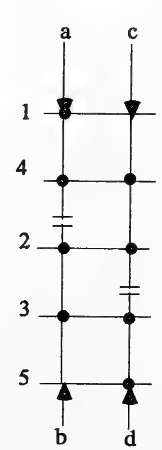


FIG. 8. Another fold of the PLA plane in Figure 6.

Method Number	Selection for Top	Selection for Bottom	Tiebreaker for Top	Tiebreaker for Bottom
1	CO	CO	N/A	N/A
2	MD	mD	CO	CO
3	MD	mD	MI	mI
4	MD	mD	MP	mP
5	MP	mP	CO	CO
6	MP	mP	MI	mI
7	MP	mP	MD	mD
8	MI	mI	CO	CO
9	MI	mI	MP	mP
10	MI	mI	MD	mD
11	MID	MID	CO	CO
12	MID	mID	CO	CO
13	Random	Random	N/A	N/A

Legend: CO = Column Order
MD = Maximum Degree
mD = Minimum Degree
MID = Max 1 density of live interval
mID = Min 1 density of live interval
MP = Maximum Number of Personalities
mP = Minimum Number of Personalities
MI = Maximum live interval
mI = Minimum live interval

FIG. 9. Selection methods studied.

```
variables: T and B are the sets of candidates
           for the top and bottom columns
           in ordered pairs. They will be pri-
           ority queues ordered according to
           the selection method being used.
           T = build1 (V)
           B = build2 (V)
           F = ∅
           while T ≠ ∅ do
             begin
                set u equal to first item in T
                find the first v in B such that
                (u, v) is a folding pair com-
                patible with F
                if such a v is found then
                   begin
                      add (u, v) to F
                      delete u and v from B
                      delete v from T
                   end
                delete u from T
             end
           output F
```

Many of these steps are very complicated. For a detailed explanation of the algorithm, see Hatchel, Newton, and Sangiovanni-Vincentelli (2) where they prove the correctness of the algorithm and show that the worst case has complexity n^3.

SELECTION POLICIES

There are 2 selection steps in the algorithm. Begin by selecting a column for the first component of a possible ordered folding pair and then select a candidate for the second component. How should one select these columns? Will these selections have any impact on the ability to find additional ordered folding pairs? Consider the small plane of a PLA in Figure 6. If column order is used for the selection method for the first component and reverse column order for the second component, then columns **a** and **d** will form a folding pair but no additional folds can be made. Figure 7 shows the folded plane of the PLA. However, if both selections use column order, then columns **a** and **b** and columns **c** and **d** will be compatible folding pairs. Hence, the folded plane of the PLA given in Figure 8 would be produced. Similarly, given any two known selection policies, say **A** and **B**, a PLA can be constructed in which method **A** would produce more compatible ordered folding pairs than method **B**. Yes, the selection policy determines the outcome. Is there a selection policy that works best for all PLAs? If there exists such a selection policy, it is yet to be found.

This paper studies 13 selection policies. Before the 13 methods are described, a definition is in order. Two columns are said to intersect

TABLE 1. Summary of results from Friedman Multiple Comparisons.

Density	Fat	Square	Skinny
15	11 > 1–10, 12, 13 1 > 2–10, 12 13 > 4, 5, 7–10	11 > 2–10, 13 12 > 2–4, 7 1 > 2–4	11 > 2–4 1 > 2–4 12 > 2–4
20	11 > 2–10, 12, 13 1 > 2–10 13 > 3–10	11 > 2 12 > 2	11 > 2, 4 1 > 2, 4 12 > 2
25	11 > 2–10, 12 1 > 2–5, 7, 10 13 > 2–4 9 > 2	12 > 2–4, 8, 10 11 > 2, 3 1 > 2, 3	No significant differences
30	11 > 2–4, 7 12 > 2	No significant differences	No significant differences
35	No significant differences	No significant differences	No significant differences
40	No significant differences	No significant differences	No significant differences
45	No significant differences	No significant differences	No significant differences
50	No significant differences	No significant differences	No significant differences

Note: Methods to left of > are statistically better than those to the right.

if there exists a row which has a personality in each of the 2 columns. The degree of a column is the number of columns that it intersects. Some of the 13 methods have the property that when one tries to select the next columns to try a tie occurs. For these policies, one must have a tie breaker. Some of the 13 methods will be essentially the same policy but with a different tie breaker.

The primary selection method for methods 2, 3 and 4 is the method recommended by Hatchel, Newton, and Sangiovanni-Vincentelli (2) with three different tie breakers. Method 1 uses a very natural method of column order which requires no tie breaker. The primary selection method for methods 5, 6, and 7 uses the number of personalities. A column with a larger number of personalities is more likely to be foldable with a column which has only a few personalities. This is why these methods were studied. Methods 8, 9, and 10 are based on the length of the live interval. If a column with a large live interval can be folded with a column with a short live interval, then the cardinality of the relation on the rows that this folding pair generates will probably be small. Method 11 takes large live intervals with a small number of personalities and compacts the live intervals but dictates a relative ordering on only a few rows. This is the new method being studied. Method 12 is based on the fact that a column with a very dense live interval

TABLE 2. Mean density after folding for FAT PLAs.

	Density before folding							
Method	15	20	25	30	35	40	45	50
1	21.33	25.21	29.10	33.12	37.49	41.84	46.20	50.77
2	20.75	24.71	28.58	32.82	37.24	41.75	46.13	50.76
3	20.83	24.71	28.58	32.86	37.30	41.81	46.11	50.75
4	20.73	24.70	28.65	32.82	37.28	41.91	46.16	51.78
5	20.71	24.68	28.72	33.01	37.42	41.93	46.17	50.78
6	20.78	24.55	28.74	32.96	37.41	41.94	46.18	50.76
7	20.68	24.65	28.69	32.89	37.32	41.92	46.16	50.78
8	20.65	24.56	28.73	33.00	37.44	41.84	46.14	50.75
9	20.68	24.63	28.80	32.91	37.44	41.86	46.16	50.76
10	20.65	24.61	28.71	32.89	37.36	41.82	46.14	50.75
11	21.87	25.49	29.21	33.18	37.54	41.95	46.17	50.76
12	20.69	24.78	28.76	33.12	37.47	41.92	46.17	50.77
13	21.07	25.09	28.97	33.10	37.58	41.81	46.15	50.75

TABLE 3. Mean density after folding for SQUARE PLAs.

Method	Density before folding							
	15	20	25	30	35	40	45	50
1	18.23	22.69	27.04	31.39	36.07	40.48	45.24	50.16
2	17.99	22.54	26.78	31.34	36.05	40.47	45.25	50.18
3	17.94	22.57	26.78	31.38	36.06	40.49	45.23	50.16
4	17.96	22.56	26.88	31.43	36.04	40.50	45.25	50.18
5	18.08	22.63	26.90	31.40	36.05	40.48	45.25	50.18
6	18.06	22.61	26.91	31.42	36.05	40.48	45.25	50.18
7	17.99	22.65	26.88	31.38	36.05	40.48	45.25	50.18
8	18.06	22.63	26.88	31.36	36.09	40.49	45.23	50.14
9	18.09	22.68	26.93	31.31	36.08	40.51	45.23	50.14
10	18.08	22.62	26.87	31.33	36.07	40.49	45.23	50.14
11	18.44	22.74	27.04	31.44	36.00	40.49	45.24	50.14
12	18.18	22.72	27.04	31.43	36.06	40.49	45.25	50.16
13	18.17	22.74	26.95	31.41	36.06	40.50	45.25	50.16

is more likely to fold with a column with a sparse live interval. Method 13 randomly selects the next columns to try to combine. If method 13 works as well as the other methods, then the selection policy used is not important. This is the reason for including Method 13.

CONCLUSIONS

As a result of a preliminary investigation, it was decided to look at 3 classes of PLAs, as the effectiveness of the selection methods is determined by the shape of the PLA. The 3 classes are fat, skinny, and square where for fat PLAs, the number of rows divided by the number of columns is less than or equal to 0.85, for skinny PLAs this ratio is greater than or equal to 1.15, and for square PLAs the ratio is between 0.85 and 1.15. It is easier to find more folding pairs for fat PLAs than for skinny PLAs. Also it is easier to find more folding pairs for PLAs of low personality density than for PLAs with a high personality density. Hence the original densities were varied as well. Each of the 13 methods was used on 300 randomly generated fat, skinny, and square PLAs having densities 15, 20, 25, 30, 35, 40, 45, and 50. The size of the PLAs was randomly generated with a maximum of 120 rows and 120 columns. Friedman's rank sum test (3) was used to test whether the methods differed. A nonparametric test was performed since the final densities were not normally distributed. An additional advantage of using ranks is that averages may be affected by extremely large or small values. It is more important that a good folding method consistently perform better than the other methods. Ranking measures this consistency. Large sample multiple comparisons based on the Friedman rank sums (3) were used to determine which (if any) of the 13 selection methods were statistically better than the others. The results of this analysis are presented in Table 1 and the average densities after folding are given in Tables 2, 3, and 4.

While the actual average densities after folding do not appear to differ much, from Table 1 it can be seen that method 11 is the primary method which consistently performs statistically better than the other methods. The only exception to this occurs for square PLAs of density 25 where method 12 is better than more methods than method 11. There is also no situation in which any method is statistically better than method 11. In addition, methods based on Hatchel, Newton, and Sangiovanni-Vincentelli's recommendations (2, 3, 4) consistently do worse than methods 1, 11, 12 and 13. This is particularly interesting since method 13 uses a random selection method and method 1 uses column order.

Method 11 is statistically better than *all* the other methods for fat PLAs of density 15. For all densities of size 35 or greater, none of the methods differ statistically. Also, the choice of a method has more bearing on PLAs where the number of rows divided by the numbers of columns is small (i.e., fat PLAs).

In general, method 11 is the recommended method since it consistently performs better than the other methods and there is no method

TABLE 4. Mean density after folding for SKINNY PLAs.

Method	Density before folding							
	15	20	25	30	35	40	45	50
1	19.21	23.03	27.08	31.25	35.60	40.36	45.07	50.02
2	18.93	22.72	26.95	31.26	35.60	40.36	45.08	50.02
3	18.91	22.81	26.96	31.29	35.61	40.36	45.08	50.02
4	18.95	22.76	27.04	31.29	35.61	40.37	45.08	50.02
5	19.07	22.85	27.05	31.28	35.60	40.37	45.08	50.02
6	19.00	22.85	27.05	31.26	35.59	40.35	45.08	50.02
7	18.98	22.81	27.05	31.28	35.61	40.37	45.08	50.02
8	19.13	22.90	27.00	31.28	35.60	40.36	45.08	50.02
9	19.15	22.88	27.01	31.27	35.60	40.36	45.08	50.02
10	19.10	22.89	27.02	31.27	35.61	40.36	45.08	50.02
11	19.16	22.97	27.06	31.32	35.58	40.36	45.07	50.02
12	19.13	22.86	27.08	31.28	35.61	40.33	45.08	50.02
13	19.13	22.95	27.04	31.30	35.61	40.36	45.08	50.02

which is ever statistically better than it. If the original density of the PLA is 35 or greater or if the number of rows divided by the number of columns is large, it does not appear to matter which method is chosen.

ACKNOWLEDGEMENT

Eastern Kentucky University made this study possible by providing release time to the first author during Spring 1991. Also Eastern Kentucky University provided the computer equipment to do this research.

LITERATURE CITED

1. G. D. Hachtel, A. R. Newton, and A. Sangiovanni-Vincentelli. 1982. Techniques for programmable logic array folding. Design Automation Conference IEEE 19: 147–155.

2. G. D. Hachtel, A. R. Newton, and A. Sangiovanni-Vincentelli. 1982. An algorithm for optimal PLA folding. IEE Trans. Computer-Aided Design of Integrated Circuits and Systems, Vol. CAD-1:63–76.

3. M. Hollander and D. A. Wolfe. 1973. Nonparametric statistical methods. John Wiley, New York.

4. W. Stallings. 1987. Computer organization and architecture. Macmillan, New York.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 46–49

Use of Fractal Dimension to Analyze Meandering Patterns in the Redbird River of Eastern Kentucky

BRENDA J. MELLETT, ROBERT W. BOSSERMAN, AND JAMES H. THORP

Department of Biology and Water Resources Laboratory, University of Louisville, Louisville, Kentucky 40292

ABSTRACT

Aspects of the geomorphic structure of streams in the Redbird River catchment in eastern Kentucky were examined using fractal geometry, a discrete mathematical technique. Fractal dimension of tributaries and stream length were calculated using data digitized from U.S. Geological Survey topographic maps (1:24,000, 1:100,000, and 1:250,000 scales).

Based on an analysis of streams of various orders and slopes from these maps, we concluded that map scale can generally be ignored when calculating fractal dimension, particularly for higher order streams. Stream order varies directly with stream length but varies inversely with slope. However, no significant relationships were evident between the fractal dimension of a stream and either stream order or slope. Results of these analyses for the Redbird River basin are contrasted with those found for the larger and more meandering Kentucky, Monongahela, and Green rivers.

INTRODUCTION

The geomorphic structure of streams, as defined by the size and shape of their channels, results from water flowing over differentially-erodible landscapes. The geomorphic features of a stream can have important implications for several public and private groups, including stream ecologists, wildlife managers, and land developers (1). Kellerhals and Church (2) developed a system that classifies streams according to channel characteristics; they grouped streams into straight, sinuous, wandering, irregular meandering, and regular meandering patterns. They also recognized streams that anastomose, with water flowing through complex channel networks, and several types of braiding, where islands split the flow of water into multiple stream channels.

While qualitative terms such as braiding, anastomosing, and meandering can be useful in a general way, a scientific or engineering comparison of stream complexity often requires precise mathematical language and techniques. This need has led to the development or application of fractal analysis that furnishes a mathematical measure of complex boundaries, surfaces, and paths (3). Scientists and mathematicians have used fractal analysis to compare geographic boundaries (3, 4), development of biological characteristics (such as branching patterns; 5), and both soil (6, 7) and atmospheric variability (8). Fractal analysis can gauge irregularities in a stream channel or other path and evaluate features of a stream not measurable with continuous methods. For example, fractal geometry can be used to measure and compare the degree of braiding in different rivers of several biomes.

"Fractal" refers to fractional dimension (or, "F.D."). Many complex, geometric figures have spatial dimensions that lie between the integers which describe straight lines (F.D. = 1), flat planes (F.D. = 2), or cubes (F.D. = 3). For example, an irregular line has an F.D. between 1 and 2, whereas an irregular plane has an F.D. between 2 and 3. The following equation defines F.D.:

$$(\text{length})^{1/D} = K\ (\text{area})^{1/2}$$

where D equals F.D., and K is a constant.

Fractional dimension can compare the complexities of river and stream channels. Figure 1a displays the graph of a relatively straight, first order stream which flows into the Redbird River in eastern Kentucky; it has an F.D. of 1.01. The Redbird River (Fig. 1b), a fourth order stream with more pronounced meandering, has an F.D. of 1.10. Braided and anastomosing rivers have higher fractal dimensions. For example, the Tygart Valley River (Fig. 1c) in the Monongahela drainage basin as many braided regions and a resulting F.D. of 1.18 (9).

Because stream meandering has important implications for landscape ecology, erosional/depositional processes, and retention of living

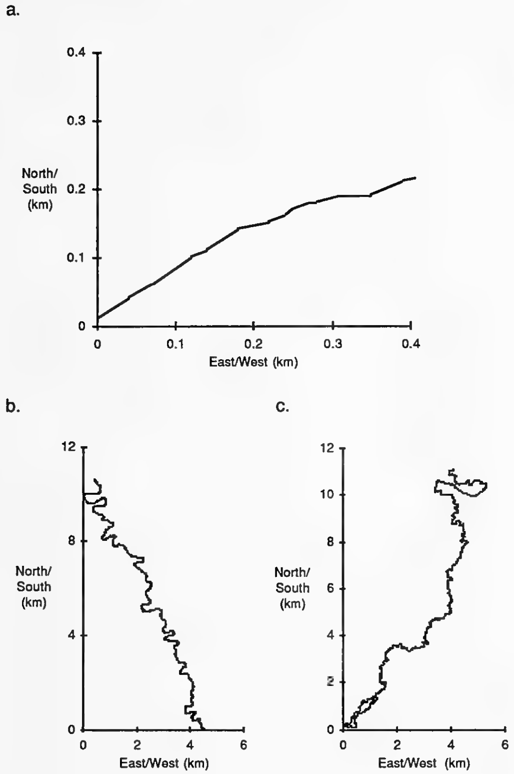


FIG. 1. (A) Graph of a first order stream in the Redbird River catchment with a fractal dimension (F.D.) of 1.01; (B) the fourth order Redbird River with an F.D. of 1.10; (C) the fourth order Tygart Valley River in the Monongahela River catchment with braids and an F.D. of 1.18.

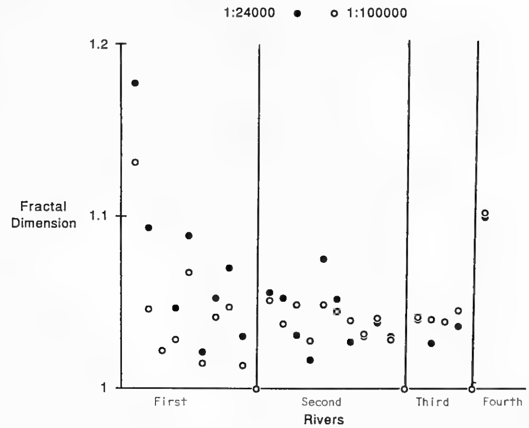


FIG. 2. Fractal dimensions of streams measured on 1:24,000 scale U.S. Geological Survey maps in comparison to F.D.s for streams measured on 1:100,000 scale maps.

and dead organic matter, channel morphology was examined for streams within and among 5 biomes in the continental United States in a study by Bosserman and Thorp (9). That study, which determined the F.D. of streams throughout the catchment areas of over 15 rivers, relied on U.S. Geological Survey 1:100,000 scale maps. An assumption was made that the determination of a river's F.D. was independent of map scale for charts produced with similar methods by the U.S. Geological Survey. In the present study, we examined this question and several others by calculating the F.D. of streams in the Redbird River drainage basin in eastern Kentucky. The following principal null hypothesis was tested. The F.D. of a stream is independent of scale for maps of 1:24,000, 1:100,000, and 1:250,000 scales. In addition, we examined two secondary, null hypotheses as part of this study. The F.D.s and lengths of streams within the Redbird River catchment are unaffected by stream order. The F.D. of a stream does not vary with slope.

MATERIALS AND METHODS

In order to establish the F.D., length, and order of a stream (for an explanation of the last parameter, see references 10 or 11), we used 3 types of U.S. Geological Survey topographic maps (1:24,000, 1:100,000 and 1:250,000) and digitized a random selection of streams of different orders from each set of maps with a Graf/Bar Mark II sonic digitizer. As the scale of a map becomes larger, the smallest streams tend to be eliminated; therefore, we were forced to calculate F.D. for fewer streams as the map scale increased. We determined stream orders on the 1:100,000 maps even though we recognized that these orders are generally one order less than would be determined by ground studies.

TABLE 1. Relationship between stream order and stream length.

Stream order	Mean length (km)	95% C.I.	Number of samples	Significant difference*
First	1.136	0.1318	92	A
Second	1.697	0.6134	25	B
Third	3.778	2.8445	4	C
Fourth	20.855	—	1	

* Means with different letters are significantly different at $P < 0.01$.

TABLE 2. Relationship between stream order and fractal dimension (F.D.).

Stream order	Range of F.D.	Mean F.D.	95% C.I.	Number of samples	Significant difference*
First	1.010–1.177	1.048	0.00329	92	A
Second	1.010–1.085	1.043	0.00450	25	A
Third	1.026–1.040	1.035	0.00433	4	A
Fourth	1.102	—		1	A

* Means with the same letter are not significantly different at $P < 0.05$.

We calculated F.D. with a BASIC computer program which analyzes random growth paths (12). This method assumes that rivers wander on a random path through a landscape, as suggested by Langbein and Leopold (13). We measured elevation differences on 1:24,000 U.S.G.S. maps and calculated slope by dividing elevation differences by stream length. We did linear regressions, paired t tests, and pooled variance t tests with SAS (14) using an alpha level for significance of 0.05 or less.

RESULTS AND DISCUSSION

Our principal null hypothesis was that the determination of a stream's F.D. was scale independent; that is, one could employ more than 1 of the 3 map scales without introducing systematic error to the analysis. Our results indicated that map scale can generally be ignored when calculating F.D., especially for higher order streams. A paired t test showed that the mean F.D. for rivers on the 1:250,000 maps (1.0520) were not significantly different from that calculated with the 1:100,000 scale maps (F.D. = 1.0525). Similarly, F.D.s of second, third, and fourth order streams do not significantly differ when calculated from 1:100,000 and 1:24,000 scale maps. However, a paired t test revealed that the F.D. of first order streams on 1:100,000 scale maps were significantly lower (approximately 4%) than the same streams on 1:24,000 maps (Fig. 2).

The second hypothesis concerned the relationship between stream order and both length and meandering tendency (i.e., F.D.) of the stream. Stream length increased significantly with stream order (Table 1; Student's t test, $P < 0.01$). Although stream length appeared to rise exponentially with stream order, a linear regression of order versus the natural logarithm of length did not explain significant variation.

The tendency of lowland streams to meander differently than headwater streams has not been tested statistically in the scientific literature. Most streams in the Redbird River catchment are fairly straight, and thus have low F.D.s. Fractal dimensions of streams in the Redbird River catchment ranged from 1.010 to 1.177, with higher average values tending to occur in smaller streams (Table 2). However, there were no significant differences in F.D. among stream orders according to the Student's t test (Table 2). [Only 1 fourth order stream—the Redbird River itself—exists in the catchment, so we could not statistically compare the F.D. of this fourth order river with lower order streams.] These results for the Redbird River contrast with the findings for the Kentucky, Monongahela, and Green rivers, where F.D. increased directly with stream order (9).

Our results from the Redbird River catchment demonstrated that slope decreased significantly from first order (mean = 341.0 m/km) to second order streams (mean = 280.5 m/km) (Student's t test, $P < 0.01$). Thereafter, the slope continued to decline from the third order streams (mean = 272.8 m/km) to the fourth order river (mean = 11.5 m/km), but the results were not significant, probably because of the low number of streams of those orders in our statistical comparisons. While slope is related inversely to stream order, a linear regression indicated that F.D. did not vary significantly with slope in the Redbird River basin. Again, these results conflict with those found for the streams within the catchments of the more meandering and much larger Kentucky, Monongahela, and Green rivers where F.D.s were inversely and significantly related to slope (9).

SUMMARY

Fractal dimension provides a discrete mathematical tool for characterizing the shape of stream channels. This tool allows us to compare stream properties such as meandering, which have been discussed in stream theory but rarely examined statistically.

Our results indicated that map scale can generally be ignored when calculating F.D., especially for higher order streams, as long as the maps were constructed with data collected by similar methods. As expected, stream order was significantly related in a direct fashion to stream length but inversely associated with slope. However, no significant relationships were evident between the F.D. of a stream and either stream order or slope—in contrast to the results found for the larger and more meandering Kentucky, Monongahela, and Green rivers.

LITERATURE CITED

1. Rechard, R. P. and V. R. Hasfarther. 1980. The use of meander parameters in the restoration of mined stream beds in the eastern Powder River basin. Final report to the Industrial Fund of the Rocky Mountain Institute of Energy and Environment. University of Wyoming, Laramie, Wyoming.

2. Kellerhals, R. and M. Church. 1989. The morphology of large rivers: characterization and management. Pp. 31–48. In D. P. Dodge (ed.) Proc. Internat. Large River Symp. Can. Spec. Publ. Fish. Aquat. Sci. 106.

3. Mandelbrot, B. B. 1967. How long is the coast of Britain? Statistical self-similarity and fractional dimension. Science 156:636–638.

4. Phillips, J. D. 1985. Measuring complexity of environmental gradients. Vegetatio 64:95–102.

5. Goldberger, A. L., D. R. Rigney, and B. J. West. 1990. Chaos and fractals in human physiology. Sci. Amer. 262(2).

6. Burrough, P. A. 1983a. Multiscale sources of spatial variation in soil. I. The application of fractal concepts to nested levels of soil variation. J. Soil Science 34:577–597.

7. Burrough, P. A. 1983b. Multiscale sources of spatial variation in soil. II. A non-Brownian fractal model and its application in soil survey. J. Soil Science 34:599–620.

8. Lovejoy, S. 1982. Area-perimeter relation for rain and cloud areas. Science 216:185–187.

9. Bosserman, R. W. and J. H. Thorp. In preparation. Interbiome comparisons of stream meandering.

10. Strahler, A. N. 1952. Dynamic basis of geomorphology. Geological Soc. of Amer. Bull. 63:1117–1142.

11. Thorp, J. H. and A. P. Covich. 1991. Chapter 1: An overview of freshwater habitats. Pages 17–36. In J. H. Thorp and A. P. Covich (eds.) Ecology and classification of North American freshwater invertebrates. Academic Press, New York.

12. Katz, M. J. and E. B. George. 1985. Fractals and the analysis of growth paths. Bull. of Math. Biology 47: 273–286.

13. Langbein, W. B. and L. B. Leopold. 1966. River meanders and the theory of minimum variance. U.S. Geol. Surv. Prof. Pap., 422-H. 15 pp.

14. SAS Institute. SAS User's Guide: Basics, Version 5. SAS Inst., Ave., Cary, North Carolina.

NOTES

New Microcaddisfly (Trichoptera: Hydroptilidae) Records for Kentucky.—Further examination of adult caddisflies collected in 1988 from the Buck Creek System, Pulaski County (Floyd, M. A. and G. A. Schuster 1990, Trans. Ky. Acad. Sci. 51:127–134) revealed a new Kentucky distributional record for *Hydroptila sandersoni* Mathis and Bowles. This species, reported as *Hydroptila* species 2 by Floyd and Schuster, was collected in light-trap samples from 7 different localities on Buck Creek (stations 2, 3, 5, 6, 7, 9, and 10) and one locality on Short Creek (station 8). It had an emergence period of May through August. Collection of *H. sandersoni* in Kentucky is a northeastern range extension for this species, known only from northern Alabama (Steven C. Harris, pers. comm.) and northern Arkansas (Mathis, M. L. and D. E. Bowles 1990, Proc. Entomol. Soc. Wash. 92:86–92). The addition of *H. sandersoni* to the caddisfly fauna of Kentucky brings the state's total up to 199 species, including 38 species within the family Hydroptilidae (Floyd, M. A. and G. A. Schuster 1990, Trans. Ky. Acad. Sci. 51:127–134; Resh, V. H. 1975, Trans. Ky. Acad. Sci. 36:6–16).

Although not representing distributional records new to Kentucky, 3 additional species were identified from the Buck Creek System and represent new records for the Cumberland River drainage. These include *Hydroptila grandiosa* Ross (known also from Paint Creek at Paintsville, Johnson County), *H. perdita* Morton (known from Anderson, Johnson, Shelby, and Spencer counties), and *Orthotrichia cristata* Morton (reported from Anderson and Spencer counties) (Resh, V. H. 1975, Trans Ky. Acad. Sci. 36:6–16). These 3 species were originally reported by Floyd and Schuster as *Hydroptila* species 3, *Hydroptila* species 1, and *Orthotrichia* nr. *curta*, respectively.

I thank Dr. Steven C. Harris, University of Alabama, for the identification of specimens. Dr. Guenter A. Schuster, Eastern Kentucky University, and Dr. John C. Morse, Clemson University, reviewed the manuscript. This is Technical Contribution No. 3229 of the South Carolina Agricultural Experiment Station, Clemson University.—**Michael A. Floyd**, Department of Entomology, Clemson University, Clemson, South Carolina 29634-0365.

Two Additions to the Known Mushroom Flora of Kentucky.—A large colony of the brick-top mushroom, *Naematoloma sublateritum* (Fr.) Karst. was found growing around the base of a dead Chinese chestnut tree in Deacon Hills Estates, Richmond, Kentucky on 22 November 1989. This species is often mistaken for *N. capnoides* (Fr.) Karst. (Weber, N. S. and Smith, A. H. 1985, Field Guide to Southern Mushrooms. Univ. Mich. Press, Ann Arbor), but that species grows almost entirely on decaying coniferous wood and is dull yellowish-brown rather than brick red.

On 11 July 1990, a small colony of the poroid aphyllporale *Tyromyces chioneus* (Fr.) Karst. was found growing on the trunk of an autumn olive tree in Deacon Hills Estates. Although widespread in North America, reports of the species are infrequent.

Neither species has been previously reported from Kentucky.—**Branley Allan Branson**, Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 51–61

FORUM

DNA Replication in Plants
A Review

Valgene L. Dunham and Lesa Dill
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

Introduction

Applications of biotechnical procedures have resulted in an increased interest in plant DNA replication. These procedures, coupled with classical methods of protein purification and enzyme analysis, are now being applied in the elucidation of proteins involved in DNA replication.

Unfortunately, elucidation of the mechanisms of DNA replication in plants has progressed more slowly than investigations of bacterial and animal systems. Progress has been hindered by the presence of cell walls, nonsynchronous cell populations and relatively low intracellular protein concentrations. The use of cell-culture techniques, including synchronization of cell division using specific inhibitors of DNA replication, have led, and will continue to lead, to protein concentrations and yields necessary for protein purification. Perhaps more importantly, proteins involved in DNA replication are being studied at the genetic level through screening of genomic and cDNA libraries using oligonucleotide probes made to known DNA sequences for proteins in animal and yeast systems.

Using the above techniques, information concerning DNA replication and the intracellular controls of proteins are beginning to accumulate more rapidly. This review is an attempt to update information concerning DNA replication in plants reviewed by one of the authors several years ago (1) and will include recent unpublished data from several sources. The text is arranged in the proposed sequence of intracellular events immediately preceding, during, and following the S phase of the cell cycle. Data from animal and other eukaryotic systems may be included when information from plants is lacking so that a clearer picture of current knowledge can be presented.

Preparation for Synthesis

Chromosome Organization

The chromosomes of plants, like other eukaryotes, are complex structures composed of numerous proteins in addition to DNA. The supercoiling of DNA and the wrapping of the DNA around nucleosomes add to this complexity. It is assumed that levels of this organization must be altered so that proteins involved in the initiation of DNA replication can bind to the DNA strands. In addition, part of chromosomal organization in eukaryotes involves transient and permanent attachment of looped domains of DNA to a nuclear matrix. These domains approximate the size of replicons, regions of DNA that are synthesized during the S phase of the cell cycle. The matrix appears to serve as a scaffold during replication and reorganization of chromosomes. DNA topoisomerase II, an enzyme that uses ATP in the relaxation of supercoiled DNA by cleavage of both strands, is present in actively dividing cells and is involved in the attachment to the matrix (2). Although this enzyme is present in plants (3, 4), its role and its relationship to the nuclear matrix in replication of plant DNA remains to be elucidated.

Replicons

After areas of DNA have been exposed for replication, initiation must be localized at sequences that act as origins. Because of the size of the plant genome, multiple origins exist on a given chromosome. A replicon, the distance on the chromosome between origins, is used as the basic replication unit in studying DNA replication. Initiation of DNA replication at different replicons along the chromosome has been shown to have a sequential order and, therefore, is not simultaneous (Fig. 1). Replicons are

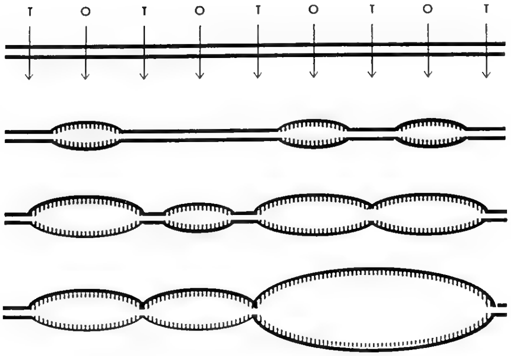


FIG. 1. Initiation of DNA replication on eukaryotic chromosomes. O = replication origin; T-T distance = one replicon.

TABLE 1. Comparison of replicons and fork movement in various organisms.

Organism	Number of replicons	Mean replicon size (Kb)	Fork movement (bp/min)
E. coli	1	4,200	50,000
S. cerevisiae	500	40	3,600
M. musculus (mouse)	25,000	150	2,200
higher plants	75,000*	66	400

References 5, 6, 7, 8, 9.
* Calculations based on: 15,000 replicons/pg DNA, 5 pg DNA/genome.

additionally organized into clusters and families. Clusters are defined as tandem replicons that may vary in organization based on the number of replicons/cluster, with up to 18 simultaneously active replicons/cluster in plants (5). Families of replicons are one or more clusters that are initiated at the same time during the S phase. Therefore, plants with large genomes require more replicon families and a longer S phase (6). In general, eukaryotic replicons are smaller than those of prokaryotes and replication forks move much more slowly (Table 1). In addition, spacing between origins is species specific and varies from 15 kb to 100 kb (7). A correlation between replicon size and the rate of fork movement has been shown in several grass species (8). Fork rates vary from 1.46 hr for complete replication of a replicon of *Oryza sativa* (DNA C value = 0.6 pg) to 2.40 hr in the hexaploid x *Triticosecale* (DNA C value = 21.5 pg). A DNA C value of 1.0 is the amount of DNA in the unreplicated nuclear genome of a gamete (9).

Origin Sequences

Initiation of DNA replication occurs at numerous origins along the eukaryotic chromosome. Demonstration of specific sequences at these sites of initiation have depended on autonomous replicating sequences (ARS) in yeast. With increasing evidence that ARSs are origins of replication, a putative origin might have the consensus ARS sequence A/T TTTATPuTTT A/T. When inserted into yeast, sequences from a number of eukaryotes have functioned as ARS sequences. The overall size of DNA fragments acting as ARS sequences may vary with species and even within species. For example, the size of ARS sequences in yeast and animal cells are approximately 300 bp, whereas ARS elements in tobacco are 1,187 bp (10), and in rape (*Brassica napus*) sequences of 220 and 926 bp have been found to be the minimum effective length (11). As expected, these plant ARS elements are A-T rich but, in the case of rape, are not the same from element to element. It is interesting to note than one of the elements from rape contained three consensus sequences, but in another element two regions of eleven consecutive T-residues were found (11). Apparently, not all ARS sequences are at origins of DNA replication in the plant genome. The cloned replication origin of the 9 kb rDNA repeats (ori-r-9) in pea is in a nontranscribed spacer region. Data from a hybridization between this clone and a labeled ARS consensus probe indicate that the ARS sequence is in a flanking region to the origin (12). These plant origins of replication resemble yeast ARS/origins in that they contain CAA..T and AAAA.. motifs, areas known to be involved in bent DNA (J. A. Bryant, pers. comm.).

In addition to these consensus sequences, origins from numerous organisms are known to contain binding sites for initiator proteins. The binding sites for yeast ARS binding proteins have been mapped using DNase I footprinting and binding techniques (13, 14). These techniques may now be employed using plant ARS-elements to assist in the identification of proteins that specifically bind at origins.

DNA Helicase

In prokaryotic cells, an ATP-dependent DNA helicase has been shown to function in the separation of DNA strands at the replication fork (15). Helicase activity has been described in mammals where it is closely associated with DNA polymerase-α and requires ATP (16), but not a replication fork-like structure for unwinding (17). Information about helicase in plant systems is restricted to the meiotic cells of *Lilium* (18). The enzyme requires a nick in the DNA for binding but has not been shown to be active at the replication fork.

Single-strand Binding Protein

Another protein located at the replication fork that functions in stabilizing DNA single strands is single-strand binding protein (SSBP). Once again, evidence for the presence of SSBPs in plants is restricted to the meiotic cells of *Lilium* (19).

DNA Topoisomerases

The separation of DNA strands during replication places torsional strain on the double-stranded DNA in front of the replication fork. This strain results in supercoiling of the DNA that must be removed by the action of topoisomerases so that movement of the fork is not inhibited. Type I topoisomerases, which do not require ATP and catalyze the relaxation of supercoiled DNA, have been studied in numerous eukaryotic organisms including plants. The enzyme has been characterized from wheat (20), pea (21, 22), soybean (23), tobacco (24), corn (4) and carrot cells (25). In general, the enzyme from plants does not require ATP, is stimulated by salt, and is not inhibited by novobiocin (an inhibitor of Type II topoisomerases). The actual association of Type I enzymes with events at the replication fork during DNA replication in plants remains to be described.

Eukaryotic Type II topoisomerase requires ATP, cleaves both strands of DNA, and catalyzes not only the reduction of supercoils but also the catenation and decatenation of closed double-stranded DNA circles (26). This enzyme has been implicated in anchoring DNA loops in animal chromosomes (3, see below), but its role in plants remains unknown.

Synthetic Activities

Priming

Once the double-stranded DNA has been separated at the origin of a replicon and required proteins (SSBPs, helicase, etc.) are present, the next step in replication is the priming of both template strands. Evidence in eukaryotic systems indicates that the primer is a short fragment of RNA that is synthesized by a unique enzyme, DNA primase. It is obvious that greater primase activity is required on the lagging strand because each Okazaki fragment must be primed.

In animal systems, primase appears to be part of a large multienzyme complex that includes DNA polymerase-α. For example, in HeLa cells the overall complex has a size of 640 kDa, which includes DNA polymerase-α, accessory proteins and a primase of 70 kDa (27). In several other eukaryotic systems the primase activity is a dimeric protein with subunits of approximately 60 and 40 kDa (28). In HeLa cells and human placenta, primer recognition proteins (PRP) I and II interact with DNA polymerase-α, allowing DNA replication under conditions similar to those during lagging-strand synthesis. PRP I has been identified as a phosphoprotein (calpactin I heavy chain) and PRP II is 3-phosphoglycerate kinase (29).

A recent investigation of a large DNA replication complex from pea (*Pisum sativum*) (30) has aided in a comparison of plant primase activity with that described for animals. Primase activity was monitored by increased DNA synthesis in the presence of (1) M13 DNA and ribonucleotides or (2) poly (dT) and rATP. Although not separately isolated and characterized, primase appears to be part of a large complex associated with DNA polymerase-α. Primase has been isolated from wheat embryos and rice cells separate from any polymerases (31, 32), but it is possible that the primase was dissociated from a DNA polymerase complex during purification.

Daughter Strand Synthesis

The most studied of the proteins involved in the synthesis of the daughter strands of DNA are the DNA polymerases. To date, 5 separate polymerases—termed α, β, γ, δ and ϵ—have been described to function in the replication of animal DNA (Table 2).

DNA polymerase-α is a large enzyme (200 kDa) with four major subunits of 180, 100, 73, and 49 kDa. The processivity of this enzyme in animals is fewer than 100 nucleotides incorporated per binding event, suggesting its involvement in lagging strand replication (33,

TABLE 2. Characteristics of Animal DNA polymerases.

Properties*	α	β	γ	δ	ϵ
Molecular weight (catalytic subunit)	100–200,000	50,000	140–200,000	120–170,000	200–250,000
Inhibition by					
N-ethylmaleimide	yes	no	yes	yes	
aphidicolin	yes	no	no	yes	yes
phosphate	no	yes	no		
high salt	yes	no	no		
Associated activities					
5′ → 3′ exonuclease	no	no	no	no	no
3′ → 5′ exonuclease	no	no	yes	yes	yes
In vivo location	nucleus	nucleus	mt, chlor	nucleus	nucleus
General function	replication on lagging strand	repair	replication	replication on leading strand	repair

* Properties may vary slightly depending on the source of the enzyme.

34, 35, 36). The animal enzyme is inhibited by aphidicolin, N-ethylmaleimide (NEM), and high salt concentrations, while it is unaffected by low phosphate concentrations or the presence of dideoxy NTPs.

Plant polymerase-α has been studied in a number of plants, most notably pea, sugar beet, soybean, turnip and spinach (see review; ref. 1). The pea enzyme, thought to be involved in the replication of nuclear DNA because of increased activity in proliferating cells (review, ref. 37), undergoes rapid breakdown from 230 kDa to catalytically active products of 180, 140, 100 and 50 kDa (30). Generally, the activity of plant polymerase-α is inhibited by potassium chloride, NEM, phosphonacetate, and aphidicolin and is unaffected by the presence of dideoxy NTPs.

DNA polymerase-β is unique among the polymerases because of its low molecular weight, a single polypeptide of about 40 kDa. The activity of the enzyme isolated from animals is inhibited by low concentrations of phosphate and dideoxy NTPs but is unaffected by aphidicolin and stimulated by high salt concentrations.

Although the enzyme has been characterized from numerous animal systems (review, 38), further investigation of the characteristics of the enzyme remains to be accomplished in plant systems. A small molecular weight enzyme with characteristics similar to the animal enzyme has been identified in several plants including sugar beet, tobacco, soybean, pea, and wheat embryos (review, 1). In recent experiments (39), the enzyme has been further characterized from etiolated soybean hypocotyls following chromatography through Sephadex G-75 and DEAE-cellulose. The enzyme has a molecular weight less than 50 kDa, is insensitive to aphidicolin, and is stimulated by high salt concentrations (Table 3). Its roles in DNA repair and recombination in plants remain to be elucidated.

DNA polymerase-γ functions in the replication of mitochondrial and chloroplastic DNA. DNA polymerase-γ has been isolated, purified, and characterized from the chloroplasts and cytoplasmic preparations of several plants including pea (40), turnip (41, 42), spinach (43) and soybean (42). As isolated from various plant tissue, DNA polymerase-γ is a large molecular weight enzyme (>100 kDa) with a catalytic subunit of 87 kDa (43, 44). A recent study using soybean and turnip indicates the presence in both plants of a γ-catalytic polypeptide of 66 kDa that is part of a much larger holoenzyme (42). In general, the enzyme is similar to animal polymerase-γ in that it is inhibited by NEM and by dideoxy NTPs and is unaffected by high salt concentrations, phosphate and low concentrations of aphidicolin.

DNA polymerase-δ is quite similar in properties to the α-enzyme but also has proofreading capabilities (3′-5′ exonuclease activity). The enzyme, as isolated from animal systems, has a large molecular weight of 170 kDa in its native form with subunits of 120 and 50–70 kDa. In the presence of proliferating cell nuclear antigen (PCNA, also known as cyclin), its processivity is greater than 1,000 nucleotides incorporated per binding event (35). These

TABLE 3. Characteristics of DNA polymerase-β from soybean hypocotyls.

Properties	
Molecular weight	<50,000
Inhibition by	
Aphidicolin	no
KCl	no
Activity on template/primer	
Poly (rA)-oligo (dT) in presence of Mn^{2+}	yes
Activated calf thymus	yes

TABLE 4. Classification of DNA polymerases based on similar conserved sequences.

Family A	Family B
E. coli polymerase I	Eukaryotic polymerase-α
S. pneumoniae polymerase I	Eukaryotic polymerase-δ
Taq polymerase I	
T7 polymerase	bacteriophage T_4
T5 polymerase	ϕ29
SPO2 mitochondrial polymerase	PR D1
Yeast mitochondrial polymerase	

References 51, 52, 53.

characteristics suggest that α and δ may work together as the major components of the multiprotein complex at the replication fork with α functioning on the lagging strand and δ synthesizing the continuous leading strand (35, 36, 45). As prepared from animals, the enzyme is sensitive to aphidicolin and NEM and is insensitive to phosphate and dideoxy NTPs. Human polymerase-δ has been shown to be immunologically distinct from polymerase-α and -ϵ. Both δ and ϵ are probably located in the nucleus (46). Recently, a plant δ-like polymerase has been identified (47) and the gene for PCNA appears to be present in rice, soybean, and tobacco genomes. These studies were based on hybridization of plant genomes with a rat PCNA cDNA probe (48). Recent evidence from pea indicates that replication of ribosomal DNA replicons is by leading strand only (49). This implies that polymerase-δ may be the polymerase involved in the replication of ribosomal DNA.

DNA polymerase-ϵ is a recently identified large molecular-weight enzyme of over 200 kDa. Originally discovered and classified as a subclass of DNA polymerase-δ, ϵ has been shown to be highly processive in the absence of PCNA and involved in DNA repair, specifically in repair induced by UV irradiation (50). DNA polymerase-ϵ has yet to be identified in plant preparations.

The above classification system (Greek letters) for eukaryotic organisms has been based on characteristics of the enzymes including molecular weight, sensitivity to inhibitors, specificity for template/primer systems, and processivity. With the techniques of recombinant genetics, a new system for the classification of DNA polymerases from both prokaryotic and eukaryotic cells is possible. This classification is based upon conserved regions in the enzymes and consists of 2 groups, family A and family B (51, 52, 53; Table 4).

Family B polymerases, the group containing the eukaryotic enzymes, possess several regions of highly conserved amino acid sequences that appear to be in the same order in all of the enzymes in the family. Several investigators have shown that one of the regions (the most highly conserved), when mutated, results in a loss of polymerase function (54, 55, 56). The pyrophosphorolytic activity of phage ϕ29 DNA polymerase (family B) has been mapped in a conserved region with the amino acid sequence YCDTD common to α-like DNA polymerases (57). The authors of this review are presently using these regions as probes for plant genes coding for DNA polymerases.

Removal of RNA Primers

Following the synthesis of daughter strands, RNA primers (especially on the lagging strand) must be removed from nascent Okazaki fragments. In prokaryotic cells, this is thought to be accomplished by the 5′-3′ exonuclease activity of DNA polymerase I, which then fills in the resulting gap. Although *Euglena* contains a 5′-3′ exonuclease activity closely associated with DNA polymerase (58), the activity has not been found associated with other eukaryotic replicative polymerases. An RNA primer could be removed by RNase H, an enzyme that removes RNA from a DNA/RNA duplex. Such activity is known to occur in some plants and increases in activity during DNA replication in carrot cells (59). The enzyme has not been shown to be associated with polymerases and can be separated from polymerase-primase (21).

Ligation

Following removal of the primer and the filling of the resultant gap, the newly synthesized fragments must be joined by the action of DNA ligase. Although DNA ligase activity is known to occur in higher plants, the enzyme has not been thoroughly characterized and its role in replication remains to be elucidated. As in animal systems, the enzyme may exist in multiple forms. Two forms of ligase from pea, soluble and chromatin-bound (60), increase during seed germination but at slightly different rates and are unequally inhibited by dTTP (61). A single DNA ligase activity has also been implicated in the repair of DNA in dry seeds (62). The loss of DNA repair activity with the increase in age of seeds appears to be associated with a loss of ligase activity. The association between ligase activity and plant DNA replication remains to be established.

POSTSYNTHETIC ACTIVITIES

Methylation

Plant DNA is highly methylated, especially in the ubiquitous sequences mCpG and mCNG. The enzyme, DNA methylase, has been identified in plants (review, ref. 1) and best characterized in pea. This enzyme has a molecular weight of 160 kDa, apparently uses CNG as the target sequence and has a preference for hemi-methylated double-stranded DNA (63). Further research is required to determine the specific timing of methylation during the plant cell cycle and the various roles that methylation plays in cellular events such as chromosome condensation and gene expression.

Separation of Daughter Molecules

Following DNA replication of both parental strands, the daughter strands must be separated before cell division. Although the role of topoisomerase II in separating daughter chromosomes in yeast has been described (64), such a function for topoisomerase II has not been shown in plants, although the enzyme has been shown to be active in cauliflower (3).

REGULATION

Regulation of DNA replication may be accomplished at several levels including entrance of cells into the S phase of the cell cycle, transcriptional and translational controls, posttranslational modification and substrate and effector concentrations. It is quite possible that these levels of control may be under more general types of control including growth regulators and other factors in the environment of the cell.

Cell Cycle

The intracellular levels and/or activity of enzymes and proteins involved in replication may be regulated directly or indirectly by mechanisms that control the entrance of cells into S phase. Extracts from the G1 phase, for example, are 10-fold less active than extracts from S phase in supporting *in vitro* replication of SV40 DNA (65).

Several enzymes exhibit changes in activity during the cell cycle with maximum activity in the S phase of proliferating cells. For example, in animal systems several proteins and protein complexes, which are specifically related to the S phase of the cell cycle, are known to interact and regulate DNA polymerases. PCNA, originally termed DNA polymerase-δ auxiliary protein, is synthesized during the S phase. In the presence of PCNA, DNA polymerase-δ increases in processivity, synthesizing long stretches of DNA per binding event (35). Activator 1 (A1) is a 5-subunit protein complex present in HeLa cells that has ATPase activity and, in conjunction with PCNA, acts in primer recognition for DNA polymerase-δ (66). The gene for PCNA has been identified in several plant genomes (48), but the expression of the gene and the role of the gene product remains to be described in plants.

Posttranslational Modification

An increasing number of studies related to the control of DNA replication at the level of the cell cycle have focused on the activity of protein kinase. For example, a protein kinase (Cdc28) is required for yeast cells to proceed from G1 into S phase. Factors that inhibit cell division, such as nutrient limitation and mating pheromones, also result in a loss of Cdc28 activity (67). A similar protein (p34), observed in human cells, does not fluctuate in concentration during the cell cycle and is a phosphoprotein itself (68). Another S phase-specific phosphoprotein from human cells, dividin, has been shown to be required for G1 to S phase transition, but its function remains to be described (69). Yet another protein, progressin, is S phase-specific and not present in quiescent cells. Like dividin, it has not been shown to be directly associated with DNA replication (69).

Several of the enzymes involved at the replication fork have been shown to be phosphoproteins. DNA polymerase-α is phosphorylated in several mammals (38). For example, the catalytic subunit of human DNA polymerase-α is hyperphosphorylated in G_2/M phase and appears to be controlled by p34 kinase (70). Topoisomerase I from Chinese hamster and mouse leukemia cells loses DNA relaxing activity along with its sensitivity to camptothecin following treatment with alkaline phosphatase (71). Both its DNA relaxing activity and inhibitor sensitivity are restored following phosphorylation by protein kinase C (PKC). Since PKC has been found in nuclei and co-purifies with topoisomerase I, phosphorylation may play a regulatory role *in vivo* (71). Topoisomerase I of calf thymus is also a phosphoprotein as evidenced by increased activity following phosphorylation by Type N II protein kinase (72). Topoisomerase II from HeLa cells has also been shown to be a phosphoprotein (73). Some evidence suggests that phosphorylation of other non-enzymatic proteins may regulate enzymes at the replication fork. For example, phosphorylation of histone-H1 in regenerating rat liver may regulate the activity of DNA primase (74).

At present, information on the phosphorylation of proteins involved in plant DNA replication has been limited to SSBPs in *Lilium* (75) and a loss of topoisomerase I and II activity following treatment of an extract from maize embryos with alkaline phosphatase (4). This mechanism of control is quite probable in plants because plant cell division and DNA replication are accompanied by an increase in phosphorylation. In earlier work, alteration of DNA polymerase activity has been shown following phosphorylation of crude nuclear protein preparations by a nuclear protein kinase from soybeans (76). In addition, protein kinase is present in a polymerase-primase complex recently isolated from pea nuclei (J. A. Bryant, pers. comm.).

Plant Growth Regulators

The long term effects of plant growth regulators on DNA synthesis have been reported by numerous investigators over the last 10–15 years (review, 6). The major problem associated with these data is the separation of increased DNA synthesis from a general increase in growth and/or nutrient supply. With improvement in the techniques employed in such studies, it may be possible to pinpoint the effects of growth regulators on the cell cycle and DNA replication. For example, using cytofluorometric techniques coupled with autoradiography, benzyladenine (BA) has been shown to induce DNA synthesis and the doubling of nuclear DNA in bean leaves (77). At a more specific level, treatment of the apical meristem of mustard with BA has been shown to activate new replicon origins resulting in a reduction of replicon size and a synchronization of replicon firing (78). The mechanism by which BA alters replicon initiation and timing remains to be described.

Reports of the effects of growth regulators on the synthesis and/or activity of proteins involved at the replicating fork are limited and do not yield information as to mechanism. Although treatment of maize embryos with 2,4-dichlorophenoxyacetic acid (2,4-D) resulted in a 200% increase in topoisomerase II activity (4), the mechanism has not been elucidated and might be the result of induced protein kinase activity.

Recently, several investigators have shown more specific mechanisms for growth regulator control at the level of gene expression. With respect to DNA replication and the involved proteins, indoleacetic acid (IAA) induces a gene in the shoot apex of *Arabidopsis* that codes for a DNA binding protein that is lysine-rich and has other properties similar to histone H1 (79). This gene, dpb, is expressed in all parts of the plant but is increased 5-fold in apical regions. Although the gene product is not H1, based on biochemical and immunological studies, it binds double-stranded DNA. These studies may begin to clarify the overwhelming amount of information relating growth regulators with DNA replication and chromosome structure.

Concluding Remarks

New technologies have resulted in numerous important additions to our knowledge of DNA replication. These include the ability to replicate SV40 DNA *in vitro* that has led to an understanding of the involvement of several

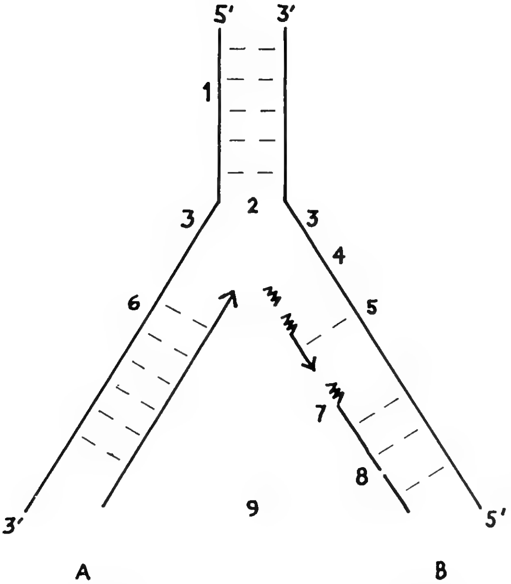


FIG. 2. Model for protein function during nuclear DNA replication in eukaryotic cells. 1. Topoisomerase I. 2. Helicase. 3. Single-strand binding protein. 4. Primase. 5. DNA polymerase-α. 6. DNA polymerase-δ. 7. Ribonuclease H. 8. DNA ligase. 9. Topoisomerase II.

proteins. Many advances have been made linking proteins associated with cell cycle controls to the regulation of DNA polymerases. They are reflected in a current model for DNA replication in eukaryotic cells (Fig. 2). The model reflects data that imply that DNA polymerase-α functions on the lagging strand and DNA polymerase-δ on the leading strand. Topoisomerase II has been included in the model to separate daughter chromosomes following replication. Unfortunately, few of these additions to information on DNA replication have come from plant research. With increased effort in several areas of plant research, including use of recombinant techniques to elucidate DNA polymerase structure, localization of proteins at replicons, and regulation of these proteins during the cell cycle, we should more rapidly clarify some of the major problems remaining in the replication of plant genomes.

ACKNOWLEDGMENTS

The authors acknowledge Kentucky-NSF-EPSCoR for financial support and the Kentucky Academy of Science for its role in establishing the NSF-EPSCoR program in the Commonwealth. We also thank Dr. John Bryant for his comments and unpublished data.

LITERATURE CITED

1. Bryant, J. A. and V. L. Dunham. 1988. DNA replication in plants. CRC Press, Boca Raton.

2. Earnshaw, W. C. and M. M. S. Heck. 1988. Cell biology of topoisomerase II. Pp. 279–288. In T. Kelly and B. Stillman (eds.) Cancer cells, Vol. 6. Eukaryotic DNA replication. Cold Spring Harbor Laboratory, New York.

3. Fukata, H., K. Ohgami, and H. Fukasawa. 1986. Isolation and characterization of DNA topoisomerase II from cauliflower inflorescences. Plant Mol. Biol. 6:137–144.

4. Carballo, M., R. Giné, M. Santos, and P. Puigdomenech. 1991. Characterization of topoisomerase I and II activities in nuclear extracts during callogenesis in immature embryos of *Zea mays*. Plant Mol. Biol. 16:59–70.

5. Van't Hof, J. 1988. Functional chromosome structure: the replicon. Pp. 1–15. In J. A. Bryant and V. L. Dunham (eds.) DNA replication in plants. CRC Press, Boca Raton.

6. Francis, D. 1988. Control of DNA replication. Pp. 55–68. In J. A. Bryant and V. L. Dunham (eds.) DNA replication in plants. CRC Press, Boca Raton.

7. Francis, D., A. D. Kidd, and M. D. Bennett. 1985. DNA replication in relation to DNA C values. Pp. 61–82. In J. A. Bryant and D. Francis (eds.) The cell division cycle in plants. Cambridge Press, Cambridge. U.K.

8. Kidd, A. D., D. Francis, and M. D. Bennett. 1989. Replicon size and rate of DNA replication fork movement are correlated in grasses. Exp. Cell Res. 184:262–267.

9. Lewin, B. 1990. Genes IV, p. 335. Oxford University Press, Oxford.

10. Ohtani, T., S. Kiyokawa, T. Ohgawara, H. Harada, and H. Uchimiya. 1985. Nucleotide sequences and stability of a *Nicotiana* nuclear DNA segment possessing autonomously replicating ability in yeast. Plant Mol. Biol. 5:35–39.

11. Sibson, D. R., S. G. Hughes, J. A. Bryant, and P. N. Fitchett. 1988. Characterization of sequences from rape (*Brassica napus*) nuclear DNA which facilitate autonomous replication of plasmids in yeast. J. Exp. Bot. 39:795–802.

12. Hernández, P., C. A. Bjerknes, S. S. Lamm, and J. van't Hof. 1988. Proximity of an ARS consensus sequence to a replication origin of pea (*Pisum sativum*). Plant Mol. Biol. 10:413–422.

13. Diffley, J. F. X. and B. Stillman. 1988. Interactions between purified cellular proteins and yeast origins of DNA replication. Pp. 235–243. In T. Kelly and B. Stillman (eds.) Cancer cells, Vol. 6. Eukaryotic DNA replication. Cold Spring Harbor Laboratory, New York.

14. Budd, M., C. Gordon, K. Sitney, K. Sweder, and J. L. Campbell. 1988. Yeast DNA polymerases and ARS-binding proteins. Pp. 347–357. In T. Kelly and B. Stillman

(eds.) Cancer cells, Vol. 6. Eukaryotic DNA replication. Cold Spring Harbor Laboratory, New York.

15. Kornberg, A. 1980. DNA replication. W.H. Freeman, New York.

16. Hübscher, U. and H. P. Stalder. 1985. Mammalian DNA helicase. Nucl. Acids Res. 13:5471–5483.

17. Tuteja, N., R. Tuteja, K. Rahman, L.-Y. Kang, and A. Falaschi. 1991. A DNA helicase from human cells. Nucl. Acids Res. 18:6785–6792.

18. Hotta, Y. and H. Stern. 1978. DNA-unwinding protein from meiotic cells of *Lilium*. Biochem. New York 17:1872–1880.

19. Hotta, Y. and H. Stern. 1971. A DNA-binding protein in meiotic cells of *Lilium*. Develop. Biol. 26:87–99.

20. Dyan, W. S., J. J. Jendrisak, D. A. Hager, and R. R. Burgess. 1981. Purification and characterization of wheat germ topoisomerase I (nicking-closing enzyme). J. Biol. Chem. 256:5860–5865.

21. Bryant, J. A., P. N. Fitchett, D. R. Sibson, and S. G. Hughes. 1985. Enzymes of the DNA-replication complex in higher plants. Biochem. Soc. Trans. 13:1200–1201.

22. Chiatante, D., J. A. Bryant, and P. Fitchett. 1991. DNA topoisomerase in nuclei purified from root meristems of *Pisum sativum*. J. Exp. Bot. In press.

23. Dye, R. B. 1989. Isolation and characterization of a type I topoisomerase from the hypocotyls of etiolated soybeans. M.S. thesis. Western Kentucky University, Bowling Green, Kentucky, 65 p.

24. Heath-Pagliuso, S., A. D. Cole, and E. B. Kmiec. 1990. Purification and characterization of a type-I topoisomerase from cultured tobacco cells. Plant Physiol. 94: 599–606.

25. Carbonera, D., R. Cella, A. Montecucco, and G. Ciarrocchi. 1988. Isolation of a type I topoisomerase from carrot cells. J. Exp. Bot. 39:70–78.

26. Wang, J. C. 1985. DNA topoisomerases. Ann. Rev. Biochem. 54:665–697.

27. Baril, E. F., L. H. Malkas, R. Hickey, C. J. Li, J. K. Vishwanatha, and S. Coughlin. 1988. A multiprotein DNA polymerase α complex from HeLa cells: interaction with other proteins in DNA replication. Pp. 373–384. In T. Kelly and B. Stillman (eds.) Cancer cells, Vol. 6. Eukaryotic DNA replication. Cold Spring Harbor Laboratory, New York.

28. Cotterill, S. M., M. E. Reyland, L. A. Loeb, and I. R. Lehman. 1988. Enzymatic activities associated with the polymerase subunit of the DNA polymerase-primase of *Drosophila melanogaster*. Pp. 367–371. In T. Kelly and B. Stillman (eds.) Cancer cells, Vol. 6. Eukaryotic DNA replication. Cold Spring Harbor Laboratory, New york.

29. Jindal, H. K., W. G. Chaney, C. W. Anderson, R. G. Davis, and J. K. Vishwanatha. 1991. The protein-tyrosine kinase substrate, calpactin I heavy chain (p 36), is part of the primer recognition protein complex that interacts with DNA polymerase α. J. Biol. Chem. 266: 5169–5176.

30. Bryant, J. A., P. N. Fitchett, S. G. Hughes, and D. R. Sibson. 1992. DNA polymerase-α in pea is part of a large multiprotein complex. J. Exp. Bot. 43:31–40.

31. Graveline, J., L. Tarrago-Litvak, M. Castroviejo, and S. Litvak. 1984. DNA primase activity from wheat embryos. Plant Mol. Biol. 3:207–215.

32. Marchesi, M. L., F. Villaggi, S. Spadari, G. Pedrali-Noy, and F. Sala. 1987. Properties of a DNA primase from rice cells. Mut. Res. 181:93–101.

33. Hohn, K. T. and F. Grosse. 1987. Processivity of the DNA polymerase α-primase complex from calf thymus. Biochem. 26:2870–2878.

34. Tan, C.-K., K. Sullivan, X. Li, E. M. Tan, K. M. Downey, and A. G. So. 1987. Autoantibody to the proliferating cell nuclear antigen neutralizes the activity of the auxiliary protein for DNA polymerase-delta. Nuc. Acids Res. 15:9299–9308.

35. Downey, K. M., C.-K. Tan, D. M. Andrews, X. Li, and A. G. So. 1988. Proposed roles for DNA polymerases α and δ at the replication fork. Pp. 403–410. In T. Kelly and B. Stillman (eds.) Cancer cells, Vol. 6. Eukaryotic DNA replication. Cold Spring Harbor Laboratory, New York.

36. Tsurimoto, T. and B. Stillman. 1991. Replication factors required for SV40 DNA replication *in vitro*. II. Switching of DNA polymerase-α and -δ during initiation of leading and lagging strand synthesis. J. Biol. Chem. 266: 1961–1968.

37. Dunham, V. L. and J. A. Bryant. 1985. Enzymic controls of DNA replication. Pp. 37–59. In J. A. Bryant and D. Francis (eds.) The cell division cycle in plants. Cambridge University Press, Cambridge, U.K.

38. Fry, M. and L. A. Loeb. 1986. Animal cell DNA polymerases. CRC Press, Boca Raton.

39. Dunham, V., L. Dill, and S. Day. 1991. Soybean polymerase-β: partial purification and characterization. Trans. Ky. Acad. Sci. 52:83.

40. McKown, R. L. and K. K. Tewari. 1984. Purification and properties of a pea chloroplast DNA polymerase. Proc. Natl. Acad. Sci. U.S.A. 81:2354–1258.

41. Dunham, V. L. and J. A. Bryant. 1986. DNA polymerase activities in healthy and cauliflower mosaic virus-infected turnip (*Brassica rapa*) plants. Ann. Bot. 57:81–89.

42. Hill, D. R. 1988. Isolation and characterization of DNA polymerase α and γ from turnips (*Brassica rapa*) and etiolated soybeans (*Glycine max*). M.S. thesis, Western Kentucky University, Bowling Green, Kentucky, 80 p.

43. Sala, F., A. R. Amileni, B. Parisi, and S. Spadari. 1980. A γ-like DNA polymerase in spinach chloroplasts. Eur. J. Biochem. 112:211–217.

44. Litvak, S. and M. Castroviejo. 1987. DNA polymerases from plant cells. Mut. Res. 181:81–91.

45. Tsurimoto, T., T. Melendy, and B. Stillman. 1990. Sequential initiation of lagging and leading strand synthesis by two different polymerase complexes at the SV40 DNA replication origin. Nature 346:534–540.

46. Lee, M. Y. W. T., Y. Q. Jiang, S. J. Zhang, and N. L. Toomey. 1991. Characterization of human DNA poly-

merase-δ and its immunochemical relationship with DNA polymerase-α and -ϵ. J. Biol. Chem. 266:2423–2429.

47. Richard, M. C., S. Litvak, and M. Castroviejo. 1991. DNA polymerase B from wheat embryos: a plant δ-like DNA polymerase. Arch. Biochem. Biophys. 287:141–150.

48. Suzuka, I., H. Daidoji, M. Matsuoka, K. Kadowaki, Y. Takasaki, P. K. Nakane, and T. Moriuchi. 1989. Gene for proliferating-cell nuclear antigen (DNA polymerase-δ auxiliary protein) is present in both mammalian and higher plant genomes. Proc. Natl. Acad. Sci. U.S.A. 86:3189–3193.

49. Van't Hof, J. and S. S. Lamm. 1991. Single-stranded replication intermediates of ribosomal DNA replicons of pea. EMBO J. 10:1949–1953.

50. Nishida, C., P. Reinhard, and S. Linn. 1988. DNA repair synthesis in human fibroblasts requires DNA polymerase-δ. J. Biol. Chem. 263:501–510.

51. Jung, G., M. C. Leavitt, J. Hsieh, and J. Ito. 1987. Bacteriophage PRD1 DNA polymerase: evolution of DNA polymerases. Proc. Natl. Acad. Sci. U.S.A. 84:8287–8291.

52. Leavitt, M. C. and J. Ito. 1989. T5 DNA polymerase: structural-functional relationships to other DNA polymerases. Proc. Natl. Acad. Sci. U.S.A. 86:4465–4469.

53. Ito, J. and D. K. Braithwaite. 1990. Yeast mitochondrial DNA polymerase is related to the family A DNA polymerases. Nuc. Acids Res. 18:6716.

54. Dorsky, D. I. and C. S. Crumpacker. 1990. Site-specific mutagenesis of a highly conserved region of the herpes simplex virus type 1 DNA polymerase gene. J. Virol. 64:1394–1397.

55. Bernad, A., J. M. Lazaro, M. Salas, and L. Blanco. 1990. The highly conserved amino acid sequence motif Tyr-Gly-Asp-Thr-Asp-Ser in α-like DNA polymerases is required by phage ϕ29 DNA polymerase for protein-primed initiation and polymerization. Proc. Natl. Acad. Sci. U.S.A. 87:4610–4614.

56. Jung, G., M. C. Leavitt, M. Schultz, and J. Ito. 1990. Site-specific mutagenesis of PRD1 DNA polymerase: mutations in highly conserved regions of the family B DNA polymerase. Biochem. Biophys. Res. Commun. 170:1294–1300.

57. Blasco, M. A., A. Bernad, L. Blanco, and M. Salas. 1991. Characterization and mapping of the pyrophosphorolytic activity of the phage-ϕ29 DNA polymerase: involvement of amino acid motifs highly conserved in α-like DNA polymerases. J. Biol. Chem. 266:7904–7909.

58. McLennan, A. G. and H. M. Keir. 1975. Deoxyribonucleic acid polymerases of *Euglena gracilis*. Primer-template utilization of, and enzyme activities associated with the two deoxyribonucleic acid polymerases of high molecular weight. Biochem. J. 151:227–238.

59. Sawai, Y., N. Sugano, and K. Tsukada. 1978. Ribonuclease-H activity in cultured plant cells. Biochim. Biophys. Acta 518:181–185.

60. Daniel, P. P., J. A. Bryant, and D. G. Barker. 1985. DNA ligase activity in pea seedlings (*Pisum sativum* L.): development of a sensitive assay system and partial characterization of soluble and chromatin-bound ligases. Biochem. Internat. 11:645–652.

61. Daniel, P. P. and J. A. Bryant. 1988. DNA ligase in pea (*Pisum sativum* L.) seedlings: changes in activity during germination and effects of deoxyribonucleotides. J. Exp. Bot. 39:481–486.

62. Elder, R. H., A. Dell'Aquila, M. Mezzina, A. Sarasin, and D. J. Osborne. 1987. DNA ligase in repair and replication in the embryos of rye, *Secale cereale*. Mut. Res. 181:61–71.

63. Yesufu, H. M. I., A. Hanley, A. Rinaldi, and R. L. P. Adams. 1991. DNA methylase from *Pisum sativum*. Biochem. J. 273:469–475.

64. DiNardo, S., K. A. Voelkel, and R. Sternglanz. 1984. DNA topoisomerase II mutants of *Saccharomyces cerevisiae*: topoisomerase II is required for segregation of daughter molecules at the termination of DNA replication. Proc. Natl. Acad. Sci. U.S.A. 81:2616–2620.

65. Roberts, J. and H. Weintraub. 1988. Positive and negative control of DNA replication. Pp. 191–196. In T. Kelly and B. Stillman (eds.) Cancer cells, Vol. 6. Eukaryotic DNA replication. Cold Spring Harbor Laboratory, New York.

66. Lee, S.-H., A. D. Kwong, Z.-Q. Pan, and J. Hurwitz. 1991. Studies on the activator 1 protein complex, an accessory factor for proliferating cell nuclear antigen-dependent DNA polymerase δ. J. Biol. Chem. 266:594–602.

67. Reed, S. I., J. A. Hadwiger, M. D. Mendenhall, and C. Wittenberg. 1988. Regulation of cell division in yeast by the Cdc 28 protein kinase. Pp. 251–258.
In T. Kelly and B. Stillman (eds.) Cancer cells, Vol. 6. Eukaryotic DNA replication. Cold Spring Harbor Laboratory, New York.

68. Draetta, G., L. Brizuela, and D. Beach. 1988. p34 protein kinase, a human homolog of the yeast cell cycle control proteins encoded by cdc 2^+ and CDC28. Pp. 259–263. In T. Kelly and B. Stillman (eds.) Cancer cells, Vol. 6. Eukaryotic DNA replication. Cold Spring Harbor Laboratory, New York.

69. Celis, J. E., P. Madsen, S. U. Nielsen, B. Gesser, H. V. Nielsen, G. P. Ratz, J. B. Lauridsen, and A. Celis. 1988. Cyclin (PCNA, auxiliary protein of DNA polymerase δ), dividin and progressin are likely components of the common pathway leading to DNA replication and cell division in human cells. Pp. 289–295. In T. Kelly and B. Stillman (eds.) Cancer cells, Vol. 6. Eukaryotic DNA replication. Cold Spring Harbor Laboratory, New York.

70. Nasheuer, H. P., A. Moore, A. F. Wahl, and T. S. F. Wang. 1991. Cell cycle-dependent phosphorylation of human DNA polymerase α. J. Biol. Chem. 266:7893–7903.

71. Pommier, Y., D. Kerrigan, K. D. Hartman, and R. I. Glazer. 1990. Phosphorylation of mammalian DNA topoisomerase I and activation by protein kinase C. J. Biol. Chem. 265:9418–9422.

72. Coderoni, S., M. Paparelli, and G. L. Gianfranceschi. 1990. Phosphorylation sites for type N II protein kinase in DNA-topoisomerase I from calf thymus. Int. J. Biochem. 22:737–746.

73. Kroll, D. J. and T. C. Rowe. 1991. Phosphorylation

of DNA topoisomerase II in a human tumor cell line. J. Biol. Chem. 266:7957–7961.

74. Takada, S., T. Magira, E. Suzuki, and M. Yamamura. 1990. Regulation of DNA primase activity by phosphorylation of histone-H1 in regenerating rat liver. Biochem. Int. 22:509–515.

75. Hotta, Y. and H. Stern. 1979. The effect of dephosphorylation on the properties of a helix-destabilising protein from meiotic cells and its partial reversal by a protein kinase. Eur. J. Biochem. 95:31–38.

76. Dunham, V. L. and W. N. Yunghans. 1977. Effects of nuclear proteins on the activity of soybean DNA polymerase. Biochem. Biophys. Res. Comm. 75:987–994.

77. Momotani, E., I. Kinoshita, E. Yokomura, and H. Tsuji. 1990. Rapid induction of synthesis and doubling of nuclear DNA by benzyladenine in intact bean leaves. Plant Cell Physiol. 31:621–625.

78. Houssa, C., A. Jacqmard, and G. Bernier. 1990. Activation of replicon origins as a possible target for cytokinins in shoot meristems of *Sinapis*. Planta 181:324–326.

79. Alliotte, T., C. Tiré, G. Engler, J. Peleman, A. Caplan, M. V. Montagu, and D. Inzé. 1989. An auxin-regulated gene of *Arabidopsis thaliana* encodes a DNA-binding protein. Plant Physiol. 89:743–752.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 62–66

ACADEMY AFFAIRS

The Seventy-Seventh Annual Business Meeting of the Kentucky Academy of Science

Executive Inn—Rivermont
Owensboro Kentucky
7–9 November 1991

Minutes of the Annual Meeting

The meeting was called to order by the President, W. Blaine Early III, at 10:08 a.m.

Reports of the Officers

Blaine Early thanked those who had been so willing to serve the Academy during his tenure. He reported that there were no nominations for the Distinguished Scientist Award this year and that more effort should be made to solicit nominations for the 1992 Annual Meeting.

He noted that the Academy has a major role to play in science education through the Kentucky Junior Academy of Science (KJAS) in the Kentucky Education Reform Act (KERA). In relation to KJAS he reported that the Director and two students attended the AAAS/NAAS/NAJAS meeting last February. At the Annual Meeting of KJAS over 300 students from 20 clubs were in attendance. He also mentioned the need for professional scientists to serve as mentors in the Junior Academy program.

The data base forms, originally developed by Larry Giesmann, have been modified with new categories. Only about 75 have been returned to the Secretary so far. There is a need for greater participation.

The Academy sponsored a Critical Thinking Workshop at the Kentucky Science Teachers Association meeting this year.

The Kentucky Mentors Program for Women in Science and Engineering has been published. The women highlighted in this publication can serve as role models for young, aspiring women scientists. He thanked Rod and Loraine Rodriguez for their efforts to bring this publication together.

The Collegiate Academy Committee has developed a program of paper competition and reward for undergraduate student presentations. This committee arranged a reception and pizza party at Brescia College for graduate and undergraduate students who were not attending the Annual Awards banquet.

On environmental issues Richard Hannan and the Kentucky Nature Preserves Commission requested that a Scientific Liaison Committee be appointed from KAS to work with the commission. That committee was approved by the Governing Board and has as members William H. Martin, Jerry Baskin, Branley Branson, and Guenter Schuster.

The Governing Board also approved a working draft of a plan to eventually have a permanent home with a full-time person to represent the Academy.

Blaine announced that the Academy has been the recipient of a bequest from the estate of Mr. Raymond Athey. The money is in trust and income will be available for research, education, and a limited amount of administration operation.

Vice-President Charlie Boehms thanked Doug Dahlman for being the program director this year and that as President Elect he will work closely with the section chairs and secretaries and the local arrangement committee for the 1992 meeting. He will need a list of officers from each section as soon as possible. He reminded the Academy that the meeting in 1992 will be 29–31 October. The first call for papers will be in the April Newsletter with return by the end of August. The program will be mailed to all those who preregister.

David Hartman distributed the Treasurer's Report and made brief comments about it.

Treasurer's Report

Kentucky Academy of Science
1991

Starting Balance (1991)		$69,184.24
Income (see below)	+38,815.51	
Expenses (see below)	−43,020.34	
Ending Balance (30 September 1991)		$64,979.41

Income—1991

Membership Dues		$12,015.00
Active (46 @ $15.00)	$ 690.00	
(218[1] @ $25.00)	5,450.00	
(27[2] @ $45.00)	1,215.00	
(65[3] @ $60.00)	3,900.00	
Family (3 @ $20.00)	60.00	
(8[1] @ $35.00)	280.00	
(1[2] @ $65.00)	65.00	
Student (3 @ $7.00)	21.00	
(17 @ $10.00)	170.00	
(12[1] @ $12.00)	144.00	
(1[2] @ $20.00)	20.00	
Life (61) 1992		
Institutional Memberships (See List Below)		5,950.00
Corporate Memberships (See List Below)		6,150.00
Library Subscriptions		850.00
Page Charges		2,897.00
Abstracts—(1991)		60.00
Annual Meeting—(1991)		856.00

Exhibits	0.00	
Preregistration & Banquet On-site Registration	856.00	
Interest Income		2,435.07
Bank	1,526.47	
CD	908.60	
Griffith Memorial Trust—1991		0.00
Endowment Fund Gifts		132.00
Life Memberships		350.00
Mentor Program		7,000.00
Miscellaneous—Overpayment of Dues		120.00
Total		$38,815.51

Expenses—1991

KJAS		$ 2,500.00
KJAS-AAAS—1991		400.00
NAAS—Dues		80.00
Printing		23,116.36
Transactions	$ 7,813.06	
Newsletter (Secretary)	2,377.17	
Other (Executive Secretary)	1,384.73	
Mentor Publication	11,541.40	
Professional Services (CPA)		590.00
Annual Meeting—1990 (Banquet)		3,000.65
1991		0.00
Transfer to Endowment Fund		6,132.00
Gifts	132.00	
Life Membership Adjustment	5,650.00	
New Life Member	350.00	
Griffith Awards		0.00
Refunds		2.00
Treasurer		72.43
Postage	21.60	
Checks	50.83	
Secretary		432.21
Postage	398.21	
Computer Supplies	34.00	
Executive Secretary		5,744.44
Postage	1,625.46	
Secretarial Services	885.95	
Computer	2,688.00	
Phone	162.81	
Kentucky Journal	20.00	
Transportation (U.K.)	362.22	
Meetings (Executive and Governing Board)		445.80
Miscellaneous		504.45
Corporate Fees	8.00	
Mailings (J. H. Carpenter)	28.60	
Trophy	41.85	
Travel (H. T. Davis)	420.00	
Bank Service Charge	6.00	
Total		$43,020.34

Kentucky Academy of Science Foundation

Endowment Fund—1991

Starting Balance (1 January 1991)		$17,568.79
Life Memberships (58)	$14,750.00	
Endowment	2,818.79	
Income		+8,076.88
Transfer from KAS		
Life Member Increase	5,650.00	
Gifts	132.00	
Direct Gifts to Endowment	100.00	
Life Memberships (1 @ $250.00)	250.00	
Life Memberships (2 @ $350.00)	700.00	
Interest		
Bank Account	363.02	
CD	881.86	
Expenses		0.00
Transfer to KAS for Life Memberships—1992		
Ending Balance (15 October 1991)		$25,645.67
Life Memberships (61)	$21,350.00	
Endowment	4,295.67	

Starting Balance (January 1, 1991)		$15,468.27
Principal	$13,296.97	
Interest	2,171.30	
Income		+945.29
Interest		
Bank Account	$ 304.36	
CD	540.93	
Donation	100.00	
Expenses		−787.00
Grant (Victor Call)	787.00	
Ending Balance (15 October 1991)		$15,626.56
Principal	$13,396.97	
Interest	2,229.59	

Marcia Athey Fund—1991

Starting Balance (1 January 1991)		$62,398.41
Principal	$54,218.52	
Interest	8,179.89	
Income		+3,462.11
Interest		
Bank Account	$ 723.36	
CD	2,738.75	
Expenses		−7,820.60
Grant (Darwin Dahl)	5,637.00	
Grant (Todd Buck)	1,333.60	
Grant (Verdie Abel)	850.00	
Ending Balance (15 October 1991)		$58,039.92
Principal	$54,218.52	
Interest	3,821.40	

Contributions from Colleges and Universities

Bellarmine College	$ 250.00
Berea College	100.00

Brescia College	100.00
Campbellsville College	100.00
Centre College	100.00
Cumberland College	250.00
Eastern Kentucky University	500.00
Georgetown College	250.00
Kentucky State University	100.00
Kentucky Wesleyan College	100.00
Midway College	100.00
Morehead State University	500.00
Murray State University	500.00
Northern Kentucky University	500.00
Spalding University	100.00
Sue Bennett College	100.00
Thomas More College	100.00
Transylvania University	100.00
Union College	100.00
University of Kentucky	1,000.00
University of Louisville	500.00
Western Kentucky University	500.00

Corporate Affiliates—1991

Air Products & Chemicals, Inc.	$ 500.00
All-Rite Pest Control	100.00
Alltech Biotechnology Center	250.00
Ashland Oil, Inc.	2,000.00
Brown and Williamson Tobacco Corporation	1,000.00
C & I Engineering, Inc.	250.00
Cohart Refractories Corporation	250.00
DataBeam Corporation	250.00
First Security Banks	100.00
GAF Chemicals Corporation	250.00
Group Financial Partners, Inc.	100.00
The Humana Foundation Inc.	200.00
International Business Machines Corporation	250.00
Litton Industrial Automation	250.00
MPD, Inc.	250.00
Proctor & Gamble	100.00
United Catalysts Inc.	250.00
Wood Hudson Cancer Research Laboratory, Inc.	100.00
Westvaco	200.00

On a motion by Ted George (seconded by Charlie Boehms) the Treasurer's Report was accepted.

The Executive Secretary, Rod Rodriguez, noted his pleasure at the acceptance of the publication on the Kentucky Mentors Program. There is a plan to update it in the future. Some of the operations of the Secretary and Treasurer have now been assumed by the Executive Secretary and in the future all mailings will be made from Lexington. He reported that the membership dues were sent in mid-Summer as they will be in the future.

COMMITTEE REPORTS

MEMBERSHIP COMMITTEE

Larry Giesmann, reporting for the Nominations, Elections, and Resolutions Committee, announced the election of Larry Elliott as Vice President, Kimberly Ward Anderson as the representative from the Division of Physical, Mathematical and Computer Sciences, and Blaine R. Ferrell as representative from the Division of Biology.

He then presented the following resolutions for approval.

Resolution I:

Whereas, the Kentucky Academy of Science, a professional society of over 900 scientists from across the Commonwealth of Kentucky and the United States, is vitally interested in the encouragement of research, the promotion of the diffusion of scientific knowledge, and the unification of scientific knowledge, and

Whereas, Brescia College, Kentucky Wesleyan College, and Owensboro Community College, all with outstanding academic programs and having dedicated and highly qualified faculty and staff, have graciously and efficiently hosted the 77th Annual Meeting of the Academy in Owensboro, Kentucky,

Therefore be it Resolved: that the Kentucky Academy of Science expresses its appreciation and gratitude to the administration, faculty, and staff of the host institutions and to the members of the city of Owensboro who have worked so diligently and effectively to make this Annual Meeting a success.

Resolution II:

Whereas, Varley E. Wiedeman has faithfully and tirelessly served as Secretary of the Kentucky Academy of Science for four years by keeping records of Academy proceedings and membership, preparing and mailing items of Academy business, editing the *Newsletter*, and tirelessly serving the Academy and its Governing Board in all other matters,

Therefore be it Resolved: that the Kentucky Academy of Science expresses its sincere appreciation and gratitude to Varley E. Wiedeman for his significant efforts in making the Kentucky Academy of Science a viable and strong presence in the Commonwealth.

Resolution III:

Whereas, the Officers, members of the Governing Board, and members of the Committees of the Kentucky Academy of Science have labored diligently and long throughout 1991 to achieve the goals of the Academy, and

Whereas, W. Blaine Early III, as President of the Kentucky Academy of Science in 1991 has served the Academy with distinction, provided creative leadership, and selflessly contributed his time and talents to the betterment of the Academy,

Therefore be it Resolved: that the members of the Kentucky Academy of Science collectively express their sincere gratitude for a job well done.

On a motion by Thomas Rambo (seconded by James Meeks) these resolutions were approved.

Blaine Early then recognized the retiring Secretary, Varley Wiedeman, and presented him with a plaque recognizing his service from 1988 through 1991.

Blaine then passed the gavel of the Office of President to Doug Dahlman who in return presented a plaque to Blaine recognizing his service as President of the Academy.

Doug Dahlman then made the following comments.

We must continue to encourage the growth of the Kentucky Junior Academy of Science through the investment of both time and resources. This should include expansion of the number of participating schools, identification of an individual to serve as the coordinator of all KJAS activities, as well as the identification of several individuals who will assume responsibilities for individual state-wide activities such as the science quiz teams, the presentation of research projects, and the science mentor program.

We must continue to foster the development of the Collegiate Academy as an integral part of the KAS. Important steps have been made in 1991 and should be implemented at the 1992 Annual Meeting. Included in this effort are Section Awards for best undergraduate paper, encouragement of affiliation of existing science clubs on various campuses with the KAS, and development of incentives to attend and participate in the Annual Meeting.

A working proposal has been approved by the KAS Governing Board which outlines a long-range plan to establish a permanent office for KAS. A substantial amount of additional planning, particularly as it relates to fiscal responsibility and logistics, remains to be completed. It is certain that during 1992 the KAS will continue to address this very important issue related to our future.

KAS has made great strides in the development of a sound membership base during the past 10 years, as evidenced by both the significant increase in numbers of currently paid memberships and in the participation of members in the Annual Meeting. However, participation is still not what it should and could be. This is particularly true with respect to our colleagues at the two Ph.D. granting institutions in the Commonwealth. Hopefully, through a united effort, we can begin to communicate to our colleagues within the ranks and administrative structure the truth that participation in KAS activities provides reward at both the academic and professional levels. Our collective concern over declining numbers of young scientists and the level of preparation of those that do choose a science career is one important reason that all Kentucky scientists should have an affiliation with KAS. Another response is to raise our level of consciousness with respect to professional citizenship and to become activists at the local and regional levels in the promotion of good science.

The meeting was adjourned at 10:58 a.m.

Chairpersons and Secretaries for KAS in 1992

Chairperson — *Secretary*

Anthropology—Section A

James F. Hopgood
Anthropology Program
Northern Kentucky University
Highland Heights, KY 41076
(606)572-5252

James Murray Walker
Dept. of Anthropology & Social Work
Eastern KY University
Richmond, KY 40475
(606)622-4387 or 1644

Botany and Microbiology—Section B

David Taylor
USDA Forest Service
1835 Big Hill Road
Berea, KY 40403
(606)986-8434

Landon McKinney
KY State Nature Preserves Commission
407 Broadway
Frankfort, KY 40601
(502)564-2886

Chemistry—Section C

Nancy Flachskam
Chemistry Department
Kentucky Wesleyan College
Owensboro, KY 42301
(502)926-3111
(502)683-0023 (home)

will let us know

Geology—Section E

Thomas R. Lierman
Dept. of Physical Sciences
Morehead State University
Morehead, KY 40351
(606)783-2166

Graham Hunt
Dept. of Geology
University of Louisville
Louisville, KY 40208
(502)588-6821

Physics—Section F

John Christopher
Dept. of Physics
University of Kentucky
117 Chem-Physics Bldg.
Lexington, KY 40506-0055
(606)257-6101

Vincent DiNoto
KAS REPRESENTATIVE
Jefferson Community College SW
Louisville, KY 40201
(502)935-9840, ext. 280

Physiology, Biophysics, Biochemistry, and Pharmacology—Section G

William W. Farrar
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606)622-1531 or 4990

Dexter Speck
Dept. of Physiology & Biophysics
MN504A Chandler Medical Ctr.
University of Kentucky
Lexington, KY 40536-0040
(606)233-5383

Science Education—Section H

Zexia K. Barnes
Dept. of Chemistry
Morehead State University
Morehead, KY 40351
(502)783-2927 or 2914

Ben Malphrus
Lappin 216
Dept. of Physical Sciences
Morehead State University
Morehead, KY 40351
(502)783-2212

Psychology—Section I

David Hogan
Dept. of Psychology
Northern KY University
Highland Heights, KY 41076
(606)572-5117

Jeff Smith
Dept. of Psychology
Northern KY University
Highland Heights, KY 41076
(606)572-5317

Sociology—Section J

Curt Bergstrand
Dept. of Sociology
Newburg Road
Bellermine College
Louisville, KY 40205

Steve Savage
Dept. of Sociology
Keith 223
Eastern Kentucky University

(502)452-8145 or 800-928-4723

Richmond, KY 40475
(606)622-1644

Zoology and Entomology—Section K

Matthew Byers
Community Research Service
Kentucky State University
Frankfort, KY 40601
(502)227-6253

Monte Johnson
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606)257-6693

Mathematics—Section M

No change yet

No change yet

Engineering—Section N

Keith Rouch
Center for Robotics
University of Kentucky
236B Anderson Hall
Lexington, KY 40506-0037
(606)257-8733

Issam Harik
Civil Engineering
University of Kentucky
224 Eng. Transportation Res. Bldg.
Lexington, KY 40506-0461
(606)257-3116

Scientific Information—Section O

no new officers

Agriculture—Section Q

Robert J. Barney
Atwood Research Facility
Kentucky State University
Frankfort, KY 40601
(502)227-6178

Robert J. Barney
Atwood Research Facility
Kentucky State University
Frankfort, KY 40601
(502)227-6178

Industrial Sciences—Section R

Estel M. Hobbs
Ashland Petroleum Co.
PO Box 391
Ashland, KY 41114
(502)329-5485

Burtron H. Davis
Center for Applied Energy Research
3572 Iron Works Pike
Lexington, KY 40511
(606)257-0251

Trans. Ky. Acad. Sci., 53(1–2), 1992, 67–92

PROGRAM, ANNUAL MEETING

KENTUCKY ACADEMY OF SCIENCE
THE SEVENTY-SEVENTH ANNUAL MEETING

Executive Inn
Owensboro, Kentucky
7–9 November 1991

KENTUCKY ACADEMY OF SCIENCE
77TH ANNUAL MEETING

Owensboro, Kentucky

University Center—UC
Natural Science Center—NS

PROGRAM SUMMARY

Thursday, 7 November 1991

9:00–12:00 p.m.
KAS Officiers and Governing Board Meeting
Tennessee Room

2:00–7:00 p.m.
Registration
Main Lobby

7:00–9:00 p.m.
Reception
Florida Room

Friday, 8 November 1991

7:30 a.m.–6:00 p.m.
Registration
Main Lobby

8:00 a.m.–3:40 p.m.
Protecting Kentucky's Biological Diversity: Current Perspectives
Texas Room

8:00 a.m.–5:30 p.m.
Scientific Poster Exhibits
Florida Room

8:00 a.m.–5:30 p.m.
Vendor Exhibits
Florida Room

8:00 a.m.–11:00 a.m.
Coal and Petroleum Symposium
Michigan Room

10:00 a.m.–10:30 a.m.
Community College Science Faculty
Hoosier Room

10:30 a.m.–12:00 noon
Community College Biology Faculty
Hoosier Room

10:30 a.m.–12:00 noon
Community College Chemistry Faculty
Illinois Room

10:30 a.m.–12:00 noon
Community College Physics Faculty
Missouri Room

8:00 a.m.–12:00 noon
Sectional Meetings
Section B—Botany and Microbiology (10:45), Colorado Room; Section C—Chemistry (11:15), Michigan Room; Section D—Geography (8:30), Arizona Room; Section G—Physiology and Biophysics (8:30), Oklahoma Room; Section I—Psychology, California Room; Section J—Sociology (10:00), Nevada Room; Section K—Zoology and Entomology, Ohio Room

9:30 a.m.–10:00 a.m.
Refreshments
International C

1:00 p.m.–3:40 p.m.
Protecting Kentucky's Biological Diversity: Current Perspectives
Texas Room

1:00 p.m.–3:30 p.m.
Sectional Meetings
Section B—Botany and Microbiology (1:15), Colorado Room; Section C—Chemistry, Michigan Room; Section D—Geography (1:30), Arizona Room; Section E—Geology, Hoosier Room; Section F—Physics (1:15), Oklahoma Room; Section H—Science Education (1:15), Missouri Room; Section I—Psychology (1:30), California Room; Section J—Sociology (1:30), Nevada Room; Section K—Zoology and Entomology, Ohio Room; Section M—Mathematics (1:30), Illinois Room

3:30 p.m.–4:00 p.m.
Refreshments
International C

4:00 p.m.–5:30 p.m.
Plenary Session
International B

Presiding

W. Blaine Early, III—President,
Kentucky Academy of Science

Welcome

Bruce Beck, Local Arrangements Chairperson

Plenary Presentation

Stratospheric Ozone Depletion as It Affects Life on Earth

Dr. Thomas P. Coohill—Western Kentucky University

7:00 p.m.–9:00 p.m.
Annual Awards Banquet
International A

Reducing Class Gender and Racial Bias in Science Teaching

Dr. Craig E. Nelson—University of Indiana

Saturday, 9 November 1991

8:00 a.m.–1:00 p.m.
Registration
Main Lobby

8:00 a.m.–2:00 p.m.
Scientific Poster Exhibits
Florida Room

8:00 a.m.–2:00 p.m.
Vendor Exhibits
Florida Room

7:55 a.m.–12:40 p.m.
Industrial Science Symposium Featuring Kentucky Mentors, Women in Science, Mathematics and Engineering
Texas Room

9:00–11:00 a.m.

Physics Workshop—Vernier Software and Use of the Computer in the Laboratory
Arizona Room

8:00 a.m.–9:30 a.m.
Sectional Meetings
Section A—Anthropology, Nevada Room; Section B—Botany and Microbiology, Colorado Room; Section C—Chemistry, Michigan Room; Section F—Physics, Oklahoma Room; Section H—Science Education (8:45), Missouri Room; Section I—Psychology, California Room; Section K—Zoology and Entomology, Ohio Room; Section L—Computer Science (8:30), Louisiana Room; Section M—Mathematics, Illinois Room; Section N—Engineering, Hoosier Room; Section R—Industrial Science (7:55), Texas Room

9:00 a.m.–12:00 noon
A Quick Introduction into Three Schemes for Critical Thinking in Science—Dr. Craig Nelson—Workshop
Tennessee Room

9:30 a.m.–10:00 a.m.
Refreshments
International C

10:00 a.m.–11:00 a.m.
Annual Business Meeting
International B

11:00 a.m.–12:00 noon
Sectional Meetings (same locations as above)

1:00 p.m.–end
Sectional Meetings
Section A—Anthropology, Hoosier Room; Section F—Physics, Illinois Room

1:00 p.m.–4:00 p.m.
A Quick Introduction into Three Schemes for Critical Thinking in Science—Dr. Craig Nelson—Workshop
Tennessee Room

Note: KJAS

Each spring the Kentucky Junior Academy of Science holds an Annual Spring Symposium. The 57th Symposium was held at Eastern Kentucky University on April 26–27, 1991. Activities at this meeting include the presentation of Science Projects by KJAS members as well as Science Bowl competition and Lab Skills competition. The winners of each division of the Science Projects presentations are invited to present their work at the annual meeting of the Kentucky Academy of Science, A KJAS precedes the title of each of the papers given by these young scientists.

PROTECTING KENTUCKY'S BIOLOGICAL DIVERSITY CURRENT PERSPECTIVES

Texas Room

Friday, 8 November 1991

Richard Hannan—Presiding

8:15 a.m.
Welcome

Section I—Conservation Organizations

8:25 a.m.
The Kentucky Chapter of The Nature Conservancy
Barry Dalton—The Nature Conservancy

8:50 a.m.
Bernheim Forest
Charles McClure—I. W. Bernheim Foundation

Section II—Colleges and Universities

9:05 a.m.
Eastern Kentucky University's Division of Natural Areas
William H. Martin—Eastern Kentucky University

9:30 a.m.
Refreshments
International C

10:00 a.m.
Robinson Forest
Robert Muller—University of Kentucky

10:25 a.m.
Berea College Forest
Ralph Thompson and John Stephenson—Berea College

10:40 a.m.
Murphy's Pond
Duke Wilder—Murray State University

Section III—State Agencies

10:55 a.m.
Kentucky State Nature Preserves Commission
Joyce Bender—Kentucky State Nature Preserves Commission

11:20 a.m.
Kentucky Department of Fish and Wildlife Resources
Lynn Garrison—Kentucky Department of Fish and Wildlife Resources

11:45 p.m.
Lunch

1:00 p.m.
Kentucky Department of Parks
Carey Tichenor—Kentucky Department of Parks

1:25 p.m.
Kentucky Division of Forestry
Cary Perkins—Kentucky Division of Forestry

Section IV—Federal Agencies

1:50 p.m.
Daniel Boone National Forest
Rex Mann—Forest Service

2:15 p.m.
Mammoth Cave National Park
Jeff Bradybaugh—National Park Service

2:30 p.m.
Big South Fork National River and Recreation Area
William Dickinson and Ron Cornelius—National Park Service

2:45 p.m.
Cumberland Gap National Historic Park
Jack Collier—National Park Service

3:00 p.m.
Land Between the Lakes
Thomas Forsythe—Tennessee Valley Authority

3:20 p.m.
Army Corps of Engineers
Robert VanHoff—Army Corps of Engineers

3:40 p.m.
Closing
Richard R. Hannan—Kentucky State Nature Preserves Commission

4:00 p.m.
Plenary Session
International B

WORKSHOP OF CRITICAL THINKING IN SCIENCE

Dr. Craig Nelson, Indiana University

A Quick Introduction into Three Schemes for Critical Thinking in Science

Saturday, November 9

9:00 a.m.–12 noon
Tennessee Room

1:00 p.m.–4:00 p.m.
(repeat of morning workshop)
Tennessee Room

This 3 hour interactive Workshop will be limited to 30 persons for each session. A variety of materials will be provided to the participants. This workshop meets the guidelines for inservice credit under the category of research-based instructional strategies. Participants should consult their local Districts regarding the availability of flexible inservice credit for this workshop. Participants will be provided with documentation of attendance and participation in the 3 hr workshop. An additional $20 fee is to be charged for participants who also are registered for the KAS meeting. Participants who do not register for the KAS meeting will be charged a fee of $30.

COMMUNITY COLLEGES SCIENCE FACULTY

Hoosier Room

Friday, 8 November 1991

10:00 a.m.
General Session—Michael Kerwin—Presiding

10:30 a.m.
Break-out Sessions
Biology Teachers, Janet Robison—Presiding—Hoosier Room
Chemistry Teachers, Kenneth Fuller—Presiding—Illinois Room
Physics Teachers, Vincent DiNoto—Presiding—Missouri Room

12:00 p.m.
Lunch

ANTHROPOLOGY SECTION

James F. Hopgood—Chairman
Jim Murray Walker—Secretary
a.m.—Nevada Room
p.m.—Hoosier Room

Saturday, 9 November 1991

James F. Hopgood—Presiding

8:00 a.m.
Reducing Regional Tensions After the Gulf War
Jules DeLambre—Frankfort, KY

8:15 a.m.
Thus Sprang Zarathushtra: The Aryan-Hebraic Background of the Ancient Iranian Prophet
Jim Murray Walker—Eastern Kentucky University

8:30 a.m.
Evidence of Intentional Large Design in Anasazi Rock Art: Three Widely Separated Sites
Robert Vallier—University of Tennessee at Chattanooga

8:45 a.m.
Navajo Sand-Painting Motifs in Chaco Rock Art
Jeannette Vallier—University of Tennessee at Chattanooga

9:00 a.m.
Angels at Smallhous—Fact or Fiction?
Bruce Beck—Owensboro Community College

9:15 a.m.
The Rise and Fall of the Ghost Dance Religions
Joseph D. Stewart—Eastern Kentucky University

9:30 a.m.
Refreshments
International C

10:00 a.m.
Annual Business Meeting
International B

11:00 a.m.
Sacred Fruit: Utilization of the Hallucinogenic Plants Among Native Americans of the Southwest and Middle America
Rocky Lear—Eastern Kentucky University

11:15 a.m.
Consent of the Governed: Is It Really Greek?
Cara Richards—Transylvania University

11:30 a.m.
The Role of Terrain in the Struggles of the Cimmarones in Latin America
Ray Lewis—Eastern Kentucky University

11:45 a.m.
Exchange Moralities and Negative Reciprocity in an Aztec Village: Practical and Ethical Problems in Fieldwork
Timothy D. Murphy—Northern Kentucky University

12:00 p.m.
Lunch

1:00 p.m.
Health Policy and Infant Development in an Urban Chinese Setting
Angela Scoggin—Eastern Kentucky University

1:15 p.m.
The Jagannath Car Festival
Robin Martin-Holmes—Northern Kentucky University

1:30 p.m.
Museum Methods: Programmatic and Pedagogic Issues
James F. Hopgood—Northern Kentucky University

1:45 p.m.
Anthropology Section Business Meeting

2:00 p.m.
Modern Aztec Wedding: Economic Cooperation and Rituals of Kinship
Patrick D. Murphy—Ohio University and Timothy D. Murphy—Northern Kentucky University

BOTANY AND MICROBIOLOGY SECTION

Allen Risk—Chairperson
David Taylor—Secretary
Colorado Room

Friday, 8 November 1991

Alan Risk—Presiding 10:45 a.m.–12 p.m.
David Taylor—Presiding 1:00–3:30 p.m.

10:45 a.m.
The Status of *Trifolium stoloniferum* Muhl. *ex* A. Eaton, Running Buffalo Clover (Fabaceae), in Kentucky
Tom Bloom* and Margaret Shea—Kentucky State Nature Preserves Comm.

11:00 a.m.
The Vascular Flora of Estill County, Kentucky
Richard G. Guetig—Eastern Kentucky University

11:15 a.m.
Fungal Composition of On-farm Stored Corn in Western Kentucky: Results of a Two Year Survey
Bryan D. Price,* John D. Sedlacek and Paul A. Weston—Kentucky State University

11:30 a.m.
Effects of Acidity, Aluminum, and Manganese on Multiplication of Lespedeza *Bradyrhizobium*
G. R. Cline—Kentucky State University

11:45 a.m.
KJAS
The Effect of Salt on Rye Grass
Andy Callahan—Moss Middle School

12:00 p.m
Lunch

1:15 p.m.
Microhabitat Variability and the Diatom Community Structure in the Bracts of Six Species of *Heliconia* spp.
Vicki Martin-Kier* and Thomas C. Rambo—Northern Kentucky University

1:30 p.m.
Effects of Simulated Rain Acidified by Nitric Acid on Wisconsin Fast Plants (*Brassica rapa* L.)
Mary K. Mastorakis—Midwestern State University and Joe E. Winstead*—Western Kentucky University

1:45 p.m.
Microbial Quality Assurance Program Developed for a Juice Bottling Company
Larry P. Elliott* and J. Mark Clauson—Western Kentucky University

2:00 p.m.
Slug Dispersal of Bryophyte Propagules
Craig C. Young and Robin W. Kimmerer—Centre College

2:15 p.m.
Species Area Relationships Among Saxicolus Bryophytes
Melanie J. Driscoll and Robin Kimmerer—Centre College

2:30 p.m.
Population Density and Resistance to Invasion in the Soil-Dwelling Bryophyte, *Dicranella heteromalla*
Julie S. Dickson and Robin W. Kimmerer—Centre College

NSF—RESEARCH EXPERIENCE FOR UNDERGRADUATES

University of Kentucky

Andrew Sih—Coordinator

2:45 p.m.
Effects of Root Herbivory on Competitive Interactions Across a Nutrient Gradient
Kenneth Hensley* and Scott Gleeson—University of Kentucky

3:00 p.m.
Root/shoot Dynamics Under Variable Nitrogen and Density Conditions
Travis Harper*—Centre College and Scott Gleeson—University of Kentucky

3:15 p.m.
Nutrient Considerations in Tidal Creeks of North Inlet, South Carolina
Steven Davis*—Georgetown College and Brian Reeder—Morehead State University

3:30 p.m.
Refreshments
International C

4:00 p.m.
Plenary Session
International B

Saturday, 9 November 1991

Alan Risk—Presiding 8:00–9:30 a.m.
David Taylor—Presiding 1:00 p.m.–12 p.m.

8:00 a.m.
Dry Matter Accumulation in Bell Pepper (*Capsicum an-*

num) Plants Grown in Association With *Azospirillum lipoferum*
Cloyd J. Bumgardner*—Pulaski County High School and David Madon—Eastern Kentucky University

8:15 a.m.
The Styracaceae of Kentucky
Edward W. Chester—Austin Peay State University

8:30 a.m.
Blooming and Triggering Patterns of *Pleiostachya pruinosa* (Marantaceae)
Amy M. Racke—Northern Kentucky University

8:45 a.m.
Effect of *Axospirillum lipoferum* on Establishment of Associative Nitrogen Fixing Bacteria in the Rhizospheral Growth Substrate of Bell Pepper (*Capsicum annum*) Plants
Cloyd J. Bumgardner*—Pulaski County High School and David Mardon—Eastern Kentucky University

9:00 a.m.
KJAS
The Effect of Municipal Waste on the Growth of Algae in Lily Creek
Tonya K. Wade—Casey County High School

9:15 a.m.
Botany and Microbiology Section Business Meeting

9:30 a.m.
Refreshments
International C

10:00 a.m.
Annual Business Meeting
International B

11:00 a.m.
Effect of *Azospirillum lipoferum* on Establishment of Types and Numbers of Non-Nitrogen Fixing Bacteria and Fungi in Bell Pepper (*Capsicum annum*)
Rhizospheral Growth Substrates
Cloyd J. Bumgardner*—Pulaski County High School and David Mardon—Eastern Kentucky University

11:15 a.m.
KJAS
Effect of Electric Discharge on Nitrification in Soil
Lara Rymarquis—Notre Dame Academy

11:30 a.m.
KJAS
Does the Amount of Sodium Ions in a Solution Provide a Shield From Microwaves
Lori Ann Clark—Southside Middle School

11:45 a.m.
The Habitat and Associates of *Helianthus eggertii* Small
Ronald L. Jones—Eastern Kentucky University

CHEMISTRY SECTION

James Niewahner—Chairperson
Nancy Flachskum—Secretary
Michigan Room

Friday, 8 November 1991

Coal and Petroleum Symposium
John T. Riley—Presiding

8:00 a.m.
Organic Sulfur in Raw and Extracted Coals
Scott Coffey,* Sarah Sadler, Jeff Stidam and John T. Riley—Western Kentucky University

8:15 a.m.
Desulfurization of Coal Using Mild Oxidative Conditions
Bucheng Wang, Junior Graham, Michelle Lewis and John T. Riley—Western Kentucky University

8:30 a.m.
FT-NMR Analysis of Sulfur in Coal
Paul Whitley,* Kanning Wu and Thomas K. Green—Western Kentucky University

8:45 a.m.
Determination of Chlorine in Gases Evolved From Coal Pyrolysis
Dakang Shao, Chan-Shon Ya and Wei-Ping Pan—Western Kentucky University

9:00 a.m.
The Determination of Volatile Matter in Coals of High Free Swelling Index by Instrumental Methods
Mark Thompson* and Henry Francis—University of Kentucky

9:15 a.m.
Design of Fluidized Bed Combustor
Erik J. Hutchinson,* Wei-Ping Pan, John Riley and John Smith—Western Kentucky University

9:30 a.m.
Evaluation of Combination Fuels for Fluidized Bed Combustors by Thermal Analytical Techniques
Tim Roth, Mary Campbell, Mingxu Zhang and Wei-Ping Pan—Western Kentucky University

9:45 a.m.
Refreshments
International C

10:00 a.m.
Vapor Sorption Studies on Argonne Premium Coals
Trent Selby* and Thomas Green—Western Kentucky University

10:15 a.m.
The Effect of Slurried Coal Particle Size on ICP Emmission Intensities
Joe Werth, Michelle Lewis, Mike Mertens and John T. Riley—Western Kentucky University

10:30 a.m.
Clean Gasoline Coal Derived Liquids
Robert A. Keough and B. H. Davis—Center for Applied Energy Research

10:45 a.m.
Deuterium Tracer Studies in Coal Liquefaction
Bluchang Shi, Robert Guthrie and B. H. Davis—Center for Applied Energy Research

11:00 a.m.
Determination of Styrene/Butadiene Copolymer by TG-FTIR
Brice Bowley,* Pei Gu and Wei-Ping Pan—Western Kentucky University

General Papers—Section C

11:15 a.m.
A Low-Cost, Precision Data Acquisition System for the Commodore 64
Terry W. McCreary* and Lisa Culver—Murray State University

11:30 a.m.
Determination of Milkweed by Thermal Technique
Pei Gu,* Rita K. Hessley and Wei-Ping Pan—Western Kentucky University

11:45 a.m.
Bimolecular Substitution Reactions of Benzyl Chlorides: Evidence for a Changing Transition State Structure
Paul E. Yeary—University of Kentucky

12:00 p.m.
Lunch

Friday, 8 November 1991

James Niewahner—Presiding

1:00 p.m.
Nucleophilic Aromatic Substitution Reactions of N-Heterocycles: Aminolysis of 2-Fluoro-1-methylpyridinium Iodide in Aqueous Solution
Songyuan Shi* and Oliver J. Muscio, Jr.—Murray State University

1:15 p.m.
Nucleophilic Aromatic Substitution Reactions of N-Heterocycles: Aminolysis of 1-Methyl-2-(4-nitrophenoxy)pyridinium Iodide in Acetonitrile
Haisheng Wang* and Oliver J. Muscio, Jr.—Murray State University

1:30 p.m.
SEM Studies of Composite Electrodes
Jeffrey B. Montgomery,* Christina L. Thompson and Jeffrey E. Anderson—Murray State University

1:45 p.m.
Thermal Properties of Some Lipid Components of Cell Membrane
Lihua Wei, David R. Hartman and Martin R. Rouston—Western Kentucky University

2:00 p.m.
Advanced NMR Spectroscopy I: Organic Analysis by the DEPT Technique
R. W. Holman, John Reasoner and Ellen Ligon—Western Kentucky University

2:15 p.m.
Advance NMR Spectroscopy II: Organic Analysis by the COSY Technique
Robert W. Holman, John W. Reasoner and Carl Whittle*—Western Kentucky University

2:30 p.m.
Advanced NMR Spectroscopy III: Organic Analysis by the HETCOR Technique
Robert W. Holman, John W. Reasoner and Todd Early*—Western Kentucky University

2:45 p.m.
Advanced NMR Spectroscopy IV: Total Structure Analysis via DEPT, COSY, and HETCOR
R. W. Holman, John Reasoner and Valerie Grantham*—Western Kentucky University

3:00 p.m.
Advanced NMR Spectroscopy V: Organic Analysis by the INADEQUATE Technique
Robert W. Holman, John W. Reasoner and Blandon Cherry*—Western Kentucky University

3:15 p.m.
A Quick Calculation of Flash Point From Boiling Point
Wade Cain—Morehead State University

3:30 p.m.
Samarium Iodide Catalyzed Reactions of Organic Bifunctional Alkenes
Robert Holman, Sherry Ladvsaw,* Melinda Lyons and Katrina Smith—Western Kentucky University

3:45 p.m.
Refreshments
International C

4:00 p.m.
Plenary Session
International B

Saturday, 9 November 1991

Nancy Flachskam—Presiding 11:00 a.m.

9:00 a.m.
Chemistry Section Business Meeting

9:30 a.m.
Refreshments
International C

10:00 a.m.
Annual Business Meeting
International B

11:00 a.m.
KJAS
The Effect of Group II Sulfates on the Physical Characteristics of Clay
Nathan Brock—Model Laboratory School

11:15 a.m.
The Brittle Fragmentation of Asteroids
Alan A. Johnson, Stephen L. Weeks—University of Louisville and John L. Remo—Quantametrics, Inc.

11:30 a.m.
An Electron Spin Resonance Spin Trapping Study of Free

Radical Involvement in Graft Failure Following Orthotopic Liver Transplantation in the Rat

Henry D. Connor*—Kentucky Wesleyan College, Wenshi Gao and Sadayuki Nukina—University of North Carolina

11:45 a.m.

Use of High Neutron Fluxes for the Determination of Trace Elements in Biological Tissues

D. J. Van Dalsem,* W. D. Ehmann, W. R. Markesbery—University of Kentucky and L. Robinson—Oak Ridge National Laboratory

GEOGRAPHY SECTION

Conrad T. Moore—Chairman
Adrian A. Wasserman—Secretary
Arizona Room

Friday, 8 November 1991

Conrad T. Moore—Presiding

8:30 a.m.

Some Oddballs of the Karst: Kentucky Rivers That Flow Backwards

Christopher G. Groves—Western Kentucky University

8:45 a.m.

Mechanisms Responsible for Sinkhole Flooding

Thomas P. Feeney* and Nichlas C. Crawford—Western Kentucky University

9:00 a.m.

Springhead Protection Study of the Shakertown, Summers', and Auburn Springs Groundwater Basins, Logan and Simpson Counties, Kentucky

William D. Howcroft* and Nicholas C. Crawford—Western Kentucky University

9:15 a.m.

Groundwater Contamination From Spills of Hazardous Liquids Upon Karst Terrain

Nicholas C. Crawford—Western Kentucky University

9:30 a.m.

Refreshments

International C

10:00 a.m.

An Investigation of Racial Segregation in Bowling Green, Kentucky

Joseph A. McGarry—Western Kentucky University

10:15 a.m.

Argentina's Mothers of Courage

Mark Lowry II—Western Kentucky University

10:30 a.m.

Pattern of Human Geography in an Indian Village

S. Reza Ahsan—Western Kentucky University

10:45 a.m.

Urban Places and Literary Influences

James L. Davis* and Nancy H. Davis—Western Kentucky University

11:00 a.m.

Tourism Development in Kentucky's I-75 Corridor (South), 1980–1991

R. L. Marionneaux—Eastern Kentucky University

11:15 a.m.

Internal Structure of Eastern European Cities

Edwin T. Weiss, Jr.—Northern Kentucky University

12:00 p.m.

Lunch

1:30 p.m.

Environmental and Economic Implications of the Distribution of Lakes and Reservoirs in Kentucky

Clara A. Leuthart* and Hugh T. Spencer—University of Louisville

1:45 p.m.

Who Uses Climatological Data?

Glen Conner—Western Kentucky University

2:00 p.m.

The Fire-origin of Grasslands Re-examined

Conrad T. Moore—Western Kentucky University

2:15 p.m.

Saving the "Other" Rainforest: Fundacao S.O.S. Mata Atlantica

L. Michael Trapasso—Western Kentucky University

2:30 p.m.

Geography Section Business Meeting

3:30 p.m.

Refreshments

International C

4:00 p.m.

Plenary Session

International B

GEOLOGY SECTION

Charles E. Mason—Chairman
Thomas R. Lierman—Secretary
Hoosier Room

Friday, 8 November 1991

Charles E. Mason and Robert T. Lierman—Presiding

1:00 p.m.

Counting Error in Petrographic Analysis: Examples from Coal Petrography

Kenneth W. Kuehn—Western Kentucky University, J. C. Hower, and G. D. Wild—University of Kentucky

1:15 p.m.

Petrology of the Corbin Member of the Lee Formation (Pennsylvanian) in East Central Kentucky

Robert Thomas Lierman* and Jolene Howard—Morehead State University

1:30 p.m.

An Examination of the Clay Mineral Assemblages from Lower Mississippian Rocks in Eastern and Central Kentucky

Robert Thomas Lierman—Morehead State University

1:45 p.m.
Fossils From the Haney Limestone, (Mississippian) Christian County, Kentucky
Malinda Washer Powell—Murray State University and James X. Corgan—Austin Peay State University

2:00 p.m.
A New Kinderhookian Ammonoid Fauna from the Borden Formation of Northeastern Kentucky
Charles E. Mason* and Greg Duke—Morehead State University

2:15 p.m.
Geology Section Business Meeting

2:30 p.m.
A Continuous Holocene Sea-level Rise—Evidence from Southwest Florida
Deborah W. Kuehn—Western Kentucky University

2:45 p.m.
Subsidence Analysis in Eastern Kentucky
Peter Goodman—University of Kentucky

3:00 p.m.
Mississippian-Pennsylvanian Uncomformity in the Cumberland Gap Area
Ann Watson—University of Kentucky

3:15 p.m.
Honokohau Bay and Pu u Nianiau Stratigraphic Sections, Maui of the East Chain Paired Volcano Sequence, Hawaii
Graham Hunt—University of Louisville

3:30 p.m.
Refreshments
International C

4:00 p.m.
Plenary Session
International B

PHYSICS SECTION

Douglas Jenkins—Chairperson
Vincent A. DiNoto—Secretary
Oklahoma Room (Fri p.m., Sat a.m.)
Illinois Room (Sat p.m.)

Friday, 8 November 1991

Vincent A. DiNoto—Presiding

1:15 p.m.
KJAS
The Effect of Air Pressure and Ball Circumference on the Bouncing Ability of Different Size Rubber Balls
Matt Hoyt—Moss Middle School

1:30 p.m.
Artificial Neural Network Model
A. K. Mukhopadhyay—Southwest Community College and V.L.N. Samra—Lincoln Memorial University

1:45 p.m.
90–96 Zr (d,d) and (d,d′) Reactions
S. Sen—Thomas More College, S. E. Darden, Z. Ayer and N. O. Gaiser—University of Notre Dame

2:00 p.m.
Evolution of Beam-Tilted-Foil Excited Hydrogen Atoms Through Electric Fields
Douglas L. Harper*—Western Kentucky University, Norman H. Tolk and Royal G. Albridge—Vanderbilt University

2:15 p.m.
A Nuclear Hazard from an Antique Firearm
C. E. Laird and John Meisenheimer—Eastern Kentucky University

2:30 p.m.
Black Hole Normal Modes
Koorosh Zaerpoor, Forzaneh S. Zaerpoor and James W. Gwinn—Bera College

2:45 p.m.
Irreversible Transport Critical Current in Polycrystalline YBCO at 77°K
K. C. Hung* and W. F. Huang—University of Louisville

3:30 p.m.
Refreshments
International C

4:00 p.m.
Plenary Session
International B

Saturday, 9 November 1991

John Christopher—Presiding

8:00 a.m.
Astronomy Laboratory Exercises Based in the Planetarium
R. Scott, K. Hackney, R. Hackney, P. Campbell, M. Robinson, G. Coles and J. George—Western Kentucky University

8:15 a.m.
Science: A Data Analysis Program for Introductory Laboratories
S. Cassady, R. Hackney, K. Hackney, R. Scott and M. Raymer—Western Kentucky University

8:30 a.m.
Improved Capacitance Bridge for Use in Elementary Physics Laboratories
M. Robinson, K. Hackney, R. Hackney, J. McClain and S. Boddeher—Western Kentucky University

8:45 a.m.
Digital Holography Generation on the Personal Computer
Keith Powell,* John T. Tarvin and Donald L. Jackson—Murray State University

9:00 a.m.
Interactive Computer Demonstrations in Physical Optics
John T. Tarvin,* Donald L. Jackson and Stephen H. Cobb—Murray State University

9:15 a.m.
Computer Study of a Gradient-Index Optical Fiber

J. Carl Hartsfield* and John T. Tarvin—Murray State University

9:30 p.m.
Refreshments
International C

10:00 p.m.
Annual Business Meeting
International B

11:00 a.m.
Shaft Encoders in the Physics Laboratory
Michael J. Moloney—Rose-Hulman Institute of Technology

11:15 a.m.
Analysis of Multiexponential Data
Dale Baltimore,* John T. Tarvin and Donald L. Jackson—Murray State University

11:30 a.m.
A Fast Integration Method for Circularity Symmetric Optical Intensities Incident on Square Detectors
Kevin Bowman,* Kenneth Zabel and Louis Beyer—Murray State University

11:45 a.m.
Physics Section Business Meeting

12:00 p.m.
Lunch

1:00 p.m.
Enhancing Physics Lectures with 3-D Stereographic Images
Donald L. Jackson* and John T. Tarvin—Murray State University

1:15 p.m.
Motion: Advanced Program for Graphical Study of Differential Equations of Motion Using a Personal Computer
M. Raymer,* R. Hackney, K. Hackney, R. Scott, D. Bryant and M. Troutman—Western Kentucky University

1:30 p.m.
Chaos: Introductory Studies of Chaotic Dynamics Using a Personal Computer
M. Troutman, R. Hackney, K. Hackney, J. Chamberlin and T. Nordmeyer—Western Kentucky University

1:45 p.m.
Fractal Foundations
G. Coker, M. Raymer, R. Hackney, K. Hackney, R. Scott and R. Crawford—Western Kentucky University

2:00 p.m.
Utilizing a Linear CCD in the Advanced Physics Laboratory
Rodney E. Graf,* Donald L. Jackson and John T. Tarvin—Murray State University

2:15 p.m.
Effect of Sticking Coefficient on Evolution of a Coagulation System
Eric Baugher,* J. T. Tarvin and H. R. Kobraei—Murray State University

2:30 p.m.
Extended Model of Interacting Monomers and Clusters for Homogeneous Nucleation
Bill Cullen,* H. R. Kobraei and B. R. Anderson—Murray State University

2:45 p.m.
Application of Model of Interacting Monomers and Clusters to Nonane, Ethanol, and Methanol
Jwain C. White,* H. R. Kobraei and B. R. Anderson—Murray State University

3:00 p.m.
Classical Nucleation Rates for Water, n-Nonane, Methanol, and Ethanol
Neil Wolf,* H. R. Kobraei and B. R. Anderson—Murray State University

3:15 p.m.
Prediction of Protein Content in Hay by Near Infrared Reflectance Spectroscopy
Carol J. Baltimore* and Stephen H. Cobb—Murray State University

3:30 p.m.
X-Ray Fluorescence Analysis of Trace Metals in the Annual Growth Layers of Freshwater Mussel Shells
Troy Howton,* William E. Maddox, James Sickel, Leon Duobinis-Gray and David Owen—Murray State University

3:45 p.m.
Monte Carlo Model of a Radioactive Beam
Barry McGuffin*—Western Kentucky University, James Kolata—Notre Dame University and Karen Hackney—Western Kentucky University

PHYSICS WORKSHOP

Arizona Room

9:00–11:00 a.m.
Vernier Software and Use of the Computer in the Laboratory
Dewey Beadle—Seneca High School

PHYSIOLOGY, BIOPHYSICS AND PHARMACOLOGY SECTION

David R. Hartman—Chairperson
William W. Farrar—Secretary
Oklahoma Room

Friday, 8 November 1991

William W. Farrar—Presiding

8:30 a.m.
Cortical Evoked Potentials in Response to Inspiratory Occlusion in Cats
Susan M. Reynolds* and W. Robert Revelette—University of Kentucky

8:45 a.m.
Effect of $GABA_A$ or Glycine Receptor Blockade on Inspi-

ratory Inhibitory Reflexes Elicited by Pontine Stimulation
Liming Ling,* Diane Karius and Dexter F. Speck—University of Kentucky

9:00 a.m.
Inspiratory Termination by Superior Laryngeal Nerve Stimulation is Interrupted by Non-N-Methyl-D-Aspartate (non-NMDA) Receptor Antagonists
Diane R. Karius,* Liming Ling and Dexter F. Speck—University of Kentucky

9:15 a.m.
Colorblindness in Kentucky: A Preliminary Report
Venna Sallan* and Timothy T. Dick—Owensboro Community College

9:30 a.m.
Refreshments
International C

10:15 a.m.
Cardiovascular Responses to Voluntary Wheel Running in Rats
Susan L. Yancey* and J. Michael Overton—University of Louisville
In vivo Microvascular Responses to Blockade of Endothelium-Derived Relaxing Factor Production in Rat Skeletal Muscle
Feng Li and Irving G. Joshua—University of Louisville

10:45 a.m.
Regulation of Female Reproductive Structure Blood Flow in Rats
April Forsberg,* R. T. Dowell and D. F. Speck—University of Kentucky Medical Center

11:00 a.m.
Preliminary Identification of a 22 KDA Protein From the Dense Tubular System (DIS) of Human Platelets
Eric Schepers—Bellarmine College

11:15 a.m.
Physiology and Biophysics Business Meeting

SCIENCE EDUCATION SECTION

Curtis C. Wilkins—Chairperson
Zexia K. Barnes—Secretary
Missouri Room

Friday, 8 November 1991

Curtis C. Wilkins—Presiding

1:15 p.m.
A Short, Homemade Videotape on Safety in the Chemistry Lab
Rhonda Pogue,* Curtis Wilkins and Norman Hunter—Western Kentucky University

1:30 p.m.
The Karlsruhe Congress
Robert Forsythe—Warren East High School and Norman Hunter—Western Kentucky University

1:45 p.m.
Preference, Increased Student Involvement and Enhanced Learning with Teacher-Prepared Objectives in Biology Courses
J. G. Shiber—Prestonsburg Community College

2:00 p.m.
An Afternoon With Dorothy Crowfoot Hodgkin, Nobel Grandmother, 1964
Norman H. Hunter—Western Kentucky University

2:15 p.m.
Revealing the Secret of the Arctic Bomb
Earl F. Pearson—Western Kentucky University

2:30 p.m.
Polymer Science: Anionic Polymerization
Jonathan West,* Trent Selby and Thomas Green—Western Kentucky University

2:45 p.m.
Science Education Business Meeting

3:30 p.m.
Refreshments
International C

4:00 p.m.
Plenary Session
International B

Saturday, 9 November 1991

Benjamin Malphrus—Presiding

8:45 a.m.
Implementing the Kentucky Education Reform Act at the University Level
Benjamin Malphrus—Morehead State University

9:00 a.m.
Polymer Science: Suspension and Emulsion Polymerization
Trent Selby,* Jonathan West and Thomas Green—Western Kentucky University

9:15 a.m.
Inquiry-Based Scientific Learning: As the Pendulum Swings
R. Hyler, R. Hackney and K. Hackney—Western Kentucky University

9:30 a.m.
Refreshments
International C

10:00 a.m.
Annual Business Meeting
International B

PSYCHOLOGY SECTION

Mykol Hamilton—Chairperson
David Hogan—Secretary
California Room

Friday, 8 November 1991

Terry Barrett—Presiding a.m.
Jeff Smith—Presiding p.m.

8:00 a.m.
Impact of Educational Reform
Dan Hudson—Murray State University

8:15 a.m.
College Resident Hall Advisors Impact on Residents
Rachel L. Morrisette—Murray State University

8:30 a.m.
Impact of the Residence Halls on Freshmen
Jim Barnett—Murray State University

8:45 a.m.
Assessment of Treatment Approaches for Sexual Offenders
Lisa Oliver—Murray State University

9:00 a.m.
The Effectiveness of Rape Awareness Programs on the Number of Reported Rapes
Tammie M. Jones—Murray State University

9:15 a.m.
The Effects of Divorce on Children
Lesa Jackson—Murray State University

9:30 a.m.
Refreshments
International C

10:00 a.m.
Sexual Fulfillment in a College Population
Dawn Mattingly—Murray State University

10:15 a.m.
The Incidence of Hallucinations Across Sensory Systems in the General Population
Terry R. Barrett—Murray State University

10:30 a.m.
The Effects of Physical Exercise on Dark Focus of Accomodation
Heather Huhn—Murray State University

10:45 a.m.
Night Work Effects
Beth Bullock—Murray State University

11:00 a.m.
Influences of Circadian Rhythms on Memory
Ronald Troy Tedder—Murray State University

11:15 a.m.
Semantic Priming in Deaf Children
Kirk Day* and Don Brown—Centre College

11:30 a.m.
Cognitive Differences in Musicians and Non-musicians
Patricia A. Liberti—Murray State University

11:45 a.m.
The Effect of Self-Esteem on Religious Procrastination
Susan Scherffius* and Don Brown—Centre College

12:00 p.m.
Lunch

1:30 a.m.
Premenstrual Dietary Shifts
Mary Perkins and Jack Thompson—Centre College

1:45 p.m.
Menstural Synchrony in College Females
Amy Wannemuehler—Murray State University

2:00 p.m.
Effects of Repeated Dopamine D1 Receptor Stimulation on the Development of Behavioral Sensitization
Carmen Perkins, Shannon Fauver and Bruce Mattingly—Morehead State University

2:15 p.m.
Effects of Repeated Dopamine D2 Receptor Stimulation on the Development of Behavioral Sensitization
Stephanie Dawson, Gina Johnson and Bruce Mattingly—Morehead State University

2:30 p.m.
Psychology Section Business Meeting

3:30 p.m.
Refreshments
International C

4:00 p.m.
Plenary Session
International B

Saturday, 9 November 1991

David Hogan—Presiding

8:00 a.m.
An Electroencephalographic (EEG) Study of Occipital Lobe Brain Waves During Meditation and Relaxation
John Cecil—Bellarmine College

9:15 a.m.
Effects of Chronic Dopamine Receptor Stimulation on Dopamine Synthesis and Behavior
Tamara Hart, Jennifer James and Bruce Mattingly—Morehead State University

8:30 a.m.
Effects of Selective Dopamine D1 and D2 Receptor Antagonists on the Development of Behavioral Sensitization to Cocaine
Karen Lim—Morehead State University, Pat Robinette—Colorado State University and Bruce Mattingly—Morehead State University

8:45 a.m.
Does Early Eye Opening in Rat Pups Affect Brain Development?
Nathan Wilson*—Asbury College, Tim Carbary and Phil Kraemer—University of Kentucky

9:00 a.m.
Impaired Two-point Tactile Discrimination in Chronic Alcoholics
Cindy Engly and Art Nonneman—Asbury College

9:15 a.m.
Do-it-yourself Individualized Materials for Statistics
Ronald L. Kuteskey—Asbury College

9:30 a.m.
Refreshments
International C

10:00 a.m.
Annual Business Meeting
International B

SOCIOLOGY SECTION

Kurt Bergstrand—Chairperson
J. Allen Singleton—Secretary
Nevada Room

Friday, 8 November 1991

Kurt Bergstrand—Presiding

10:00 a.m.
Scared Straight—Using Prison Inmates to Counsel High-Risk Middle School Students: A Project Report
Marty Perreiah, Harry Seeger, IV, Mary Saffer and Elizabeth Embry—Bellarmine College

10:15 a.m.
Do Long-Term Prisoners Have Mid-Life Crises? Implications For Adult Developmental Theory
Curtis R. Bergstrand—Bellarmine College and Nancy A. Schrepf—Luther Luckett Correctional Complex

10:30 a.m.
The Relationship Between Drug Use and Level of Violence Used When Committing Crimes: An Empirical Examination
Edgar Humphries—Bellarmine College

10:45 a.m.
Dysfunctional Family Background and Lowered Self-Esteem: Is the Relationship Inevitable?
Patty Payne—Bellarmine College

11:00 a.m.
Relative Deprivation Among the Children of Homeless, Divorced, and Intact Families
Andrea Cohen—Bellarmine College

11:15 a.m.
The Relevance of Herbert Spencer Today: A Conceptual Examination
Timothy Brothers—Bellarmine College

11:30 a.m.
Stereotypes and the Female Athlete
Christy Halbert—Western Kentucky University

12:00 p.m.
Lunch

1:30 p.m.
The Tanning Industry in KY
J. Allen Singleton—Eastern Kentucky University

1:45 p.m.
The Everyday Life-World of the Street Person: An Ethnographic Analysis
William Mathis—Bellarmine College

2:00 p.m.
Louisville: A "Mecca" for the Homeless?
Bobbie Bilz, Andrew Brothers, Julie Smith—Bellarmine College

2:15 p.m.
The Characteristics of Homeless Families In Louisville
Patty Snook—Bellarmine College

2:30 p.m.
Commitment in Intentional Communities
Shari Mattingly—Eastern Kentucky University

2:45 p.m.
Sociology Business Meeting

3:30 p.m.
Refreshments
International C

4:00 p.m.
Plenary Session
International B

ZOOLOGY AND ENTOMOLOGY SECTION

Paul A. Weston—Chairperson
Matthew Byers—Secretary
Ohio Room

Friday, 8 November 1991

Matthew Byers—Presiding

8:00 a.m.
Insect Abundance on Potatoes, Sweet Potatoes and Okra Mulched With Different Colored Plastic Sheetings
Patti L. Rattlingourd,* John D. Sedlacek, Bryan D. Price, Monica McWilliams and Dietra W. Draper—Kentucky State University

8:15 a.m.
Oviposition of Angoumois Grain Moth on Shelled Corn Varying in Moisture Content
Paul A. Weston,* Tashawa L. Reaves and Patti L. Rattlingourd—Kentucky State University

8:30 a.m.
Occurrence of Insects in On-Farm Stored Corn in Kentucky
John D. Sedlacek,* Paul A. Weston, Bryan D. Price and Patti L. Rattlingourd—Kentucky State University

8:45 a.m.
Is Aphid Feeding Affected on Endophyte Infected Tall Fescue?
Herbert Eichenseer and Douglas Dahlman—University of Kentucky

9:00 a.m.
KJAS
A Comparative Analysis of the Effects of Natural Insecticides on *Blatella germanica* vs. *Tenebrio molitor*
Kristy Hixson—Moss Middle School

9:15 a.m.
The Freshwter Unionids Mussels (Bivalvia: Unionoidea) of Kentucky
R. R. Cicerello*—Kentucky State Nature Preserves Commiss., M. L. Warren, Jr.—VA Polytechnic & State University and G. A. Schuster—Eastern Kentucky University

9:30 a.m.

Refreshments
International C

10:00 a.m.
Growth, Feed Conversion, and Protein Utilization of Male Bluegill × Female Green Sunfish Hybrids Fed Isocaloric Diets With Different Protein Levels
James H. Tidwell, Carl D. Webster and Julia A. Clark*—Kentucky State University

10:15 a.m.
Winter Feeding and Growth of Channel Catfish Fed Diets Containing Varying Percentages of Distillers Grains With Solubles as a Total Replacement of Fish Meal
Carl D. Webster, James H. Tidwell and Laura S. Goodgame*—Kentucky State University

10:30 a.m.
An Overview of the Fishes of Kentucky: Tales of Chubbies, Bubblers and Devil-Jack Diamond Fish
Brooks M. Burr—Southern Illinois University

11:00 a.m.
Later Developmental Stages of the Sawfish, *Pristis perotteti*
Madeline T. Oetinger—Kentucky Wesleyan College

11:15 a.m.
Movement and Exploitation of Catfishes and Smallmouth Buffalo in Kentucky Lake, Kentucky and Tennessee
Tom J. Timmons—Murray State University

11:30 a.m.
Sex-specific Differences in Diet and Growth of Kentucky Snubnose Darters (Pisces: Percidae)
Gordon K. Weddle—Campbellsville College

11:45 a.m.
Habitat Partitioning in a Russell Creek Darter Community
Gordon K. Weddle—Campbellsville College, Richie Kessler*—University of Louisville and Roger Farmer—FDA (Cincinnati)

12:00 p.m.
Lunch

NSF—Research Experience for Undergraduates

University of Kentucky

Andrew Sih—Coordinator

1:00 p.m.
Sex and the Generation Gap: Effects of Young Adults on the Mating Success of Older Water Striders
William Moore*—Eastern Kentucky University and Andrew Sih—University of Kentucky

1:15 p.m.
Female Selection for a Condition-dependent Trait in the Fathead Minnow, *Pimephales promelas*
Robin Rudd*—Berea College and Trey LaCharite—University of Kentucky

1:30 p.m.
Sulfuric Acid, Sunfish Smell and Selective Consumption by Streamside Salamanders
Jim Willenbrink*—Morehead State University and Andrew Sih—University of Kentucky

1:45 p.m.
Density-dependent Cannibalism Among *Tetragoneuria cynosura* Larvae
Donna Kielman*—Kentucky State University, Kevin Hopper* and Philip Crowley—University of Kentucky

2:00 p.m.
Genetic Variability of the Northern Studfish (*Fundulus catenatus*) From Three Central Kentucky Stream Systems
Laurel Montgomery* and Christine Barton—Centre College

2:15 p.m.
Impact of Predation on Microhabitat Preferences of Northern Studfish (*Fundulus catenatus*)
Natalie Jacobs* and Michael Barton—Centre College

General Papers—Section K

2:30 p.m.
Role of Vibrational Communication in Mating Behavior of the Treehopper *Spissistilus festinus* (Homoptera: Membracidae)
Randy E. Hunt—University of Kentucky

2:45 p.m.
Canopidae in Kentucky
Paul H. Freytag—University of Kentucky

3:00 p.m.
Bagworm Development and Feeding Preference on Juniper Cultivars
Monte P. Johnson, Geoff S. Gilmore* and Daniel A. Potter—University of Kentucky

3:15 p.m.
Biology of *Proterometra macrostoma* (Trematoda: Azygiidae), an Intestinal Parasite of Sunfishes in Central Kentucky
Melissa V. Kesler, Milton W. Riley and Gary L. Uglem—University of Kentucky

3:30 p.m.
Zoology and Entomology Business Meeting

3:45 p.m.
Refreshments
International C

4:00 p.m.
Plenary Session
International B

Saturday, 9 November 1991

Matthew Byers—Presiding

8:00 a.m.
Constructed Wetlands for Treatment of Wastewater from Single Family Dwellings
Matthew E. Byers*—Kentucky State University, Barbara Porter—Lexington-Fayette Health Department and George F. Antonious—Kentucky State University

8:15 a.m.
Biomonitoring of a Constructed Wetland Site
Barbara A. Ramey*—Eastern Kentucky University and Howard G. Halverson—USDA Forest Service

8:30 a.m.
KJAS
Possible Phototoxicity Effects of Phenol on *Daphnia*
Ellen Air—Notre Dame Academy

8:45 a.m.
Activities of an Apparent Ant-mimic at Extrafloral Nectaries of *Heliconia latispatha*
Thomas C. Rambo—Northern Kentucky University

9:00 a.m.
Predatory Behavior and Territoriality in Tropical Jumping Spiders (Araneae, Salticidae) Associated with *Heliconia* spp.
Stephen R. Skaggs—Northern Kentucky University

9:15 a.m.
Isolation of an Unknown Pathogen to *Aedes triseriatus* (Culicidae)
Kenneth W. Blank,* Dennis Lye and Thomas Rambo—Northern Kentucky University

9:30 a.m.
Refreshments
International C

10:00 a.m.
Annual Business Meeting
International B

11:00 a.m.
Impact of Teratocytes from *Microplitis croceipes* on the Physiology of *Heliothis virescens*
Deqing Zhang,* Douglas L. Dahlman and Ulla E. Jarlfors—University of Kentucky

11:15 a.m.
Small Mammal Surveys in the Stanton and Morehead Districts of the Daniel Boone National Forest
Les Meade—Morehead State University

11:30 a.m.
Use of the Zygodactylus Hand by Captive Woolly Monkeys (*Lagothrix lagotricha*)
Patrick Keesee and Brent White—Centre College

11:45 a.m.
The Bluegrass and Western Coal Field: Filter Barriers to the Dispersal of Kentucky Amphibians and Reptiles
Les Meade—Morehead State University

12:00 p.m.
Growth of the Acanthocephalan, *Moniliformis moniliformis* (Bremser, 1811) Travassos, 1915, in the Laboratory Rat
David F. Oetinger—Kentucky Wesleyan College

12:15 p.m.
Fostering Behavior of Lion-Tailed Macaques
Timothy T. Dick—Owensboro Community College

12:30 p.m.
Breeding Biology of a Southeastern Population of Tree Swallows, *Tachycineta bicolor*
Denise Rouse Stephens and Blaine R. Ferrell—Western Kentucky University

12:45 p.m.
Brazillian Catfish (*Rhamuia*) Culture
J. Raduz, D. Stiles,* W. Lewis and C. Kohler—Western Kentucky University

COMPUTER SCIENCE SECTION

Richard A. Fink—Chairperson
Kenneth Cooper, Jr.—Secretary
Louisiana Room

Saturday, 9 November 1991

Richard Fink—Presiding

8:30 a.m.
Report on the Teaching of Education and Values From the National Conference on Computing and Values
Sylvia Clark Pulliam—Western Kentucky University

8:45 a.m.
Spreading the Gospel of GAIGS: An Algorithm Visualization System
Carol W. Wilson—Western Kentucky University

9:00 a.m.
Trilogy: A Multi-Paradigm Programming Language
Art Shindhelm—Western Kentucky University

9:15 a.m.
MIDI: A Musical Analog to Computer Network Communication
John Crenshaw—Western Kentucky University

9:30 a.m.
Refreshments
International C

10:00 a.m.
Annual Business Meeting
International B

11:00 a.m.
Computer Science Business Meeting

MATHEMATICS SECTION

Carroll G. Wells—Chairperson
Russell M. Brengelman—Secretary
Illinois Room

Friday, 8 November 1991

Russell M. Brengelman—Presiding

1:30 p.m.
The Scientific Method in Mathematics
Joseph F. Stokes—Western Kentucky University

2:00 p.m.
Mathematics Avoidance: A Light-hearted Look at a Serious American Problem
Russell M. Brengelman—Morehead State University

2:30 p.m.

Applications of the Graphics Calculator in the College Classroom
Jennifer Stevens—Owensboro Community College

3:00 p.m.
Subjective Probability
Walter Feibes—Bellarmine College

3:30 p.m.
Refreshments
International C

4:00 p.m.
Plenary Session
International B

Saturday, 9 November 1991

Carroll G. Wells—Presiding

8:00 a.m.
Dirichlet Problem, Harmonic Measure, and Hardy Spaces—A Quick Review
John S. Spraker—Western Kentucky University

8:30 a.m.
Analysis of Rate-dependent Activation in Single Atrioventricular Nodal Cells: An Extension Result
Richard Bowen—Asbury College

9:00 a.m.
Matrices in Cryptography
Carroll G. Wells—Western Kentucky University

9:30 a.m.
The Numerical Solution of Problems in Underwater Acoustics Using a Finite Element Method
Mark P. Robinson*—Western Kentucky University and Graeme Fairweather—University of Kentucky

10:00 a.m.
Annual Business Meeting
International B

11:00 a.m.
Mathematics Section Business Meeting

ENGINEERING SECTION

Bruce Walcott—Chairperson
Phillip Reucroft—Secretary
Hoosier Room

Saturday, 9 November 1991

B. L. Walcott and P. J. Reucroft—Presiding

8:00 a.m.
Active Optimal Vibration Control Using a Dynamic Absorber
S. G. Tewani,* B. L. Walcott and K. E. Rouch—University of Kentucky

8:15 a.m.
KJAS
An Application of "Unsteady" Aerodynamics by Use of a Fixed Canard and a Grooved Wing to Create Lift
Susan Brundige—Henderson Co. High School

8:30 a.m.
Optimal Milling Process Stability Using Passive Dynamic Absorber
K. J. Liu* and K. E. Rouch—University of Kentucky

8:45 a.m.
Industrial Marketing of Coal By-products
Alan D. Smith—Robert Morris College

9:00 a.m.
Seismic Analysis of the Brent-Spence Bridge
Issam E. Harik,* Meiwen Guo and David L. Allen—University of Kentucky

9:15 a.m.
Engineering Section Business Meeting

9:30 a.m.
Refreshments
International C

10:00 a.m.
Annual Business Meeting
International B

INDUSTRIAL SCIENCES SECTION

Estel M. Hobbs—Chairperson
Burtron H. Davis—Secretary
Texas Room

Industrial Science Symposium
Featuring Kentucky Mentors, Women in Science, Mathematics and Engineering

Saturday, 9 November 1991

Burt Davis—Presiding

7:55 a.m.
Introductory Remarks

8:00 a.m.
Multiple Helix-Coil Transitions
Deborah J. Houpt and Donald B. Dupre—University of Louisville

8:25 a.m.
Topics of Interest in Water Treatment
Katheryn D. Higgins—Louisville Water Company

8:50 a.m.
Underground Storage Tank Investigation at U.S. DOE Paducah Gaseous Diffusion Plant Operated by Martin Marietta Energy Systems, Inc.
Colleen J. Winkler—Martin Marietta Energy Systems, Inc.

9:15 a.m.
Microgravity Processing of Catalytic Materials
Phyllis Brusky—Batelle, Columbus, OH

9:40 a.m.
Industrial Science Section Business Meeting

10:00 a.m.
Annual Business Meeting
International B

11:00 a.m.
Environmental Aspects of Catalytic Cracking
Patricia K. Doolin—Ashland Oil, Inc.

11:25 a.m.
Preparation of a Precipitated Iron Oxide for Fischer-Tropsch Synthesis
Diane R. Milburn and Robert L. Spicer—Center for Applied Energy Research

11:50 a.m.
A Multi-Detector GC Technique for the Detailed Analysis of Vapor-Phase Smoke
E. D. Alford, J. H. Lauterbach and J. E. Matiella—Brown & Williamson Tobacco Corporation

12:15 p.m.
Use of Near Infrared Techniques in Determining Various Properties of Motor Gasoline
Steven M. Maggard—Ashland Oil, Inc.

POSTER PRESENTATIONS

Florida Room

Friday 8:00 a.m.–Saturday 2:00 p.m.

NSF YOUNG SCHOLARS
Western Kentucky University
Valgene Dunham—Coordinator

1 The Biochemical Characterization of the Proteins in Flagella in *Euglena gracilis*
Amelia Alexander—Fulton County High School
2 RNA Sequencing of the Southern Bean Mosaic Virus
Manuel Amburgey—Letcher County High School
3 Brassica Genomic Library
Thomas Blackburn—Union County High School
4 The Comparison of Proteins in the Axolotl Salamander During Non-regeneration and Regeneration
Jonathan Bradley—North Hardin High School
5 DNA Dot Quantitation Using Ethidium Bromide and Hoeschst 33258
Shawn Campbell—Allen County-Scottsville High School
6 Isolating Large Molecular Weight DNA for the Purpose of Making a Genomic Library of the Chick
Sarah Cottongim—Scott High School
7 Structure of Hair Cell Epithelium as Revealed in Plastic Sections
April Dow—Eastern High School
8 RNA Sequencing of the Southern Bean Mosaic Virus Genome
Josh Endicott—Henry Clay High School
9 Microscopic Examination of Euglenoid Flagellates
Tresie Fishback—Warren East High School
10 Restriction Fragment Length Polymorphism Analysis of Wisconsin Fast Plants
Karie Gauze—East Carter High School
11 The Effect of Selenium on Isocitrate Dehydrogenase in Tobacco Plants
Brian Grace—South Hopkins High School
12 The Effects of Lead Toxicity on Isocitrate Dehydrogenase in Tobacco
Heather Henry—Beechwood School
13 Isolation of Hair Cell Death and Regeneration of the Lateral Line System
Jennifer Jefferson—Oneida Baptist Institute
14 Transmission Electron Microscopic Investigation of *Euglena gracilis*
Angela Jeffries—Metcalfe County High School
15 Spectrin-like Proteins in the Flagella and Cells of the Euglenoid *Euglena gracilis*
Lawrence Johnson—Logan County High School
16 Toxicity of Selenium and Lead on Ribulose 1,5 Bisphosphate Carboxylase Concentration in Tobacco
Sondra Massey—Edmonson County High School
17 Biochemical Analysis of Paraxial Rod Proteins in Flagella of *Euglena gracilis*
Julie Nihols—Glasgow High School
18 The Making of a Genomic Library Using Axoloth Tissue
LaTonia Peters—North Hardin High School
19 The Effects of Lead Toxicity on Ribulose 1,5 Bisphosphate Carboxylase in Tobacco Plants
Keith Pollock—Atherton High School
20 The Effects of Selenium on Rubisco in Tobacco Plants With Respect to Top and Bottom Leaves
Ginger Watkins—Franklin County High School

SECTIONAL POSTERS

21 Molecular Orbital Assignments of 3,4-Bis(amino)-3-cyclobutene-1,2-dione
B. J. Stigall, L. Bigham and J. L. Meeks—Paducah Community College
22 KJAS
The Effects of Acid Preparation on Radish Plants
John Hafner—Southside Middle School
23 The Production of Activated Carbons From Coals by Chemical Activation
Mant Jagtoyen,* Frank Derbyshire, John Stencel, Brian McEraney and Michael W. Thwaites—University of Kentucky
24 Impact of OBRA (Federal) Legislation on Dental Services for Long-Term Care Facilities in Kentucky
Arthur Van Stewart and Bryan Harness—University of Louisville, Ford Grant-University of Louisville/Univ of Kentucky
25 A Chemical Analysis of the Enzyme "Catalase"
Jennifer M. Burnett—Southside Middle School
26 Inspiratory Duration is Altered by Arachidonic Acid Activation of Diaphragmatic Receptors
K. M. Krause,* D. T. Frazier and W. R. Revelette—University of Kentucky Medical Center
27 Study of Somatic Mutation in Nonproductively Rearranged Kappa Immunoglobulin Genes
Manuel San* and Cheryl Dell—Berea College
28 Aggressive Behavior in Zigzag Salamanders, *Plethodon dorsalis*
Martha P. Dahlgren* and Paul V. Cupp, Jr.—Eastern Kentucky University

ABSTRACTS OF SOME PAPERS PRESENTED AT THE ANNUAL MEETING, 1991

PHYSICS

A nuclear hazard from an antique firearm. JOHN L. MEISENHEIMER, Department of Chemistry and C. E. LAIRD,* Department of Physics and Astronomy, Eastern Kentucky University, Richmond, KY 40475.

Although the era of the Kentucky Rifle (flintlocks) was during the late 1700s and early 1800s, there are a number of marksmen who still hunt and target-shoot with reproduction flintlock rifles. The guns are fired by a piece of flint striking a frizzen that emits sparks, first resulting in the burning of a primer powder, then the ignition of the main powder charge in the barrel. Competition shooters are constantly trying to improve and shorten the time of the ignition sequence.

It has been found that in order to increase the amount of sparks from the frizzen, some gunsmiths have faced the frizzen with a non-steel substance that produces an abundance of white-hot sparks when struck by a flint. We have determined from the gamma-ray spectrum that this facing material contains mostly uranium and its decay products. It emits not only gamma radiation, but also x-rays and alpha and beta particles. Therefore, these frizzens are a danger to the shooters and to persons in their vicinity. Since the process of creating sparks introduces a number of small, radioactive particles into the air, the use of these modified frizzens may be particularly hazardous with respect to the potential to cause respiratory tract cancer.

Electroencephalographic (EEG) study of occipital lobe brain waves during meditation and relaxation. JOHN RAYMOND CECIL, JR,* Department of Biology, Bellarmine College, Louisville, KY 40205.

A pilot study demonstrated a unique brain wave with characteristics of both alpha and theta waves. The hybrid alpha-theta wave bursts had the following characteristics: frequency from 6 to 9 Hz, amplitude greater than 10 μV and less than 50 μV, and a duration of 1 second. It was then hypothesized that a greater number of hybrid alpha-theta wave bursts would be transmitted during meditation than during relaxation. Subjects in the meditating group were instructed to silently state the word "peace" on each exhale. Those in the relaxation group were instructed to simply relax without focusing on any particular word. Electroencephalograms were recorded for 20 minutes for all subjects. A between-groups design was used with six subjects in the meditation (experimental) group and six subjects in the relaxation (control) group. There were an equal number of males and females of ages 17–23. A Narco Biosystems Physiograph with a high-grain coupler and EEG electrodes were used with the 10–20 International System for Electrode Placement. Environmental conditions were kept constant for each subject. A Mann-Whitney statistical analysis showed that the differences in the mean numbers of hybrid alpha-theta wave bursts from the meditators ($\bar{x} = 18$) and relaxers ($\bar{x} = 1.5$) were not significant at a $P \leq 0.05$ level. Since the level of significance was $P \leq 0.10$, further studies are warranted to examine whether the meditative state can be scientifically validated using electroencephalographic methods.

BOTANY AND MICROBIOLOGY

Blooming and triggering patterns of *Pleiostachya pruinosa* (Marantaceae). AMY M. RACKE, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41706.

Blooming and triggering patterns of the neotropical herb *Pleiostachya pruinosa* were studied in the tropical rainforest of Corcovado National Park, Costa Rica. This species has a pollinating mechanism with a springlike style usually triggered by a pollinator when it comes to feed. Flowers were monitored from the time they opened until the style was triggered. However, no insect or avian pollinators were observed in the course of the study, but the flowers were still triggered. The presence of sprouting seeds on and near the plants would seem to indicate that these plants are also self fertile. Those insects that did visit the plant did not spring the trigger. Plants located in shaded areas bloomed later and did not open so fully as those in open areas. They also had a shorter time period between blooming and triggering. On sunny days the flowers opened earlier than on cloudy days.

Dry matter accumulation in bell pepper (*Capsicum annum*) plants grown in association with *Azospirillum lipoferum*. CLOYD J. BUMGARDNER,* Science Department, Pulaski County High School, Somerset, KY 42501, and DAVID MARDON, Department of Biological Sciences, Eastern Kentucky University, Richmond, KY 40475.

Bell pepper (*Capsicum annum*) plants were grown in a controlled greenhouse environment. Surface sterile seeds were planted in a pre-sterilized growth system and an *Azospirillum lipoferum* (ALM) isolate added to the system at a concentration of 5.5×10^8 cells per gram of growth substrate. Pepper plants were removed from the growth substrate at various stages of plant development and dry matter accumulation was noted in the root, stem, foliar, and fruit portions. At the six-leaf and first-bloom stages of growth no substantial gain was noted in dry matter accumulation in roots, stems, and foliar portions of the plants grown with added *A. lipoferum* (ALM+) over control plants grown without added *A. lipoferum* (ALM−). Upon maturation of the first fruit, ALM+ plants possessed less dry matter in the root, stem, and foliar portions than ALM− control plants but produced larger fruit containing substantially more dry matter than plants grown without *A. lipoferum* association.

Effect of *Azospirillum lipoferum* on establishment of associative nitrogen fixing bacteria in the rhizospheral growth substrate of bell pepper (*Capsicum annum*) plants. CLOYD J. BUMGARDNER,* Science Department, Pulaski County High School, Somerset, KY 42501, and DAVID MARDON, Department of Biological Sciences, Eastern Kentucky University, Richmond, KY 40475.

Bell pepper (*Capsicum annum*) plants were grown in pre-sterilized growth systems in which *Azospirillum lipoferum* (ALM) was added at a concentration of approximately 5.5 × 10^8 cells per gram of growth substrate. Determination of numbers and genera of associative nitrogen-fixing bacteria (bacteria that fix nitrogen in the absence of nodular structures on plant roots) established in rhizosphere growth substrates was carried out at selected stages of bell pepper growth. At each sampling time total numbers of associative nitrogen-fixing bacteria were substantially higher in systems receiving added *A. lipoferum* (ALM+) than in those not receiving *Azospirillum* addition (ALM−). Although *A. lipoferum* persisted as the primary nitrogen-fixing species present in systems to which it was added, other nitrogen-fixing bacteria isolated on nitrogen-free minimal salts media from both ALM+ and ALM− systems include members of *Azotobacter* and *Bacillus*.

Microhabitat variability and the diatom community structure in the bracts of six species of *Heliconia*. VICKI MARTIN-KIER* and THOMAS C. RAMBO, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41099.

The branch-bract fluid reservoirs of *Heliconia* spp. are microhabitats known to support diatom communities. Physical and chemical parameters were observed for the microhabitats in the infloresences of six species of *Heliconia* at Sirena Station, Corcovado National Park, Costa Rica. Chemical analyses, light level, and air temperature data were collected for branch-bract fluids from *Heliconia latispatha, H. imbricata, H. imbricata* × *H. latispatha, H. wagneriana, H. stilesii,* and *H. irrasa* supsp. *irrasa*. The diatom species in the branch-bract fluids were compared to determine the effect of microhabitat variability on diatom community structure and diversity.

Population density and resistance to invasion in the soil-dwelling moss *Dicranella heteromalla*. JULIE S. DICKSON* and ROBIN W. KIMMERER, Biology Department, Centre College, Danville, KY 40422.

Soil dwelling bryophytes are often considered to be short-lived, opportunistic species temporarily occupying disturbed soil. Such species are quickly outcompeted by vascular plants. However, our data demonstrate that *Dicranella heteromalla* is a long-lived pioneer species that persists on disturbed soil. How does this diminutive bryophyte resist invasion and competitive exclusion by vascular plants? The objectives of this study are to assess the role of moss population density in resistance to invasion by vascular competitors. Populations of *D. heteromalla* were experimentally thinned to reduce shoot density and then sown with seeds of *Lactuca sativa*. Germination and establishment of the seedlings were monitored. Seedling establishment on unthinned moss mats was minimal. Successful invasion of *D. heteromalla* was significantly increased by reduced population density.

Effects of simulated rain acidified by nitric acid on Wisconsin fast plants (*Brassica rapa*). MARY K. MASTORAKIS and JOE E. WINSTEAD,* Departments of Biology, Midwestern State University, Wichita Falls, TX 76308 and Western Kentucky University, Bowling Green, 42101.

Two different age groups of *Brassica rapa* plants grown in a controlled environment were treated with simulated nitric acid rain acidities of pH 4.5, 3.5, and 2.5, and compared with controls (pH 5.6). Plant biomass significantly increased and chlorophyll levels increased in all groups treated with pH 3.5 solutions. Nitrogen percentages were elevated in the tissues subjected to pH treatments of 3.5 and 2.5 when collectively compared to the controls. Trends of reductions in sulfur incorporation in tissues formed under the pH of 3.5 acidified by nitric acid were seen. The growth-stimulating effects on the pH 3.5 group may be attributed to nitrogen uptake and incorporation through the foliage.

Slug dispersal of bryophyte propagules. CRAIG C. YOUNG* and ROBIN W. KIMMERER, Biology Department, Centre College, Danville, KY 40422.

Reports of animal dispersal of bryophyte propagules are extremely limited. The role of terrestrial slugs in dispersal of forest floor mosses was examined. Slugs are frequently observed on moss mats on stumps and logs. Both asexual propagules and sporophyte capsules become entrapped in the slime secretions of slugs. Dispersal distance of propagules was highly skewed and averaged 5.2 cm. Propagules were carried as far as 30 cm from the source colony. We conclude that slugs may be a significant disperser of mosses in the field. Contact with slugs significantly increased the probability of a propagule adhering to a substrate. Ninety-five percent of the asexual propagules of *Dicranum flagellare* adhered to vertical wood substrates in the presence of slug secretions, but less than 10% of the propagules adhered to dry wood. Slug secretions had no significant effect on the germination and subsequent development of *D. flagellare* propagules.

Species-area relationships among saxicolous bryophytes. MELANIE J. DRISCOLL,* ROBIN W. KIMMERER, and DONNA FELDKAMP, Biology Department, Centre College, Danville, KY 40422.

Glacial erratic boulders are a characteristic feature of the forests of the Adirondack region. Bryophyte species richness and diversity varies considerably among these granitic boulders. The objective of these studies was to determine the environmental correlates of moss species diversity. The bryophyte communities of 40 boulders varying in size and microtopography were intensively sampled.

Slope, microtopographic class, elevation, size, and distance to nearest boulders were measured for each of the boulders sampled. Bryophyte species diversity was found to be independent of variation in any of these factors. These findings contradict the species-area relationships predicted by the theory of island biogeography. The data suggest that frequent disturbance of the moss mats may reduce interspecific competition and maintain the community in a non-equilibrium state. Small, frequent disturbances are often recolonized by the local dominant, but larger patches seem to initiate species change.

CHEMISTRY

Use of high neutron fluxes for the determination of trace elements in biological tissues. D. J. VAN DALSEM,* W. D. EHMANN, Department of Chemistry, W. R. MARKESBERY, Sanders Brown Center on Aging, University of Kentucky, Lexington, KY 40506, and L. ROBINSON, Oak Ridge National Laboratory, Oak Ridge, TN 37831.

Determination of trace element concentrations in biological tissues is important in central nervous system diseases. Alzheimer's disease (AD) is the fourth leading cause of death in adults and will continue to be a leading cause of death as the average age of Americans increases in the years ahead. Trace element imbalances may be related to either the etiology or the pathogenesis of AD. Of great current interest is the concentration of aluminum (Al) in AD brain tissue. Presently, the determination of brain Al by any technique is beset with many problems. Studies are underway at the University of Kentucky and Oak Ridge National Laboratory (ORNL) to develop a method of isolating Al from other elements that present primary reaction and spectral interferences in determining brain Al by neutron activation analysis. Preliminary studies have involved the activation of various test samples and standard reference materials in a thermal neutron flux density of 5×10^{13} n cm^{-2} s^{-1} at ORNL's High Flux Isotope Reactor (HFIR). Future studies call for the activation of age-matched samples from AD and control brains after development of a pre-irradiation chemical separation of Al from interfering elements. In addition to Al, calcium and manganese will also be determined in brain to study possible interelement relationships in AD. Extra-neural tissues such as kidney and liver will be examined to determine if systematic imbalances are present in AD.

The thermal properties of some lipid components of membrane. LIHUA WEI,* DAVID R. HARTMAN, MARTIN R. HOUSTON, and WEI P. PAN, Department of Chemistry, Western Kentucky University, Bowing Green, KY 42101.

The physical properties of a series of pure phosphatidylcholines have been studied by a variety of physical methods including X-ray diffraction, thermal analysis, and spectroscopic techniques. Many substances, such as soaps and phospholipids, do not undergo a direct transition on heating from a crystalline form to a liquid. A number of states intermediate between a crystal and liquid are found to exist. These states have been variously called mesomorphic, liquid crystalline, or anisotropic liquid. Phosphatidylcholine generally exists in the monohydrate form. The thermal properties of a series of phospholipids from natural sources—phosphatidylcholine, phosphatidylethanolamine, phosphatidylserine, and sphingomyelin—were examined using differential scanning calorimetry and thermogravimetric analysis linked to a Fourier transform infrared spectrophotometer. All the phospholipids examined exhibited at least two mesomorphic states. The phospholipids appear to exist in the form of hydrates. Phosphatidylcholine, phosphatidylethanolamine, and phosphatidylserine are monohydrates; sphingomyelin is dihydrate. Crystallization from different solvents altered the form of liquid crystals.

Constructed wetlands for treatment of wastewater from single family dwellings. MATTHEW E. BYERS, BARBARA PORTER, and GEORGE F. ANTONIOUS, Kentucky State University, Frankfort, KY, 40601 and Lexington Fayette Health Dept., Lexington, KY, 40508.

The need for wetland systems in Kentucky has been established through data gathered by state and local governmental agencies. These data indicate rural residents typically have on-site septic treatment (or simply disposal) as sewer is not an option. And due to adverse geological factors including areas of modified to well developed Karstic topography, areas of bedrock near the surface, and regions having clayey soils, many of the estimated 633,000 on-site systems are failed, resulting in non-point source water pollution.

A location in Lexington Kentucky is currently being studied as a representative wetland system. The study system is a plastic lined trench 70 feet in length, 4 feet wide and 18 inches in depth. The trench is filled with #2 rock to approximately 14 inches, then capped with 5- and 6-size rock to 18 inches. The water level is maintained at 14 inches. The inlet end of the system is fed wastewater from the septic tank, water trickles through the rock bed where the rocks provide a suitable substrate for benthic microorganisms to come in contact with the flowage and metabolize the nutrients in the water. In addition, emergent macrophytes (cat tails, *Typha*), have been planted as tubers and their metabolism and that of their symbionts will contribute to nutrient and pathogen removal.

The system has been sampled once monthly, during a morning, mid-day and evening, from February through October 1991. Samples were drawn from ports in the septic tank, as well as the inlet, middle and discharge end of the wetland system. Samples were tested for dissolved oxygen, nitrate, ammonia, phosphate (total), biochemical oxygen demand (BOD), fecal coliform bacteria, total solids and pH. Results to date indicate mean monthly effluent levels for nitrate, ammonia, and total suspended solids of 25.1-PPM NO_3, 11.2-PPM NH_3, and 5.6-mg solids/liter, respectively. Mean monthly effluent fecal coliform bacteria were 632 colonies per 100-ml, with a 99.9% reduction from septic tank. Mean monthly BOD (5-d) effluent was 3.3 mg/liter, with system efficiency of 98.3 percent reduction. BOD upper levels for Fayette County discharge are 20-mg/liter. This study has not involved a flawless system; however, it has performed generally well.

COMPUTER SCIENCE

Spreading the gospel of GAIGS: an algorithm visualization system. CAROL W. WILSON, Computer Science Department, Western Kentucky University, Bowling Green, KY 42101.

GAIGS is a general algorithm visualization system developed by Tom Naps (NAPS@LAWRENCE.BITNET), at Lawrence College, Appleton, WI. It is an excellent, easy-to-use visualization tool that can be incorporated into student laboratory experiences to allow the student to "visualize and explore the conceptual foundations of algorithms instead of the code behind them." Language independent, GAIGS reads data from a text file of snapshots to "produce graphical pictures of nine abstract data structures: one-dimensional arrays, two-dimensional arrays, linked lists, stacks, queues, binary trees, general trees, graphs, and networks." Creating a GAIGS snapshot text file is as easy as "monitoring a program's execution by inserting tracer output statements." Versions have been developed to run on VaxStations under VMS, PC-compatibles, and Macintosh machines.

ENGINEERING

Seismic analysis of the Brent-Spence Bridge. ISSAM E. HARIK and MEIWEN GUO, Department of Civil Engineering, and DAVID L. ALLEN, Kentucky Transportation Center, University of Kentucky, Lexington, KY 40506.

The 1989 Loma Prieta earthquake has heightened concern for large highway structures and particularly double-decked bridges. There are two double-decked bridges that cross the Ohio River from Kentucky to adjoining states. These are the Brent-Spence Bridge that carries Interstate 75 in Northern Kentucky, and the Sherman-Minton Bridge in Louisville. The purpose of this study is to perform a seismic analysis of the Brent-Spence Bridge to determine its behavior in a typical seismic event that may occur in the Northern Kentucky area. Extensive analytical and experimental investigations will be conducted to determine parameters of major interest in earthquake problems. These are effective damping, three dimensional mode shapes, and associated frequencies of the bridge vibration. These parameters will be used in the seismic analysis to estimate the possibility of partial or total bridge collapse due to expected earthquake induced ground motion. The most critical damage is the so called "span-loss" type of bridge collapse (i.e., bridge span falling due to lack of support). After determining the bridge components that are most susceptible to a seismic event, various retrofitting schemes will be studied, and the most feasible one will be recommended.

GEOGRAPHY

Environmental and economic implications of the distribution of lakes and reservoirs in Kentucky. CLARA A. LEUTHART,* Department of Geography, and HUGH T. SPENCER, Department of Chemical Engineering, University of Louisville, Louisville, KY 40292.

Kentucky benefits from an abundance of water resources. The entire northern boundary is formed by the Ohio River, and major waterways drain from the interior of the Commonwealth to the Ohio. Additional water resources are found in the natural lakes and man-made reservoirs. The differences in distributions of the lakes and reservoirs have potential impact on the environment and economy of the Commonwealth. These distributions and potential impacts are the subject of this paper.

Mechanisms responsible for sinkhole flooding. THOMAS P. FEENEY* and NICHOLAS C. CRAWFORD, Department of Geography and Geology, Western Kentucky University, Bowling Green, KY 42101.

Sinkholes naturally flood during periods of heavy precipitation. In urban areas, the degree of flooding is usually magnified due to changes in land use that result in an increase in the amount of impervious cover. In an attempt to mitigate the flood impact, techniques such as zoning, diversion of water to retention basins, and modification of natural sinkhole drains via well installation are employed where best suited. Flooding, however, continues to persist in select sinkholes despite the presence of numerous drainage wells that were installed in an effort to increase the sinks' capacity to drain water to the karst aquifer below. The purpose of this study was to identify the mechanism responsible for sinkhole flooding in areas plagued by persistent flooding. It was hypothesized that flood water is derived from surface runoff that exceeds the drainage capacity of the sinkhole, or that groundwater has risen into the sinkhole from the cave system below. To test this, the South Sunrise/Media Drive sinkhole in Bowling Green, Kentucky, was studied by comparing the flood levels of four historic events with those calculated by an empirical runoff determination method. The volume of runoff generated by the 3-hour maximum rainfall intensity compared very closely to the peak volume actually ponded in the sinkhole, indicating that flooding was due to excess surface runoff.

MATHEMATICS

Dirichlet problem, harmonic measure, and Hardy spaces—a quick review. JOHN SPRAKER, Department of Mathematics, Western Kentucky University, Bowling Green, KY 42101.

The relationship between harmonic measure, the Riesz representation theorem, and Hardy spaces will be discussed. A few classical results will be stated.

Solving systems of equations using Lotus 1-2-3. EDGAR N. HOWELL, Division of Business, Mathematics, and Related Technologies, Hazard Community College, Hazard, KY 41701.

Last summer, a courseware unit was prepared to help students of college algebra learn both algebraic and graphical methods of solving systems of equations. The textual material consists of three chapters whose titles are (1) Systems of Two Linear Equations, (2) Systems of Three Linear Equations, and (3) Non-linear Systems of Equations Solved by Graphing. Accompanying the text are several templates, created with the help of Lotus 1-2-3, Release 2.2, requiring the user to enter only the coefficients and constants for the algebraic solutions and the usual number of x-values for the graphical solutions. The required 1-2-3 commands and the instructions for using the templates are included in the textual material.

Subjective probability. WALTER FEIBES, Rubel School of Business, Bellarmine College, Louisville, KY 40205.

What is meant by the statement, "In my judgment the chance of getting this contract is .20"? Clearly, this is not an experiment that can be repeated many times under identical conditions. Hence, the long-term frequency approach of objective probability is not appropriate. This leads to the consideration of subjective probability. The basic behavioral axioms are considered with emphasis on the assumptions of "coherence." Violation of the coherence axiom leads to the infamous money pump. A standard lottery is introduced to assess discrete probabilities. Continuous random variables are assessed with a cumulative distribution. The Ellsberg Paradox is used to show common errors in assessing subjective probabilities. How good are the assessed probabilities and do decision makers tend to bias their subjective probability assessments? These problems are discussed with consideration of the quadratic, logarithmic, and spherical "scoring rules." An outline of a more mathematically rigorous approach to subjective probability is presented. It is shown that the behavioral axioms of subjective probability lead to the Kolmogorov axioms of objective probability. In short, Kolmogorov's axioms of objective probability are now theorems of subjective probability.

PHYSIOLOGY, BIOPHYSICS, BIOCHEMISTRY, AND PHARMACOLOGY

Effect of $GABA_A$, or glycine receptor blockade on inspiratory inhibitory reflexes elicited by pontine stimulation. L. LING,* D. R. KARIUS, and D. F. SPECK, Department of Physiology, University of Kentucky, Lexington, KY 40536.

Electrical stimulation of pontine respiratory group (PRG) neurons had profound effects on the phrenic motor activity. Single shock stimulation of the PRG elicits a transient inhibition of inspiratory motor activity; stimulus trains produce premature inspiratory termination. The neurotransmitters involved in the inhibitory reflexes elicited by the PRG stimulation have not been elucidated. The classic central inhibitory transmitters, glycine and GABA, are involved in many inhibitory reflexes. This study examined the involvement of $GABA_A$ or glycine receptors in these inhibitory reflexes elicited by the PRG stimulation.

Experiments were conducted in decerebrate, paralyzed, and vagotomized cats. Electrical stimulation was delivered through a tungsten microelectrode stereotaxically positioned in the right PRG. Control responses to PRG stimulation were obtained from recordings of the left phrenic nerve activity. After systemic injection of bicuculline or strychnine (antagonists to $GABA_A$ or glycine receptors, respectively), responses to stimulation were again recorded. Inspiratory termination elicited by PRG stimulation persisted after antagonism of $GABA_A$ or glycine receptors. The onset latency and duration of the transient inhibition were not changed after administration of bicuculline, but were significantly prolonged after strychnine. These data suggest that neither receptor type is required in the inspiratory termination reflex and that $GABA_A$ or glycine receptor mediated neurotransmission is not essential to the transient inhibitory reflex. However, the marked changes in the onset latency and duration of the transient inhibition after strychnine suggest that glycine is involved in some way in the transient inhibitory reflex.

Characterization of a 22 kDa protein from the dense tubular system of human platelets. ERIC J. SCHEPERS,* Department of Biology, Bellarmine College, Louisville, KY 40205, and WILLIAM L. DEAN, Department of Biochemistry, University of Louisville, Louisville, KY 40292.

Human platelets contain a Ca^{2+}-ATPase in the dense tubular system that regulates intracellular Ca^{1+} levels and resembles the cardiac muscle sarcoplasmic reticulum Ca^{2+}-ATPase in functional properties. In platelets it has been shown that a 22 kiloDalton (kDa) protein is phosphorylated by cAMP dependent protein kinase which stimulates the Ca^{2+}-ATPase. This is similar to the phospholamban system in cardiac muscle, yet it is clear that the platelet 22 kDa protein is physically different from phospholamban. The purpose of this experiment was to further characterize the 22 kDa protein that stimulates the platelet Ca^{2+}-ATPase. The internal membrane Ca^{2+}-ATPase showed greatest activity when purified from a 65%–80% glycerol gradient. It was also found that some platelet proteins reacted with a low molecular weight (M.W.) G-protein antibody, rap-1b, in the 22 kDa range. This is significant for it shows that the 22 kDa protein that stimulates the Ca^{2+} pump could possibly be a G-protein. A two-dimensional Western Blot control with unphosphorylated rap-1b G-proteins was compared to a blot with the membrane phosphorylated with cAMP dependent protein kinase. It was found that a protein with a M.W. of 22 kDa and a pI of 5.3 was phosphorylated. When radioactive [^{32}P] labeled ATP was used for phosphorylation, autoradiography demonstrated that rap-1b was phosphorylated along with two other proteins with molecular weights of 25 kDa and pIs of 5.2 and 4.9. These results indicate the rap-1b or other slightly larger proteins are involved in stimulating the platelet Ca^{2+}-ATPase.

In vivo microvascular responses to blockade of endothelium-derived relaxing factor production in rat skeletal muscle. FENG LI* and IRVING G. JOSHUA, Department of Physiology and Biophysics, University of Louisville, Louisville, KY 40292.

The objective of this study was to compare the effects of the L-arginine analogues, N^G-monomethyl-L-arginine (L-NMMA) and N^W-nitro-L-arginine (L-NO_2-arg), on the endothelium-dependent vasodilation in the rat skeletal muscle microcirculation. Male, Sprague-Dawley rats were anesthetized with sodium pentobarbital (50 mg/kg, i.p.) and the cremaster muscle was observed using *in vivo* television microscopy. Both L-NMMA and L-NO_2-arg specifically block the basal and stimulated production of EDRF in the rat cremaster muscle microcirculation. However, the blockade effect of L-NMMA on the basal production of EDRF was short-lived, lasting about 10 minutes. In addition, L-NMMA only partially blocked the stimulated production of EDRF by high concentrations of acetylcholine (Ach, $\geq 10^{-6}$ M), an EDRF synthesis stimulator. L-NO_2-arg, on the other hand, specifically blocked the basal production of EDRF for a period of 15 minutes and also completely blocked the vasodilator effect of Ach up to 10^{-5} M. Neither agent blocked the vasodilator effect of sodium nitroprusside, an endothelium-independent vasodilator. These data suggest that L-NO_2-Arg is a better blocker of EDRF production in rat skeletal muscle microcirculation.

SCIENCE EDUCATION

Preference, increased student involvement, and enhanced learning with teacher-prepared objectives in biology courses. J. G. SHIBER, Division of Biological Sciences and Related Technologies, Prestonsburg Community College, Prestonsburg, KY 41653.

Over one half of students enrolled in four biology courses at Prestonsburg Community College (1990–1991) were provided with sets of explicit instructional objectives that they were expected to complete and learn each semester. Objectives were prepared by their instructor and covered each topic discussed. Three tests were given during the semester strictly on material the objectives covered; at the end the students answered a brief questionnaire concerning their "feelings" and opinions about the objectives and if they helped them to learn. Their final grades were compared with students enrolled in other sections of the same courses with traditional instruction and not using instructional objectives. Over 95% of the students completing the questionnaire expressed a definite preference for instructional objectives in all biology courses, stating that they were helpful in preparing for tests and learning the material. Their comments were reinforced by and reflected in the grades they earned, i.e., they had 9% more successful grades (A's, B's, and C's) and 8% fewer D's and E's than students who did not use objectives.

Students' final grades, their comments on the questionnaire, and their level of active involvement as observed by the instructor—these indicate that the provision of teacher-prepared objectives encourages a positive student attitude and a feeling of more control over one's grade. Interest and confidence in learning the subject matter increase and ultimately enhance student achievement.

ZOOLOGY AND ENTOMOLOGY

Activities of an apparent ant-mimic at extrafloral nectaries of *Heliconia latispatha*. THOMAS C. RAMBO, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41099.

The extrafloral nectaries on bracts of *Heliconia latispatha* (Heliconiaceae) attract a large variety of insects, including mosquitoes, other dipterans, and ants. A dipteran ant-mimic regularly appears at the nectaries. It is avoided by mosquitoes and so may be a form of Batesian mimicry. However, the ant-mimic is more likely to occur on buds frequented by ants than on buds without ants and actively attempts to approach feeding ants. This behavior indicates that Wasmannian mimicry is a more likely explanation of this mimicry.

Bluegrass Region and Western Coal Field: filter barriers to the dispersal of Kentucky amphibians and reptiles. LES MEADE, Department of Biological and Environmental Sciences, Morehead State University, Morehead, KY 40351.

The Bluegrass region and Western Coal Field act as filter barriers that regulate the dispersal of amphibians and reptiles. Several species and subspecies of the Kentucky herpetofauna have colonized peripheral areas of the Bluegrass or have a limited dispersal across this region. Such distributional patterns are shown by Kentucky salamanders (*Ambystoma opacum, A. maculatum, Notophthalmus v. viridescens*), frogs (*Pseudacris brachyphona, P. triseriata feriarum, Rana sylvatica, R. u. utricularia*), lizards (*Eumeces fasciatus, Scincella lateralis*), and snakes (*Carphophis a. amoenus, Lampropeltis getula nigra, Agkistrodon contortrix mokasen, Crotalus horridus*). These organisms may have entered the Bluegrass along the Kentucky River and Licking River drainages.

Selected species and subspecies of Kentucky herptiles that have colonized peripheral areas of the Western Coal Field or have a limited dispersal throughout this region include salamanders (*Eurycea bislineata, E. lucifuga*), frogs (*Bufo americanus, Gastrophryne carolinensis, P. crucifer, R. palustris*), lizards (*Cnemidophorus s. sexlineatus*), and snakes (*Virginia valeriae elegans, Tantilla coronata, Lampropeltis c. calligaster*).

Other species have a limited dispersal in both the Bluegrass region and Western Coal Field. Four salamanders (*Desmognathus f. fuscus, Pseudotriton montanus diastictus, P. r. ruber, E. l. longicauda*) and four snakes (*Storeria o. occipitomaculata, S. d. dekayi × wrightorum, Diadophis punctatus, C. a. helenae*) show such a distributional pattern.

Fostering behavior of lion-tailed macaques. TIMOTHY T. DICK,* Owensboro Community College, Owensboro, KY 42303.

Twin lion-tailed macaques were born in June 1989 at Mesker Park Zoo in Evansville, IN. Due to the inability of the mother to feed the twins (one male, one female), the male was removed and supervised by a human surrogate. As expected, the male exhibited human behavior within 3 weeks, which is particularly unacceptable for an endangered species. Therefore, the male was introduced to an infantless female to serve as a surrogate mother. Over a period of 5 months, the behavior of the male with the surrogate mother and the behavior of the female with the biological mother were compared. The results of this study will be presented.

Isolation of an unknown pathogen to *Aedes triseriatus* (Culicidae). KENNETH W. BLANK,* DENNIS LYE, and THOMAS C. RAMBO, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41099.

Attempts to isolate a pathogen of the mosquito *Aedes triseriatus* have led to several findings. The pathogen affects the mosquito in the fourth instar stage, whereas other pathogens usually affect the first or second instar. The pathogen does not turn the larvae milky white, but allows them to retain normal pigmentation. The pathogen works within 24 to 48 hours compared to the typical 72 hours of most other known pathogens. The pathogen appears to be a fastidious Gram (−) bacillus.

In attempts to isolate the pathogenic microorganism from infected larvae, many microscopic organisms have been observed. An amoebaflagellate has been isolated from all stages of mosquitos, yet the organism does not appear to be pathogenic. It may be a normal inhabitant of *A. triseriatus*.

Predatory behavior and territoriality in tropical jumping spiders (Araneae, Salticidae) associated with *Heliconia* spp. STEPHEN R. SKAGGS, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41099.

The distribution, predatory behavior, and territoriality of tropical jumping spiders associated with two species of *Heliconia* (*H. latispatha* and *H. imbricata*) were studied.

All studies were carried out at Estación Sirena in Corcovado National Park, Costa Rica. Individual spiders from six different species were marked and released at the points they were collected. Spiders were monitored for several hours each day for 3 weeks for interactions with prey and for movements from or faithfulness to a particular plant or area. The main prey item for all of these spiders was ants. The effects of intraspecific and interspecific competition were studied to determine the extent of territoriality among these spiders. Although some spiders stayed on one plant up to 5 days there was not enough conclusive information to state that these spiders maintain territories.

Small-mammal surveys in the Stanton and Morehead districts of the Daniel Boone National Forest, Kentucky. LES MEADE, Department of Biological and Environmental Sciences, Morehead State University, Morehead, KY 40351.

With the cooperation of the U.S. Forest Service, Kentucky Fish and Wildlife Resources, and Kentucky Nature Preserves Commission, a survey of rare, threatened, and endangered plants and animals in the Daniel Boone National Forest was undertaken by the Nature Conservancy. Fieldwork in the Morehead Ranger District began in May 1991. Previous studies in the Daniel Boone National Forest were completed in the Somerset District (1988), Stanton District (1989), Stearns District (1990), and Berea District (1991). Small mammals were surveyed in the Morehead District by using pitfall traps (32 oz. plastic cups) and snap traps placed in selected habitats throughout national forest lands. Major habitat types sampled during this study included: open, mixed mesophytic forest; mixed mesophytic forest with boulder talus; floodplain forest; swamp forest; prairie sites; upland fields; and lowland fields with sedges, grasses and buttonbush. Eleven species of mammals were collected. These included four species of shrews (*Sorex fumeus, S. longirostris, S. hoyi*, and *Blarina brevicauda*) and seven species of rodents (*Peromyscus leucopus, Reithrodontomys humulis, Synaptomys cooperi, Microtus pennsylvanicus, M. ochrogaster, M. pinetorum*, and *Napeozapus insignis*). Small mammals were sampled in the Stanton District in similar habitats by using bottles and pitfall traps. About 215 bottle sets (each with 5 bottles) and 90 pitfall traps were used. Seven species of small mammals were captured, including shrews (*S. fumeus, S. hoyi* and *B. brevicauda*), moles (*Parascalops breweri*) and rodents (*P. leucopus, M. pinetorum*, and *N. insignis*). Dominant species collected in the national forest were *B. brevicauda, S. fumeus*, and *P. leucopus*. Small mammals found in the national forest near Morehead and Stanton, but not collected during these research projects, included *Cryptotis parva, Ochrotomys nuttalli, Peromyscus maniculatus, Mus musculus*, and *Tamias striatus*.

Growth of the acanthocephalan *Moniliformis moniliformis* in the laboratory rat. DAVID F. OETINGER, Department of Biology, Kentucky Wesleyan College, Owensboro, KY 42302.

Eight 3-month-old male Sprague Dawley rats were each fed, by pipet, twelve 4-month-old *Moniliformis moniliformis* cystacanths obtained from three laboratory-infected *Periplaneta americana*. Rats were killed and necropsied at weekly intervals. Fifty-three worms were recovered (32 males, 21 females) by 58 days post infection. Each group of worms was allowed to become turgid during 2 days in two changes of tapwater at room temperature; proboscides were excised and trunks were fixed in AFA. Proboscides were allowed to remain in tapwater for another day and then fixed in absolute ethanol. They were then cleaned and mounted in Euparol within 2 days. Proboscides and hooks were traced as projected on a video monitor to total enlargements of ×888 (proboscides) and ×2,000 (hooks). Tracings were subsequently measured. Trunks were processed as for routine wholemounts of acanthocephalans, except that they were measured, after having been stained, in Petri dishes of 95% ethanol. Dishes containing the worms were placed on the surface of an overhead projector and projected onto a bulletin board where outlines of the worms were sketched by pencil. Sketches were measured by string and metric rule. During a 58-day period, male and female *M. moniliformis* increased in trunk length by approximately 7,000% and 15,000%, respectively. When data were tested by simple linear regression analysis (length vs. age in days) there were high Coefficients of Determination (0.98) for both male and female worms. Use of volume approximations or log transformations of data did not improve the mathematical descriptions of the results. There was no trend toward increasing size (length or width) of the proboscides of male or female *M. moniliformis* during a 58-day infection period in the rat small intestine. Hooks were comparable in size to those of mature cystacanths. The validity of reported sexual dimorphism in proboscis and hook measurements is challenged by the results of this study.

GEOLOGY

Honokohau Bay and Pu u Nianiau stratigraphic sections, Maui, of the East Chain Paired Volcano Sequence, Hawaii. GRAHAM HUNT, Department of Geology, University of Louisville, Louisville, KY 40292.

The Honokohau Bay volcanic section consists of three volcanic series of Maui: (1) the Wailuku shield building series, (2) the overlying lavas of the Honolua volcanic series, and (3) the post erosional rocks of the Lahina volcanic series. The alkalic trachytes of the Honolua lavas are underlain by a 10 meter thick, unnamed, pyroclastic unit of yellow ash and tachylite, which overlies the pre-existing tholeiitic lavas of the Wailuku volcanic series exposed at the shoreline of Honokohau Bay of northwest Maui. Studies of the petrography and morphology of the Bay section suggests that these volcanic rocks may be placed into a genetic category similar to present day volcanic beach processes of formation that are occurring at Kaimu Black Sand Beach, Hawaii. Field studies by the author—(1) a cinder cone, Pu u Nianiau, at the northwest flank of Haleakala Crater, (2) Kaluanui road section of east Oahu, and (3) the volcanics of the Kupianaha vent of Kilauea—give data to indicate a similar stratigraphic history of evolutionary change of the Hawaiian magma. The volcanic activity of Honokohau Bay, Pu u Nianiau, east Oahu, and Kilauea may be all part of the east line of a paired volcano sequence caused by a bifurcating plume of the Hawaiian mantle.

A new Kinderhookian ammonoid fauna from the Borden Formation of northeastern Kentucky. CHARLES E. MASON* and GREGORY A. DUKE, Department of Physical Sciences, Morehead State University, Morehead, KY 40351.

The Henley Bed of the Farmers Member of the Borden Formation was studied along state highway 546 in Lewis County, Kentucky. The sections examined are located on the Vanceburg and Garrison 7.5 minute topographic quadrangles. The Henley is predominantly composed of an argillaceous, mudshale with minor interbeds of siltstone. It is underlain by the Sunbury Shale and overlain by the Farmers Member. Fourteen (6-kg) samples collected at the top and bottom of the sections and above and below marker beds were broken down and washed through a 20 and 140 mesh sieve to collect macrofossils and microfossils, respectively. The Lower Mississippian Kinderhookian-Osagean boundary was found in the Henley Bed between 0.76 and 3.99 m above its base in the Garrison area. This boundary is well defined on the basis of conodonts, with the *Siphonodella iosticha* upper *Crenulata*-Zone representing the upper most Kinderhookian and *Gnathodus typicus*-Zone representing the lower Osagean. Macrofossils, occurring in the basal 12 cm, are the first ever found in the Henley interval and represent a dysaerobic fauna, being predominantly juveniles replaced with pyrite. Ammonoids are the most abundant and diverse of the mollusk dominated fauna, *Protocanites* being the only genus of three to be identified with certainty to date. This is the first Kinderhookian age ammonoid fauna found in Kentucky and is its eastern most occurrence in North America. *Protocanites* is found in midcontinent Kinderhookian rocks for the first time.

Petrology of the Corbin Member of the Lee Formation (Pennsylvanian) in east central Kentucky. ROBERT THOMAS LIERMAN* and JOLENE HOWARD, Department of Physical Sciences, Morehead State University, Morehead, KY 40351.

In a study of the petrology of the Lower to Middle Pennsylvanian Corbin Sandstone Member of the Lee Formation in east central Kentucky, major compositional differences were noted between the exposures located at Tater Knob in Bath County and along U.S. 460 near Frenchburg, Menifee County. Thin-sections of 25 samples of the Corbin from Bath County (Tater Knob section) and 14 from Menifee County (Frenchburg section) were examined petrographically, and statistical comparisons of the lithologies were made. Components were tabulated by point-counting and included monocrystalline mineral grains, such as quartz and feldspar; polycrystalline quartz grains; rock fragments, including sedimentary, metamorphic, and chert; pore filling cements; interstitial pore spaces; and gain size. A statistical comparison of the two sections was made through the use of the Student *t* test. The Tater Knob section was found to consist of both quartzarenites and sublitharenites; the Frenchburg section was exclusively a sublitharenite. The Tater Knob samples had higher percentages of sedimentary rock fragments; the

Frenchburg samples had more metamorphic rock fragments. Other compositional differences between the two sections included the percent of straight and undulose quartz, percent of polycrystalline quartz, percent of cement, interstitial pore space, and grain size. It is suggested that these two sections represent separate, fluvial sandstone bodies within the Lee Formation each with a different source area, the Tater Knob section being a mature sandstone derived from reworked sedimentary/low grade metamorphic rocks, and the Frenchburg samples apparently derived from a metamorphic/plutonic igneous source area.

Examination of clay mineral assemblages from Lower Mississippian rocks in eastern and central Kentucky. ROBERT THOMAS LIERMAN,* Department of Physical Sciences, Morehead State University, Morehead, KY 40351.

An examination was made of major components comprising shales and mudstones from Lower Mississippian rocks in eastern and central Kentucky. These include the black shales of the Sunbury and uppermost New Albany, the green shales and mudstones of the Nancy and New Providence members, and the Henley Bed of the lower Borden Formation. This interval represents the deposition of fine grained, clastic sediments in the deeper water portions of the Borden delta complex as it prograded from the northeast to the southwest.

Major components examined included the percent clay and silt in each sample; the total percent of organic matter; the types of clay minerals found in the $<2\ \mu$ fraction; and an estimation of the crystallinity of illite. Statistical analysis of the distribution of these components demonstrates several vertical trends: (1) a gradual increase in the percent of clay and decrease in the percent of silt as one proceeds up-section, (2) an increase in the percent of kaolinite and chlorite up-section, and (3) a steady increase in the crystallinity of lllite up-section. These vertical changes are reflected horizontally as one proceeds from northeast to southwest, in a basinward direction. Here, a decrease in the percent of clay, and increase in silt can be seen, along with a steady decrease in the percent of chlorite and kaolinite. This mirror image of clay/silt and kaolinite/chlorite nicely reflects the operation of Wather's Law in regard to the textural and mineralogical components making up these rocks.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 93–94

OUTSTANDING SECONDARY SCHOOL TEACHER AWARD OUTSTANDING COLLEGE SCIENCE TEACHER AWARD INDUSTRIAL SCIENTIST AWARD

Each year the Academy recognizes individuals for their contributions in advancing science in the Commonwealth. This year awards were given to the Outstanding Secondary School Teacher, the Outstanding College Science Teacher, and the Industrial Scientist.

Outstanding Secondary School Science Teacher

Mr. Joe Milam, who teaches Biology and Environmental Science at Russellville High School, is the recipient of the 1991 Outstanding Secondary School Science Teacher Award. Mr. Milam is a veteran teacher, teaching Biology five years at Lewisburg High School, Environmental Science eight years at Paducah Tilghman High School, and A.P. Biology and Environmental Science for 13 years at Russellville. For eight summers he taught environmental education at Land Between the Lakes to high school students and teachers and to elementary and college teachers in a program funded by TVA. He is married to another teacher, the former Cheryl Mallory. Cheryl teaches at the Russellville Middle School.

Mr. Milam has a B.S. degree in Biology and Agriculture and a M.A. degree in Education with emphasis in ecology. He has earned 24 hours above the Rank I. M. Milam's qualifications can be exemplified by a comment from one of his nominators, "Joe is an exceptional person and teacher because he is endowed with an abundance of knowledge and common sense. Joe's teaching methods go far beyond strictly imparting knowledge to his students. He requires his students to apply, analyze, and synthesize what they learn. Seldom do they miss a day performing 'hands-on' tasks. Because learning is real and alive. Joe's environmental biology class at Russellville High School has traditionally been one of the most popular classes in the curriculum although it is also one of the most demanding." In addition to the evidence that Mr. Milam is a good teacher, the Awards Committee was impressed by the out-of-class activities and accomplishments of his students. Each year he conducts a working day at LBL where his students study such things as the "ABCs of plants, lichens, ecology of animal tracks, and ways in which ecology can be incorporated into every aspect of the curriculum." His students have been winners in local, regional, and national science fairs. One of Joe's students described his classes in this way, "In his two courses, environmental science and A.P. Biology, he has challenged me to think and use what I know, not just memorize what the book said. He is interested in his students' lives—their activities, feelings, and goals for the future. Mr. Milam has been a great influence on me. I only hope I encounter many other people like him in my lifetime."

Joe Milam not only finds time to be involved with his students and their classes, he has also published an Environmental Education Manual for the Paducah School System which was ranked as one to the tope ten publications in the nation in this field, he developed and wrote programs for the TVA sponsored, *The Energy Sourcebook*, and he received state and national attention for his research on the snail darter. Joe Milam demonstrates those characteristics of a truly great teacher. He is capable of instilling the love of knowledge in the minds of his high school students.

Outstanding College Science Teacher

The award of the Outstanding College Science Teacher was presented to Dr. Larry A. Giesmann, Associate Professor of Biology, Northern Kentucky University, Highland Heights, KY. Dr. Giesmann received his Ph.D. in Botany from the University of Kentucky in 1972 and joined the Biology faculty at Northern Kentucky University the same year. He has remained in the Biology Department at Northern Kentucky since that time except for 1982–1985 when he served as Associate Dean of Arts and Sciences. Dr. Giesmann holds the B.A. degree in Biology from Susquehanna University. Over his career at Northern Kentucky, Dr. Giesmann has taught a variety of General Biology and Botany courses with the upper division courses being primarily in plant anatomy and plant morphology. Additionally, he has developed and taught courses in Techniques in Biological Sciences; Field Ecology for Elementary Teacher; Earth, Land, and Man; and Orientation to College indicating his broad diversity.

Evaluations of Dr. Giesmann's classroom teaching have been consistently high. He has the reputation of being hard but fair. In 1982 Giesmann was recognized as the Outstanding Professor at NKU.

Dr. Giesmann has served on a wide array of University committees, a few of which are: Chairman of Pre-medical/Pre-dental Committee (over 100 NKU graduates have entered medical school during his tenure), Chairman of Retention Committee, Chairman of the SACS Self-Study Committee on Institutional Effectiveness, and Vice President of the Faculty Senate. While teaching and performing University service Dr. Giesmann has found time to publish and present numerous professional papers and programs. He has also found time to write several successful grant proposals, the most recent two being a $60,000 NSF Laboratory Improvement Grant and an Eisenhower Grant to conduct a summer institute for high school teachers during 1992.

Dr. Giesmann has been active in community service with 45 presentations or science fair activities. Larry's activities have not been limited to his University not its geographical region. Since 1982 he has served on the Governor's Council on Science and Technology, he served on the Kentucky Education Department Merit Rating Team at Lafayette High School in Fayette County and on two separate occasions he served on the State Science Advisory Council. Dr. Giesmann is a dedicated, hard working supporter of the Kentucky Academy of Science. From 1985–1989 he served as Vice President, President-elect, President, and Past President. He currently serves as Chairman of the Nominations, Elections, and Resolutions Committee. It was through his efforts that we have the data base for keeping up with our members.

One of Dr. Larry Giesmann's recommenders summed up the justification for this award when he wrote, "in summary, Larry's teaching record is characterized by outstanding classroom teaching, accompanied by integrity, concern for students, concern for the University and the community, and innovation in carrying out his goals."

INDUSTRIAL SCIENTIST AWARD

The 1991 recipient of the Industrial Scientist Award was Dr. Lee T. Todd, Jr., of Lexington. Dr. Todd is the founder of two Lexington-based high technology firms, Databeam Corporation and Projectron, Inc. He currently serves as Chairman and CEO of DataBeam Corp. and Vice President for Hughes Display Products. Hughes Display Products, a subsidiary of Hughes Aircraft, purchased Projectron.

Projectron, Inc. is a highly successful design and manufacturing operation producing cathode ray tubes for the flight simulation industry. As a result of their acquisition of Projectron, Inc., Hughes Display Products relocated its operation to Lexington.

DataBeam Corporation manufactures teleconferencing systems which use high resolution displays. The DataBeam CT 100 Document Conferencing System is currently used by the Department of Defense in the Strategic Defense Initiative's "Star Wars" Program, by NASA in the Space Shuttle Program, and by a large number of governmental and private functions.

Dr. Todd is a native of Earlington, KY. He earned his B.S. in electrical engineering from the University of Kentucky. While at the University of Kentucky, Dr. Todd received a Hertz Foundation Scholarship to attend the Massachusetts Institute of Technology where he earned his M.S. and Ph.D. in electrical engineering. While in graduate school Dr. Todd was awarded 6 U.S. patents. In 1974 Dr. Todd joined the faculty of the Electrical Engineering Department at the University of Kentucky and taught nine years prior to founding the two private corporations.

While at the University of Kentucky, Dr. Todd received several teaching awards including the UK Alumni Association Great Teacher Award. He served on the University Senate for 8 years and was faculty advisor for Omicron Delta Kappa, National Student Leadership Fraternity.

Dr. Todd is very active in encouraging the formation of other high technology companies and in the improvement of the science and technology curriculum in Kentucky schools and colleges. Toward that end Dr. Todd is President of the Kentucky Science and Technology Council, chairs the Kentucky EPSCoR Committee, serves on the Georgetown College Board of Trustees, the Board of Directors of the Kentucky Academy of Science, the Pritchard Committee for Academic Excellence, the Board of Advocates for Higher Education, and the Board of the University of Kentucky Research Foundation.

Dr. Todd holds eight patents in cathode ray tube technology. He has to his credit over 90 publications and presentations. In 1989 he was awarded the INC. Magazine Entrepreneur of the Year Award.

Dr. Todd is a member and supporter of the Kentucky Academy of Science serving on its board of directors and on the Science and Government Committee.

He is married to the former Patricia Brantley, also of Earlington; the Todd's have two children aged 15 and 9. Patricia is a former public school teacher and currently serves as the Fayette County Community Co-Chair of the Primary School Program for the Kentucky Educational Reform.

Dr. Todd is a member of Calvary Baptist Church where he has served as Chairman of the Deacons Board.

There is no question that Dr. Lee Todd deserves the recognition as the 1991 Industrial Scientist. As one of his nominators said, "Dr. Todd has done more than anyone I know in Kentucky to further the awareness of the importance of science and technology in this state. . . . He has been personally responsible for raising significantly the level of high technology in Kentucky." Another nominator commented, "Dr. Todd had been a leader in many areas: in academia, in public service, and as an industrial entrepreneur." The fact that Dr. Todd established two high tech companies is sufficient to warrant the award. Even more significant is that he was instrumental in attracting Hughes Display Products to locate in Lexington and help advance the development of a "High-tech Triangle" in Kentucky.

Trans. Ky. Acad. Sci., 53(1–2), 1992, 95

NEWS AND COMMENTS

Important Publication

Haragan, P. D. 1991. Weeds of Kentucky and adjacent states. A field guide. Universities of Kentucky Press, Lexington. 218 pp. ($29.00).

Annual Meeting

The 78th meeting of the Kentucky Academy of Science will be held at the Ashland Community College, Ashland, Kentucky, October 29–31, 1992.

Instructions for Contributors

Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

Manuscripts may be submitted at any time to the Editor. Each manuscript will be reviewed by one or more persons prior to its acceptance for publication, and once accepted, an attempt will be made to publish papers in the order of acceptance. Manuscripts should be typed double spaced throughout on good quality white paper 8½ × 11 inches. NOTE: For format of feature articles and notes see Volume 43(3–4) 1982. The original and one copy should be sent to the Editor and the author should retain a copy for use in correcting proof. Metric and Celsius units shall be used for all measurements. The basic pattern of presentation will be consistent for all manuscripts. The Style Manual of the Council of Biological Editors (CBE Style Manual), the Handbook for Authors of the American Institute of Physics, Webster's Third New International Dictionary, and a Manual of Style (Chicago University Press) are most useful guides in matters of style, form, and spelling. Only those words intended to be italicized in the final publication should be underlined. All authors must be members of the Academy.

The sequence of material in feature-length manuscripts should be: title page, abstract, body of the manuscript, acknowledgments, literature cited, tables with table headings, and figure legends and figures.

1. The title page should include the title of the paper, the authors' names and addresses, and any footnote material concerning credits, changes of address, and so forth.

2. The abstract should be concise and descriptive of the information contained in the paper. It should be complete in itself without reference to the paper.

3. The body of the manuscript should include the following sections: Introduction, Materials and Methods, Results, Discussion, Summary, Acknowledgments, and Literature Cited. All tables and figures, as well as all literature cited, must be referred to in the text.

4. All references in the Literature Cited must be typewritten, double spaced, and should provide complete information on the material referred to. See Volume 43(3–4) 1982 for style.

5. For style of abstract preparation for papers presented at annual meetings, see Volume 43(3–4) 1982.

6. Each table, together with its heading, must be double spaced, numbered in Arabic numerals, and set on a separate page. The heading of the table should be informative of its contents.

Each figure should be reproduced as a glossy print either 5 × 7 or 8 × 10 inches. Line drawings in India ink on white paper are acceptable, but should be no larger than 8½ × 11 inches. Photographs should have good contrast so they can be reproduced satisfactorily. All figures should be numbered in Arabic numerals and should be accompanied by an appropriate legend. It is strongly suggested that all contributors follow the guidelines of Allen's (1977) "Steps Toward Better Scientific Illustrations" published by the Allen Press, Inc., Lawrence, Kansas 66044.

The author is responsible for correcting galley proofs. He is also responsible for checking all literature cited to make certain that each article or book is cited correctly. Extensive alterations on the galley proofs are expensive and costs will be borne by the author. Reprints are to be ordered when the galley proofs are returned by the Editor.

CONTENTS

TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

Volume 53
Numbers 3–4
September 1992

Official Publication of the Academy

The Kentucky Academy of Science

Founded 8 May 1914

All manuscripts and correspondence concerning manuscripts should be addressed to the Editor. Authors must be members of the Academy.

The TRANSACTIONS are indexed in the Science Citation Index. Coden TKASAT. ISSN No. 0023–0081.

Membership in the Academy is open to interested persons upon nomination, payment of dues, and election. Application forms for membership may be obtained from the Secretary. The TRANSACTIONS are sent free to all members in good standing.

Annual dues are $25.00 for Active Members; $10.00 for Student Members; $35.00 for Family; $350.00 for Life Members. Subscription rates for nonmembers are: domestic, $45.00; foreign $50.00; back issues are $30.00 per volume.

The TRANSACTIONS are issued semiannually in March and September. Four numbers comprise a volume.

Correspondence concerning memberships or subscriptions should be addressed to the Secretary. Exchanges and correspondence relating to exchanges should be addressed to the Librarian, University of Louisville, Louisville, Kentucky 40292, the exchange agent for the Academy.

THIS PUBLICATION IS PRINTED ON ACID-FREE PAPER.

EDUCATIONAL AFFILIATES

Fellow

University of Kentucky

Sustaining Member

Eastern Kentucky University
Morehead State University
Murray State University
Northern Kentucky University
University of Louisville
Western Kentucky University

Members

Bellarmine College
Cumberland College
Georgetown College

Associate Members

Berea College
Brescia College
Campbellsville College
Centre College
Kentucky State University
Kentucky Wesleyan College
Midway College
Spalding University
Sue Bennett College
Thomas More College
Translvania University
Union College

INDUSTRIAL AFFILIATES

Associate Patron

Ashland Oil, Inc.

Fellow

Brown and Williamson Tobacco Corporation

Sustaining Member

Air Products & Chemicals, Inc.

Members

All-Rite Pest Control
Alltech Biotechnology Center
Chemical & Industrial Engineering, Inc.
Corhart Refractories Corporation
Databeam Corporation
First Security Banks
Gaf Chemicals Corporation
The Humana Foundation Inc.
International Business Machines Corporation
Litton Industrial Automation
MPD, Inc.
United Catalysts Inc.
Westvaco

Associate Members

Group Financial Partners, Inc.
Procter & Gamble Mfg. Co.
Wood Hudson Cancer Research Lab., Inc.

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

September 1992
Volume 53
Numbers 3–4

Trans. Ky. Acad. Sci., 53(3–4), 1992, 97–100

Effects of Protein Level on Growth and Body Composition of Hybrid Sunfish (*Lepomis cyanellus* × *L. macrochirus*) Reared in Ponds

Carl D. Webster, James H. Tidwell, Laura S. Goodgame, Julia A. Clark, and Daniel H. Yancey

Aquaculture Research Center, Kentucky State University, Frankfort, Kentucky 40601

Abstract

Hybrid sunfish (*Lepomis cyanellus* × *L. macrochirus*) juveniles (3.4 g) were stocked into six 0.04 ha ponds at a rate of 12,350 fish/ha and fed twice daily 1 of 2 diets containing either 32% or 38% protein. After 100 days, no significant differences ($P > 0.05$) in individual fish weight, percentage survival, food conversion, or growth rate were found among treatments. Final individual fish weights were 49 and 43 g for fish fed diets containing 32% and 38% protein, respectively. No significant differences ($P > 0.05$) in percentage moisture and protein were found in fish fed either diet. However, percentage fat was significantly higher ($P < 0.05$) in fish fed a diet containing 32% protein (18.7%) compared to fish fed a diet containing 38% protein (12.6%). These data indicate that, when stocked at the rate of 12,350 fish/ha, hybrid sunfish can utilize a 32% protein diet with similar growth rates as fish fed a diet containing 38% protein.

Introduction

The pay-lake industry (fee-fishing ponds) is an important sector of the aquaculture industry in many states, including Kentucky (1). Pay lakes provide a source of income for the pond owner, a source of food and recreation for the public, and a market for producers of live fish. The hybrid sunfish (female green sunfish, *Lepomis cyanellus* × male bluegill, *L. macrochirus*) appears to have potential as a desirable fish for the pay-lake industry.

Growth of green sunfish × bluegill (GS × BG) hybrids has been reported to be higher than that of either parental stock (2). The GS × BG sunfish reach an acceptable catch-size in a shorter period of time than channel catfish, *Ictalurus punctatus*, a very popular pay-lake fish (1).

Increasing the growth rate of GS × BG sunfish by feeding prepared diets is desirable. Lewis and Heidinger (3) reported that, of the sunfish crosses evaluated, only the GS × BG sunfish is well suited to feeding prepared diets. This is due primarily to the aggressive feeding response the hybrid exhibits (4). This response also increases the vulnerability to hook-and-line capture by fisherman. Approximately 66% of GS × BG sunfish stocked into a pond were captured by hook-and-line after 18 hours of angling (5). From a fisherman's viewpoint, a larger fish is desirable. Larger fish also are of benefit to the fish producer and pay-lake operator in that higher prices can be attained for their products.

Because protein is the most expensive component of a diet, knowledge about the protein requirements of the fish is essential for the formulation of nutritious, economical diets. Various studies have shown that the percentage of protein required for optimum growth varies with species (6–8). However, information about the nutritional requirements for GS × BG sunfish is lacking. This impedes formulation of a nutritionally complete diet and limits the culture of the fish. Tidwell et al. (9) reported that growth of GS × BG sunfish reared in aquaria increased with increasing protein levels. It is essential to know the minimum protein requirements for optimum growth in ponds. The objective of this study was to determine the growth, food conversion, survival, and body composition of fingerling GS×BG sunfish fed two protein levels (32% and 38%) reared in ponds.

MATERIALS AND METHODS

Diets.—Fish were fed 1 of 2 extruded diets formulated by a commercial feed mill (Delta Western, Indianola, Mississippi) to contain either 32% or 38% protein. Diets were analyzed for crude protein, fat, and moisture. Crude protein was determined using macro-Kjeldahl, crude fat was determined by the acid-hydrolysis method, and moisture was determined by placing 2 g of the diet in a drying oven (95°C) until constant weight (10). Chemical analysis of the diets showed the 32% protein diet had 33.1 ± 0.07% protein and 4.4 ± 0.02% fat, while the 38% protein diet had 37.8 ± 0.02% protein and 3.4 ± 0.02% fat. Diets were stored (−30°C) in plastic-lined bags until fish were fed.

Grow-out.—Juvenile hybrid bluegill (female green sunfish, *Lepomis cyanellus* × male bluegill, *L. macrochirus*; average weight 3.4 ± 0.1 g) were stocked on 3 July 1991 in six 0.04-ha earthen ponds at the Aquaculture Research Center, Kentucky State University, at a rate of 12,350 fish/ha. Ponds were approximately 1.5 m deep and were supplied with water from a reservoir which was filled by rain runoff. Water levels in ponds were maintained at a constant depth by periodic additions.

Fish were fed a fixed amount (0.92 kg/day) of either a 32% or a 38% protein diet twice (0900 and 1530) daily for 100 days. One-half of the total amount was fed in each of the 2 feedings. Each treatment was replicated in 3 ponds. Diets were spread uniformly inside a 3.0-m diameter floating feeding ring in the pond and the immediate surrounding area to prevent a feeding "pecking order" from being established. Rings were made from 1-cm diameter plastic pipe and had a 0.58-mm plastic mesh skirt extending 20 cm below the water surface.

Dissolved oxygen (DO) and temperature of all ponds were monitored twice daily (0800 and 1430) by means of a YSI Model 57 oxygen meter. When the DO level of any pond was predicted (graphically) to decline to below 4.0 mg/liter, aeration was provided. Total ammonia nitrogen (TAN) and nitrite were measured once weekly (at 1300) by means of a Hach DREL/5 spectrophotometer, and pH was measured once weekly (at 1300) using an electronic pH meter (Accumet 900, Fisher Scientific). Through the duration of the study, these water quality features were not significantly different ($P > 0.05$) among treatments, and means were (±SE): morning water temperature, 24.7 ± 0.3°C; afternoon water temperature, 25.8 ± 0.4°C; morning DO, 7.2 ± 0.3 mg/liter; afternoon DO, 10.4 ± 1.0 mg/liter; TAN, 0.25 ± 0.15 mg/liter; nitrite, 0.03 ± 0.02 mg/liter; pH, 8.85 ± 0.23.

Harvest Data.—Fish were not fed 24 hours prior to harvest and were harvested by seine on 14 October 1991. Total number and weight of fish in each pond were determined at harvest. Fifty fish were randomly sampled from each pond and were individually weighed to the nearest gram and measured (total length) to the nearest 0.5 centimeter. Ten fish were randomly sampled for analysis of body composition. Whole fish were homogenized in a blender and analyzed for moisture, protein, and fat. protein was analyzed using a LECO FP-228 nitrogen determinator (11); fat was analyzed by ether extraction; and moisture was determined by drying in a convection oven (95°C) until constant weight (10).

Food conversion ratio (FCR) and specific growth rate (SGR) were calculated as follows: FCR = total diet fed (kg)/total wet weight gain (kg); SGR (%/day) = $(\ln W_t - \ln W_i/T) \times 100$, where W_t is the weight of fish at time t, W_i is the weight of fish at time 0, and T is the culture period in days.

Statistical Analysis.—Data were analyzed using the SAS ANOVA procedure (12) for significance. Differences between means were determined by Duncan's multiple range test. All percentage and ratio data were transformed to arcsine values prior to analysis (13).

RESULTS AND DISCUSSION

There were no significant differences ($P > 0.05$) in individual fish length, individual fish weight, survival, food conversion ratio (FCR), specific growth rate (SGR), and yield (kg/ha) between GS×BG sunfish fed either a 32% or 38% protein diet (Table 1).

The lack of significant differences in weight gain and food conversion in GS × BG sunfish fed diets containing 32% and 38% protein suggests that the diets may be within optimal range for fish growth when fish are stocked at the low rate used in the present study. It is not known if a diet with a higher percentage of protein (i.e., 45%) would have significantly improved growth rates. Protein is the most expensive dietary component in finfish diets and is a primary concern in diet formulation. Feed producers desire to provide the minimum level of protein in a diet that will supply essential amino acids and nitrogen to support acceptable weight gain in fish.

Growth rates for GS × BG sunfish cultured in ponds are not currently available in the literature for comparison. The SGR reported in this study (2.6) is somewhat higher than other studies and other fishes. Tidwell et al. (9) reported that hybrid bluegill fed a diet containing 35% protein had an SGR of 1.98. Specific growth rates for other fish species have been reported at 2.1 for channel catfish, *Ictalurus punctatus* (14), 2.1 for chinook salmon, *Oncorhynchus tshawytscha* (15), 1.9 for blue catfish, *Ictalurus furcatus* (16), and 0.7 for rainbow trout, *Oncorhynchus mykiss* (17). This higher value may indicate that BG×GS hybrids have faster growth rates than more commonly reared species. Webster et al. (18) reported an SGR value of 1.8 for pond-reared channel catfish. Comparison of results of protein requirements from other studies is complicated by different experimental conditions including species, size and age of the fish used, stocking density, protein quality, and variations in abiotic factors (e.g., water temperature) (19).

Growth data reported in the present study may be confounded by the availability of natural foods present in the pond. Stocking density in the present study was lower than intensively-stocked channel catfish ponds. Research should be conducted on the optimum stocking rates for GS × BG sunfish. With fewer fish present in ponds, natural foods in the ponds may have been utilized as food items. The high FCR value (3.7) may indicate that the prepared diets were not optimally consumed. Juvenile bluegill could feed on zooplankton and benthic organisms to supplement the diet (20). The high FCR may also indicate that the fixed amount of diet fed per day was too high. However, in conducting feeding studies, diet should not be limiting and feeding to excess is preferable to underfeeding (19).

TABLE 1. Average yield, individual fish weight, individual fish length, survival, food conversion ratio (FCR), and specific growth rate (SGR) for hybrid bluegill fed diets containing either 32% or 38% protein.[1]

	Protein (%)	
	32	38
Yield (kg/ha)	522.5 ± 5.58[a]	505.3 ± 27.8[a]
Indiv. fish weight (g)	49.1 ± 1.6[a]	43.5 ± 2.0[a]
Indiv. fish length (cm)	13.0 ± 0.1[a]	12.4 ± 0.2[a]
Survival (%)	94.87 ± 1.54[a]	92.00 ± 3.11[a]
FCR	3.72 ± 0.04[a]	3.87 ± 0.20[a]
SGR	2.67 ± 0.03[a]	2.55 ± 0.05[a]

[1] Values are means ± SE of three replications. Means within a row that have the same superscript are not significantly different ($P > 0.05$).

Whole-body composition analysis indicates that diet did not affect percentage body protein in GS × BG sunfish (Table 2). No significant differences ($P > 0.05$) in percentage moisture and protein were found between treatments. Percentage protein averaged 63.3%. Percentage fat of fish fed a diet containing 32% protein was significantly higher (18.7%) than fish fed a diet containing 38% protein (12.6%) ($P < 0.05$). The level of digestible energy in a diet affects the amount of food consumed by fish and the ratio of energy to protein in the diet will influence conversion efficiency of the diet (21). A high ratio may increase fat deposition in fish, whereas a low ratio will cause protein to be used as an energy source. In the present study, the higher percentage of fat in fish fed a diet containing 32% protein may indicate that this diet had a higher energy-to-protein ratio for GS × BG sunfish than the diet containing 38% protein. This would lead to the increase in percentage fat reported in this study.

Formulation of a nutritious diet for GS × BG sunfish will allow producers to feed the most economical diet possible, while allowing for optimal growth. The present study indicates that a 32% protein diet appears to be suitable for rearing hybrid bluegill juveniles in ponds when stocked at 12,350 fish/ha. Protein requirements may change if fish are stocked at higher rates. Research into feeding diets with various protein levels and higher stocking rates

TABLE 2. Whole-body composition (percentage moisture, protein, and fat) of juvenile hybrid bluegill at stocking and fed diets containing either 32 or 38% protein.[1]

	At stocking	Diet (% Protein)	
		32	38
Moisture (%)	77.05 ± 0.25	73.64 ± 0.26[a]	73.99 ± 0.40[a]
Protein (%)[2]	66.74 ± 0.52	63.33 ± 1.28[a]	63.93 ± 3.21[a]
Fat (%)[2]	7.09 ± 0.30	18.72 ± 1.48[a]	12.62 ± 1.33[b]

[1] Values are means ± SE for three replications. Means in the same row with different superscripts were significantly different ($P < 0.05$).
[2] Dry-weight basis.

should be conducted to more fully elucidate protein requirements of GS × BG sunfish.

ACKNOWLEDGMENTS

We thank Eddie Reed, Steven Mims, and Wendell Harris for their technical assistance, and Paul Weston for use of his laboratory. We also thank Sandra Hall for typing this manuscript. This study was partially funded by a USDA/CSRS grant to Kentucky State University under agreement KYX-80-91-04A.

LITERATURE CITED

1. Lopinot, A. C. 1972. Pond fish and fishing in Illinois. Illinois Department of Conservation, Fisheries Bulletin 5, Springfield, Illinois.

2. Cremer, M. C., S. D. Mims, and G. M. Sullivan. 1984. Pay lakes as a marketing alternative for Kentucky fish producers. Research Bulletin No. 8, Kentucky State University, Frankfort, Kentucky.

3. Lewis, W. M. and R. C. Heidinger. 1971. Supplemental feeding of hybrid sunfish populations. Trans. Am. Fish. Soc. 100:619–623.

4. Lewis, W. M. and R. C. Heidinger. 1978. Use of hybrid sunfishes in the management of small impoundments. Pp. 104–108. In G. D. Novinger and J. C. Dillard (eds.) New approaches to the management of small impoundments. North Central Division, American Fisheries Society, Special Publication 5, Bethesda, Maryland.

5. Brunson, M. W. and H. R. Robinette. 1986. Evaluation of male bluegill × female green sunfish hybrids for stocking Mississippi farm ponds. N. Am. J. Fish. Manage. 6:156–167.

6. DeLong, D. C., J. E. Halver, and E. T. Mertz. 1958. Nutrition of salmonid fishes. VI. Protein requirements of chinook salmon at two water temperatures. J. Nutr. 65: 589–599.

7. Satia, B. P. 1974. Quantitative protein requirements of rainbow trout. Prog. Fish-Cult. 36:80–85.

8. Prather, E. E. and R. T. Lovell. 1973. Response of intensively fed channel catfish to diets containing various protein-energy ratios. Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm. 27:455–458.

9. Tidwell, J. H., C. D. Webster, and J. A. Clark. In press. Growth, feed conversion, and protein utilization of female green sunfish (*Lepomis cyanellus*) × male bluegill (*L. macrochirus*) hybrids fed isocaloric diets with different protein levels. Prog. Fish-Cult.

10. AOAC. 1990. Official methods of analysis of the Association of Official Analytical Chemists, 15th ed. AOAC, Arlington, Va.

11. Sweeney, R. A. and P. R. Rexroad. 1987. Comparison of LECO FP-228 'nitrogen determinator' with AOAC copper catalyst Kjeldahl method for crude protein. J. Assoc. Off. Anal. Chem. 70:1028–1030.

12. Statistical Analysis Systems. 1988. SAS/STAT user's guide. Release 6.03 Edition. SAS Institute, Cary, N.C.

13. Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, N.J.

14. Webster, C. D., J. H. Tidwell, and D. H. Yancey. 1991. Evaluation of distillers grain with solubles as a protein source in diets for channel catfish. Aquaculture 96: 179–190.

15. Fowler, L. G. 1990. Feather meal as a dietary protein source during parr smolt transformation in fall chinook salmon. Aquaculture 89:301–314.

16. Webster, C. D., J. H. Tidwell, and D. H. Yancey. 1992. Effect of partially or totally replacing fish meal with soybean meal on growth in blue catfish (*Ictalurus furcatus*). Aquaculture 103:141–152.

17. Tidwell, J. H., C. D. Webster, and R. S. Knaub. 1991. Seasonal production of rainbow trout, *Oncorhynchus mykiss*, in ponds using different feeding practices. Aquacult. Fish. Manage. 22:335–341.

18. Webster, C. D., J. H. Tidwell, J. A. Clark, and D. H. Yancey. 1992. Effects of feeding diets containing 34 or 38% protein at two feeding frequencies on growth and body composition of channel catfish. J. Appl. Aquacult. 1: 67–80.

19. Jauncey, K. and B. Ross. 1982. A guide to Tilapia feeds and feeding. Institute for Aquaculture, Univ. of Stirling, United Kingdom.

20. Brunson, M. W. and H. R. Robinette. 1982. Supplemental winter feeding of hybrid sunfish in Mississippi. Proc. Ann. Conf. Southeast. Fish Wildl. Agencies 36:157–161.

21. Reis, L. M., E. M. Reutebuch, and R. T. Lovell. 1989. Protein-to-energy ratios in production diets and growth, feed conversion and body composition of channel catfish, *Ictalurus punctatus*. Aquaculture 77:21–27.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 101–108

Effects of *Azospirillum lipoferum* on Dry-Matter Accumulation and Fruit Production in Greenhouse-Grown Bell Pepper (*Capsicum annum*) Plants

Cloyd J. Bumgardner and David Mardon
Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

The growth and fruit production of bell pepper (*Capsicum annum*) plants grown in association with an *Azospirillum lipoferum* isolate (ALM) were followed from the seedling stage of growth until the ripening of the first fruit. Plants receiving supplemental nitrogenous fertilization (10-10-10 fertilizer), and grown in association with ALM (ALM+), produced fruit with substantially greater amounts of dry matter than those of plants grown under the same conditions of nitrogen fertilization but without the ALM association (ALM−). ALM+ plants receiving 0-20-20 non-nitrogenous fertilization and ALM+ plants receiving no fertilizer during the growth cycle developed sufficiently to produce fruit. ALM− plants grown under these same fertilizer regimens did not. These data indicate the initial availability of nitrogen in the absence of ALM supplementation and in growth substrates receiving no nitrogenous fertilization was insufficient to support the growth of plants into the generative phase.

Introduction

The genus *Azospirillum* contains 2 species, *A. lipoferum* and *A. brasilense*, both of which have been isolated from the rhizospheres of herbaceous plants and mycorrhizal fungi growing in nitrogen-deprived environments (1, 2, 3, 4). Both species are positive in the acetylene reduction assay for dinitrogenase, denoting that the microbes are nitrogen-fixing, preforming in casual association with plants and fungi (5, 6).

When added to the rhizospheral region of grasses, *Azospirillum* species have been shown to significantly affect plant dry-matter accumulation and nitrogen uptake (7, 8, 9, 10). Studies utilizing sweet potato (*Imomoea batatas*) and tomato (*Colanum esacalatum*) grown in association with *A. lipoferum* have yielded results similar to the *Azospirillum*-grass studies noted above (11, 12). Although positive effects have been noted on productivity of these garden variety plants, no data are available pertaining to bell pepper (*Capsicum annum*) grown in association with *A. lipoferum*. Therefore, the focus of this study was to determine the effects of *A. lipoferum* supplementation on dry matter and fruit production of greenhouse-grown bell peppers.

Materials and Methods

Test Organisms.—*Azospirillum lipoferum* (ALM) used in this study were initially isolated from the rhizospheral soil of *Festuca arudinacea* growing on a coal surface-mined site in Eastern Kentucky (4). The bell pepper seeds used in this study were obtained from Ball Seed Co. (West Chicago, Ill.) and were of the Better Bell variety.

Bacterial Culture Medium.—*Azospirillum lipoferum* (ALM) was maintained with bimonthly transfers on agar slants of the nitrogen-free sodium-malate media of Mardon and Rothwell (4).

Growth System Design.—Rectangular potting structures were constructed from ½-inch plywood and designed for a holding capacity of 6 liters. The interior was lined with a double layer of autoclave bags and a single layer of 2.0-mm fiberglass netting suspended 4.0 cm above the growth-system bottom to support the growth substrate. Wooden partitions were inserted 4.0 cm from each end of the containers, allowing even watering, aeration and fertilization of the growing plants. Six liters of a 1:1:1 by volume mixture of perlite, vermiculite and soil were passed through a 5.0-mm sieve to remove large particles, placed into the growth structures and the units sterilized in a gravity type autoclave. Growth substrate samples from each potting unit were removed with presterilized 5.0-mm soil corers and aseptically inoculated into 10-ml tubes of Thioglycollate medium (BBL). No evidence of growth in the Thioglycollate medium after incubation at 35°C for 14 days was indication of substrate sterility (13).

Preparation of Cultures and Seeds.—The ALM cells were grown on the nitrogen-free minimal salts medium described above for 48 hours at 35°C. Cultures were washed 3 times in sterile 0.85% saline and adjusted to a 30 Klett reading on a Klett-Sumerson colorimeter (#66 red filter). Bell pepper seeds were surface sterilized by immersion in a 3% sodium hypochlorite solution for 10 minutes and aseptically planted in the growth substrates approximately 15.0 mm below the growth substrate surface in a configuration allowing 600 cm^3 for the expansion of each plant rhizosphere. Then 3.7 liters of the *Azospirillum* suspension was evenly added to each growth system using a presterilized sprinkler assembly. Numbers of viable cells corresponded to approximately 5.5×10^8 CFU's per gram of growth substrate as determined by replicate plating on the nitrogen-free medium above and growth on 5% Sheep's Blood Agar (Difco Laboratories, Detroit Michigan).

Watering and Fertilization Regimens.—When water was no longer visible in the bottom of the growth system, ½ liter of sterile, distilled, deionized water was added to the potting units. Fertilized plants included those receiving supplemental nitrogenous fertilization (10-10-10 fertilization) and those receiving supplemental non-nitrogenous fertilization (0-20-20 fertilization). Additional plants were grown to maturity with no supplemental fertilization. Fertilized plants received 1 fertilizer sample prior to plant blooming, further fertilization was bi-weekly for the next 6 weeks and once per week thereafter. One 10-10-10 fertilizer aliquot contained 200.0 ml of a fertilizer mixture consisting of 60.0 g of 10-10-10 fertilizer, 1.0 g $MgSO_4 \cdot 7H_2O$, 25.0 ml of a micronutrient solution of (1.0 g H_3BO_3, 1.0 g $FeSO_4 \cdot 7H_2O$, 0.2 g $MnCl_2 \cdot 4H_2O$, 0.2 g $CoCl_2 \cdot 6H_2O$, 1.0 g $ZnCl_2$ and 1.0 g $CaSO_4 \cdot 5H_2O$ per liter), and 15.0 g $CaCO_3$ per liter added to 800 ml of sterile, distilled, deionized water. Growth systems which were fertilized according to the 0-20-20 regimen received the fertilization mixture above modified by the substitution of 30.0 g of 0-20-20 fertilizer for the 10-10-10 mixture. All plants were placed on a daily 14-hour partial photoperiod with supplemental light supplied by fluorescent lights 1.0 m above all growth systems. The average night temperature was 23°C and the average day temperature 33°C.

Sampling of Plants and Microorganisms.—At least 36 plants were sampled within one day of entering each of the six-leaf, first-bloom and first-fruiting stages of growth. These plants were representative of each condition of supplemental nitrogen availability and plant growth stage. Plants were divided into root, stem, foliar and fruit portions, dried for 7 days at 110°C in a drying oven and weighed on a Fisher Scientific XA analytical balance. Microbial samples from rhizosphere growth substrates were obtained by aseptically washing the growth substrate from the plant roots with sterile 0.85% saline. This material was decimally diluted in 9.0-ml blanks containing 0.85% saline. One ml of each dilution was transferred into triplicate plates containing nitrogen-free medium, plate count agar (Difco) and 5% sheep's Blood Agar (Difco). These plates were incubated at 35°C and counted after 72 hr. *Azospirillum lipoferum* was identified using standard morphological and physiological tests (14).

Statistical Analysis.—The data were analyzed with an ANOVA statistical analysis package (SAS Institute Inc., Cary, N.C.) using the VAX 6410 computer located on the Eastern Kentucky University campus (Richmond, Ky.)

Nitrogen Content of Growth Substrates.—The level of organic nitrogen present in the growth substrates was determined according to standard Kjeldahl analysis (15). Inorganic nitrogen present in the growth substrates in the forms of ammonium ion, nitrite ion and nitrate ion were determined according to the colorimetric procedures specified in the Manual of Methods for General Bacteriology (16).

RESULTS

Plant Dry Weights.—All plant dry-weight measurements fell within one ± standard deviation from the mean.

Six-leaf Growth Stage.—The mean average dry weights of root, stem and foliar portions of pepper plants grown in association with *Azospirillum lipoferum* (ALM+) did not differ significantly ($P < 0.05$) from corresponding portions of control plants grown without the *A. lipoferum* association (ALM−) (Fig. 1). No

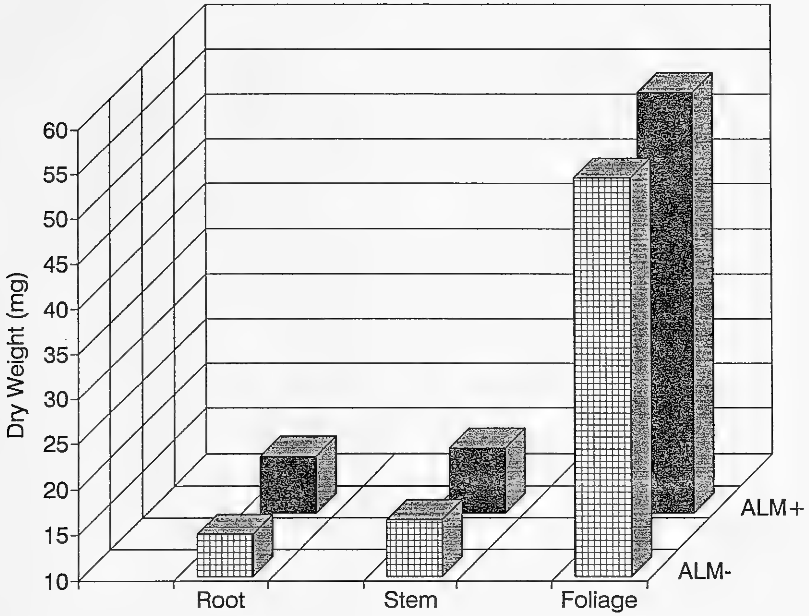


FIG. 1. Mean average root, stem and foliage dry weights of ALM+ and ALM− bell pepper (*Capsicum annum*) plants at the six-leaf stage of growth.

plants at this stage of growth received any supplemental fertilization.

First-bloom Growth Stage.—When sampled at the first-bloom stage of growth and receiving 10-10-10 nitrogenous fertilization, no significant difference ($P < 0.05$) was noted between root, stem and foliage dry weights when ALM+ plants were compared with corresponding ALM− plants (Fig. 2). However, ALM+ plants at the first-bloom stage of growth receiving 0-20-20 non-nitrogenous fertilization possessed substantially greater amounts of dry matter in their roots ($P > 0.05$) , stems ($P > 0.05$) and foliar ($P > 0.05$) portions than corresponding ALM− grown plants (Fig. 3). This same trend (ALM+ plants possessing substantially greater amounts of dry matter in root ($P > 0.05$), stem ($P > 0.05$) and foliar ($P > 0.05$) portions than ALM− plants) was also noted in growth systems receiving no supplemental fertilization (Fig. 4).

First-fruiting Growth Stage.—As indicated in Figure 5, ALM+ plants receiving 10-10-10 fertilization produced fruit containing significantly greater amounts of dry matter ($P > 0.05$) than ALM− plants grown under conditions of supplemental nitrogen additions. However, total dry weight of the ALM+ plant roots, stems and foliar portions did not differ significantly ($P < 0.05$) from those of ALM− plants grown under the same conditions of nitrogen availability. When both ALM+ and ALM− plants were relegated to an 0-20-20 fertilization regimen, ALM+ plants not only possessed significantly greater amounts of dry matter than ALM− plants in the root ($P > 0.05$), stem ($P > 0.05$) and foliar ($P > 0.05$) portions but also produced fruit. As can be seen in Figure 6 comparable ALM− plants did not mature sufficiently to produce fruit. This same significant ($P > 0.05$) difference between ALM+ and ALM− plant dry weights and fruit production can also be noted in plants receiving no supplemental fertilization (Fig. 7).

Establishment of ALM in Rhizosphere Growth Substrates.—*Azospirillum lipoferum* was established in, and isolated from, the rhizosphere growth substrate of all ALM+ pepper plants at each sampling time. Furthermore *A. lipoferum* was not isolated from ALM-rhizosphere growth substrates of any sets of ALM− grown plants.

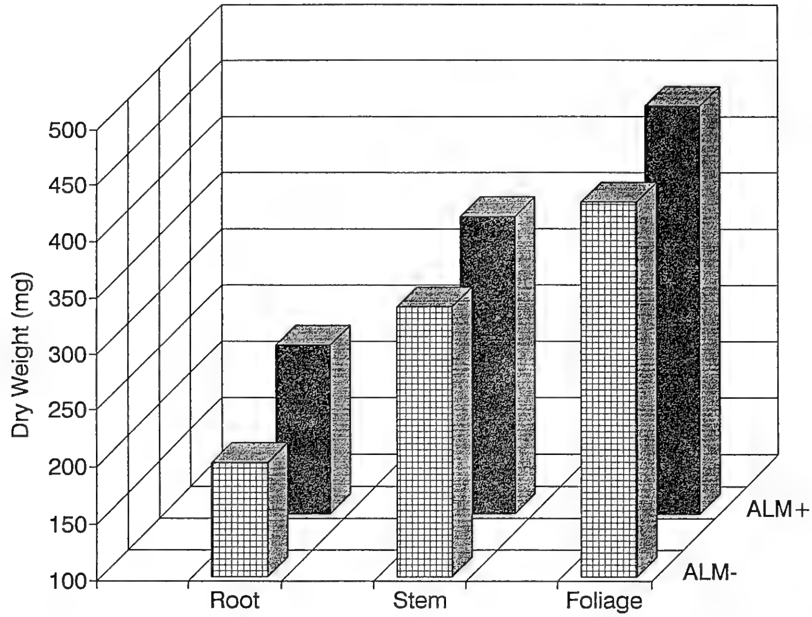


FIG. 2. Mean average root, stem and foliage dry weights of ALM+ and ALM− bell pepper (*Capsicum annum*) plants at the first-bloom stage of growth with 10-10-10 fertilization.

DISCUSSION

Beneficial results on crop production due to inoculation of plant seeds with *Azospirillum* have been noted over the last 2 decades. However, the predominant mechanism through which the bacteria benefit the plant has yet to be elucidated. The 2 primary hypotheses proposed by researchers to account for the ben-

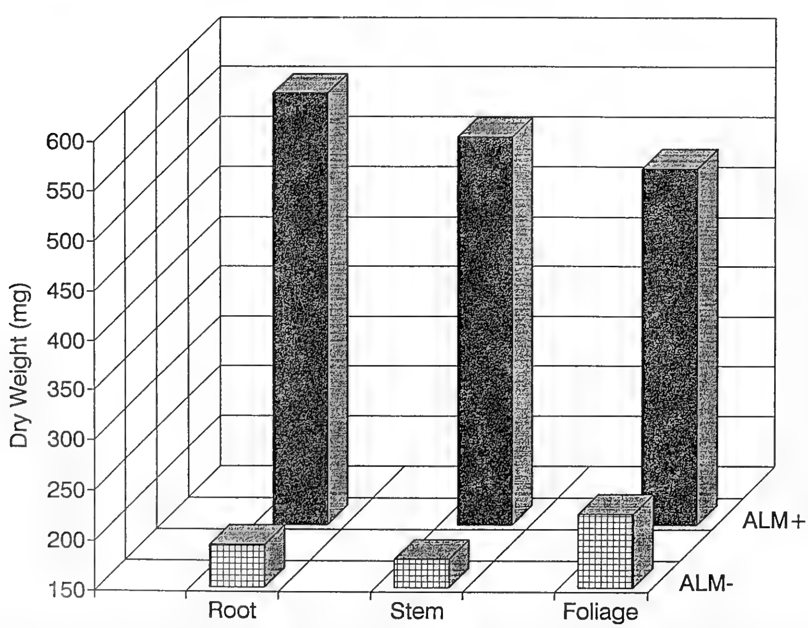


FIG. 3. Mean average root, stem and foliage dry weights of ALM+ and ALM− bell pepper (*Capsicum annum*) plants at the first-bloom stage of growth with 0-20-20 fertilization.

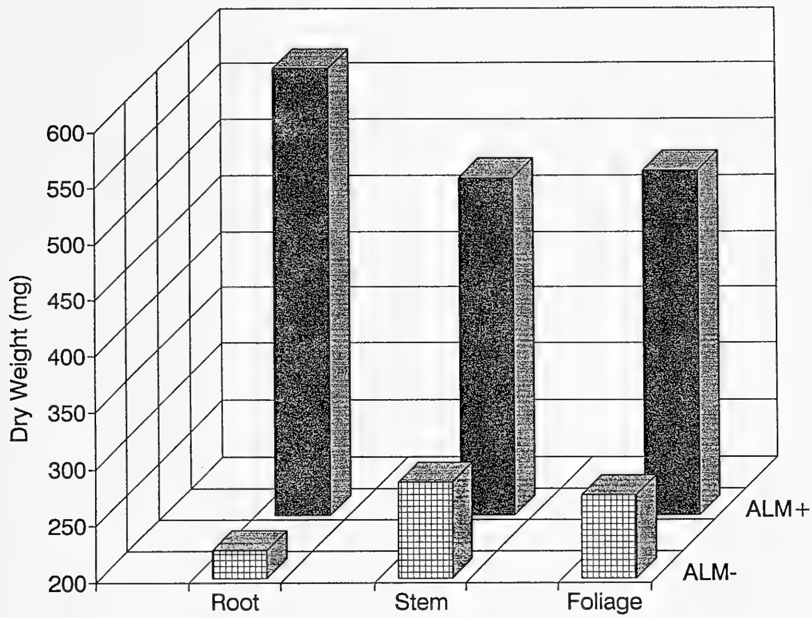


FIG. 4. Mean average root, stem and foliage dry weights of ALM+ and ALM− bell pepper (*Capsicum annum*) plants at the first-bloom stage of growth with no fertilizer added.

eficial effects on plant growth have been (1) the *Azospirillum* providing nitrogen to the plant via it's nitrogen-fixing capabilities and (2) the *Azospirillum* producing plant growth hormones which stimulate plant development (7).

Many investigators have shown that nitrogen is frequently a critical limiting nutrient in

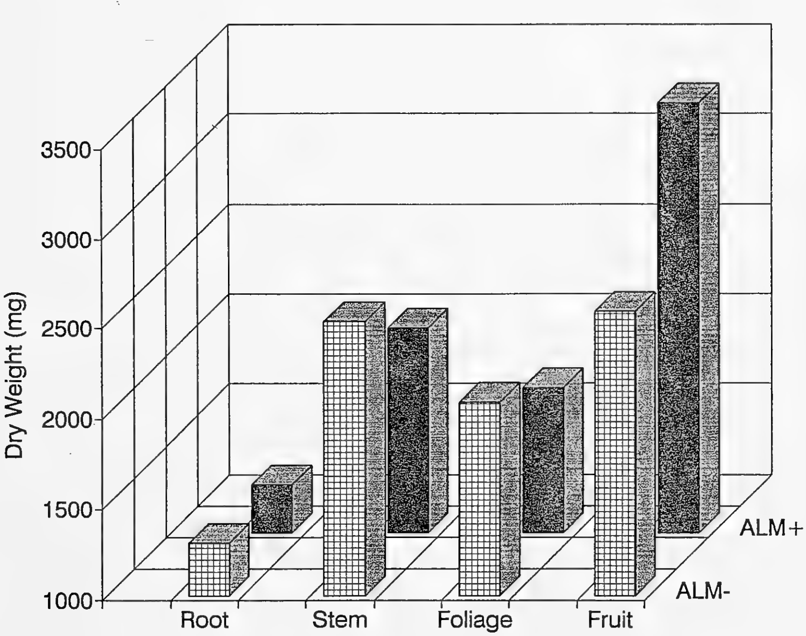


FIG. 5. Mean average root, stem, foliar and fruit dry weights of ALM+ and ALM− bell pepper (*Capsicum annum*) plants at the first-fruiting stage of growth with 10-10-10 fertilization.

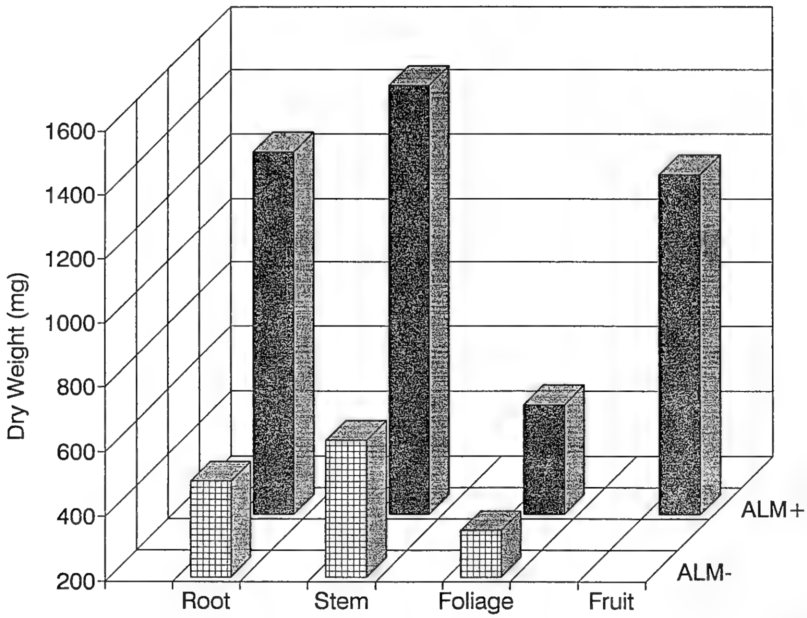


FIG. 6. Mean average root, stem, foliage and fruit dry weights of ALM+ and ALM− bell pepper (*Capsicum annum*) plants at the first-fruiting stage of growth with 0-20-20 fertilization.

soil for plant growth (17). *Azospirillum lipoferum* (ALM) has been implicated as a bacterium with the potential to asymbiotically fix nitrogen in greater amounts than *Azotobacter paspali* or other *Azospirillum* isolates cited in the literature, and should nitrogen be depleted from growth substrate through plant or microbial use *Azospirillum* may sometimes have an advantage for survival by fixing atmospheric nitrogen in sufficient excess that it may also be used for growth by the plants (4). Introduction of *Azospirillum* into plant rhizospheres will often cause an increase in dry-matter production of the plant with no detectable increase in nitrogen concentration in the plant tissues. This indicates possible influences of bacterially produced growth hormones on plant development (18, 19). However in other plants such as *Setaria italica* (20), wheat (21), sorghum (22), and maize (23) the per cent nitrogen content of the plant tissues did not increase indicating possible effects on plant growth due to bacterially assimilated nitrogen (17). Thus, the increased amounts of dry matter in all ALM+ plant portions sampled in this study are in agreement with previously reported data indicating that increased nitrogen availability increases dry-matter accumulation in both vegetative and generative portions of certain *Solanaceae* (24, 25, 26).

In this study, sufficient nitrogen was available for all plants receiving supplemental 10-10-10 fertilization to reach maturity and produce fruit. However, although the ALM+ plants grown with supplemental 10-10-10 fertilization produced fruit with significantly ($P > 0.05$) greater amounts of dry matter than ALM− plants grown under the same conditions of nitrogen availability, the total dry weights of these plants did not differ significantly ($P < 0.05$). This partitioning of a greater amount of plant dry matter into fruit is in agreement with results obtained with pepper plants grown under different levels of nitrogen availability (26). In contrast to the nitrogen-fertilized plants above, the ALM− plants in this study receiving no supplemental nitrogen fertilization (either the 0-20-20 fertilization regimen or no added fertilizer) had only approximately 0.08 g of total nitrogen (organic and inorganic) available per plant since this amount was in the growth substrate for use throughout the 22-week study period. ALM+ plants grown without added nitrogen or with 0-20-20 fertilization also had 0.08 g of nitrogen per plant present in the growth substrate plus

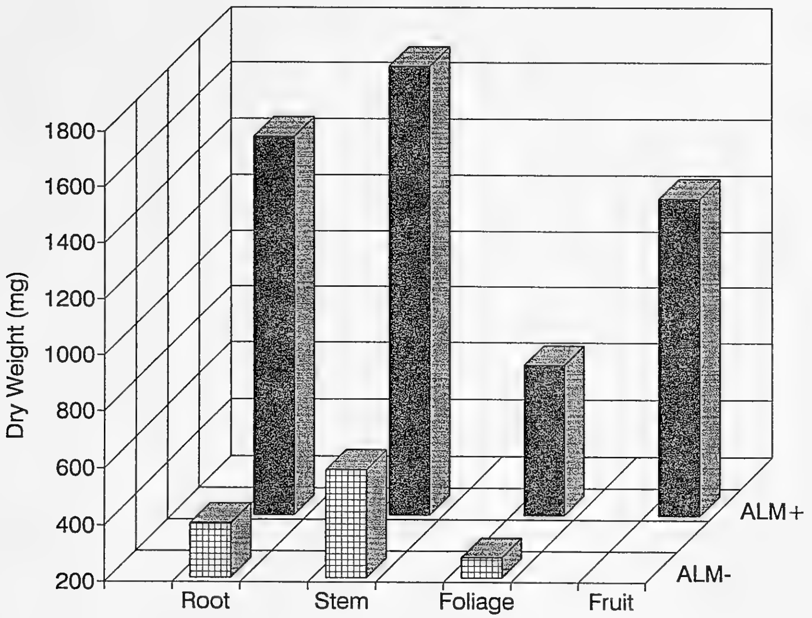


FIG. 7. Mean average root, stem, foliage and fruit dry weights of ALM+ and ALM− bell pepper (*Capsicum annum*) plants at the first-fruiting stage of growth with no fertilizer added.

the nitrogen contained in the added ALM cells. This raises a question whether the plants are utilizing nitrogen from dead bacterial cells or nitrogen fixed by live bacteria in the growth system to explain the continued growth of ALM+ supplemented pepper plants. *Azospirillum lipoferum* cells grown on nitrogen-free minimal salts medium contain 4–5% nitrogen by weight (27). The total calculated nitrogen input into ALM+ growth systems attributable to all ALM cells initially placed into the systems was 0.01 g per plant for a total of 0.09 g of available nitrogen for each plant to use for growth if all ALM cells died and their nitrogen was absorbed by the plants. Nitrogen may be expected to account for approximately 3.2% of the total dry weight of bell peppers and the 0.01 g of nitrogen input into the ALM+ systems via the ALM cells was by itself insufficient to account for the approximately 3-fold difference in ALM+ and ALM− plant weights. Although it has been suggested by Hartmann et al. (27) that *Azospirillum* produces plant growth hormones in association with plants this has not been directly demonstrated in situ in plant rhizospheres. In summary, although the nitrogen for enhanced plant growth may have come from bacterially (ALM) fixed nitrogen; these data do not preclude the possibility that ALM also may have produced growth modulating chemicals resulting in enhanced plant development.

ACKNOWLEDGMENTS

This study was supported by the Eastern Kentucky University Department of Biological Sciences. Also, great thanks go to Kim Worley of Somerset Community College for help in preparing the graphical representations.

LITERATURE CITED

1. Dobereiner, J. and J. M. Day. 1976. Associative symbiosis in tropical grasses: characterization of microorganisms and dinitrogen fixing sites. In Proceedings of the first international symposium on nitrogen fixation. Washington State University Press, Pullman.

2. Dobereiner, J., E. Mariel, and M. Nery. 1976. Ecological distribution of *Spirillum lipoferum*. Can. J. Microbiol. 22:1464–1473.

3. Li, C. Y. and M. A. Castellano. 1987. *Azospirillum* isolated from within sporocarps of the mycorrhizal fungi *Hebeloma crustuliniforme, Laccaria laccata* and *Rhizopogon vinicolor*. Trans. Br. Mycol. Soc. 88:563–565.

4. Mardon, D. W. and F. M. Rothwell. 1985. An *Azospirillum* isolate with high nitrogen-fixing capabilities from a coal surface mined site. Trans. KY Acad. Sci. 46:33–35.

5. Nelson, L. M. and R. Knowles. 1978. Effect of oxygen and nitrate on nitrogen fixation and denitrification

by *Azospirillum brasilense* grown in continuous culture. Can. J. Microbiol. 24:1395–1403.

6. Neyra, C. A. and P. VanBerkum. 1977. Nitrate reduction and nitrogenous activity in *Spirillum lipoferum*. Can. J. Microbiol. 23:306–310.

7. Barbieri, P., T. Zanelli, E. Galli, and G. Zanetti. 1986. Wheat inoculation with *Azospirillum brasilense* SP6 and some mutants altered in nitrogen fixation and indole-3-acetic acid production. FEMS Microbiol. Lett. 36:87–90.

8. Okon, Y. 1985. *Azospirillum* as a potential inoculant for agriculture. Trends in Biotechnol. 3:223–232.

9. Okon, Y., P. G. Heytler, and R. W. F. Hardy. 1983. N_2 fixation by *Azospirillum brasilense* and its incorporation into host *Setaria italica*. Appl. Environ. Microbiol. 46: 694–697.

10. Smith, R. L., S. C. Shank, K. H. Quesenberry, M. E. Tyler, J. R. Milan, M. H. Gaskins, and R. C. Littel. 1976. Nitrogen fixation in grasses inoculated with *Spirillum lipoferum*. Science 193:1003–1005.

11. Crossman, S. M. and W. A. Hill. 1987. Inoculation of sweet potato with *Azospirillum*. Hortscience 22:420–422.

12. Hadas. R., and Y. Okon. 1987. Effect of *Azospirillum brasilense* inoculation on root morphology and respiration in tomato seedlings. Biol. Fertil. Soils 5:241–247.

13. The United States Pharmacopeia. Unites States Pharmacopeial Convention, Inc., Rockville, Md.

14. Kreig, N. R. and J. Dobereiner. 1984. Genus *Azospirillum* Tarrand, Kreig, and Dobereiner 1979, 79[AL]. Pp. 94–104. In N. R. Kreig and J. G. Holt (ed.) Bergey's manual of systematic bacteriology, Vol. 4. The Williams and Wilkins Co., Baltimore.

15. Quantitative Chemical Analysis. Harris, D. C. 1987. W. H. Freeman and Co. New York.

16. Hanson, R. S. and J. A. Phillips. 1981. Chemical composition. Pp. 328–364. In P. Gerhardt, R. G. E. Murray, R. N. Costilow, E. W. Nester, W. A. Wood, N. R. Kreig, and G. B. Phillips (ed.) Manual of methods for general bacteriology, 1st ed. American Soc. Microbiol., Washington, D.C.

17. Gutshick, V. P. 1978. Energy and nitrogen fixation. Bioscience 28:571–575.

18. Jain, D. K. and D. G. Patriquin. 1985. Characterization of a substance produced by *Azospirillum* which causes branching of wheat root hairs. Can J. Microbiol. 31:206–210.

19. Rai, S. A. and A. C. Gaur. 1982. Nitrogen fixation by *Azospirillum* spp. and the effect of *Azospirillum lipoferum* on the yield and nitrogen uptake of wheat crops. Plant and Soil 69:233–238.

20. Kapulnik, Y., Y. Okon, J. Kigel, I. Nur, and Y. Henis. 1981. Effects of temperature, nitrogen-fertilization and plant-age on nitrogen fixation by *Setaria italica* inoculated with *Azospirillum brasilense*. Plant Physiol. 68:340–343.

21. Baldani, V. L. D., J. I. Baldani, and J. Dobereiner. 1983. Effects of *Azospirillum* inoculation on root infection and nitrogen incorporation in wheat. Can. J. Microbiol. 29:924–929.

22. Kapulnik, Y., J. Kigel, Y. Okon, I. Nur, and Y. Henis. 1981. Effects of *Azospirillum* inoculation on some growth parameters and N-content of wheat, sorghum and panicum. Plant and Soil 61:65–70.

23. Hegazi, N. A., M. Monib, H. A. Amer, and E. S. Shokr. 1983. Response of maize plants to inoculation with *Azospirillum* and (or) straw amendment in Egypt. Can J. Microbiol. 29:888–894.

24. Dolan, D. D. and E. P. Christopher. 1949. Effect of modified fertilizer ration on yield of vegetables. Proc. Amer. Soc. Hort. Sci. 53:402–406.

25. Hedge, D. M. 1987. Effect of soil moisture and N fertilization on growth, yield, N uptake and water use of bell pepper (*Capsicum annum* L.). Gartenbauwissenschaft 52:180–185.

26. Hedge, D. M. 1987. Growth analysis of bell pepper (*Capsicum annum* L.) in relation to soil moisture and nitrogen fertilization. Sci. Hort. 33:179–187.

27. Hartmann, A., M. Singh, and W. Klingmuller. 1983. Isolation and characterization of *Azospirillum* mutants excreting high amounts of indoleacetic acid. Can. J. Microbiol. 29:915–923.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 109–112

Mulch Color Effects on Reflected Light, Rhizosphere Temperature, and Pepper Yield

KARAN KAUL AND M. J. KASPERBAUER

CRS Plant and Soil Science Research, Kentucky State University,
Frankfort, Kentucky 40601 and
Coastal Plains Research Center, USDA-ARS, Florence, South Carolina 29502-3039

ABSTRACT

Peppers (*Capsicum annuum* L. cv. Lady Bell) were grown with white, blue, red and black plastic mulches in trickle-irrigated field plots. Data were collected on rhizosphere temperature, spectral balance of reflected light, and fruit yield. When plants were transplanted early (at the first "frost-free" date of spring), fruit yields were highest over red mulch even though rhizosphere temperatures did not differ under red, black, and blue mulches and were 24 ± 0.5°C. However, plants grown over red mulch received more reflected far-red light and higher far-red to red light ratios. When transplanting was delayed until about a month after the frost-free date, highest yields were obtained with white mulch which kept rhizosphere temperature near 25°C. Under red, blue, and black mulches, rhizosphere temperature was 28.5 to 29.3°C. It was concluded that yields of peppers grown with different colored mulches were influenced by both rhizosphere temperature and the relative amounts of far-red and red light reflected from the various mulches.

INTRODUCTION

Plastic mulches are used in a number of horticultural crops to suppress weeds, conserve soil moisture, and alter temperature in the rhizosphere. Traditionally, plastic mulches are black or white. Black plastic is often used to warm soil early in the season, and white plastic can moderate soil temperature in summer. Recent studies of the effects of soil and mulch colors revealed differences in plant growth in response to spectral balance of reflected visible [including red (R)] and near-visible [especially far-red (FR)] light (4, 8).

Experiments conducted under controlled environments have demonstrated that plants respond differently to different colors of light, such as R and FR (3). The ratio of FR photons relative to R photons controls the equilibrium of the phytochrome system (7), which regulates a number of developmental responses, such as stem elongation, leaf shape, shoot/root biomass ratios and partitioning of photosynthate among shoots, roots and fruits (6). The responses of plants to FR/R ratio are independent of the source of altered light [i.e., colored light bulbs or colored filters below the bulbs (3), sunlight reflected from green plants (5) or upward reflection from different colored soils (4, 8)].

Use of colored plastic mulches offers the possibility of using basic principles of photomorphogenesis to enhance plant productivity in the field at a relatively low cost. In such a system, plants will grow in sunlight and mulches of the appropriate surface color will reflect light of predetermined spectral balance up to the plant where it will be absorbed by photoreceptors, such as phytochrome, and result in a desired plant response such as larger fruits or an altered shoot/root biomass ratio (1, 2, 5, 9). The present study was undertaken to investigate the effects of different surface colors of plastic mulches on spectrum of reflected light and yield of field-grown green pepper (*Capsicum annuum* L.). Possible influence of planting date on effects of mulch colors was also examined.

MATERIALS AND METHODS

Plant Material

Seedlings (cv. Lady Bell) were started and grown in 5-cm peat pots of potting soil (Ball No. 2 potting mixture,[1] Ball Seed Co., West Chicago, Illinois) in a polyethylene covered greenhouse for six weeks before transplanting to field plots. The day and night temperatures in the greenhouse were maintained at 27 ± 2½°C and 17 ± 2½°C, respectively.

[1] Mention of a trade name does not constitute a guarantee or warranty of the product by Kentucky State University, USDA/CSRS or USDA/ARS and does not imply approval to the exclusion of other products that may also be suitable.

Experimental Design

For each experiment, 6-week-old seedlings were transplanted to field plots on the Kentucky State University research farm near Frankfort. The soil was a Lowell silt loam (fine, mixed, mesic Typic Hapludalfs). The plots were plowed, and broadcast with 100 kg/Ha K_2O and 55 kg/Ha NH_4NO_3. Trickle irrigation tubes and plastic mulches were placed before transplanting. The plastic panels were 4.2 m wide so that the only light reflected up to the plants would be from the indicated surface color. For the early transplanting date, plants were transplanted during the second week of May (very soon after the danger of frost was over). The other set was transplanted during the second week of June (after the soil had warmed).

Four replicated 15 × 4.2 m blocks were prepared by placing trickle irrigation tubes 1.5 m apart throughout the length of each block before placing the mulch. Within each block, four 3 × 4.2 m plots were covered with 4 mil black plastic mulch, and a 3 × 4.2 m plot was left uncovered (i.e., bare soil). One of the mulched plots remained black (unpainted) while others were painted with oil-based exterior paint to get white, blue, and red mulch surfaces. The colors were randomized within each block. Ten-cm diameter holes were cut in the plastic mulch at 45 cm intervals in rows that were 1.5 m apart. Peat pots containing the transplants were hand set in these openings, and were similarly spaced on the bare soil plots. Fifteen plants (i.e., 5 plants in each of 3 rows) were grown in each 3 × 4.2 m plot. All plots were irrigated as needed, and bare soil plots were weeded and cultivated as necessary.

Data Collection and Analysis

There were 6 harvests per plot at 10-day intervals. Peppers were harvested when they were at marketable size. All mulch color treatments within an experiment were harvested on the same dates. The fruits were classified according to U.S. grade standards and grouped as "U.S. Fancy," "U.S. No. 1," or "other." Weights in each class and the totals per plot were recorded. Data are presented as mean weight per hectare (under the experimental conditions described there would be approximately 14,500 plants per hectare). Yield data were analyzed by analysis of variance and mean separation was done by Duncan's procedure.

Rhizosphere temperatures were taken 15 cm away from the main stem 10 cm below the soil surface using an Orion SA 250 portable meter (Orion Research, Inc., Boston, MA) fitted with a stainless steel temperature probe. Temperature readings were taken in the middle of each plot at 10:00 a.m. ± 1 hr at least once per week for the first 3 weeks after transplanting. This period was selected because plant shading of the soil surface was not a major factor, as it was later.

Reflected light from each mulch color was determined at solar noon ±30 min on a cloudless day, using a LI-COR 1800 spectroradiometer (LI-COR, Lincoln, Nebraska) with a remote light collector on a 1.5-m fiber optic probe. Upwardly reflected light was measured at a point 10 cm above the mulch surface in order to measure relative spectral differences received by plants growing over the various colors. Measurements were taken at 5-nm intervals from 400 to 800 nm. The reflected light was expressed as a percentage of incoming sunlight at each measured wavelength. Far-red/red light ratios in reflected light were calculated.

RESULTS AND DISCUSSION

The yields from plants grown on bare soil were lower than those from plants grown on any of the plastic mulches, regardless of the transplant date.

When transplanting was done soon after the first frost-free date of spring (the second week of May), the highest early harvest yield as well as the highest total harvest yield were obtained from the plants grown on red plastic mulch (Table 1). The lowest yields, among the plants grown on mulched plots, were obtained from plants growing on white mulch (Table 1). The yields from plants grown on blue and black plastic mulch were intermediate between those on red and white mulch (Table 1). However, when transplanting was done after the soil had warmed (the second week of June), the highest early as well as total yield were obtained on white mulch (Table 2).

The differences in yield responses to mulch color between the early and late transplanting dates suggest that early season soil warming under dark colors (Table 3) may have favored higher yields; whereas, excessive soil warming under the dark colors later in the season may

TABLE 1. Effects of colored plastic mulches on yield of May-transplanted peppers. Yields are expressed as metric tons per hectare. Early harvest included the fruits picked during the first three weeks of harvest. Within each column, entries followed by the same letter do not differ significantly at the 5% level.

Mulch color	Early harvest: U.S. Fancy + U.S. No. 1	Early harvest: Total	Total harvest: U.S. Fancy + U.S. No. 1	Total harvest: Total
White	3.19c	7.83d	12.62bc	23.78b
Blue	5.08bc	10.88bcd	11.31bcd	24.36b
Red	10.73a	15.08a	23.20a	36.98a
Black	7.25ab	12.47abc	16.82ab	30.02ab
Bare soil	1.45c	4.35e	7.25cd	14.21c

TABLE 3. Effect of mulch color on rhizosphere temperatures for about three weeks after the early and late transplanting dates. The temperature readings were taken 10 cm below the soil level. Within each column, entries followed by the same letter do not differ significantly at the 5% level.

Mulch color	May 19 to June 3 (mean of 7 readings)	June 13 to July 8 (mean of 5 readings)
White	20.2ab	24.8a
Blue	23.5bc	28.5ab
Red	24.0c	28.5ab
Black	24.3c	29.3b
Bare soil	23.9c	27.2ab

have contributed to higher yields under lighter colored mulches (i.e., white versus red, black or blue).

Although comparison of yields from the two transplanting dates (Tables 1 and 2) suggests influence of soil temperature, it must be noted that recent studies (4, 8) demonstrated significant differences in shoot and root growth when plants were grown over different soil colors, even when insulation panels kept soil temperatures constant below the various surface colors. Those authors concluded that the FR/R ratio in the upwardly reflected light over the various soil surface colors acted through the phytochrome system and played a major role in plant development, especially in the relative amount of photosynthate partitioned to various parts of the plant.

In the present study, highest early season yields from the May transplants were obtained from plants grown over the red mulch (Table 1). This is consistent with the observations of Decoteau et al. (2), who obtained higher tomato (*Lycopersicon esculentum* Mill.) yields over red than over white or black plastic mulch. At least part of the difference in pepper yield in the present study appears to be related to the differences in FR/R ratios received by the plants. In previous investigations, modifications in plant growth patterns by very subtle changes in FR/R ratios have been documented in controlled environments (7) and in the field (1, 5, 9). Nevertheless, it is apparent from our results (Tables 1, 2 and 4) that change in FR/R ratio is not the only factor determining photosynthate partitioning and yield. Likewise, the highest amount of photosynthetically active light (Table 4) did not always result in the highest yields (Table 1). Also, higher soil temperature in early season (Table 3) did not always result in higher early yields. For example, although rhizosphere temperatures were not significantly different under red, black and blue mulches (Table 3), early yield on blue mulch was significantly lower than that on red mulch (Table 1). Thus, under field conditions, green pepper yield appeared to be influenced by a

TABLE 2. Effect of colored plastic mulches on yield of June-transplanted peppers. Yields are expressed as metric tons per hectare. Early harvest included the fruits picked during the first three weeks of harvest. Within each column, entries followed by the same letter do not differ significantly at the 5% level.

Mulch color	Early harvest: U.S. Fancy + U.S. No. 1	Early harvest: Total	Total harvest: U.S. Fancy + U.S. No. 1	Total harvest: Total
White	21.03a	22.77a	29.58a	35.82a
Blue	12.04b	14.94b	16.39b	23.49b
Red	11.46b	14.36b	17.26b	25.23b
Black	11.31b	14.36b	14.50b	21.03b
Bare soil	4.06c	7.40c	6.53c	13.20c

TABLE 4. Effect of mulch color on upwardly reflected light (10 cm above the surface). Data were collected at solar noon ± 30 min on a cloudless day. Data are means of duplicate readings. The FR/R ratio in sunlight was arbitrarily assigned a value of 1.00. Other ratios are relative to that in sunlight.

Mulch color	Reflected light, 10 cm above surface: Photosynthetic (400–700 nm) (as % of sunlight)	Reflected light, 10 cm above surface: FR/R ratio (relative to sunlight)
White	42	1.00
Blue	8	1.05
Red	13	1.12
Black	6	1.03

combination of rhizosphere temperature, photosynthetically active light and spectral properties of reflected light, all of which are affected by mulch color. Based on the results presented, we conclude that appropriately colored mulches can improve pepper productivity under field conditions. But the appropriate color will vary depending upon the planting conditions.

ACKNOWLEDGMENTS

This research was funded in part by Specific Cooperative Agreement No. 58-43YK-8-0036 between Kentucky State University and USDA, Agricultural Research Service and USDA/CSRS research grant KYX-900-3373. We thank J. Lamb, W. Sanders, M. Stone and L. Winkle for technical assistance and S. Templeton and E. Greer for help with the statistical analysis. Administrative support of Drs. H. R. Benson, P. G. Hunt and R. J. Barney is gratefully acknowledged.

LITERATURE CITED

1. Bradburne, J. A., M. J. Kasperbauer, and J. N. Mathis. 1989. Reflected far-red light effects on chlorophyll and light-harvesting chlorophyll protein (LHC-II) contents under field conditions. Plant Physiol. 91:800–803.

2. Decoteau, D. R., M. J. Kasperbauer, and P. G. Hunt. 1989. Mulch surface color affects yield of fresh market tomatoes. J. Amer. Soc. Hort. Sci. 114:216–219.

3. Downs, R. J., S. B. Hendricks, and H. A. Borthwick. 1957. Photoreversible control of elongation of pinto beans & other plants. Bot. Gaz. 188:199–208.

4. Hunt, P. G., M. J. Kasperbauer, and T. A. Matheny. 1989. Soybean seedling growth responses to light reflected from different colored soil surfaces. Crop Sci. 29:30–33.

5. Kasperbauer, M. J. 1987. Far-red light reflection from green leaves and effects on phytochrome-mediated assimilate partitioning under field conditions. Plant Physiol. 85:350–354.

6. Kasperbauer, M. J. 1988. Phytochrome involvement in regulation of the photosynthetic apparatus and plant adaptation. Plant Physiol. Biochem. 26:519–524.

7. Kasperbauer, M. J., H. A. Borthwick, and S. B. Hendricks. 1964. Reversion of phytochrome 730 (Pfr) to P660 (Pr) in *Chenopodium rubrum* L. Bot. Gaz. 125:75–80.

8. Kasperbauer, M. J. and P. G. Hunt. 1987. Soil color and surface residue effects on seedling light environment. Plant and Soil 97:295–298.

9. Kaul, K. and M. J. Kasperbauer. 1988. Row orientation effects on FR/R light ratio, growth and development of field-grown bush bean. Physiol. Plant. 74:415–417.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 113–120

Knowledge and Attitudes of High School Students Toward Medical Technology and Nursing

DONNA S. BLACKBURN, MSN, RN AND LARRY P. ELLIOTT, PHD

Department of Nursing and Department of Biology, Western Kentucky University, Bowling Green, Kentucky

ABSTRACT

The attitudes and knowledge of 810 Kentucky high school students toward medical technology and nursing were examined to determine why students are not entering these fields. Data collection revealed significant misconceptions and knowledge deficit about these professions. This research focuses on identification of factors influencing attraction to, rather than attrition from, these health-care fields.

INTRODUCTION

There currently exists a shortage of health care professionals in the United States, especially in the fields of nursing and medical technology (1). Several theses have been advanced in an attempt to explain why this shortage exists: lack of economic and personal incentives to become a medical technologist have made the profession less competitive with other fields that offer greater rewards, such as higher salaries, salary issues, such as bonuses and perks, and more job recognition (2).

A 1990 study conducted by the Institute of Medicine (IM), Washington, D.C., found the demand for nurses far exceeded the supply (3). Identified as the central issues influencing the nursing shortage were: AIDS; an increasing geriatric population; and advances in medical technology. Another study on "the status of health personnel" was submitted to Congress and the President in the summer of 1990 by the Department of Health and Human Services (HHS). This report projects a decline in the RN population in the U.S. after the year 2000 and predicts that the nursing shortage could top 800,000 by 2020, swelling to 875,000 over the next 30 years (4). Though comprehensive, these studies, like others, only underscore what practitioners already know—there exists a critical shortage of nursing professionals.

An important factor which appears to influence today's students when selecting a career is salary. Snyder and Bonke (5) found that freshman medical technology majors placed a high priority on earning potential when selecting a career. Salaries were addressed by Castleberry et al. (6), who conducted a national survey of wages for 9 positions that typically exist in medical laboratories and found variations ranging from $19,822 to $27,040 per year. Differences in salaries were found to vary with the site, size and location of the laboratory. Hospital-based laboratories have higher salaries and shift differentials than private laboratories. They found salaries to be directly proportional with hospital size, with hospitals of less than 100 beds paying the lowest salaries. Salaries were highest in the far west and northeast regions and lowest in the central regions. In a follow-up study (6), they found a 9.3% vacancy rate for staff medical technologists. The most common action taken to fill these vacancies was to increase salaries.

The editors of *Nursing 88* published a report of 8,023 nurses who responded to a poll addressing the nursing shortage and how it is affecting nurses today (7). In evaluating their present jobs, nurses cited salaries, benefits and a minimum of every other weekend off important to them.

Stress and overtime have been identified as factors adversely influencing health care workers. Starzynski (8) found that the number of extra hours worked was part of the reason why medical technologists leave the hospital laboratory. Although stress has been reported as a problem in this field by Martin and Reyes (9), they stated that good laboratory management instead of crisis management could reduce stress.

Little opportunity for advancement and the fear of AIDS have been cited as other factors for creating the current shortage in medical technology. However Castleberry et al. (6)

reported that advancement for an entry-level staff medical technologist to supervisor will provide an increase in salary of $12,481, representing a 63% raise. Working in a high-risk environment, with the possibility of infection by such microbes as the AIDS virus, has been reported by Mass (2) as a negative factor deterring potential students from these health care professions.

According to Farrell (10), demographers reported a decline in the number of 18- to 24-year-olds seeking college education. Indicators suggested that the intellectually capable students are pursuing other professions such as business, medicine, pharmacy, and computer science. These professions offer greater financial rewards, better working conditions, and a more attractive lifestyle than most nursing positions (10).

As a result of a telephone survey of high school guidance counselors in Massachusetts, the authors agreed that guidance counselors were a vital link to the recruitment of students into nursing. Guidance counselors could become excellent channels for marketing nursing to students at crucial points in their vocational development (11).

Notwithstanding these types of studies, research must now be focused on examining the factors influencing attraction to, rather than attrition from, the profession. Research, centered on young adults contemplating entry into the health care professions, would provide baseline information for attracting and keeping students. Measurements of knowledge about and attitudes toward the profession would certainly help practitioners identify misconceptions, attitudes, and concerns of individuals considering nursing and medical technology as professions. Research of this type would equip the profession with the vehicle necessary to combat the significant shortages now being experienced. Only through data analysis will researchers be able to determine why students are not entering these fields. Knowledge of this information will help contribute to solving the shortage of health care professionals, a shortage which threatens our nation's well-being.

The purpose of this study was to examine the attitudes and knowledge of high school biology students toward the medical technology and nursing professions. Items pertaining to health care, nursing and medical technology careers, and student demographics were included. Demographic information was used to help identify characteristics of students expressing interest in health care professions.

MATERIALS AND METHODS

A survey questionnaire was designed by the authors and submitted for review by a panel of experts within the nursing and medical technology departments at Western Kentucky University. Items on the questionnaire were selected based on data found in the review of the literature. A five-point Likert scale was selected for use with the items relating to nursing and medical technology. After this review process, revisions were made and a final copy developed and subjected to final review. The survey instrument focused on 4 major areas: (1) student demographics; (2) questions related to health care; (3) knowledge about health care professions; (4) attitudes toward health care professions.

Based upon an established working relationship with high school biology teachers across the state, and the fact that Kentucky law requires all high school students to complete one unit of biology, high school biology students were identified as the target group for this study. Questionnaires were distributed and returned through randomly selected biology classes across the Commonwealth of Kentucky in the Fall of 1989.

Initially, all of Kentucky's 178 school superintendents were contacted and asked to select a high school to participate in this study. Only 52 superintendents (29%) responded and agreed to participate. A letter was then sent to the principals of the selected high schools asking them to administer the student questionnaire to a random group of 20 biology students during the fall semester. Only 20 questionnaires were sent to each school to prevent large school districts from biasing the data.

A postage-paid envelope was included in the mailing for return of the completed questionnaires. At the beginning of the 1990 spring semester, a follow-up letter was sent to those schools that had not returned questionnaires. A total of 810 questionnaires, representing 43 high schools, were ultimately returned. All data were processed and analyzed using the Statistical Analysis System (SAS) computer software at Western Kentucky University.

FIG. 1. Kentucky state board and judicial districts.

RESULTS

Data collected in this study spanned 6 of Kentucky's 7 state board and judicial districts (Fig. 1). Though most schools surveyed were classified as rural, 5 schools were classified as urban due to the fact that each was located in a city with a population of 50,000 or more and/or was located within close proximity to a large metropolitan area.

District I, located in the extreme western part of the state, had 6 high schools participating, representing 14% of the total respondents. District II had 9 schools participating, representing 18% of the student responses. District III was represented by 6 schools (13.8% of the respondents). District V has 7 schools participating in this study, representing 14% of the responses. The largest number of schools (N = 10) from one district was from District VI, representing 21.2% of the responses. District VII with 5 schools participating, accounted for 18.8% of the responses (see Table 1).

The final return of 810 completed questionnaires from 43 high schools represented a 77.5% return rate. More than half of those responding were female (57.7%), and most respondents were Caucasian (85.1%).

When asked about grade-point average (GPA), about half (49.6%) reported making A's and B's, about one-third (33.5%) made B's and C's, while the remaining students reported making C's or less. GPA's in science courses were reported as slightly lower: 44.1% indicated making A's and B's, 40% made B's and C's, and the remaining students made less than C's.

In terms of career choices, about one-fourth of the respondents (25.4%) indicated they were considering a career in the health-care field when they graduated; 27% indicated they were undecided about a career choice. Of those students contemplating a health care profession, 15% reported they would consider medical technology and 30.5% would consider nursing. More than half (54.5%) indicated they were interested in other health-care fields.

Only 28.2% of the students had immediate family members employed in the health-care field and these students were not more knowledgeable about health careers than students who do not have family members in this field. Nearly all students (94.6%) said their parents would support a decision to pursue a career in the health-care field. The single most important factor which would influence them to enter the fields of medical technology or nursing was salary (56.5%), with the remaining factors listed in order of importance: opportunity for advancement (16.1%), job security (13.7%), flexible hours (7.3%) and status (6.5%). Nearly half (45.5%) of the students stated they would like more information about a career in medical technology and nursing.

Each high school was contacted to see if the curriculum offered a health careers course. Nearly two-thirds (62.8%) of the schools offered this course. Nearly half (48.8%) of these health careers courses were offered though a

TABLE 1. Demographic data by district.

Demographic	District 1 N	1 %	2 N	2 %	3 N	3 %	5 N	5 %	6 N	6 %	7 N	7 %	Totals
Sex													
Female	56	49.1	84	57.5	63	56.3	66	57.9	94	54.7	62	40.8	425
Male	38	33.3	59	40.4	47	42.0	45	39.5	68	39.5	55	36.2	312
No response	20	17.6	3	2.1	2	1.7	3	2.6	10	5.8	35	23.0	73
Totals	114		146		112		114		172		152		810
Ethnic origin													
Afro-American	10	9.0	8	5.5	4	3.6	7	6.6	1	0.6	7	4.7	37
Caucasian	80	72.1	129	89.0	101	91.0	84	79.2	150	88.0	133	89.8	677
Oriental	4	3.6	3	2.0	2	1.8	5	4.7	4	2.3	2	1.4	20
Spanish American	7	6.3	1	0.8	1	0.9	1	1.0	5	2.8	0	0	15
American Indian	10	9.0	4	2.7	3	2.7	9	8.5	11	6.3	6	4.1	43
Totals	111		145		111		106		171		148		792
Overall grades													
A's and B's	55	48.7	70	48.6	59	53.2	52	46.9	78	46.7	80	53.3	394
B's and C's	31	27.4	54	37.5	38	34.2	36	32.4	62	37.1	46	30.7	267
Mostly C's	18	15.9	11	7.6	8	7.2	10	9.0	7	4.2	12	8.0	66
C's and D's	9	8.0	8	5.6	3	2.7	10	9.0	14	8.4	8	5.3	52
D's and F's	0	0	1	0.7	3	2.7	3	2.7	6	3.6	4	2.7	17
Totals	113		144		111		111		167		150		796
Science grades													
A's and B's	41	36.6	57	39.3	53	47.3	47	41.9	79	47.3	76	51.0	353
B's and C's	31	27.6	41	28.3	33	29.4	34	30.4	42	25.1	36	24.2	217
Mostly C's	18	16.1	25	17.2	16	14.3	16	14.3	8	4.8	17	11.4	100
C's and D's	18	16.1	17	11.7	4	3.6	10	8.9	19	11.4	11	7.4	79
D's and F's	4	3.6	5	3.5	6	5.4	5	4.5	19	11.4	9	6.0	48
Totals	112		145		112		112		167		149		797
Are you considering a career in a health-care field?													
Yes	28	25.0	39	26.9	33	30.0	21	19.3	35	21.1	46	30.9	202
No	57	50.9	54	37.2	50	45.5	66	60.5	89	53.6	59	39.6	375
Undecided	27	24.1	52	35.9	27	24.5	22	20.2	42	25.3	44	29.5	214
Totals	112		145		110		109		166		149		791
Of those students considering a health career, these professions were selected:													
Medical Tech.	8	11.4	14	14.1	12	15.0	11	18.0	26	22.6	15	15.2	86
Nursing	12	17.2	25	25.3	11	13.7	13	21.3	17	14.8	9	9.0	87
Other	50	71.4	60	60.6	57	71.3	37	60.7	72	62.6	75	75.8	351
Totals	70		99		80		61		115		99		524
Are any members of student's immediate family employed in the health-care field?													
Yes	26	23.4	43	30.1	28	25.5	30	27.0	54	32.9	43	30.0	224
No	85	76.6	100	69.9	82	74.5	81	73.0	110	67.1	101	70.0	559
Totals	111		143		110		111		164		144		783
Would parents support or discourage a decision to pursue a career in health care?													
Support	106	93.8	138	94.5	105	94.6	108	96.4	158	93.5	143	96.0	758
Discourage	7	6.2	8	5.5	6	5.4	4	3.6	11	6.5	6	4.0	42
Totals	113		146		111		112		169		149		800

TABLE 1. Continued.

	District												
	1		2		3		5		6		7		
Demographic	N	%	N	%	N	%	N	%	N	%	N	%	Totals
Factors which might influence students to choose medical technology or nursing:													
Salary	62	56.9	75	51.7	60	55.0	63	57.2	98	60.1	88	58.3	446
Advancement	19	17.4	25	17.3	15	13.8	21	19.1	26	16.0	22	14.6	128
Flexible hours	7	6.4	11	7.6	6	5.5	7	6.4	14	8.6	10	6.6	55
Job security	17	15.6	26	17.9	19	17.4	6	5.5	18	11.0	21	13.9	107
Status	4	3.7	8	5.5	9	8.3	13	11.8	7	4.3	10	6.6	51
Totals	109		145		109		110		163		151		787
Would you like more information about a career in medical technology or nursing?													
Yes	51	45.5	78	54.5	52	48.6	49	44.5	65	39.9	64	43.5	359
No	61	54.5	65	45.5	55	51.4	61	55.5	98	60.1	83	56.5	423
Totals	112		143		107		110		163		147		782

Totals vary due to no response to some items.

vocational school which was not always located in close proximity. The enrollment ranged from 5 to 15 students with a mean in the single digits.

Students were asked to rate their level of knowledge about and attitudes toward a career in medical technology. The frequency count and percentage for each response are presented in Table 2.

Over half (56%) were unsure of the starting salary for a medical technologist. Only half (50%) of the students felt that a medical technologist has much status. Nearly half (48%) of the respondents were unsure whether or not medical technologists work too many hours. A small percentage (11%) of the students thought that this profession is not very stressful.

Over half (59%) of all respondents thought there are many opportunities for advancement in medical technology. About one-third (37%) of the students agreed with the statement that "there is too much risk of infection, e.g. AIDS." One-third (35%) of the respondents were unsure of the required training for a medical technologist.

Over two-thirds (69%) of the students had not been told they were too talented to enter the field of medical technology. Nearly two-thirds (62%) of the respondents knew which science courses are necessary for preparation to be a medical technologist. Over half (58%) knew that physicians diagnose patient illnesses based on the results of lab testing by the medical technologist. Nearly two-thirds (62%) of the students knew that medical technologists are not employed only in hospitals. Most students (84%) think this field gives one a chance to help others. Nearly three-fourths (73%) believe this career is for those who like the sciences and enjoy laboratory work.

Using chi square analyses, responses were compared between those students considering a career in medical technology and those who were not or undecided. It was statistically significant that those students considering medical technology knew that the medical technologist does not work only with blood products (χ^2 = 14.62, df = 4, $P \leq 0.006$); a medical technologist has much status (χ^2 = 14.99, df = 4, $P \leq 0.005$); a medical technologist works too many hours (χ^2 = 18.07, df = 4, $P \leq 0.001$); there are many opportunities for advancement (χ^2 = 10.41, df = 4, $P \leq 0.034$); the field does not require too much training (χ^2 = 37.11, df = 4, $P \leq 0.00$); a medical technologist uses principles from science courses when doing lab testing (χ^2 = 13.76, df = 4, $P \leq 0.008$); a medical technologist is not employed only in hospitals (χ^2 = 11.13, df = 4, $P \leq 0.025$); and a career in medical technology gives you a chance to help others (χ^2 = 18.56, df = 4, $P \leq 0.001$).

In addition to the demographic questions, students were asked to rate their level of knowledge about and attitudes toward a career in nursing. Table 3 reports the frequency count and percentage for each nursing item on the questionnaire.

When asked about a nurse's main responsibility, three-fourths (76%) were unsure or disagreed. Over half of the respondents (62%)

TABLE 2. Frequency count and percentage for each medical technology item.

	SA		A		U		D		SD	
	N	%	N	%	N	%	N	%	N	%
10. A med tech works only with blood products.	30	3	58	7	340	43	243	31	121	15
11. The starting salary is $20,000.	37	5	159	20	456	56	107	13	51	6
12. A med tech has much status.	91	11	309	39	303	38	77	9	24	3
13. A med tech works too many hours.	51	6	158	20	384	48	171	21	36	5
14. This profession is not very stressful.	21	3	63	8	228	28	290	36	206	25
15. There are many opportunities for advancement.	169	21	306	38	248	31	60	7	20	3
16. There is too much risk of infections, e.g., AIDS.	127	16	172	21	217	27	198	25	84	11
17. This field requires too much training.	76	10	165	21	282	35	219	27	60	7
18. You have been told "you are too talented to enter the field of medical technology."	55	7	49	6	146	18	240	30	311	39
19. A med tech uses principles from microbiology, biochemistry, immunology, genetics, and physiology when doing tests.	188	24	304	38	283	35	15	2	11	1
20. Physicians diagnose patient illnesses based on the results of lab testing by med tech.	122	15	350	43	284	35	35	5	16	2
21. Med techs are employed only in hospitals.	26	3	69	8	217	27	355	44	142	18
22. A career in medical technology gives you a chance to help others.	398	49	283	35	97	12	23	3	9	1
23. This career choice is for those who like the sciences and enjoy laboratory work.	243	30	350	43	134	17	64	8	18	2

Based on a five-point Likert-type scale, where 1 = strongly disagree (SD); 2 = disagree (D); 3 = undecided (U); 4 = agree (A); and 5 = strongly agree (SA). Totals vary due to no responses to some items.

were unsure or disagreed with this statement. asked about opportunity for advancement in a nursing career, over half of the students (52%) were unsure or disagree with this statement. Nearly two-thirds of the students (63%) were unsure or felt there is too much risk of infection when working in this field.

Continuing education for nurses in Kentucky is mandatory, but many of the respondents (65%) were unaware of this requirement. When asked if nurses use principles from science courses when giving patient care, about half of the students (49%) were unsure or disagreed.

Approximately two-thirds of the students (69%) disagreed with the statement that "nursing is a career primarily for women." The stereotype of a female nurse is apparently not as prevalent today. Over half (57%) consider nursing a highly respected profession which gives one a chance to help others (86%).

Using chi square analyses, responses were compared between those students considering a career in the health care field and those who were not or undecided. A larger percentage of students not considering a health career was unsure of a nurse's starting salary ($\chi^2 = 16.33$, df = 4, $P \leq 0.003$). These same students were much less aware that there are many opportunities for advancement in nursing ($\chi^2 = 36.33$, df = 4, $P \leq 0.00$); Those respondents not considering a health career were less knowledgeable about the science courses needed by the nurse when giving patient care ($\chi^2 = 15.89$; df = 4, $P \leq 0.003$). Those students not considering a health career thought that nursing "requires too much training," when in fact a student can complete an associate degree nursing program in two years ($\chi^2 = 45.73$, df = 4, $P \leq 0.00$).

DISCUSSION

From the data collection it appears that most students have a positive attitude toward nursing but have some knowledge deficit about the career itself. Those students not considering a health career, or who are undecided, have a significantly greater knowledge deficit about nursing than those who are considering a health career field. Through dissemination of knowledge, students will be better able to make an informed decision about their career choice. Students need information about educational preparation and professional opportunities that are available. Education of students is necessary so that they understand that good aseptic technique and the use of "universal precautions" will promote little or no chance of in-

TABLE 3. Frequency count and percentage for each nursing item.

	SA		A		U		D		SD	
	N	%	N	%	N	%	N	%	N	%
24. A nurse's main duty is giving medications.	40	5	155	19	158	20	321	40	132	16
25. This is a career primarily for women.	47	6	129	16	75	9	305	38	249	31
26. A nurse has too much responsibility.	41	5	137	17	245	31	319	40	56	7
27. A nurse has much status.	53	6	159	20	322	40	202	25	69	9
28. The starting salary for a nurse is $20,000.	30	4	112	14	499	62	121	15	42	5
29. There are many opportunities for advancement.	101	13	285	35	249	31	127	16	40	5
30. There is too much risk of infection, e.g., AIDS.	91	11	169	21	253	31	230	28	63	9
31. This field requires too much training.	54	7	116	14	234	29	339	42	66	8
32. You have been told "you are too talented to enter the field of nursing."	60	7	67	8	155	20	280	35	240	30
33. Continuing education is mandatory in Ky.	120	15	157	20	285	35	133	17	105	13
34. The nurse is a physician's helper.	135	17	447	56	128	16	71	9	21	2
35. Nursing is a highly respected profession.	151	19	299	38	169	21	139	18	36	4
36. A career in nursing gives you a chance to help others.	412	52	268	34	78	9	17	2	18	3
37. A nurse uses principles from anatomy, physiology, chemistry, and microbiology when giving patient care.	155	20	244	31	311	39	55	7	25	3

Based on a five-point Likert-type scale, where 1 = strongly disagree (SD); 2 = disagree (D); 3 = undecided (U); 4 = agree (A); and 5 = strongly agree (SA). Totals vary due to no responses to some items.

fection when working in these fields. Targeting the high school population is critical as we confront the national shortage of nurses and medical technologists.

Making health care professions desirable is very important. Since salaries are continuing to increase, this information should be shared with students considering a health career. Knowledge of monetary reward may provide an incentive for advancement. Competitive salaries as well as benefits need to be advertised so that students will be attracted to these rewarding professions. Other enticements include tuition reimbursement programs offered by many employers and flexible schedules such as the Baylor Plan which allows a nurse to work Monday through Friday only or work two 12-hour shifts each weekend with full pay and benefits.

The students surveyed appear to have some perception and knowledge of the field of medical technology. Since laboratories are having staffing shortages, it is imperative that medical technologists and guidance counselors thoroughly articulate the totality of the field to these students. Students need to be informed that the medical technologist is an integral part of the health care team and a critical link in the diagnosis and treatment of patients. This scientific discipline requires cognitive and technical skills and allows for professional flexibility into such fields as computing, health care administration, education, research, and consulting. The long-standing title "medical technologist" might be replaced by a more appealing title such as "clinical laboratory scientist or specialist."

The majority of health careers courses are taught in the vocational school. By offering this course at the high school, it would be more readily accessible to interested students.

In view of the decline in the number of 18- to 24-year-olds seeking college education, all science-based professions will compete for a dwindling number of students. If medical technologists, nurses and guidance counselors inform high school students about these interesting and challenging professions, students will have the knowledge about these health-care fields when choosing a career.

ACKNOWLEDGMENTS

This research was supported by a grant from the Faculty Research Committee of Western Kentucky University. Constructive input was given by Dr. Mary Hazzard and Dr. Valgene Dunham when we were developing our questionnaire. Last but not least we wish to acknowledge the capable assistance of Mr. Robert Cobb, Academic Computing and Research Services Project Consultant, who conducted the statistical analyses of our data.

LITERATURE CITED

1. Coleman, B. 1989. Worker shortage weakens U.S. health care system. AARP News Bulletin 30(3):4.

2. Mass, D. 1988. Medical technologists: a vanishing breed? Lab. Manag. 26:51–53.

3. Legislative Research Committee. 1989. Nursing shortage is called threat to nation's health. Kentucky Horizons 1:3.

4. Bergman, E. 1990. RN population seen declining after the year 2000. Amer. J. Nursing 90:97, 110.

5. Snyder, J. and B. Bonke. 1987. Preprofessional medical technology student career planning and counseling. Lab. Med. 18:781–785.

6. Castleberry, B., A. Kuby, and B. Bryant. 1989. Wages and vacancy survey of medical laboratory positions in 1988. Lab. Med. 20:226–332.

7. Editors of Nursing 88. 1988. Nursing shortage poll report. Nursing 88 18:33–41.

8. Starzynski, G. 1988. Staffing: problems and solutions in 19 New England laboratories. Med. Lab. Obs. 20: 51–54.

9. Martin, B. and E. Reyes. 1988. The low image of MTs as professionals: reasons and solutions. Med. Lab. Obs. 20:31–32.

10. Farrell, J. 1988. The changing pool of candidates for nursing. J. Prof. Nursing 4:145, 230.

11. King, P. and T. Sherman. 1990. Recruitment target: the guidance counselor connection. Nursing Manag. 21:38–9, 42, 44.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 121–126

Seasonal, Sexual, and Size Class Variation in the Diet of the Kentucky Darter, *Etheostoma rafinesquei* (Pisces: Percidae), in Middle Pitman Creek, Kentucky

GORDON K. WEDDLE

Department of Biology, Campbellsville College, Campbellsville, Kentucky 42718-2799

ABSTRACT

Food habits of *Etheostoma rafinesquei* were determined using monthly samples from Middle Pitman Creek, KY (Aug 1986–Jul 1987). A total of 9,637 food organisms was identified from 153 adults (>29.9 mm SL; 70 males, 83 females) and 15 juveniles (<30 mm SL). The predominant foods of adults and juveniles were larval midges (Diptera, Chironomidae; 91.8 and 80.2% of the total, respectively) and microcrustaceans (Cladocera, Copepoda, and Ostracoda; 4.2 and 16.0%). Seasonally important foods included dipteran pupae, aquatic mites (Hydracarina), and larval Trichoptera. Significantly more food items were consumed during autumn (Sep–Nov) and late spring (Apr–May) than in summer (Jul–Aug) and winter (Dec–Jan). Adult males and females consumed similar numbers of food items during all periods of the year except Feb-May, when females consumed statistically greater numbers of food items than males ($F = 6.132$, $P < 0.001$). This difference is interpreted as evidence that females compensate for reproductive energy losses by augmented feeding.

INTRODUCTION

The Kentucky darter, *Etheostoma rafinesquei* Burr and Page, 1982, is endemic to the lower Barren and upper Green river drainages in southcentral Kentucky where it is common in upland streams (1, 2, 3). Although this colorful fish was recognized as a distinct form long before its original description (3), little is known of its ecology or that of other species assigned by Page (4) to the subgenus *Nanostoma* and commonly known as snubnose darters. Six of 8 species of snubnose darter known to occur in Kentucky (2) have been named in the last 10 years (3, 5, 6).

Published accounts of *E. rafinesquei* are limited to reports on reproductive biology (7, 8, 9, 10, 11), brief life history notes included in species accounts (1, 2, 3, 12), and discussions of zoogeography (2, 13). This report of food habits is largely excerpted from my doctoral dissertation on the life history of *E. rafinesquei* (14).

In this study, I compare diets of juvenile and adult *E. rafinesquei* and examine seasonal and sexual variation in diets of adult fish. I discuss sex-specific differences in diets of adults in the context of differential expenditures of energy on reproduction.

MATERIALS AND METHODS

Approximately monthly samples of *E. rafinesquei* were collected from Middle Pitman Creek (Green River drainage), Taylor Co., KY (August 1986–July 1987). From August 1986 to June 1987, minnow seine collections were made at the Kentucky Highway 289 bridge (Station 1; 5.5 km NNW of Campbellsville). Drought made it impossible to collect from this site after June 1987, and a second site (Station 2; Salem Church Road bridge; 6 km NW of Campbellsville, about 3 km downstream from Station 1) was utilized for the July 1987 collection.

Fish were fixed in 10% formalin and preserved in 70% ethanol. Formalin solutions were buffered to pH 7.0 with calcium carbonate. Specimens are housed in the fish collections of the Department of Zoology at Southern Illinois University at Carbondale and of the Biology Department at Campbellsville College.

All collected adults and juveniles were sexed by examination of external morphology and gonads. Standard length (SL) was measured with a vernier caliper (±0.05 mm); eviscerated body weight (WT, blotted dry weight of alcohol-stored specimen with stomach, intestine, liver, and gonads removed) was determined with an analytical balance (±0.001 gm).

Stomachs were examined from 153 adult and large yearling fish (>29.9 mm SL; 70 males, 83 females), 15 juveniles (<30.0 mm SL) collected at Station 1 (August 1986–June 1987) and Station 2 (July 1987), and 2 larval fish (Station 2, June 1988). The number of food

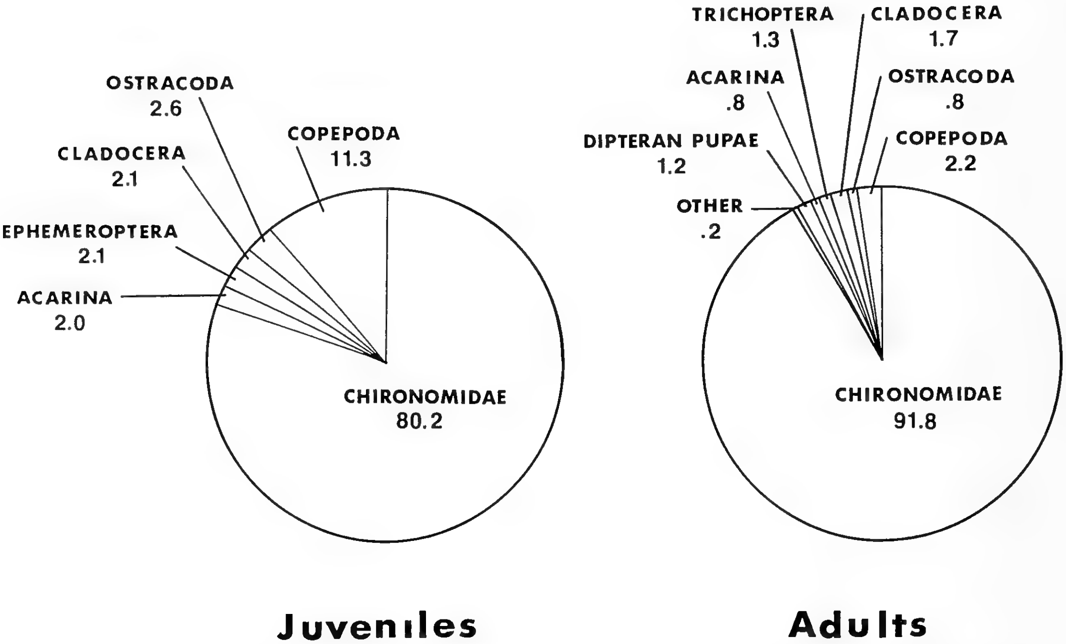


FIG. 1. Percent composition of diet for juvenile (<30 mm SL; n = 15) and adult (>29.9 mm SL; n = 153) *E. rafinesquei* from Middle Pitman Creek, Taylor Co., KY (Aug 1986–Jul 1987). Numbers represent % of total food items consumed.

items/stomach was recorded by counting whole organisms or recognizable parts, such as head capsules of midge larvae (Diptera: Chironomidae). Nematodes were not considered food items, because they frequently parasitize chironomid larvae (15, 16). Many chironomid larvae removed from stomachs of *E. rafinesquei* contained nematode parasites, and I could not be certain whether nematodes found in darter stomachs were parasites or food.

Bivariate regression analysis (Pearson's product moment correlations) was used to examine the relationship between WT and total number of food items consumed. Following the finding that WT was not significantly related to mean number of food organisms consumed (r = −0.177, n = 153), individuals of all sizes, except obvious juveniles, were lumped for analyses. Two-way ANOVA was used to examine temporal and sexual differences in mean total numbers of organisms consumed. Statistical analyses were performed using BIOSTAT I (17). Hypotheses were rejected at the 5% level. Normality of distributions was determined by Kolmogorov-Smirnov D tests. ANOVA was used to determine equality of means. Student-Newman-Keuls multiple range tests (SNK) were used to compare means.

RESULTS

A total of 9,637 food items was identified (August 1986–June 1987, Station 1; July 1987, Station 2). The diet of *E. rafinesquei* (Fig. 1) is similar to that reported for other benthic percids (18). Adults (n = 153) and juveniles (n = 15) consumed mostly chironomid larvae (91.8 and 80.2% of the total number of food items, respectively; Fig. 1), but juveniles relied more heavily on microcrustaceans than did adults (16.0 and 4.7%, respectively). The smallest fish examined (12.3 and 12.4 mm total length; June 1988, Station 2) consumed very small, presumably first instar chironomid larvae (78.9% of total) and microcrustaceans. The stomach of one of these individuals contained a first instar ephemeropteran naiad which was too small to identify to family.

In every month, except January and February, midge larvae were consumed by 90% or more of examined fish (Table 1). When individuals with empty stomachs were excluded, one or more midge larvae were found in 98.0%

TABLE 1. Stomach contents of adult *Etheostoma rafinesquei* (>29.9 mm SL) from Middle Pitman Creek, Taylor Co., KY (Aug 1986–Jul 1987). Data are presented as percentage of stomachs in which each food category occurred. Parenthetic numbers are the mean number of a food organism per stomach. Sample sizes are listed under month.

Food organism category	Aug 18	Sep 13	Oct 15	Nov 13	Dec 14	Jan 18	Feb 13	Mar 12	Apr 10	May 10	Jun 8	Jul 9
Crustacea												
Cladocera	44.4 (1.64)	53.8 (2.38)	73.3 (3.27)	46.2 (1.46)	14.3 (0.21)	5.6 (0.06)	—	—	—	40.0 (1.30)	25.0 (0.38)	—
Ostracoda	50.0 (1.61)	61.5 (2.92)	20.0 (0.20)	—	—	—	—	—	—	—	—	22.2 (0.33)
Copepoda	50.0 (2.11)	53.8 (6.38)	66.7 (1.47)	23.1 (1.23)	7.7 (0.07)	16.7 (0.28)	23.1 (0.46)	25.0 (0.50)	20.0 (0.20)	30.0 (0.90)	—	22.2 (1.56)
Arachnida												
Hydracarina	11.1 (0.11)	84.6 (4.23)	—	7.7 (0.08)	—	—	—	16.7 (0.17)	—	10.0 (0.20)	37.8 (0.38)	22.2 (0.67)
Insecta												
Ephemeroptera	22.2 (0.33)	38.5 (1.54)	33.3 (0.47)	—	14.3 (0.14)	5.6 (0.06)	7.7 (0.08)	8.3 (0.08)	10.0 (0.10)	10.0 (0.10)	37.8 (0.88)	55.6 (0.89)
Plecoptera	—	—	—	—	14.3 (0.14)	—	7.7 (0.08)	—	—	—	—	—
Trichoptera	11.1 (0.11)	38.5 (0.54)	6.7 (0.07)	7.7 (0.08)	7.1 (0.07)	5.6 (0.06)	15.4 (0.15)	66.7 (1.17)	70.0 (3.60)	10.0 (0.10)	12.5 (0.12)	11.1 (0.11)
Diptera												
Chironomidae larvae	100.0 (18.9)	100.0 (93.1)	100.0 (58.9)	100.0 (166.9)	92.9 (6.8)	71.4 (7.6)	77.8 (34.2)	100.0 (51.9)	90.0 (54.1)	100.0 (118.4)	100.0 (73.1)	100.0 (10.4)
pupae	5.6 (0.06)	15.4 (0.23)	86.7 (0.20)	14.3 (0.38)	—	—	38.5 (0.08)	16.7 (0.42)	60.0 (2.10)	50.0 (2.50)	25.0 (1.00)	—
Lepidoptera	5.6 (0.06)	—	—	—	—	—	—	—	—	—	—	—
Other	5.6 (0.06)	23.1 (0.23)	13.3 (0.20)	23.1 (0.38)	28.6 (0.43)	5.6 (0.06)	7.7 (0.08)	—	—	—	—	—
Fish eggs	—	—	—	—	—	—	—	8.3 (0.08)	—	—	—	—
Empty	—	—	—	—	14.3	22.2	—	—	—	—	—	—

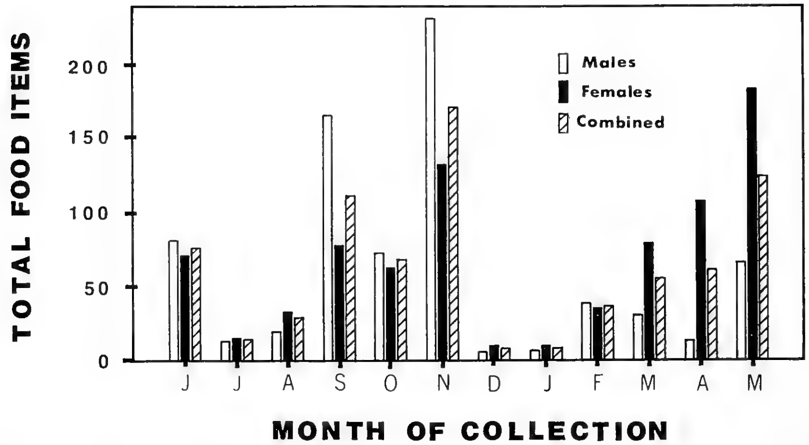


FIG. 2. Seasonal variation in mean total number of food items consumed by adult *E. rafinesquei* (Middle Pitman Creek, Taylor Co., KY; Aug 1986–Jul 1987). Open bar = males; closed bar = females; striped bar = sexes combined.

of adult stomachs. Copepod crustaceans were also an important temporally stable food source, occurring in 28.2% of the adult fish examined and in every month except June. From August to October, copepods were found in more than 50% of examined stomachs (Table 1). Although chironomid midge larvae and copepods were staples of the diet of *E. rafinesquei,* other food organisms were seasonally important (Table 1).

Cladocerans and ostracods were important foods, particularly during autumn (August–November), when 54.4% of the sampled adults consumed cladocerans and 32.9% consumed ostracods (Table 1). Mites (Hydracarina) were present in 84.6% of stomachs in September (Table 1). Immature caddisflies and mayflies were found in stomachs throughout the year but, generally, were of low incidence (Table 1). More darters consumed caddisflies and mayflies during spring and summer than in autumn and winter (Table 1). Most often, the caddisflies and mayflies found in stomachs were small individuals not substantially larger than chironomid larvae. During the period from March–April, which coincides roughly with the spawning season (9), 68.4% of adults consumed small purse caddisfly larvae of the family Hydroptilidae. These were not found in stomachs of adults during any other month of the year and, presumably, could represent an important dietary supplement during the spawning season. Dipteran pupae were most often consumed during autumn and spring and were particularly common in October (86.7%, Table 1).

The mean number of food items in stomachs of adult fish was 59.2 (n = 153, SE = 5.5). The greatest number of items found in any individual was 357 (45.8-mm male collected in November). The stomach of this individual contained only chironomid midge larvae. Empty stomachs were found only in fish collected during December (n = 2) and January (n = 4).

The mean number of food items found in stomachs of adult fish varied significantly with month of collection (Table 1 and Fig. 2; F = 8.019, $P < 0.001$). Stomachs of adult darters contained significantly greater numbers of food organisms (SNK) during autumn (September–November) and late spring (April–May) than in other seasons. During winter (December–January) and mid-summer (July–August) feeding was substantially and abruptly curtailed (Fig. 2).

Adult males and females did not differ significantly in total numbers of food items consumed during the year (F = 0.238, $P = 0.632$) but did differ in the numbers of items consumed during the period from February to May when females consumed more food items than males (F = 6.132, $P < 0.001$). During this period, the intensity of feeding was lowest in February and increased to a maximum in May (F = 3.156, $P = 0.036$; Fig. 2) in males and females (F = 1.376, $P = 0.265$). However, males fed at declining rates during the first 3 months of the period (Fig. 2). During autumn (August–November), males and females consumed statistically similar numbers of food items ($F = 0.542$, $P = 0.529$), and feeding intensity of both sexes increased to a maximum in November ($F = 8.780$, $P < 0.001$).

Discussion

Etheostoma rafinesquei is a benthic invertivore feeding principally on chironomid larvae and microcrustaceans. Similar diets have been reported for other species of the subgenus *Nanostoma*, including *E. baileyi* (19), *E. coosae* (20), *E. etnieri* (21), *E. pyrrhogaster* (22), *E. simoterum* (23), *E. zonale* (15, 24, 25, 26), and *E. zonistium* (22).

Three species of the subgenus *Nanostoma*, including *E. baileyi* (19), *E. pyrrhogaster* (22), and *E. zonistium* (22), exhibit summer feeding maxima. Spring feeding maxima have been reported for *E. etnieri* (21) and *E. simoterum* (23). *Etheostoma rafinesquei* appears most similar to *E. simoterum*, exhibiting maximum feeding intensity during autumn and spring. Page and Mayden (23) concluded that winter and summer declines in feeding were the result of lessened activity during periods of extremely high or low water temperature. It is also possible that autumn and spring increases in feeding intensity mirror seasonal changes in benthic macroinvertebrate abundance and biomass (27). The absence or paucity of dipteran pupae in stomachs of summer- and winter-collected-fish (Table 1) coupled with the relatively high frequencies of occurrence of pupae in stomachs of fish collected during October (86.7%), April (60.0%), and May (50.0%), is interpreted as evidence that two major periods of dipteran emergence occurred. If, although a tenuous assumption, this is true, then low levels of feeding in summer and winter may reflect low macroinvertebrate abundances. The mid-summer decline in feeding by adult *E. rafinesquei* observed during this study (Fig. 2) may have been influenced by drought during the summer of 1987, but because both years of my study (14) encompassed an extremely dry period in Kentucky (pers. comm., K. Ruhle, USGS), no baseline food habit data are available for years of more typical flow. Evidence that changes in discharge can affect feeding has been presented by Clayton (19) who reported relatively small numbers of food items in stomachs of *E. baileyi* during his spring samples and concluded that reduced feeding was related to increased discharge. Craddock (28) reported that feeding by banded sculpin, *Cottus carolinae*, was curtailed during periods of high discharge.

Periods of maximum food consumption by adult *E. rafinesquei* generally coincided, as should be expected, with periods of maximum weight gain (Fig. 2, 14), but this was not true for breeding adult females. During the spawning seasons of 1987 and 1988, females grew at declining rates (14), but, during the spawning season of 1988, they consumed significantly more food items than males (Fig. 2). Differences in growth patterns of adult male and female *E. rafinesquei* have been attributed, in part, to differential expenditures of energy for reproduction (14), but sex-specific differences in adult size are not as large as should have been expected based on numbers of eggs produced (9). Adult female *E. rafinesquei* apparently compensate for energy expended on reproduction by increasing food consumption but not sufficiently to recoup spawning-related energy losses completely.

Etheostoma rafinesquei is a multiple spawning fish for which clutch size and, presumably, energy expenditures vary predictively during the spawning season (9). If female *E. rafinesquei* compensate for reproductive energy expenditures by augmented feeding, numbers of food items consumed should be positively correlated with clutch size and should vary predictively during the spawning season. Future investigations of the cost of reproduction in fishes will best further our understanding of the evolution of reproductive strategies if estimates of feeding intensity are correlated with simultaneous estimates of fecundity. Studies that examine within season variation in batch fecundity and feeding intensity will likely be the most productive.

Acknowledgments

The body of this paper was originally drafted as a chapter in my doctoral dissertation at Southern Illinois University. I am indebted to Brooks M. Burr, who served as chair of my committee, for providing encouragement and advice throughout the project, and for reading earlier versions of the paper. Other committee members including Ronald A. Brandon, Beth Middleton, M. Ann Phillippi, and John B. Stahl provided useful critiques of earlier versions of the manuscript. I sincerely appreciate the efforts of Roger Farmer, Richard Kessler, and Pam Morris, who provided invaluable assistance with field work. I thank Kelly Milby for reading the manuscript and for providing secretarial assistance. Financial support was provided by the Science Division and Faculty Development Committee of Campbellsville College.

LITERATURE CITED

1. Burr, B. M. and L. M. Page. 1983. *Etheostoma rafinesquei*. Page 685.5. In D. S. Lee, C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. (eds.) Atlas of North American freshwater fishes. North Carolina State Mus. Nat. Hist.

2. Burr, B. M. and M. L. Warren, Jr. 1986. A distributional atlas of Kentucky fishes. Kentucky Nature Preserves Commission, Sci. Tech. Ser. No. 4. 398 pp.

3. Page, L. M. and B. M. Burr. 1982. Three new species of darters (Percidae, *Etheostoma*) of the subgenus *Nanostoma* from Kentucky and Tennessee. Occas. Pap. Mus. Nat. Hist. Univ. Kansas No. 101. 20 pp.

4. Page, L. M. 1981. The genera and subgenera of darters (Percidae, Etheostomatini). Occas. Pap. Mus. Nat. Hist. Univ. Kansas No. 90. 69 pp.

5. Bailey, R. M. and D. A. Etnier. 1988. Comments on the subgenera of darters (Percidae) with descriptions of two new species of *Etheostoma* (*Ulocentra*) from southeastern United States. Misc. Publ. Mus. Zool., Univ. Michigan No. 175. 48 pp.

6. Etnier, D. A. and R. M. Bailey. 1989. *Etheostoma* (*Ulocentra*) *flavum*, a new darter from the Tennessee and Cumberland river drainages. Occas. Pap. Mus. Zool., Univ. Michigan No. 717. 23 pp.

7. Stiles, R. A. 1974. The reproductive behavior of the Green and Barren river *Ulocentra* (Osteichthyes: Percidae: *Etheostoma*). Assoc. Southeast. Biol. Bull. 21:86–87.

8. Weddle, G. K. 1990. Spawning orientation preferences of the Kentucky snubnose darter: an in-stream study of *Etheostoma rafinesquei*. Trans. Ky. Acad. Sci. 51:159–165.

9. Weddle, G. K. and B. M. Burr. 1991. Fecundity and the dynamics of spawning in darters: an in-stream study of *Etheostoma rafinesquei*. Copeia 1991:419–435.

10. Winn, H. E. 1958. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces-Percidae). Ecol. Monogr. 28:155–191.

11. Winn, H. E. 1958. Observations on the reproductive habits of darters (Pisces-Percidae). Amer. Midl. Nat. 59:190–212.

12. Kuehne, R. A. and R. W. Barbour. 1983. The American darters. University Press of Kentucky, Lexington, Kentucky.

13. Burr, B. M. and L. M. Page. 1986. Zoogeography of fishes of the lower Ohio-upper Mississippi basin. Pp. 287–327. In C. H. Hocutt and E. O. Wiley (eds.) The zoogeography of North American freshwater fishes. John Wiley and Sons, New York, New York.

14. Weddle, G. K. 1991. Life history of the Kentucky snubnose darter, *Etheostoma rafinesquei* (Pisces: Percidae), with emphasis on reproductive biology. Unpubl. Ph.D. Dissertation. Southern Illinois University, Carbondale, Illinois.

15. Adamson, S. W. and T. E. Wissing. 1977. Food habits and feeding periodicity of the rainbow, fantail, and banded darters in Four Mile Creek. Ohio J. Sci. 77:164–169.

16. LeSage, L. and A. D. Harrison. 1980. The biology of *Cricotopus* (Chironomidae: Orthocladiinae) in an algal-enriched stream: Part II. Effects of parasitism. Arch. Hydrobiol./Suppl. 58:1–25.

17. Pimentel, H. A. and J. D. Smith. 1986. BIOSTAT I. Sigma Soft, Placentia, California.

18. Page, L. M. 1983. Handbook of darters. TFH Publications Inc., Ltd., Neptune City, New Jersey.

19. Clayton, J. M. 1984. Population differences and life history of the emerald darter, *Etheostoma baileyi* (Pisces: Percidae). Unpubl. M.S. Thesis. University of Kentucky, Lexington, Kentucky.

20. O'Neil, P. E. 1981. Life history of *Etheostoma coosae* (Pisces: Percidae) in Barbaree Creek, Alabama. Tulane. Stud. Zool. Bot. 23:75–83.

21. Hicks, D. T. 1990. Distribution and life history aspects of the cherry darter, *Etheostoma etnieri* (Osteichthyes: Percidae). Unpubl. M.S. Thesis. Tennessee Technological University, Cookville, Tennessee.

22. Carney, D. A. and B. M. Burr. 1989. The life history of the bandfin darter, *Etheostoma zonistium*, and the firebelly darter, *Etheostoma pyrrhogaster*, in western Kentucky. Ill. Nat. Hist. Surv. Biol. Notes No. 134. 16 pp.

23. Page, L. M. and R. L. Mayden. 1981. The life history of the Tennessee snubnose darter, *Etheostoma simoterum*, in Brush Creek, Tennessee. Ill. Nat. His. Surv. Biol. Notes No. 117. 11 pp.

24. Cordes, L. E. and L. M. Page. 1980. Feeding chronology and diet composition of two darters (Percidae) in the Iroquois River system, Illinois. Amer. Midl. Nat. 104:202–206.

25. Forbes, S. A. and R. E. Richardson. 1920. The fishes of Illinois, 2nd ed. Ill. Nat. Hist. Surv.

26. Wynes, D. L. and T. E. Wissing. 1982. Resource sharing among darters in an Ohio stream. Amer. Midl. Nat. 107:294–304.

27. Hynes, H. B. N. 1970. The ecology of running waters. Oxford University Press. Oxford, England.

28. Craddock, J. E. 1965. Some aspects of the life history of the banded sculpin, *Cottus carolinae carolinae*, in Doe Run, Meade County, Kentucky. Unpubl. Ph.D. Dissertation. University of Louisville, Louisville, Kentucky.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 127–132

New Distributional Records for Selected Species of Kentucky Mammals

Les Meade

Department of Biological and Environmental Sciences, Morehead State University
Morehead, Kentucky 40351

Abstract

New distributional records are presented for 10 species of mammals from Kentucky; these include new county records for *Sorex hoyi winnemana, Sorex longirostris, Parascalops breweri, Myotis septentrionalis, Lasionycteris noctivagans, Plecotus rafinesquii, Plecotus townsendii virginianus, Napaeozapus insignis, Mustela nivalis* and *Spilogale putorius.*

Six of these species are listed as endangered, threatened or rare by the United States Fish and Wildlife Service and/or by the Endangered Species Committee of the Kentucky Academy of Science and Kentucky Nature Preserves Commission (KAS-KNPC).

Introduction

New distributional records have been recorded in recent years for several small Kentucky mammals. These records were observed and photographed, collected by hand, or collected with standard procedures; several specimens were brought in by domestic cats. New county records are listed below for *Sorex hoyi winnemana, S. longirostris, Parascalops breweri, Myotis septentrionalis, Lasionycteris noctivagans, Plecotus rafinesquii, P. townsendii virginianus, Napaeozapus insignis, Mustela nivalis* and *Spilogale putorius.* These include the first records of *N. insignis* and *M. nivalis* for northeastern Kentucky, and verify the presence of *S. longirostris, P. rafinesquii* and *P. t. virginianus* in the region.

Species Accounts

Pygmy Shrew, *Sorex hoyi winnemana* (Preble)

This shrew, formerly known as *Microsorex hoyi winnemana,* was transferred to the Genus *Sorex* by Diersing (1). *Sorex hoyi winnemana* is listed in category C2 (Status Review) by the United States Fish and Wildlife Service (2). Barbour (3) and Barbour and Davis (4) reported that a specimen found in the mammal collection at the University of Kentucky was labeled as "Ky., Dec. 30, 1904. *S. hoyi*? Miller." Apparently, this specimen was collected by Dr. Arthur Miller, but no collecting site or other information were given. Guilday et al. (5) reported that jaw and skull fragments of *S. hoyi* were found in Pleistotocene deposits from Welsh Cave in Woodford County. However, the first recent specimens of *S. hoyi* with collection data were collected at Bad Branch in Letcher County (6). Harker et al. (7) included records for Breckinridge, Greenup, Harlan, Ohio and Warren counties. Additional records have been reported for Breathitt County (Robinson Forest) (8); McCreary and Pulaski counties (9); Bell, Boyle, Bullitt, Grayson, Jackson, Madison, Rockcastle, Rowan and Wolfe counties (10); and Bath, Leslie, Menifee, Pike and Wayne counties (11). New county records in the MSU Vertebrate Collection included specimens from Lewis County (2 mi N of Camp Dix) and Morgan County (along Craney Creek, nr. Craney) (Fig. 1).

Southeastern Shrew, *Sorex longirostris* Bachman

The southeastern shrew was first collected in Kentucky at Bernheim Forest in Bullitt County (12). Barbour and Davis (4) added records for Caldwell, Calloway, Livingston and Meade counties. Additional records are known for Hardin County (headwaters of East Rhudes Creek) and Henry County (nr. the Kentucky River) (13); Carlisle, Franklin, Henderson, Hickman, Knox and McLean counties (7); Ballard and McCracken counties (Ohio River floodplain) (14); Barren, Grayson, Hancock and Ohio counties (8); Montgomery County (Foley Hollow) (15); and Anderson, Bell, Breckinridge, Fulton, Graves, Madison, Marshall, Metcalfe, Morgan, Muhlenberg, Nelson, Oldham, Rowan, Shelby, Washington and Whitley counties (11). New county records in the MSU Vertebrate Collection included specimens from

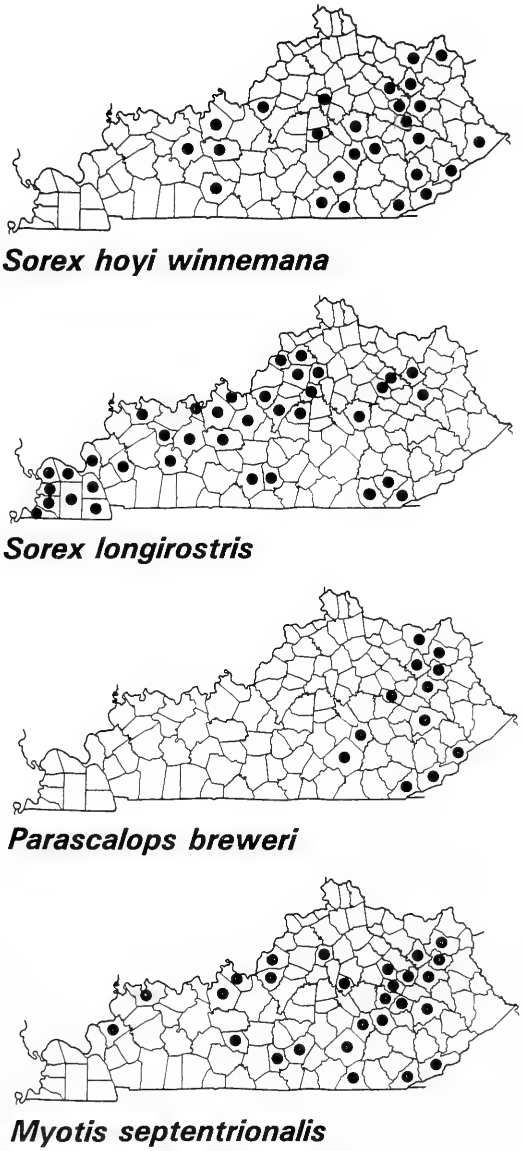


FIG. 1. Distributional records for *Sorex hoyi winnemana*, *Sorex longirostris*, *Parascalops breweri* and *Myotis septentrionalis* in Kentucky.

Bath County (Hog Hollow, .3 mi S of Cave Run Dam) (Fig. 1).

Hairy-tailed Mole, *Parascalops breweri* (Bachman)

This species was first reported for Kentucky by Welter and Sollberger (16) based on specimens found along Triplett Creek, nr. Clearfield, Rowan County. Additional county records have been reported for Harlan County (Big Black Mountain) (17); Breathitt County (Robinson Forest) (18); Rockcastle County (.5 mi SW of Morrill) (19); Bell and Carter counties (4); Pulaski County (nr. Plato) (20); and Powell County (10). New county records in the MSU Vertebrate Collection included specimens from Elliott County (Ky 7, ca. .4 mi NE of Newfoundland), Lewis County (Firebrick), Letcher County (Bill Moore Branch) and Morgan County (Ky 191, Cannel City) (Fig. 1).

Northern Long-eared Bat, *Myotis septentrionalis* (Trouessart)

This species is sporadically found in Kentucky caves and rock crevices. It is always found in small numbers; however, while mist-netting with Dave Fassler at Sloan's Valley Cave near Somerset in the fall of 1973, we netted 15–20 of these bats within an hour as they entered the cave. *Myotis septentrionalis* is listed by the Endangered Species Committee of the Kentucky Academy of Science and Kentucky Nature Preserves Commission (KAS-KNPC) in category S (Special Concern) (2). It was reported by Barbour and Davis (4) from Breckinridge, Crittenden, Edmonson, Elliott, Jefferson, Meade and Pulaski counties. Their Pulaski County records coincide with those of Fassler (20). Additional county records have been reported for Bell County (Cumberland Gap National Historical Park) (21); Franklin and Lee counties (7); McCreary (22); Menifee County (West Fork) (15); and Adair, Bullitt, Carter, Estill, Jackson, Jessamine, Metcalfe, Montgomery, Powell and Rockcastle counties (10). New county records in the MSU Vertebrate Collection included specimens from Morgan County (Mine Branch Cave) and Rowan County (Clack Mountain Railroad Tunnel); specimens listed by FWIS (Fish and Wildlife Information System) included new county records for Henderson and Breathitt counties; specimens collected by John MacGregor and James Kiser on Big Black Mountain were new county records for Harlan County (Fig. 1).

Silver-haired Bat, *Lasionycteris noctivagans* (LeConte)

The silver-haired bat, an uncommon species, is usually found in rock crevices at the mouth of caves. Funkhouser (23) reported this species from the Cumberland River in Bell County.

Welter and Sollberger (16) found a specimen in Morehead, Rowan County. Barbour and Davis (4) added records for Clark, Edmonson, Jefferson and Pulaski counties. Their Pulaski County records coincide with those of Fassler (20). Bryan and MacGregor (24) reported additional records for Carter, Harlan, Jackson, Lee, Letcher and Rockcastle counties. Campbell et al. (10) found a specimen in Powell County. New county records in the MSU Vertebrate Collection included specimens from Menifee County (Murder Branch Cave), Morgan County (Mine Branch Cave) and Lewis County (2 mi N of Camp Dix) (Fig. 2).

Virginia Big-eared bat, *Plecotus townsendii virginianus* Handley

This subspecies is rare in Kentucky and is listed on the KAS-KNPC and federal lists as Endangered (2). The first authentic Kentucky record for this bat was given by Welter and Sollberger (16). They found a single specimen at X-Cave, Carter Caves State Park, Carter County; the bat was examined and identified, but subsequently escaped (25). Barbour (26) reported specimens from a cave at Natural Bridge State Park in Powell County; Barbour (27) added records for Lee, Estill and Jackson counties. Additional records have been reported for Wolfe County (4), and Menifee, Morgan and Rowan counties (10). A new county record is known for Rockcastle County (FWIS).

The original specimens for Menifee, Morgan and Rowan counties were found during field surveys that included myself, Harry Pawelczyk, John MacGregor, Matt Meadows and John Donahue. At the Clack Mountain Railroad Tunnel in Rowan County, a single specimen was found in the early 1980s. At Murder Branch Cave in Menifee County, 3 bats were found on 5 February 1982 and one on 1 February 1984; at Donahue Sandstone Cave in Morgan County, 3 bats were found on 1 February 1984 and 2 on 17 March 1986 (Fig. 2).

Eastern Big-eared Bat, *Plecotus rafinesquii* Lesson

This somewhat uncommon species is placed on the KAS-KNPC list in category T (Threatened) and on the federal list in category C2 (Status Review). It was first recorded for Kentucky by Garman (28), after a specimen was found in Bowling Green, Warren County. Hamilton (29) reported a specimen from Breathitt County (Quicksand). Additional county records have been reported for Breathitt County (Robinson Forest) (26, 18); Edmonson County (Mammoth Cave National Park) (30); Lee County (Old Landing) (25); Pulaski County (Sloan's Valley Cave; cave ca. 7.7 km ESE of Somerset; and abandoned house 3.2 km

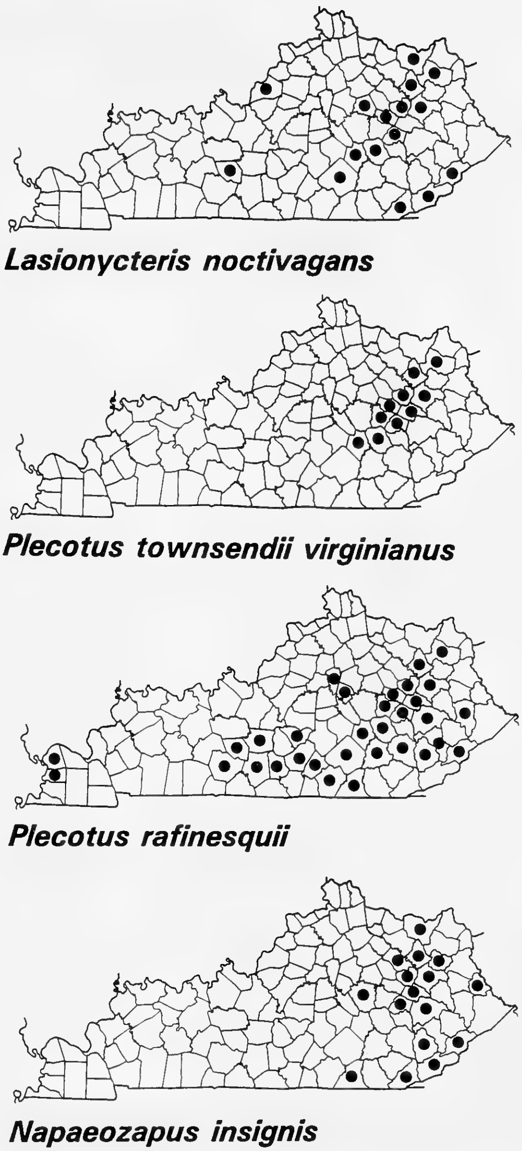


FIG. 2. Distributional records for *Lasionycteris noctivagans, Plecotus townsendii virginianus, Plecotus rafinesquii* and *Napaeozapus insignis* in Kentucky.

WSW of Ingle) (31, 20); Carter, Estill, Jackson, Rockcastle and Wayne counties (4); Carlisle County (7); McCreary County (22); Menifee, Morgan, Powell and Rowan counties (10); and Ballard County (32). New county records are known for Adair, Barren, Clay, Floyd, Hart, Jessamine, Laurel, Leslie, Letcher, Metcalfe, Perry, Russell, Taylor, Wolfe and Woodford counties (John MacGregor, U.S. Forest Service document; FWIS records).

On 19 February 1982, a colony of 15 bats was found in Rowan County at the Clack Mountain Railroad Tunnel; on 1 February 1984, this site was revisited and 8 bats were found. Another significant find was the discovery of a larger population at Donahue Sandstone Cave in Morgan County; this is one of the largest known colonies that occurs in Kentucky. In February of 1982, 61 specimens of *P. rafinesquii* were found at Donahue Sandstone Cave; in February of 1984, 134 specimens were counted; in January of 1986, 118 were identified. Other than big-eared bats, this cave also provided shelter for *Myotis lucifugus, Eptesicus fuscus, Pipistrellus subflavus*, and *Neotoma floridana magister* (Fig 2).

Woodland Jumping Mouse,
Napaeozapus insignis (Miller)

This species was first reported for Kentucky by Barbour (33, 17) based on specimens from Harlan County (Big Black Mountain). Barbour and Davis (4) listed additional records for Leslie and Elliott counties. The Elliott County specimens were actually found in the Shop Branch of Minor Creek on the Morgan-Rowan County line in Rowan County; they were shown to Dr. Barbour while he was in Morehead. Two individuals were found while they were hibernating beneath a small sandstone boulder in a rock shelter. In 1979, Davis and Barbour (34) reported new records from Bell County (Cumberland Gap National Historical Park), Letcher County (Letcher) and McCreary County (Rock Creek; and Ky 92, at W side of Big South Fork). Caldwell (6) collected specimens at Bad Branch in Letcher County. Houtcooper (35) summarized all known records and collected additional records from Breathitt County (Robinson Forest), Madison County (Berea College Forest), Menifee County (Red River Gorge), Martin County (tributary of Tug Fork, N of Warfield) and Wolfe County (Red River Gorge). Campbell et al. (10) collected a specimen in Lee County. New county records in the MSU Vertebrate Collection included specimens from Bath County (Glady Hollow), Elliott County (Big Caney Creek), Lewis County (2 mi N of Camp Dix) and Morgan County (Craney Creek, nr. Craney) (Fig 2).

Least Weasel, *Mustela nivalis* Linnaeus

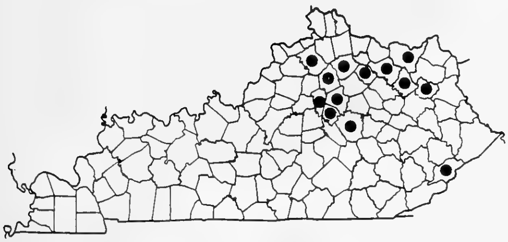
This species is known from 3 published reports. It is listed on the KAS-KNPC list in category S (Special Concern) (2). Specimens are known from Letcher County (Letcher) (34); Woodford County (Ky 1685, ca. 0.2 km N of US 421) (36); and Madison County (Richmond) (37). David (37) found six skulls in barn owl pellets he examined in Madison County. The recent discovery of this species in several counties indicates that the least weasel is probably not endangered or threatened in eastern Kentucky. New county records are based on specimens in the MSU Vertebrate Collection from Elliott County (Ky 7, ca. 0.4 mi NE of Newfoundland), Fleming County (nr. Ringos Mills), Lewis County (2 mi N of Camp Dix) and Rowan County (Clay Lick Boat Ramp); FWIS records from Harrison, Owen and Scott counties; records from Jessamine and Fayette counties (John MacGregor, pers. comm.); and a record from North-Central 4-H Camp, Nicholas County (Jennifer Lynn, pers. comm.) (Fig. 3).

Spotted Skunk, *Spilogale putorius* (Linnaeus)

The spotted skunk is a rare species in Kentucky. It is included on the KAS-KNPC list in category S (Special Concern) (4). Specimens are known from Rowan County (16); Bell, Elliott and McCreary counties (4); and Henderson County (nr. Ky 359, ca. 2 mi SW of Smith Mills) (38). Harker, et al. (7) cited additional records for Campbell and Martin counties. Campbell et al. (10) reported specimens from Knott, Laurel, Powell, Pulaski, Wayne and Wolfe counties. A specimen on display at Morehead State University is a new county record for Morgan County (Fig. 3).

ACKNOWLEDGMENTS

Thanks and appreciation to John MacGregor, Harry Pawelczyk, Matt Meadows, John Donahue, Tim Slone, Greg Eldridge, James Kiser, Charles Mason, Ted Adams and former mammalogy students at Morehead State Uni-



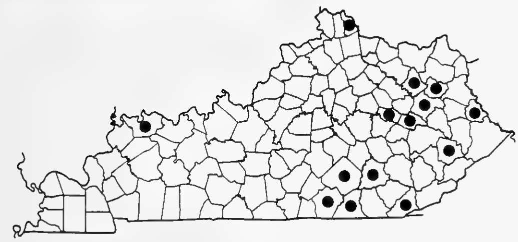


FIG. 3. Distributional records for *Mustela nivalis* and *Spilogale putorius* in Kentucky.

versity for their assistance in the field; to John MacGregor for access to FWIS records, U.S. Forest Service records and field notes; to Brenda Hamm for help with additional FWIS records; and to Jennifer Lynn, North-Central 4-H Camp, Carlisle, Kentucky for her observations.

LITERATURE CITED

1. Diersing, V. E. 1980. Systematics and Evolution of the Pygmy Shrews (Subgenus *Microsorex*) of North America. J. Mamm. 61(1):76–101.

2. Warren, M. L., Jr., W. H. Davis, R. R. Hannan, M. Evans, D. L. Batch, B. D. Anderson, B. Palmer-Ball, Jr., J. R. MacGregor, R. R. Cicerello, R. Athey, B. A. Branson, G. J. Fallo, B. M. Burr, M. E. Medley and J. M. Baskin. 1986. Endangered, threatened, and rare plants and animals of Kentucky. Trans. Ky. Acad. Sci. 47:83–98.

3. Barbour, R. W. 1956. A record of *Microsorex hoyi* from Kentucky. J. Mamm. 37:438.

4. Barbour, R. W. and W. H. Davis. 1974. Mammals of Kentucky. Univ. Press Kentucky, Lexington.

5. Guilday, J. E., H. W. Hamilton, and A. D. McGrady. 1971. The Welsh Cave Peccaries (*Platygonus*) and associated fauna, Kentucky Pleistocene. Ann. Carnegie Mus. 43:249–320.

6. Caldwell, R. S. 1980. First records of *Sorex dispar* and *Microsorex thompsoni* in Kentucky with distributional notes on associated species. Trans. Ky. Acad. Sci. 49: 46–47.

7. Harker, D. F., Jr., M. E. Medley, W. C. Houtcooper, and A. Phillippi. 1980. Kentucky Natural Areas Plan. Kentucky Nature Preserves Commission, Frankfort.

8. Caldwell, R. S. and H. Bryan. 1982. Notes on distribution and habitats of *Sorex* and *Microsorex* (Insectivora: Soricidae) in Kentucky. Brimleyana 8:91–100.

9. Palmer-Ball, B., Jr., J. J. N. Campbell, M. E. Medley, D. T. Towles, J. R. MacGregor, and R. R. Cicerello. 1988. Cooperative inventory of endangered, threatened, sensitive and rare species, Daniel Boone National Forest, Somerset Ranger District. Technical Report, Kentucky Nature Preserves Commission, Frankfort.

10. Campbell, J. J. N., D. T. Towles, J. R. MacGregor, R. R. Cicerello, B. Palmer-Ball, Jr., M. E. Medley, and S. Olson. 1989. Cooperative inventory of endangered, threatened, sensitive and rare species, Daniel Boone National Forest, Stanton Ranger District. Technical Report, Kentucky Nature Preserves Commission, Frankfort.

11. Bryan, H. D. 1991. The distribution, habitat, and ecology of Shrews (Soricidae: *Blarina, Sorex,* and *Cryptotis*) in Kentucky. J. Tenn. Acad. Sci. 66:187–189.

12. Barbour, R. W. 1956. Two new mammal records from Kentucky. J. Mamm. 37:110–111.

13. Bryan, H. 1979. The occurrence of two species of shrews in Central Kentucky. Trans. Ky. Acad. Sci. 40:41–42.

14. Rose, R. K. and G. L. Seegert. 1982. Small mammals of the Ohio River Floodplain in Western Kentucky and adjacent Illinois. Trans. Ky. Acad. Sci. 43:150–155.

15. Chadwick, J. W. and W. H. Davis. 1984. Notes on Kentucky mammals: *Myotis keenii* and *Sorex longirostris*. Trans. Ky. Acad. Sci. 45:159.

16. Welter, W. A. and D. E. Sollberger. 1939. Notes on the mammals of Rowan and adjacent counties in Eastern Kentucky. J. Mamm. 20:77–81.

17. Barbour, R. W. 1951. The mammals of Big Black Mountain, Harlan County, Kentucky. J. Mamm. 32:100–110.

18. Barbour, R. W. and S. Hardjasasmita. 1966. A preliminary list of the mammals of Robinson Forest, Breathitt County, Kentucky. Trans. Ky. Acad. Sci. 27:85–89.

19. Wallace, J. T. and R. Houp. 1968. Marginal record of *Parascalops breweri* (Bachman) from Kentucky. Trans. Ky. Acad. Sci. 29:9.

20. Fassler, D. J. 1974. Mammals of Pulaski County, Kentucky. Trans. Ky. Acad. Sci. 35:37–43.

21. Barbour, R. W., W. H. Davis, and R. A. Kuehne. 1979. The vertebrate fauna of Cumberland Gap National Historical Park. Final Report, National Park Service.

22. Barclay, L. A., Jr. and D. R. Parsons. 1983. An endangered species survey of abandoned mine shafts in the Big South Fork National River and Recreation Area, Kentucky and Tennessee U.S. Army Corps of Engineers, Nashville District.

23. Funkhouser, W. D. 1925. Wild life in Kentucky. Ky. Geol. Surv., Frankfort.

24. Bryan, H. D. and J. R. MacGregor. 1988. Bat notes from Eastern Kentucky. Trans. Ky. Acad. Sci. 49:140.

25. Rippy, C. L. and M. J. Harvey. 1965. Notes on *Plecotus townsendii virginianus* in Kentucky. J. Mamm. 46:499.

26. Barbour, R. W. 1957. Some additional mammal records from Kentucky. J. Mamm. 38:140–141.

27. Barbour, R. W. 1965. The Western Big-Eared Bat. Ky. Happy Hunt. Ground. 21:33.

28. Garman, H. 1894. A preliminary list of the vertebrate animals of Kentucky. Bull. Essex Inst. 26:1–63.

29. Hamilton, W. J., Jr. 1930. Notes on the mammals of Breathitt County, Kentucky. J. Mamm. 11:306–311.

30. Hall, J. S. 1963. Notes on *Plecotus rafinesquii* in Central Kentucky. J. Mamm. 44:119–120.

31. Fassler, D. J. 1971. A range extension of Rafinesque's Big-eared Bat in Kentucky. Bat Res. News 12:41.

32. Kentucky Nature Preserves Commission. 1992. Biological inventory of the Jackson Purchase. Kentucky Nature Preserves Commission, Frankfort (In Preparation).

33. Barbour, R. W. 1941. Three new mammal records from Kentucky. J. Mamm. 22:195–196.

34. Davis, W. H. and R. W. Barbour. 1979. Distributional records of Some Kentucky Mammals. Trans. Ky. Acad. Sci. 40:111.

35. Houtcooper, W. C. 1982. Current distribution and status of Jumping Mice (Zapodidae) in Kentucky. Trans. Ky. Acad. Sci. 43(3–4):97–102.

36. Prather, K. W. 1984. New distributional record for *Mustela nivalis* in Kentucky. Trans. Ky. Acad. Sci. 45: 76.

37. David, P. G. 1988. Further distribution of *Mustela nivalis* in Kentucky. Trans. Ky. Acad. Sci. 49:37.

38. Richins, G. H. and R. D. Panke. 1976. Sighting of an Eastern Spotted Skunk in Henderson County, Kentucky. Trans. Ky. Acad. Sci. 37:103.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 133–138

The Influence of pH, Salt Concentration, and Incubation Time on Hatching Brine Shrimp Cysts

ROBERT M. HOYT
Moss Middle School, Bowling Green, Kentucky 42101

AND

ROBERT D. HOYT
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

ABSTRACT

The influence of pH, incubation time, and salt concentration on the hatching success of brine shrimp was determined. Salt Lake, Australia brand brine shrimp were incubated at pH levels 6.5, 7.5, and 8.5, and the number of cysts hatched after 24 and 36 hr in 28 ppt salt compared with the number hatched at 35 ppt salt. Brine shrimp were incubated in a 28°C water bath at Western Kentucky University. Hatching success was highly correlated with specific combinations of environmental variables. At 28 ppt salt, hatching was greatest at pH 7.5 and least at pH 8.5, while at 35 ppt salt most hatched at pH 6.5 and fewest at 8.5. More shrimp hatched in 28 ppt salt water than 35 ppt at all pH levels except one. Incubation time and hatching success were strongly correlated with pH and salt concentrations. Maximum hatching success at longer incubation times was correlated with non-optimal environmental conditions.

INTRODUCTION

The brine shrimp, *Artemia*, presently represents the most important and widely used food organism for rearing marine larval fishes and invertebrates for aquaculture or for research (1). Most aquatic larvae cannot, or will not, accept dry foods and must be fed live organisms (2). Consequently, early efforts in aquaculture and aquatic research were hampered by inadequate and unsuitable food supplies for young organisms. With the finding that newly hatched brine shrimp represented an excellent food source for larval aquatic organisms that could be easily cultured (3), significant advances were made in the field of aquaculture. As a result, the demand for brine shrimp for fish rearing projects became so great, that during the 1970s the demand exceeded the available supply (4). Since then, tremendous efforts have been directed to the biology and culture of brine shrimp. Although a more complete understanding of the biology and culture of brine shrimp is now available, little new information has been provided on its ecology. Persoone and Sorgeloos (5) pointed out that in spite of the increased interest in brine shrimp, fewer than 50 published studies exist on brine shrimp ecology.

Artemia is reported to occur naturally in more than 80 kinds of saline environments on all 5 continents (5). With such a broad geographic distribution, brine shrimp strains represent a wide spectrum of optimal ranges for physical and chemical features of the environment (5). Therefore, the optimum environmental conditions for maximum hatching and rearing success must vary for different strains of brine shrimp.

The objectives of this study were to determine the effects that different pH levels, salt concentrations, and incubation times would have on the hatching success of brine shrimp from Salt Lake, Australia.

METHODS AND MATERIALS

Two different salt concentrations were tested, 28 parts per thousand (ppt) and 35 ppt. Seven grams of reagent-grade sodium chloride were dissolved in 250 ml tap water and added to a 250 ml Erlenmeyer flask for 28 ppt solutions while 8.75 g of salt were added to 250 ml water for the 35 ppt solutions. Brine shrimp cysts (Argentemia Brand from Salt Lake, Australia) were weighed in 0.20 g lots and placed in 20 ml rubber-stoppered vials. The pH of the salt solutions was determined with a Fisher Accumet Model 900 pH meter and adjusted with 1 N Sodium Hydroxide and 1 N Hydrochloric Acid. pH concentrations of 6.5, 7.5, and 8.5 were prepared in replicate for each salt concentration. One 0.20 g sample of brine shrimp cysts was added to each pH solution and an air stone added to each flask. Brine shrimp flasks were placed in a 28°C water bath and the pH checked and adjusted every 12 hours over a 36 hour period from 8 A.M. Saturday morning until 8 P.M. Sunday night. Salt concentration trials were conducted on 15–16 February 1992 (28 ppt salt) and 22–23 February 1992 (35 ppt salt).

After 24 hr incubation, 3, 1.0 ml samples of each pH, salt solution were pipetted into 3 10.0 ml plastic petri dishes. Three ml of 10% formaldehyde solution were added to each brine shrimp sample to kill the hatched, swimming nauplii. Grid fields were etched on the bottom of the plastic petri dishes to allow for individualized block counting. Brine shrimp counts were made using a dissecting microscope. Three life cycle stages were counted as described by Sorgeloos (6). Non-hatched cysts were counted but could not be reliably distinguished from hatched cyst cases. Pre-nauplius E-1 stage (in which hatching had started with the breaking of the cyst case but the organisms had not separated from the shell), and E-2 and Nauplius Instar I stages combined were counted. Similar samples were taken and counted from each pH salt solution after 36 hr incubation.

Data were analyzed by intra- and inter-block design ANOVA statistical treatment using the Human Systems Dynamics, Statistical Analysis Software package for Apple Computing System.

RESULTS

The total number of cysts and variously hatched stages of brine shrimp averaged 360 per ml salt solution or per 0.8 mg of dry cysts. The total number of cysts that had either initiated or completed hatching at 24 hr was essentially the same as that observed at 36 hr at pH 6.5 and 7.5 at 28 ppt salt (Figs. 1, 2). As E-2 and Napulius Instar I stages increased from 24 to 36 hr, E-1 stages decreased proportionally. However, at 35 ppt salt and pH 8.5, this relationship was not observed as E-1 stages were equal to or more numerous than E-2 and Nauplii stages after 24 hr.

Replicate Tests.—Replicate test data were similar at pH 6.5 and 7.5 at both salt concentrations and incubation times, but significantly different at pH 8.5 in 3 of the 4 comparisons (Table 1).

Incubation Times.—No difference in hatching ($P > 0.05$) was observed between 24 and 36 hr hatching times in 28 ppt salt water at pH 6.5 (141 vs. 141, respectively) and pH 7.5 (202 vs. 210, respectively) (Table 2; Fig. 1). However, at pH 8.5, more cysts ($P < 0.01$) hatched after 36 hr than at 24 hr (95 vs. 53, respectively). In 35 ppt salt water, more cysts ($P < 0.01$) hatched at 36 hr at all pH levels than at 24 hr (Table 2; Figs. 1, 2).

pH Concentrations.—More cysts hatched at pH 7.5 after 24 hr and 36 hr in 28 ppt salt (Figs. 1, 2). Fewer ($P < 0.01$) hatched at pH 8.5 at both incubation times (Table 3; Figs. 1, 2). At 35 ppt salt, more cysts ($P < 0.01$) hatched at pH 6.5 at both incubation times while fewer ($P < 0.05$ and 0.01) hatched at pH 8.5 at both times (Table 3; Figs. 1, 2).

Salt Concentrations.—More brine shrimp ($P < 0.01$) hatched at 28 ppt salt than at 35 ppt at all pH levels except 6.5 (Table 4; Fig. 2).

DISCUSSION AND CONCLUSIONS

The number of unhatched cysts remaining following test treatments could not be used as evidence of non-hatching since the number of hatched cyst cases could not be reliably separated from unhatched eggs. This conclusion was supported by more eggs remaining at 36 hr than 24 hr while the number of hatched nauplii was greater at 36 hr than 24 hr.

The number of Instar I nauplii that hatched per ml at 28 ppt salt at pH 7.5 in this study was greater than that reported in the literature. Kuwabara et al. (7), in establishing control hatching rates of San Francisco Bay brand brine shrimp, reported mean hatching rates of 172 nauplii per mg of dry eggs at 24 hr, 20 ppt salt, pH 7–8, and 27°C water. Nauplii hatch rates of 222/mg dry eggs were observed in this study at 24 hr, 28 ppt salt, pH 7.5, and 28°C. The findings of these 2 studies support the contention that brine shrimp from different saline environments will provide maximum hatching efficiencies when incubated under conditions similar to those of their native origin.

Replicate differences observed were limited to pH 8.5 and occurred at both salt concentrations tested. These intra-level differences

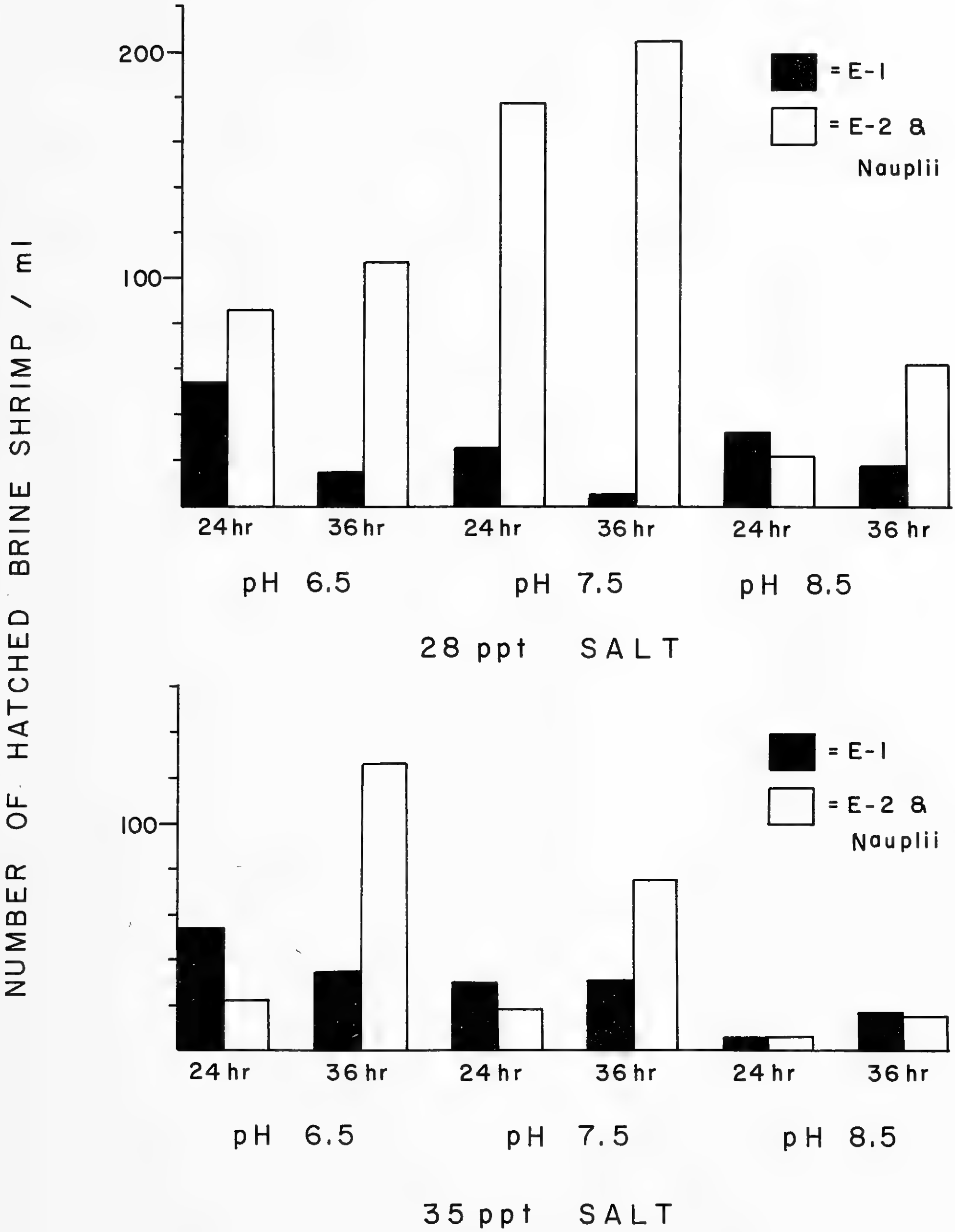


FIG. 1. Number of E-1, and combined E-2 and Nauplius Instar I stages of brine shrimp hatched per ml at pH 6.5, 7.5, and 8.5 after 24 and 36 hours at 28 and 35 ppt salt concentration.

appeared to result from the pH treatment and not sampling inconsistencies. The poor hatch rates observed at pH 8.5 for all treatments supported this conclusion.

Incubation times recommended by commercial vendors for culturing brine shrimp varies by strain, ranging from 20 to 36 hr. Kuwabara et al. (7) showed San Francisco Bay brine shrimp to produce significantly better hatches at 48 hr versus 24 hr with no additional increase after 72 hr at 20 ppt salt. The trend of this finding was similar to that in this study

TABLE 1. Probability levels for replicate test comparisons of numbers of E-1, E2, and Nauplii of brine shrimp hatched at different pH's, salt concentrations, and incubation times.

pH	Salt ppt	Time	Comparison	Probability level
6.5	28	24 hr	Trial 1 = 2	ns
7.5	28	24 hr	Trial 1 = 2	ns
8.5	28	24 hr	Trial 1 < 2	0.01**
6.5	35	24 hr	Trial 1 = 2	ns
7.5	35	24 hr	Trial 1 = 2	ns
8.5	35	24 hr	Trial 1 = 2	ns
6.5	28	36 hr	Trial 1 = 2	ns
7.5	28	36 hr	Trial 1 = 2	ns
8.5	28	36 hr	Trial 1 > 2	0.01**
6.5	35	36 hr	Trial 1 = 2	ns
7.5	35	36 hr	Trial 1 = 2	ns
8.5	35	36 hr	Trial 1 < 2	0.05*

TABLE 2. Probability levels for comparisons of incubation time effects on numbers of E-1, E-2, and Nauplii of brine shrimp hatched at different pH's levels and salt concentrations.

pH	Salt ppt	Comparison	Probability level
6.5	28	24 hr = 36 hr	ns
7.5	28	24 hr = 36 hr	ns
8.5	28	24 hr < 36 hr	0.01**
6.5	35	24 hr < 36 hr	0.01**
7.5	35	24 hr < 36 hr	0.01**
8.5	35	24 hr < 36 hr	0.01**

in 35 ppt salt water, significantly greater hatches occurred at 36 hr over 24 hr. However, equal or greater hatches were observed at each pH tested at 24 hr in 28 ppt salt. It is not unlikely that had Kuwabara et al. (7) tested for hatching at a combination of pH and salt concentrations, the same or greater hatch success might have been obtained in a shorter incubation time.

At optimum, or near optimum, culturing conditions, the maximum number of cysts that activated pre-emergent development had begun to do so at 24 hr incubation time and did not increase measurably by 36 hr. This condition was observed at pH 6.5 and 7.5 in 28

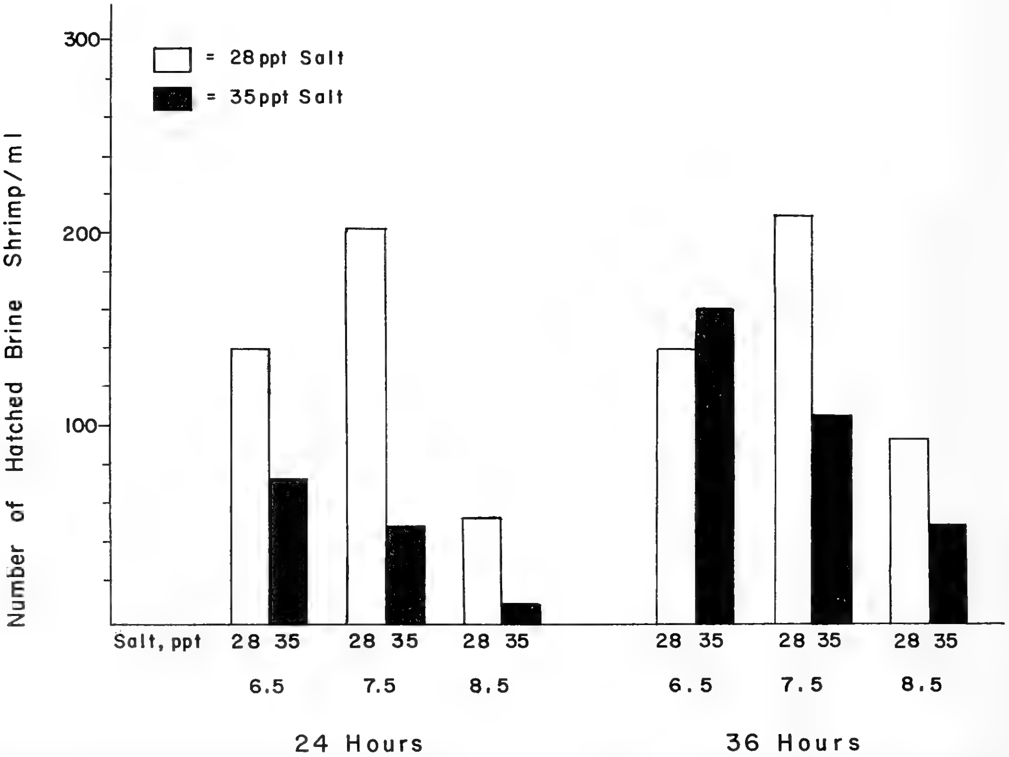


FIG. 2. Total number of brine shrimp hatched per ml at pH 6.5, 7.5, and 8.5 at 28 and 35 ppt salt concentration after 24 and 36 hours.

TABLE 3. Probability levels for comparisons of pH effects on numbers of E-1, E-2, and Nauplii of brine shrimp hatched at different pH levels and salt concentrations.

Salt ppt	Time	Comparison	Probability level
28	24 hr	pH 6.5 = pH 7.5	ns
28	24 hr	pH 6.5 > pH 8.5	0.01**
28	24 hr	pH 7.5 > pH 8.5	0.01**
35	24 hr	pH 6.5 > pH 7.5	0.01**
35	24 hr	pH 6.5 > pH 8.5	0.05*
35	24 hr	pH 7.5 > pH 8.5	0.05*
28	36 hr	pH 6.5 < pH 7.5	0.01**
28	36 hr	pH 6.5 > pH 8.5	0.01**
28	36 hr	pH 7.5 > pH 8.5	0.01**
35	36 hr	pH 6.5 > pH 7.5	0.01**
35	36 hr	pH 6.5 > pH 8.5	0.01**
35	36 hr	pH 7.5 > pH 8.5	0.01**

TABLE 4. Probability levels for comparisons of salt concentration effects on numbers of E-1, E-2, and Nauplii of brine shrimp hatched at different pH levels and incubation times.

pH	Time	Comparison	Probability level
6.5	24 hr	28 ppt > 35 ppt	0.01**
7.5	24 hr	28 ppt > 35 ppt	0.01**
8.5	24 hr	28 ppt > 35 ppt	0.01**
6.5	36 hr	28 ppt = 35 ppt	ns
7.5	36 hr	28 ppt > 35 ppt	0.01**
8.5	36 hr	28 ppt > 35 ppt	0.01**

ppt salt when the combined number of E-1, E-2, and Nauplius Instar I individuals was similar at 24 and 36 hr, although the proportion of the different stages changed with time. At pH 8.5 and all pH levels in 35 ppt salt; however, the total number of hatching stages increased at 36 hr over 24 hr. This strongly suggested that post-dormant activity is more subject to environmental conditions than responsive to incubation time.

Of all the environmental variables that have been studied in relation to the biology of brine shrimp, pH has probably received most attention (8, 9, 10). pH serves as a fundamental regulator of the transition between dormancy (cyst) and metabolism (emerging nauplius) (8). Acidification of pH down to 6.3 to 6.8 induces a quiescent condition (9) while alkalinization evokes normal metabolism (8) in a reversible fashion. The mechanism behind pH control of dormancy and pre-emergent development appears to relate to the disaccharide trehalose which is directly controlled by pH shifts (9).

Recommended pH values for culturing brine shrimp are as varied as temperature and salinity, ranging from no recommended pH given, to 7.5 to 8.5, to 8.5+. Of the pHs tested in this study, different levels produced varying hatching success in relation to other environmental variables. At 28 ppt salt, pH 7.5 proved to be the most productive at both 24 and 36 hours while pH 8.5 was the least productive. At 35 ppt salt; however, pH 6.5 was the most productive at both incubation times with pH 8.5 again being the least productive. The relationship of pH and other environmental variables has not gone unnoticed. Sorgeloos (2) reported one of the key factors for successful hatching of brine shrimp at low salinities was to increase the pH range to 8 to 9. The reverse of this pattern was observed in this study with the lowest pH, 6.5, producing the greatest hatch success at the higher salt concentration. Why this low pH did not initiate dormancy as suggested in the literature cited above cannot be explained. A possible interaction might be related to oxygen concentration. Holliday (11) reported oxygen content of water to be inversely related to salinity. Aeration in the incubation procedures of this study were not altered to accomodate this relationship. Consequently, lowered oxygen availability at the reduced pH level might have precluded dormancy when interacting with the other environmental parameters operating. Obviously the interacting influences of different environmental variables alters the trehalase metabolic pathway in ways as yet undescribed.

Salt concentration, like temperature, has been shown to be interrelated with other environmental features in controlling brine shrimp hatching. Persoone and Sorgeloos (5) reported that there is no well-defined optimum for salinity; however, for physiological reasons it must be situated towards the lower end of the salinity range. While brine shrimp are very seldom found in waters less than 45 ppt salt, their cysts hatch successfully at salt concentrations as low as 5 ppt (2). San Francisco Bay brine shrimp cysts will not develop until salt levels fall below 85 ppt (5). However, natural seawater (35 ppt) is mainly used to hatch cysts and it has been reported that hatching rates increase at lower salinities (2). Thus, commercial vendors recommend salinities from 10 ppt to 35 ppt for various brine shrimp strains. In this study, 28 ppt was found to be superior to sea water salt (35 ppt) in hatching Salt Lake, Australia brine shrimp under all test conditions except pH 6.5 at 36 hours.

Based on the observations made in this study, brine shrimp hatching success is correlated with pH, salinity, and temperature of the culture water; non-optimum conditions producing greater hatch success over longer time intervals.

LITERATURE CITED

1. Beck, A. D., D. A. Bengtson, and W. H. Howell. 1980. International study on *Artemia* V. Nutritional value of five geographical strains of *Artemia*: effects on survival and growth of larval Atlantic silverside *Menidia menidia*. Pp. 249–259. In G. Persoone et al. (eds.) The brine shrimp *Artemia*, Proc. Intl. Symp. on the brine shrimp *Artemia salina*. Corpus Christi, Texas. Universa Press, Wetteren, Belgium.

2. Sorgeloos, P. 1980. The use of the brine shrimp *Artemia* in aquaculture. Pp. 25–46. In G. Persoone et al. (eds.) The brine shrimp *Artemia*, Proc. Intl. Symp. on the brine shrimp *Artemia salina*. Corpus Christi, Texas. Universa Press, Wetteren, Belgium.

3. Seale, A. 1933. Brine shrimp (*Artemia*) as a satisfactory live food for fishes. Trans. Am. Fish. Soc. 63:129–130.

4. Royan, J. P. 1980. Laboratory and field studies on an Indian strain of the brine shrimp *Artemia*. Pp. 223–230. In G. Persoone et al. (eds.) The brine shrimp *Artemia*, Proc. Intl. Symp. on the brine shrimp *Artemia salina*. Corpus Christi, Texas. Universa Press, Wetteren, Belgium.

5. Persoone, G. and P. Sorgeloos. 1980. General aspects of the ecology and biogeography of *Artemia*. Pp. 1–24. In G. Persoone et al. (eds.) The brine shrimp *Artemia*, Proc. Intl. Symp. on the brine shrimp *Artemia salina*. Corpus Christi, Texas. Universa Press, Wetteren, Belgium.

6. Sorgeloos, P. 1980. Life history of the brine shrimp *Artemia*. Pp. xiv–xxiii. In G. Persoone et al. (eds.) The brine shrimp *Artemia*, Proc. Intl. Symp. on the brine shrimp *Artemia salina*. Corpus Christi, Texas. Universa Press, Wetteren, Belgium.

7. Kuwabara, K., A. Nakamura, and T. Kashimoto. 1980. Effect of petroleum oil, pesticides, PCB's and other environmental contaminants on the hatchability of *Artemia salina* eggs. Bull. Environ. Contam. Toxicol. 25:69–74.

8. Busa, W. B. and J. H. Crowe. 1983. Intracellular pH regulates transitions between dormancy and development of brine shrimp (*Artemia salina*) embryos. Science 221:366–368.

9. Hand, S. C. and J. C. Carpenter. 1986. pH-induced metabolic transitions in *Artemia* embryos mediated by a novel hysteretic trehalase. Science 232:1535–1537.

10. Hand, S. C. and E. Gnaiger. 1988. Anaerobic dormancy quantified in *Artemia* embryos: a calorimetric test of the control mechanism. Science 239:1425–1427.

11. Holliday, F. G. T. 1969. The effects of salinity on the eggs and larvae of teleosts. Pp. 293–313. In W. S. Hoar and D. J. Randall (eds.) Fish physiology, Vol. 1. Academic Press, New York.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 139–140

A New Species of the Genus *Largulara* (Homoptera: Cicadellidae)[1]

PAUL H. FREYTAG[2]

ABSTRACT

A new species from Venezuela is described in the Genus *Largulara* DeLong and Freytag, new status.

INTRODUCTION

While reviewing the leafhopper species of Venezuela, a new species was found which is closely related to *Polana* (*Largulara*) *fantasa* DeLong and Freytag (1). These 2 species were found to be different enough to be separated from *Polana* as a separate genus.

I wish to thank Marco Gaiani and the late Dr. F. Fernandez Yepes of the Universidad Central de Venezuela (MIZA), Maracay, Venezuela for the loan of the material used in this study.

RESULTS

Largulara DeLong and Freytag New Status

Polana subgenus *Largulara* DeLong and Freytag 1972, p. 292. Type species: *Polana fantasa* DeLong and Freytag.

Head narrower than pronotum, crown rounded to face, striae transverse, ocelli on crown closer to anterior than to posterior margin. Pronotum with lateral angles flared, extending beyond lateral margin of scutellum. Forewing with small appendix and normal venation. Male genitalia with plates with long tufts of hair, pygofer without processes, and aedeagus with robust basal processes.

This genus can easily be separated from *Polana* by having the head much narrower than the pronotum, the unique male genitalia including the broad aedeagus, long tufts of setae on the genital plates, and the pronotum with lateral angles flaring, much like some Membracidae.

Key to Species

1. Aedeagal shaft without processes (Fig. 6–7), with pair of lateral spurs near middle. .... *elegans* n. sp.

1′. Aedeagal shaft with pair of small, short, bifid processes near middle .... *fantasa* DeLong and Freytag

Largulara elegans new species
(Figs. 1–10)

Length of male 8 mm, head width 2.1 mm, female unknown. Similar to *fantasa* but with different male genitala.

Head narrower than pronotum, crown broadly rounded, 2½ times as broad between eyes at base as median length. Pronotum with flaring lateral angles.

Generally brown to yellow brown. Crown with two small black spots on base, one behind each ocellus. Pronotum with irregular black markings just behind anterior margin. Scutellum with black basal angles. Forewings with yellow-brown transverse band just beyond tip of clavus, apical cells smoky brown, costal area and along base of transverse band, darker brown. Ventral surface mostly yellow to yellow brown.

Male genitalia: Genital plates longer than broad, with 2 long tufts of setae, one laterally at base and one at apex (Fig. 10). Pygofer without processes, apical margin lobed (Fig. 9). Style broadened beyond middle, ventral margin thickened, apex pointed (Fig. 8). Aedeagus with stout shaft, ventrally flattened, with pair of spurs two-thirds distance from base, basal processes stout, curving outward, then back toward shaft, with spur near middle of apical part (Figs. 6–7).

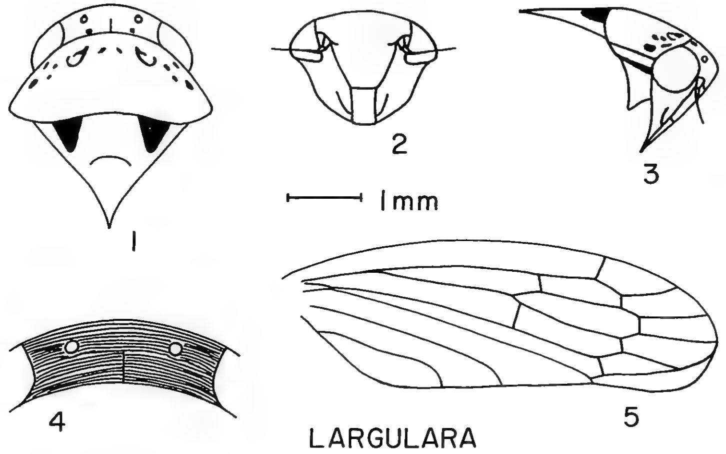
Holotype male, Venezuela—T. F. Amazonas, 25-XI-4-XII-1984, Rio Bavia, 140 m., 0°10′N, 66°10′W, E. Osuna and A. Chacón (MIZA).

This species can be separated from *fantasa* by the lack of processes on the aedeagal shaft and the different and shorter spur on the basal aedeagal processes.

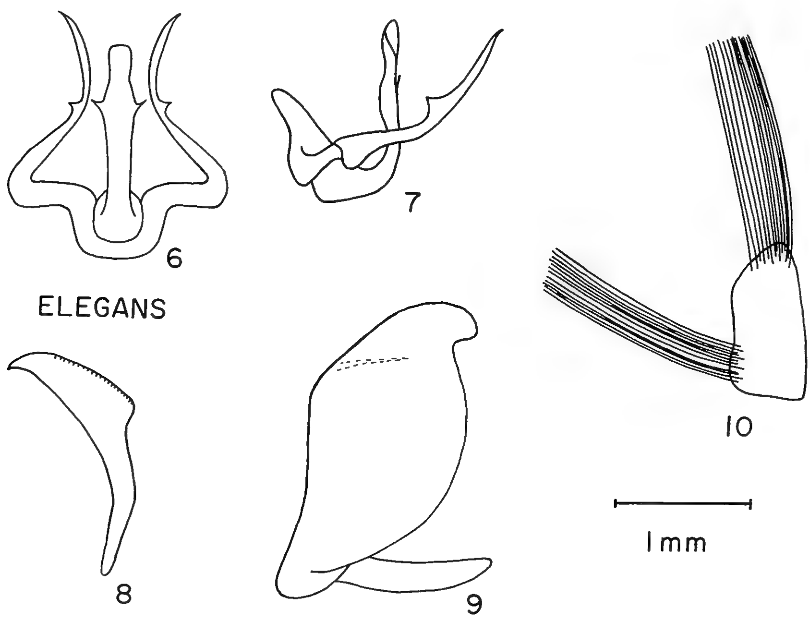
---

[1] The investigation reported in this paper (No. 92-7-49) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director.

[2] Department of Entomology, University of Kentucky, Lexington, Kentucky 40546-0091.



FIGS. 1–5. *Largulara elegans* n. sp. 1. head, pronotum and scutellum, dorsal view, 2. head, facial view, 3. head, pronotum and scutellum, lateral view, 4. crown (showing striae), dorsal view, 5. forewing. All drawn to the same scale, except Fig. 4 which is twice magnification.



FIGS. 6–10. *Largulara elegans* n. sp., male genitalia 6. aedeagus, ventral view, 7. aedeagus, lateral view, 8. style, lateroventral view, 9. pygofer and genital plate, lateral view (setae not shown), 10. genital plate, ventral view. All drawn to the same scale.

Polana (*Largulara*) *elera* DeLong and Freytag is not closely related to the 2 above species being placed in *Largulara*, so is redesignated to the subgenus *Parvulana* in the genus *Polana*.

LITERATURE CITED

1. DeLong, D. M. and P. H. Freytag. 1972. Studies of the World Gyponinae (Homoptera, Cicadellidae). The Genus *Polana*. Arquivos de Zoologia, S. Paulo 22:239–324.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 141–153

Wetland and Riparian Flora of the Upper Green River Basin, South-Central Kentucky

Bruce W. Hoagland[1] and Ronald L. Jones

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

Vascular plant collections of the wetland and riparian flora of the Upper Green River Basin yielded 500 species in 297 genera from 105 families. The greatest number of species belonged to the Asteraceae (59), Poaceae (36), Cyperaceae (35), Fabaceae (23), and Lamiaceae (19). Exotic species represented 12% of the flora. Several rare and other noteworthy species are *Heteranthera dubia, Polygala cruciata, Sagittaria brevirostra, Bartonia paniculata, Dichanthelium scoparium, Hymenocallis caroliniana, Quercus michauxii, Q. phellos, Triadenum tubulosum, Viola lanceolata, Panax quinquefolius, Platanthera peramoena, Heteranthera reniformis,* and *Xyris torta.* Six wetland habitat types in the region are described.

Introduction

This paper represents the first comprehensive floristic study of the wetland and riparian habitats of a major Kentucky river drainage basin, the Upper Green River Basin (UGRB). The significance of these wetland and riparian habitats, the rapid loss, and the need for preservation have been well documented (1, 2, 3). There have been previous studies in the UGRB area by Murphy (4), Meijer et al. (5), and some general collecting by various workers. This study is the first to target the wetland and riparian flora of the entire UGRB. Lack of plant records from this region is readily evident from the distribution maps prepared by Beal and Thieret (6). The Kentucky State Nature Preserves Commission (KSNPC) (3) identified about 90 potential wetland sites involving about 2,500 acres in the UGRB using soil maps, topographic maps, and aerial photographs. The UGRB continues to be heavily impacted through agricultural development, timber harvesting, and other disturbances. Therefore, inventory of these wetland sites is an urgent priority.

A few previous investigations have targeted the wetland and riparian habitats of the Highland Rim (7, 8, 9). In addition, there have also been several more general floristic studies of the Highland Rim that provide information on wetland and riparian habitats (4, 10, 11, 12, 13). The vegetation of the Eastern Highland Rim was summarized by McKinney (14) and Smalley (15). Wetland studies from the Bluegrass and the Shawnee Hills Sections of the Interior Low Plateaus also provide some comparable information (3, 5, 16, 17). Several studies provide overviews of the flora and vegetation of these regions (18, 19, 20).

The objectives of this study were to: (1) document the wetland and riparian flora of the UGRB, (2) note the presence of rare or other noteworthy species, and (3) compare the flora with those of similar areas on the Highland Rim and adjacent sections of the Interior Low Plateaus. This paper is based on a Master's thesis deposited at Eastern Kentucky University (21).

Study Area

The focus of this study was the UGRB inclusive of the main stem and tributaries (Fig. 1). The study area extended from the Green River Reservoir, near Casey Creek, to the headwaters of the Green River in Lincoln County, encompassing about 108,000 hectares in Lincoln, Casey, Adair, and Russell Counties. Elevations in the region range from 305 m to 396 m. Temperature averages range from 2.8°C in winter to 23°C in the summer, and total annual precipitation is 127 cm (22).

The Green River originates in the Knobstone Escarpment and Knobs Subsection of the Blue Grass Section and flows onto the Greensburg Upland Subsection of the Highland Rim Section, all within the Interior Low Plateaus Province (23). The great majority of the study site is on the Highland Rim. The upper Green River flows on a bed of Devonian New Albany Shale in Lincoln County, and westward the

[1] Current Address: Oklahoma Natural Heritage Inventory, 2001 Priestly Ave. Building 605, Norman, Oklahoma 73019.

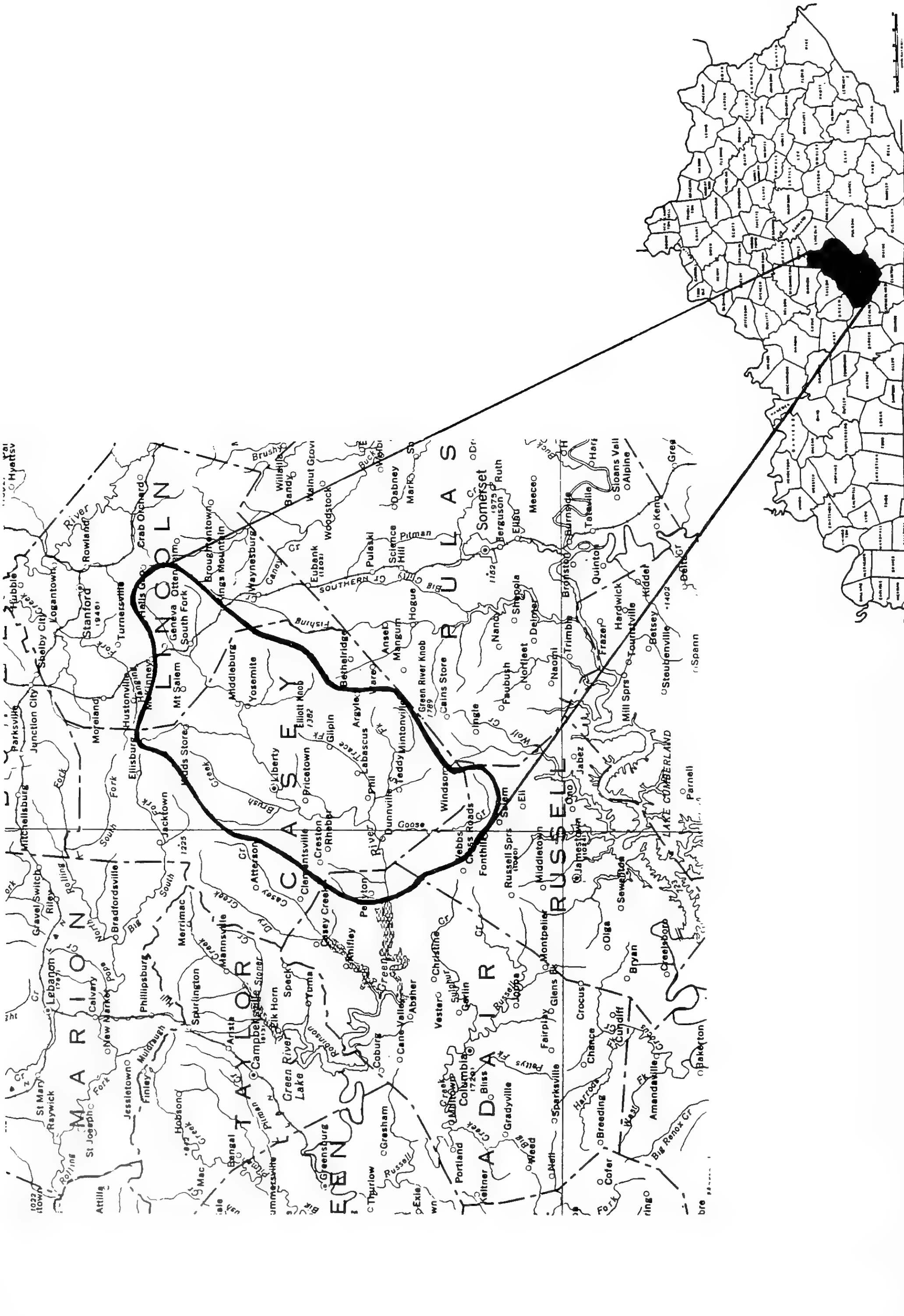


FIG. 1. Location of the Upper Green River Basin study area.

surface bedrock of the area is dominated by Mississippian limestone, with exposed Borden Formation prevalent in the drainage area (24). The Staser-Taft-Landisburg Association, the main soil association along the Green River, is somewhat poorly to well drained, and occurs on level floodplains and on gently sloping stream terraces (22).

Braun (25) described the vegetation of the UGRB region as a mosaic of "climax" types in the Western Mesophytic Forest of the Mississippian Plateau Section, and her account of the wetlands of the region are summarized in the following statements. Swamp forests occurred on poorly drained flats and in shallow depressions, with oak swamp in the wettest spots (*Quercus palustris, Q. bicolor, Q. michauxii,* and *Q. phellos*), and mixed swamp of oaks, sweet gum, red maple, sour gum, and beech, merging into wet beech woods on the wet to moist areas. Forest openings had a variety of swamp shrub and herbs, many being southern or Coastal Plain species.

MATERIAL AND METHODS

Topographic and geologic quadrangles, soil surveys, and KSNPC wetland inventory maps were consulted to identify 21 study sites in the UGRB. These sites were visited biweekly during the 1988 field season, and incidental collections were made throughout the study area. Standard herbarium techniques were used in collecting and preparing specimens. Voucher specimens were deposited in the Eastern Kentucky University Herbarium (EKU) and the Berea College Herbarium (BEREA). Additional records from the study area were obtained by surveying collections at EKU.

Classification and nomenclature follow Kartesz and Kartesz (26) except for the taxonomic differences in Cranfill (27) and Beal and Thieret (6). Wetland sites are described using the Cowardin et al. (28) classification scheme. Regional and state distributions are based on several sources (6, 29, 30, 31, 32), and on updated information from the KSNPC (pers. comm.). Rare species status is based on Warren et al. (33).

RESULTS

Flora Summary

A total of 500 species in 297 genera from 105 families were collected in the Upper Green River Basin (Table 1). Taxa consisted of 400 herbaceous plants, 86 trees and shrubs, and 14 woody vines. The greatest number of species occurred in the Asteraceae, 59, Poaceae, 36, Cyperaceae, 35, Fabaceae, 23, and Lamiaceae, 19. The genera with the largest number of species were *Carex*, 19, *Quercus*, 11, *Aster*, 10, *Juncus*, 9, and *Solidago*, 8. A total of 130 county records are reported, based upon Beal and Thieret (6). Exotic species amounted to 60 species, or 12% of the flora. The greatest number of exotic species belonged to the Poaceae, 9, Fabaceae, 9, Asteraceae, 6, Brassicaceae, 5, and Polygonaceae, 4. Three state-listed species are reported. Representatives of more northerly flora–*Quercus bicolor, Q. palustris, Populus grandidentata* and *Heteranthera dubia*, and more easterly floras—*Magnolia acuminata, Trautvetteria caroliniana, Stachys nuttallii, Aster surculosus*, and *Trillium luteum* are included. Seven extraneous taxa with a primarily Coastal Plain distribution also occur in the region. The great majority of species within the basin are eastern, southern, and central U.S. species, well within the limits of their distributions.

Rare, Coastal Plain, and Notable Exotic Species

Kentucky rare species that were previously documented from wetland and riparian habitats of the study region are *Heteranthera dubia*, a Threatened species, from 5 counties, including Adair; *Lilium superbum*, an Endangered species, from 4 counties, including Casey; *Polygala cruciata*, an Endangered species, from 5 counties, including Russell; and *Sagittaria brevirostra*, a Special Concern species, from 14 counties, including Adair and Casey (KSNPC, pers. comm.). During this study a few stems of *Heteranthera dubia* were found along Old KY 551, near Knifley, in Adair County; *Lilium superbum* was not verified, but a sterile *Lilium* specimen was found along the South Fork of Green River in Lincoln County; 6 individuals of *Polygala cruciata* were found in association with *Platanthera ciliaris* and *Dichanthelium dichotomum* in a "perched" forested wetland at the head of the Good Creek Drainage in Russell County; and scattered individuals of *Sagittaria brevirostra* were found in Casey and Adair County. Other notable infrequent taxa in the region that are

TABLE 1. An annotated floristic list for the Upper Green River Basin, Kentucky. Frequency of occurrence values abbreviated and defined as: R = rare (5 or less individuals at 1 site), I = infrequent (6–30 individuals at 1–2 sites), F = frequent (31–100 individuals at 3–6 sites), A = abundant (over 100 individuals at more than 6 sites). Counties denoted as: A = Adair, C = Casey, L = Lincoln, R = Russell. New county records follow the county entry as (r). Community association denoted as: 1 = unconsolidated shore, 2 = aquatic bed, 3 = emergent, 4 = scrub-shrub, 5 = forested wetland, 6 = mesic forest, 7 = roadside or disturbed, 8 = Riverine System. Exotic species are preceded by an asterisk. For collections at EKY other than those of the first author, only the collector and county are given. KSNPC collectors R. Hannan and L. Phillippe are abbreviated as H & P.

SPHENOPHYTA

Equisetaceae

Equisetum arvense L. I; L; 8.

LYCOPHYTA

Lycopodiaceae

Lycopodium digitatum A. Braun. I; L; 6.

PTERIDOPHYTA

Marsileaceae

Marsilea quadrifolia L. R; C; 3.

Ophioglossaceae

Botrychium dissectum Spreng. F; A, C, L; 5, 6.
B. virginianum (L.) Sw. F; A, C, L; 5, 6.

Osmundaceae

Osmunda cinnamomea L. I; R(r); 5.
O. regalis L. I; L(r), R(r); 5.

Adiantaceae

Adiantum pedatum L. I; C; 5.

Aspleniaceae

Asplenium platyneuron (L.) Oakes. I; C; 5.
Athyrium asplenoides (Michx.) A. A. Eaton. I; A; 5.
Athyrium pyconocarpon (Spreng.) Tidestrom. I; A; 5.
A. thelypteroides (Michx.) Desv. I; L; 6.
Onoclea sensibilis L. F; A(r), C(r), L(r), R(r); 5.
Polystichum acrostichoides (Michx.) Schott. A; A, C, R; 5, 6.

Thelypteridaceae

Phegopteris hexagonoptera (Michx.) Fee. F; C; 5.
Thelypteris noveboracensis (L.) Nieuwl. F; A; 5.

CONIFEROPHYTA

Cupressaceae

Juniperus virginiana L. F; A; 5.

ANTHOPHYTA

Magnoliopsida

Acanthaceae

Justicia americana (L.) Vahl. A; A(r), C; 4.
Ruellia strepens L. A; A; 5.

Aceraceae

Acer negundo L. A; C; 5.
A. nigrum Michx. f. A; A, C, L; 5, 6.
A. rubrum L. A; A, C, L, R; 5.
A. saccharinum L. A; A; 5.
A. saccharum Marsh. F; C, L; 6.

Anacardiaceae

Rhus copallina L. F; A, C; 5.
Toxicodendron radicans (L.) Kuntze. A; A, C, L, R; 5.

Annonaceae

Asimina triloba (L.) Dunal. F; A, C, L; 5, 6.

Apiaceae

Chaerophyllum procumbens (L.) Crantz. F; A; 5.
Cicuta maculata L. A; A; 5.
Cryptotaenia canadensis (L.) DC. F; A; 5.
**Daucus carota* L. A; A, C; 7.
Osmorhiza claytonii (Michx.) Clarke. *H & P* (Casey).
**Pastinaca sativa* L. R; A; 7.
Sanicula canadensis L. *H & P* (Casey).
S. gregaria Bicknell. F; L; 6.
S. smallii Bicknell. *H & P* (Casey).
S. trifoliata Bicknell. *H & P* (Casey).
Thaspium barbinode (Michx.) Nutt. I; C; 5.

Apocynaceae

Apocynum cannabinum L. I; A; 3.

Aquifoliaceae

Ilex opaca Ait. I; R; 5.
I. verticillata (L.) Gray. F; A, R, 5.

Araliaceae

Panax quinquefolia L. I; C; 6.

Aristolochiaceae

Asarum canadense L. F; A; 5.

Asclepiadaceae

Asclepias incarnata L. F, A(r), C; 3.
A. purpurescens L. F; L; 7.
A. syriaca L. F; A; 7.
A. tuberosa L. F; A, C, L; 7.
A. variegata L. *H & P* (Casey).

Asteraceae

**Achillea millefolium* L. F; C; 7.
**Anthemis cotula* L. I; C; 7.
Aster lateriflorus (L.) Britt. F; A, L; 3.
A. ontarionis Wieg. I; C; 3.
A. patens Ait. F; C; 6.
A. paternus Cronq. I; C; 5.
A. pilosus Willd. F; L; 3.
A. sagittifolius Wedemeyer. I; L; 6.
A. surculosus Michx. I; C; 7.
A. umbellatus Mill. I; R(r); 3.
A. undulatus L. F; L; 6.
A. vimineus Lam. F; C, L; 5.
Bidens aristosa (Michx.) Britt. F; A(r), C(r); 3.

TABLE 1. Continued.

B. cernua L. A; L(r), R(r); 3.
B. frondosa L. F; C(r); 3.
B. tripartita L. I; C(r); 3.
**Carduus nutans* L. F; A, C, L; 7.
Chrysopsis mariana (L.) DC. F; C; 3.
**Chrysanthemum leucanthemum* L. A; A; 7.
**Cichorium intybus* L. A; A, C, L; 7.
**Cirsium discolor* (Muhl.) Spreng. F; A, C; 7.
Conyza canadensis (L.) Cronq. F; R; 5.
Coreopsis major Walt. F; C; 3.
**Eclipta prostrata* (L.) L. F; C; 3.
Elephantopus carolinianus Willd. F; A, C, L; 5, 6.
Erechtites hieracifolia (L.) Raf. ex DC. I; C; 3.
Erigeron annuus (L.) Pers. F; A; 3.
E. philadelphicus L. F; C; 3.
E. strigosus Muhl. F; A, C; 3.
Eupatorium coelestinum L. A; A, C, R; 3, 5.
E. fistulosum Barratt A;. R(r); 5.
E. perfoliatum L. F; A(r), C(r); 5.
E. rugosum Houtt. F; A, C, L, R; 5.
E. serotinum Michx. F; C; 5.
Euthamia graminifolia (L.) Nutt. ex Cass. F; A, C, L; 5.
Helenium flexuosum Raf. F; A(r), C(r), L(r); 3.
Helianthus decapetalus L. I; L; 6.
H. tuberosa L. I; C; 7.
Hieracium gronovii L. I; C; 6.
Krigia biflora (Walt.) Blake. I; C; 6.
Lactuca floridana (L.) Gaertn. A; A, C, L; 7.
Pyrrhopappus carolinianus (Walt.) DC. I; L; 6.
Rudbeckia fulgida Ait. I; C; 3.
R. hirta L. F; A, L; 3.
Senecio anonymus Wood. I; A; 3.
S. aureus L. F; C; 3.
Silphium trifoliatum L. F; C, L; 3.
Solidago caesia L. I; C; 3.
S. canadensis L. I; C; 3.
S. erecta Pursh. F; C; 5.
S. flexicaulis I; A, C; 5.
S. gigantea Ait. F; A, C, L; 3.
S. nemoralis Ait. I; C; 3.
S. rugosa Mill. I; R; 5.
S. ulmifolia Muhl. F; A; 5.
**Taraxacum officinale* Weber. A; A, C, L, R; 7.
Verbesina alternifolia (L.) Britt. F; C; 3.
Vernonia gigantea (Walt.) Trel. ex Bronner & Coville. A; A, C, R; 3.
Xanthium strumarium L. A; A, C, L; 3.

Balsaminaceae

Impatiens capensis Meerb. A; A(r), C, L; 5.
I. pallida Nutt. F; A, C; 5.

Berberidaceae

Jeffersonia diphylla (L.) Pers. F; A; 5.
Podophyllum peltatum L. A; C; 6.

Betulaceae

Alnus serrulata (Ait.) Willd. A; A, C, L; 4, 5.
Betula nigra l. F; A; 5.
Carpinus caroliniana Walt. A; A, C, L; 5.
Corylus americana Walt. F; C; 6.

Bignoniaceae

Bignonia capreolata L. I; C; 4, 5.
Campsis radicans (L.) Seem. ex Bureau. F; C; 5.

Brassicaceae

**Barbarea vulgaris* R. Br. F; C; 3.
Cardamine bulbosa (Schreb.) BSP F;. A, C(r), R; 5.
**C. hirsuta* L. F; A; 5.
Dentaria laciniata Muhl. ex Willd. F; C; 6.
**Lepidium campestre* (L.) R. Br. I; L; 7.
**Nasturtium officinale* R. Br. F; A(r); 5.
Rorippa palustris (L.) Bess. F; A(r), C; 5.
Sisymbrium officinale (L.) Scop. I; L; 3.

Buxaceae

Pachysandra procumbens Michx. I; A, L; 6.

Campanulaceae

Campanula americana L. F; A, C; 5.
Lobelia cardinalis L. A; A, C; 3.
L. inflata L. A; A, C, L; 3.
L. puberula Michx. I; R(r); 5.
L. siphilitica L. F; A(r), C(r), L(r); 5.
L. spicata Lam. I; C; 3.

Caprifoliaceae

**Lonicera japonica* Thunb. A; A, C; 5.
Sambucus canadensis L. I; C; 5.
Symphoricarpos orbiculatus Moench. F; C; 6.
Viburnum acerifolium L. R; C; 6.
V. dentatum L. var. *scabrellum* T. & G. R; C; 6.
V. prunifolium L. I; A, R; 5.

Caryophyllaceae

**Saponaria officinalis* L. F; A; 7.
Silene virginica L. I; A; 6.
**Stellaria media* (L.) Cyrill. F; C; 5.
S. pubera Michx. F; C; 5.

Celastraceae

Euonymus americanus L. A; A, C; 5.

Ceratophyllaceae

Ceratophyllum demersum L. I; C; 2.

Chenopodiaceae

**Chenopodium ambrosioides* L. I; R; 5.

Convolvulaceae

Cuscuta glomerata Choisey. I; R; 3.
C. obtusiflora HBK. F; A, L; 3.
**Ipomoea hederacea* (L.) Jacq. R; A; 1.
I. lacunosa L. F; A, C; 7.
I. pandurata (L.) G. F. W. Meyers. F; A; 7.

Cornaceae

Cornus florida L. A; A, C, L, R; 5.
C. amomum P. Mill. ssp. *obliqua* (Raf.) J. S. Wilson. F; A, C; 5.

Crassulaceae

Penthorum sedoides L. F; A(r), C; 3.
Sedum ternatum Michx. I; A; 5.

TABLE 1. Continued.

Cucurbitaceae

Sicyos angulatus L. I; R; 5.

Dipsacaceae

**Dipsacus sylvestris* Huds. F; C; 7.

Ericaceae

Chimaphila maculata (L.) Pursh. F; A, C, L; 5, 6.
Monotropa uniflora L. F; L; 6.
Oxydendrum arboreum (L.) DC. F; C, R; 5.
Rhododendron periclymenoides (Michx.) Shinners. I; R; 5.
Vaccinium corymbosum L. F; R; 5.
V. pallidum Ait. A; A, C, R; 5.

Euphorbiaceae

Acalypha virginica L. I; L; 6.
Chamaesyce maculata (L.) Small F; L, R; 3.
Euphorbia commutata Engelm. I; A; 3.
E. corollata L. F; A, C; 3.

Fabaceae

Amorpha fruticosa L. I; A; 5.
Amphicarpaea bracteata (L.) Fern. I; L; 3.
Apios americana Medic. I; C; 5.
Cassia fasciculata Michx. I; C; 5.
C. nictitans L. I; R; 5.
Cercis canadensis L. F; C; 6.
Desmodium nudiflorum (L.) DC. I; C; 3.
D. paniculatum (L.) DC. I; A; 3.
D. pauciflorum (Nutt.) DC. F; A, C; 3.
D. viridiflorum (L.) DC. I; R; 3.
Gleditsia triacanthos L. F; R; 5.
**Kummerowia stipulacea* (Maxim.) Makino. F; A, R; 3, 7.
**Lathyrus latifolius* L. I; A; 3.
**Lespedeza cuneata* (Dumont-Cours.) G. Don. F; A, C; 3.
**Medicago sativa* L. F; L; 6.
**Melilotus alba* Desr. A; A; 3.
**M. officinalis* (L.) Desr. F; L; 6.
Psoralea psoralioides (Walt.) Cory. var. *eglandulosa* (Ell.) Freeman F; C; 3.
Strophostyles helvola (L.) Ell. I; C; 6.
**Trifolium campestre* Schreb A; C; 7.
**T. pratense* L. A; C; 7.
Vicia caroliniana Walt. I; C; 6.
**V. dasycarpa* Tenore. F; A; 5.

Fagaceae

Fagus grandifolia Ehrh. A; A, C, L, R; 5, 6.
Quercus alba L. A; A, C, L, R; 5, 6.
Q. bicolor Willd. F; A, C, R; 5.
Q. falcata Michx. I; A, L; 5, 6.
Q. marilandica Muenchh. I; R; 6.
Q. michauxii Nutt. R; A; 5.
Q. muhlenbergii Engelm. I; R; 5.
Q. palustris Muenchh. F; A; 5.
Q. phellos L. F; A, R; 5.
Q. rubra L. var. *borealis* (Michx. f.) Farw. F; C; 5.
Q. shumardii Buckl. F; C, R; 5, 6.
Q. velutina Lam. F; C; 5.

Gentianaceae

Bartonia paniculata (Michx.) Muhl. R; A(r); 5.
Sabatia angularis (L.) Pursh. I; A(r), L(r); 3.
Obolaria virginica L. *Shelton* (Adair).

Geraniaceae

Geranium carolinianum L. I, A, 7.

Halogaridaceae

**Myriophyllum aquaticum* (Vellezo) Verdcourt. R; C(r); 2.

Hamamelidaceae

Hamamelis virginiana L. I; L; 6.
Liquidambar styraciflua L. A; A, C, L, R; 5, 6.

Hippocastanaceae

Aesculus glabra Willd. F; A, L; 5, 6.

Hydrophyllaceae

Hydrophyllum canadense L. R; L; 5.
Phacelia purshii Buckl. F; C; 7.

Hypericaceae

Hypericum gentianoides (L.) BSP. I; C, L; 3.
H. mutilum L. F; A(r), C(r), L; 5.
**H. perforatum* L. I; L; 5.
H. prolificum Michx. I; A; 5.
H. punctatum Lam. F; C; 3.
Triadenum tubulosum (Walt.) Gleason. I; A; 3.

Juglandaceae

Carya cordiformis (Wang.) K. Koch. F; A, C, L; 5.
C. glabra (P. Mill.) Sweet. F; A; 5.
C. laciniosa (Michx. f.) Loud. F; A, C; 5.
C. ovata (P. Mill.) K. Koch. F; A, C, L; 5, 6.
Juglans nigra L. I; L; 6.

Lamiaceae

**Glechoma hederacea* L. A; C; 5.
Lycopus americanus Muhl. ex. Bart. A; A(r), C(r); 3.
L. virginicus L. F; A(r), C(r), R(r); 5.
**Mentha* X *piperata* L.* I; C(r); 3.
Monarda fistulosa L. F; A; 7.
**Perilla frutescens* (L.) Britt. I; R; 8.
Physostegia virginiana (L.) Benth. R; C(r); 5.
Prunella vulgaris L. F; A, C, L; 5.
Pycnanthemum flexuosum Schrad. I; A, C; 5.
P. pilosum Nutt. I; C; 6.
P. pycnanthemoides (Leavenw.) Fern. R; C; 6.
P. tenuifolium Schrad. I; A; 5.
Salvia lyrata L. F; C, L; 5.
Scutellaria incana Biehler. R; L; 6.
S. integrifolia L. I; A; 3.
S. laterifolia L. F; L; 6.
S. parvula Michx. R; L; 6.
Stachys nuttallii Shuttlw. ex Benth. *H & P* (Casey).
Teucrium canadense L. I; C, L; 3.

Lauraceae

Lindera benzoin (L.) Blume. F; A, L; 5, 6.
Sassafras albidum (Nutt.) Nees. F; A, L, R; 5, 6.

TABLE 1. Continued.

Linaceae

Linum striatum Walt. I; C; 3.

Lythraceae

Ammannia coccinea Rottb. I; A(r), L(r); 3.
Cuphea viscosissima Jacq. R; C; 3.
Rotala ramosior (L.) Koehne. *Lassetter* (Casey).

Magnoliaceae

Liriodendron tulipifera L. A; A, C, L, R; 5, 6.
Magnolia acuminata L. *H* & *P* (Casey).

Malvaceae

Hibiscus laevis All. R: C(r); 3.
H. moscheutos L. A; A(r), C(r); 3, 4.
**Sida spinosa* L. I; A; 3.

Melastomataceae

Rhexia mariana R; R; 5.
R. virginica L. R; R; 5.

Moraceae

**Morus alba* L. I; R; 5.
M. rubra L. I: R; 5.

Nymphaeaceae

Nuphar luteum (L.) Sibtn. & Sm. A; A, C; 2, 4.

Nyssaceae

Nyssa sylvatica Marsh. A; A, C, R; 5.

Oleaceae

Chionanthus virginicus L. R; C; 6.
Fraxinus americana L. F; A, C; 5, 6.
F. pennsylvanica Marsh. F; A, C; 5.

Onagraceae

Epilobium coloratum Biehler. I; C(r); 5.
Ludwigia alternifolia L. F; A, C, L; 5.
L. decurrens Walt. F; A(r); 5.
L. palustris (L.) Ell. A; A(r), C, L; 3.
Oenothera biennis L. F; A, C; 5.
O. parviflora L. R; A; 5.
O. tetragona Roth. R; A: 5.

Orobanchaceae

Conopholis americana (L.) Wallr. I; A; 6.
Epifagus virginiana (L.) Bart. F; A, C; 5, 6.

Oxalidaceae

O. stricta L. F; A, L; 7.

Papaveraceae

Corydalis flavula (Raf.) DC. I; A; 5.
Dicentra cucullaria (L.) Bernh. I; A; 5.
Sanguinaria canadensis L. I; R; 5.
Stylophorum diphyllum (Michx.) Nutt. I; A; 5.

Phytolaccaceae

Phytolacca americana L. F; A; 7.

Plantaginaceae

Plantago aristida Michx. R; A; 7.
**P. lanceolata* L. F; L; 7.
P. rugelii Dcne. F; C, L; 7.

Platanaceae

Platanus occidentalis L. F; A, C, L; 5.

Polemoniaceae

Phlox divaricata L. F; A, C; 5.
P. paniculata L. F; C, L; 5.
Polemonium reptans L. I; A; 5.

Polygalaceae

Polygala cruciata L. R; R; 5.
P. sanguinea L. F; A, C; 3.

Polygonaceae

**Polygonum caespitosum* Blume var. *longisetum* (de Bruyn) A. N. Stewart. F;. C(r), L(r), R(r); 3, 5.
P. pensylvanicum L. I; C, R(r); 5.
**P. persicaria* L. F; C; 3.
P. punctatum Ell. I; C, L, R(r); 5.
P. sagittatum L. F; C(r); 3.
**Rumex conglomeratus* Murr. I; C; 3.
**R. crispus* L. F; L; 1, 3.
R. verticillatus L. F; A, C; 3.

Primulaceae

Lysimachia ciliata L. *Lassetter* (Casey).
**L. nummularia* L. F; C(r); 3.
L. quadrifolia L. I; A(r), L(r); 5.

Ranunculaceae

Actaea pachypoda Ell. R; L; 6.
Cimcifuga racemosa (L.) Nutt. R; L; 6.
Clematis virginiana L. I; C; 3.
Delphinium tricorne Michx. I; A; 5.
Ranunculus abortivus L. F; A(r); 5.
R. hispidus Michx. F; A, C; 5.
R. pensylvanicus L.f. I; C; 5.
R. recurvatus Poir. I; A; 5.
Thalictrum pubescens Pursh. I; A; 5.
T. thalictroides (L.) Eames and Boivin. I; A; 5.
Trautvetteria carolinensis (Walt.) Vail. *H* & *P* (Casey).

Rhamnaceae

Rhamnus caroliniana Walt. I; C; 6.

Rosaceae

Agrimonia parviflora Ait. F; C, L; 6.
Amelanchier arborea (Michx. f.) Fern. F; C, R; 5, 6.
Aronia melanocarpa (Michx.) Ell. R; R; 5.
Crataegus pruinosa (Wendl. f.) K. Koch. I; C; 6.
Geum canadense Jacq. F; A, L; 5, 6.
Potentilla norvegica L. I; C; 5.
P. simplex Michx. F; C; 5.
Prunus americana Marsh. I; C; 6.
P. munsoniana Wright & Hedrick. I; A; 5.
P. serotina Ehrh. F; A, L; 5, 6.
Rosa carolina L. F; L; 6.
**R. multiflora* Thunb. F; L; 6.
R. palustris Marsh. F; A, C; 3, 5.
R. setigera Michx. I; A; 5.
Spiraea tomentosa L. F; A; 3.

TABLE 1. Continued.

Rubiaceae

Cephalanthus occidentalis L. A; A, C; 4.
Diodia teres Walt. F; A, C; 3.
D. virginiana L. F; A(r), C(r), L(r), R(r); 3, 5.
Galium aparine L. *Shelton* (Adair).
G. obtusum Bigelow. I; A(r); 5.
G. tinctorium L. F; A(r), C(r); 5.
Hedyotis caerulea (L.) Hook. F; C; 7.
H. purpurea (L.) T. & G. I; L; 6.
Mitchella repens L. F; A, C; 5.

Salicaceae

Populus deltoides Bartr. ex Marsh. I; A, C; 5.
P. grandidentata Michx. I; L; 6.
Salix caroliniana Michx. F; A; 5.
S. nigra Marsh. F; C, L; 4, 5.
S. sericea Marsh. F; A, L; 5.

Saururaceae

Saururus cernuus L. A; A(r), C; 3, 5.

Saxifragaceae

Hydrangea arborescens L. I; C; 6.

Scrophulariaceae

Agalinis purpurea (L.) Pennell. F: C: 7.
Aureolaria virginica (L.) Pennell F; R; 5.
Gratiola virginiana L. F; C(r); 3.
**Kickxia elatine* (L.) Dum. R; A; 5.
Lindernia dubia (L.) Pennell. I; A(r); 5.
Mimulus alatus Ait. A; A(r), C; 3.
M. ringens L. A; A(r), C(r); 3.
Penstemon calycosus Small. R; L; 6.
**Verbascum thapsus* L. F; C; 7.

Solanaceae

Datura stramonium L. I; A; 7.
Physalis longifolia Nutt. I; C; 5.
Solanum americanum P. Mill. I; R; 5.
S. carolinense L. F; A, C, L; 7.

Tiliaceae

Tilia americana L. *H* & *P* (Casey).

Ulmaceae

Ulmus alata Michx. I; A, C; 5.
U. americana L. F; A, C, L; 5, 6.
U. rubra Muhl. F; A, C, L; 5, 6.

Urticaceae

Boehmeria cylindrica (L.) Sw. F; L(r), C; 5.
Laportea canadensis (L.) Weddell. F; L; 5.
Pilea pumila (L.) Gray. F; R(r); 5.

Valerianaceae

Valerianella radiata (L.) Dufr. I; C; 3.

Verbenaceae

Phyla lanceolata (Michx.) Greene. R; A(r); 3.
Verbena hastata L. F; A(r), C(r); 3.
V. urticifolia L. F; C, R; 3, 5.

Violaceae

Viola lanceolata L. I; A(r); 5.
V. pubescens Ait. var. *eriocarpa* (Schwein.) Russell. I; A; 5.
V. rostrata Pursh. I; C; 5.
V. sororia Willd. F; C; 6.
V. striata Ait. F; A, C; 5.

Vitaceae

Amelopsis cordata Michx. I; C; 5.
Parthenocissus quinquefolia (L.) Planch. A; A, C, L, R; 5, 6.
Vitis aestivalis Michx. I; A; 5.
V. cinerea Engelm. ex Millard. I; R; 5.
V. vulpina L. I; C; 5.

LILIOPSIDA

Alismataceae

Alisma subcordatum Raf. F; A, C; 3, 5.
Sagittaria australis (J. G. Sm.) Small. I; A; 3.
S. brevirostra Mack. & Bush. F; A(r), C(r); 3.
S. calycina Engelm. *Jeffries* (Casey).
S. latifolia Willd. F; C(r); 3.

Araceae

Acorus calamus L. A; A(r), C(r); 3.
Arisaema triphyllum (L.) Schott. F; C; 5.
A. dracontium (L.) Schott. R; L; 6.

Commeliniaceae

**Commelina communis* L. F; A; 8.

Cyperaceae

Carex complanata Torr. & Hook. I; C; 5.
C. crinata Lam. I; A(r); 5.
C. cristatella Britt. *Jeffries* (Casey).
C. digitalis Willd. I; C; 5.
C. frankii Kunth. I; L(r); 3.
C. granularis Muhl. ex Willd. *Jones* (Casey).
C. grayi Carey. I; A(r); 5.
C. intumescens Rudge. I; R(r); 5.
C. lupulina Willd. F; A(r), C(r), L(r); 5.
C. lurida Wahlenb. F; C, R(r); 5.
C. rosea Willd. F; A; 5.
C. squarrosa L. F; A; 5.
C. stipata Muhl. ex Willd. I; C; 5.
C. swanii (Fern.) Mackenzie. I; C; 6.
C. torta Boott. R; C(r); 8.
C. tribuloides Wahlenb. F; A(r), C(r); 3.
C. umbellata Schkuhr. ex Willd. I; C; 5.
C. virescens Willd. I: C; 5.
C. vulpinoidea Michx. *Jones* (Casey).
Cyperus esculentus L. I; A(r); 3.
C. flavescens L. I; L(r); 3.
C. pseudovegetus Steud. F; A(r), C(r); 3.
C. strigosus L. A; A(r), C(r), L, R(r); 3.
Eleocharis acicularis (L.) R. & S. A; A; 1.
E. erythropoda Steud. I; A; 3.
E. ovata (Roth) R & S. A; A(r), C, L; 3.
E. tenuis (Willd.) Schult. A; A, C, L; 3.
Fimbristylis autumnalis (L.) R. & S. R; L; 3.
Rhynchospora glomerata (L.) Vahl. R; R(r); 5.
Scirpus atrovirens Willd. A; A, C, L; 3.

TABLE 1. Continued.

S. cyperinus (L.) Kunth. I; A(r), C(r); 3.
S. pendulus Muhl. F; C, L; 3.
S. polyphyllus Vahl. I; A(r); 3.
S. validus Vahl. A; A, C, L; 3.
Scleria oligantha Michx. R; C; 5.

Dioscoreaceae

Dioscorea quaternata (Walt.) J. F. Gmel. I; R; 5.

Iridaceae

Iris cristata Soland. F; C; 6.
**I. pseudoacorus* L. R; C(r); 3.
I. virginica L. F; A(r), C(r); 3, 4, 5.
Sisyrinchium angustifolium P. Mill. F; A; 5.

Juncaceae

Juncus acuminatus Ell. F; A(r), C, L; 3.
J. biflorus Ell. I; C; 3.
J. brachycarpus Engelm. A; A(r), C(r), L, R(r); 3.
J. diffusissumus Buckl. F; A(r), C(r); 3.
J. dudleyi Wieg. F; C(r); 3.
J. effusus L. Var. *solutus* Fern. & Wieg. A; A(r), C(r), L; 3.
J. marginatus Rostk. I; C(r); 3.
J. tenuis Willd. A; A, C, L, R; 3, 6.
J. torreyi Coville. I; C(r); 5.
Luzula campestris (L.) DC. F; C; 5.

Lemnaceae

Spirodela polyrhiza (L.) Schleid. F; A(r), C(r); 2.

Liliaceae

Allium cernuum Roth. F; C; 5.
**A. vineale* L. F; A, L; 5, 6.
Erythronium americanum Ker-Gawl. F; C; 5.
**Hemerocallis fulva* L. I; A; 7.
Hymenocallis caroliniana (L.) Herb. R; A; 5.
Lilium sp. R; L; 5.
Polygonatum biflorum (Walt.) Ell. I; C; 5.
Smilacina racemosa (L.) Desf. I; C; 5.
Trillium luteum (Muhl.) Harbison. I; R; 6.
T. sessile L. F; A; 5.
Uvularia perfoliata L. I; L; 5.

Najadaceae

Najas guadalupensis (Sprang) Magnus. I; L(r); 2.

Orchidaceae

Goodyera pubescens (Willd.) R. Br. I: A; 5.
Isotria verticillata (Muhl. ex Willd.) Raf. *H* & *P* (Casey).
Liparis liliifolia (L.) L. C. Rich. ex Lindl. *H* & *P* (Casey).
Platanthera ciliaris (L.) Lindl. R; R(r); 5.
P. flava (L.) Lindl. R; A(r); 5.
P. peramoena (Gray) Gray. I; A; 5.
Spiranthes cernua (L.) L. C. Rich. R; A; 3.

Poaceae

**Agrostis gigantea* Roth. I; L; 6.
A. perennans (Walt.) Tuckerm. F; A, C, L; 5.
A. scabra Willd. F; A, L; 5.
Alopecurus carolinianus Walt. F; A; 5.
Andropogon virginicus L. F; C; 7.
**Anthoxanthum odoratum* L. F; L; 6.
Arundinaria gigantea (Walt.) Muhl. F; A, C, L; 6.
**Bromus commutatus* Shrad. I; C; 6.
Chasmanthium latifolium (Michx.) Yates. F; A, C, L; 5, 6.
Cinna arundinacea L. F; A, L; 5.
Dichanthelium acuminatum (Sw.) Gould & Clark. I: A; 5.
D. clandestinum (L.) Gould. I; L; 6.
D. commutatum (Schultes.) Gould. I; C; 5.
D. dichotomum (L.) Gould. F; C, R; 5.
D. scoparium (Lam.) Gould. F; C; 5.
D. sphaerocarpon (Ell.) Gould. F; C; 5.
**Echinochloa crusgalli* (L.) Beavu. F; A(r); 3.
Elymus virginicus L. F; A, C; 5.
**Festuca arundinacea* Schreb. A; A, C; 5.
F. obtusa Biehler. I; A; 5.
Glyceria striata (Lam.) A. S. Hitchc. A; A(r), C(r); 3.
**Holcus lanatus* L. F; C, L; 5.
Hystrix patula Moench. I; L; 6.
Leersia oryzoides (L.) Sw. A; C; 3.
**Microstegium vimineum* (Trin.) A. Camus. I; L; 5.
Muhlenbergia tenuiflora (Willd.) BSP. I; A; 5.
Panicum anceps Michx. I; A(r); 5.
P. laxiflorum Lam. I; A; 5.
P. rigidulum Bosc. ex Nees. I; C; 5.
Paspalum leave Michx. F; C; 6.
Poa autumnalis Muhl. ex Ell. F; C; 5.
**P. pratensis* L. A; A, C, L; 5, 6.
P. sylvestris Gray. F; A; 5.
**Setaria glauca* (L.) Beav. F; A, C; 7.
**Sorghum halapense* (L.) Pers. F; C; 7.
Tridens flavus (L.) A. S. Hitchc. A; C; 7.

Pontederiaceae

Heteranthera dubia (Jacq.) MacM. R; A(r); 2.
H. reniformis R&P. R; A(r); 2.

Potamogetonaceae

Potamogeton foliosus Raf. I: C(r); 2.

Smilacaceae

Smilax bona-nox L. I; A; 5.
S. glauca Walt. F; A, L; 5, 6.
S. hispida Muhl. I; L; 6.
S. rotundifolia L. F; A, L, R; 5, 6.

Sparganiaceae

Sparganium americanum Nutt. F; A(r), C; 3, 4.

Typhaceae

Typha latifolia L. A; A(r), C, L(r); 3.

Xyridaceae

Xyris torta Sm. R; C(r); 5.

not currently listed by KSNPC are *Panax quinquefolius*, *Viola lanceolata*, *Platanthera peramoena*, *Xyris torta*, and *Heteranthera reniformis*.

New county records, based on Beal and Thieret (6), were documented for several Coastal Plain taxa. *Hymenocallis caroliniana*, primarily distributed in the western one-third of the state, was found in a forested wetland in Adair Co. *Bartonia paniculata*, with scattered records across southern Kentucky was found in *Sphagnum* spp. clumps in a forested wetland in Adair Co. *Dichanthelium scoparium*, with scattered records across western and southern Kentucky (J. Campbell, unpub. data), was observed frequently in the forested wetlands of Casey County. *Triadenum tubulosum*, previously documented from the Jackson Purchase and several Highland Rim counties, was found in an emergent wetland in Adair County. Other Coastal Plain species previously documented from this region include *Polygala cruciata*, *Quercus michauxii*, and *Q. phellos*. *Calamagrostis cinnoides* (Muhl.) Bart. was reported from Casey County wetlands by Braun (34) but was not verified during this study.

Three notable exotics were found in the emergent wetland near the junction of US 127 and KY 70, at Liberty, in Casey County. *Iris pseudoacorus* was known previously from some counties adjacent to the Ohio River. *Marsilea quadrifolia* was first collected from this site by M. L. Branson in 1978. The only other known site for the state was from the Inner Bluegrass and it is thought to be extirpated. A recent check of the population at Liberty indicates that, although road construction has destroyed a portion of the site, the plants are still thriving, colonizing extensive areas along a slow-moving stream, and producing abundant sporocarps. *Myriophyllum aquaticum*, the third notable exotic, has also been documented from Trigg and Russell Counties and it should be monitored because of its tendency to become a troublesome aquatic weed.

Wetland Habitat Types

1. Vegetated Unconsolidated Shore Class.—These habitats are composed of lake, pond, and river sediments that are exposed along the margins by drawdowns or drought. Late summer drawdowns lead to prolific colonization by *Eleocharis acicularis* at lake sites in the Green River Reservoir Wildlife Management Area (GRRWMA). At other sites *Cyperus flavescens*, *Elecharis ovata*, *Ipomea hederacea*, *Xanthium strumarium*, *Echinochloa crus-galli*, and other weedy species were found. No rare or Coastal Plain species were found.

2. Aquatic Bed Class.—This community type was typically found in deep-water habitats lacking emergent vegetation. The only free-floating plant noted was *Spirodela polyrhiza*, and the dominant rooted and floating-leaved plant was *Nuphar luteum*. Rooted submergents included *Ceratophyllum demersum*, *Potamogeton foliosus*, *Najas quadalupensis*, and *Ludwigia palustris*. The only rare species was *Heteranthera dubia*.

3. Emergent Wetland Class.— Wetland sites dominated by herbaceous plants varied a great deal from site to site, but were typically dominated by sedges, grasses and rushes. *Glyceria striata* and *Leersia oryzoides* were found at nearly all emergent wetland sites, under light to dense cover. *Juncus brachycephalus*, *J. effusus*, and *J. tenuis*, and other rushes were also important species. *Carex tribuloides*, *Cyperus strigosus*, *Eleocharis ovata*, *Scirpus atrovirens* and *S. validus* were sedges found at most sites. *Typha latifolia* and *Acorus calamus* often formed monotypic patches within emergent wetlands. Dicotyledonous plants did not dominate particular stands, but were often important associates. *Bidens cernua*, *Eupatorium coelestinum*, *Hibiscus moscheutos*, *Lobelia cardinalis*, *Ludwigia palustris*, *Mimulus alatus*, *M. ringens*, and *Polygonum sagittatum* were included. Notable species were *Sagittaria brevirostra* and *Triadenum tubulosum*.

4. Scrub-Shrub Wetland Class.—*Cephalanthus occidentalis* was very common in areas dominated by small woody plants, along with *Alnus serrulata*, *Salix nigra* and *S. sericea*. Herbaceous associates included many of the same taxa found in emergent wetland communities.

5. Forested Wetland Class.—Forested wetlands occurred on floodplains and on moist upland flats and slight depressions over poorly drained soils. Sinkhole swamp forests were not found in the region. The most prevalent canopy member in the forested wetland was *Acer rubrum*. *Betula nigra*, *Fagus grandifolia*, *Fraxinus pennsylvanica*, *Liquidambar styraciflua*, *Liriodendron tulipifera*, and *Nyssa sylvatica* were common associates. Wetland oaks

present in the region were *Quercus bicolor, Q. palustris,* and *Q. phellos.* Common shrubs included *Euonymus americana, Lindera benzoin, Sambucus canadensis, Rhododendron periclymenoides, Ilex verticillata,* and *Vaccinium corymbosum.*

The most common wetland ferns were *Onoclea sensibilis, Athyrium thelypteroides,* and *Polystichum acrostichoides. Osmunda regalis* and *O. cinnamomea* were found at only one site. Herbaceous plants common in wet forests, some of which have standing water for prolonged periods, included *Boehmeria cylindrica, Carex grayii, C. lurida, C. rosea, C. squarrosa, Cinna arundinacea, Impatiens capensis, I. pallida, Iris cristata, I. virginica, Juncus effusus, Laportea canadensis, Mitchella repens,* and *Dichanthelium dichotomum. Platanthera peramoena* was frequently seen in this habitat and *Xyris torta* was infrequent. Rare or Coastal Plain species in these habitats were *Bartonia paniculata, Hymenocallis caroliniana,* and *Polygala cruciata.*

Collection sites in the headwaters of the study area were similar to mesic forest sites. Common graminoids at these sites included *Carex swanii, C. vulpinoidea, Cinna arundinacea, Hystrix patula,* and *Juncus tenuis.* Other mesic herbaceous elements included *Actaea pachypoda, Arisaema dracontium, A. triphyllum, Chimaphila maculata, Cimicifuga racemosa, Geum canadensis, Houstonia purpurea, Monotropa uniflora, Podophyllum peltatum, Polemonium reptans,* and *Sanicula canadensis.*

6. Lower Perennial Emergent Class.—On the main stem of the Green River, these sites were almost entirely dominated by *Justicia americana.* Associates were *Bidens cernua, B. frondosa, Cyperus strigosus, Eupatorium rugosum, Pilea pumila, Polygonum caespitosum, P. pennsylvanicum, P. punctatum, Solanum americanum,* and *Verbena urticifolia. Glyceria striata, Impatiens capensis, Juncus effusus, Scirpus atrovirens,* and *S. pendulus* occurred in the streambed or near the water's edge, under thin canopies or on bankside slumps.

DISCUSSION

Although the UGRB has been heavily disturbed, it still has a relatively high species richness, with 500 species documented for wetland and riparian habitats. The 130 new county records provide additional information on the known distributions of aquatic and wetland species in Kentucky. While most of the species are intraneous, there is evidence of some intermixing of floras from different regions. *Quercus bicolor* and *Q. palustris* are north-central species, and the former species is near the southerly limit of its range. These 2 wetland oaks are good indicator species for most central Kentucky wetlands (5). Several Appalachian species also occur in the area, and others, *Aesculus flava* and *Tilia heterophylla,* occur just outside the study area in northern Casey County (KSNPC, unpub. data). In comparing this region to other similar sites on the Interior Low Plateaus the occurrence of Coastal Plain species was of interest. The presence of these extraneous species provides evidence of the geographic affinities of these sites, and on the extent of northward plant migrations through the region.

The similarities and differences between the flora of the UGRB and those of other sites on the Highland Rim (4, 5, 7, 8, 9, 10, 11, 12, 13) is summarized in the following account. A total of 125 of the 253 species previously reported for Casey County (4) were documented. Twenty eight of the 31 species listed for the upper Green River by Meijer et al. (5) were found, and 131 of the 197 species listed for the nearby Brodhead swamp (7) were collected. The Highland Rim riparian and floodplain floras were generally similar in all of the studies, with many of the same intraneous species in the open water, drawdown, emergent, scrub-shrub, and forested wetlands. Highland Rim sites with sinkhole swamps and more persistent open water sites (7, 8, 9, 11) tend to have a higher percentage of Coastal Plain species, e.g., *Quercus lyrata, Decodon verticillatus,* and *Itea virginica,* and higher numbers of floating-leaved and submerged species, probably because of the longer existence of the habitat and lesser disturbance.

Some similarities and differences with the UGRB can also be noted in comparing wetlands in adjacent sections of the Interior Low Plateaus. The lowlands of the Shawnee Hill Section differed from the study area in having more deep-water forested wetlands and in the greater numbers of Coastal Plain species, e.g., *Taxodium distichum* and *Fraxinus profunda* (18). Wetland sites elsewhere in the Knobs region (5, 19, 20) are generally very similar to those reported for the study area. Bluegrass wetlands are very infrequent and often associated with sinking creeks or abandoned river channels (16, 17), and are noted for the presence of *Q. bicolor,* and for several species not yet found in the UGRB.

The wetland habitat types of the Upper Green River Basin are thus not as high in species richness as some other sites on the Interior Low Plateaus, especially those with higher numbers of southern species. However, some rare species and some species of geographic interest can still be found. Coastal Plain and other extraneous species on the Interior Low Plateaus are of interest from a phytogeographic standpoint, and it is only by further documentation of these occurrences that past and present species distributions can be better understood.

There are several individual areas of high species richness in the Upper Green River Basin, especially open to partially wooded sites with seasonal standing water. These sites, however, are disappearing rapidly. The emergent wetland at the junction of KY 70 and US 127, virtually in downtown Liberty, was once a highly rich area with a number of interesting plants. Unfortunately, it has now been heavily impacted by road construction. Continued studies focusing on the location and monitoring of these sites should therefore have high priority, in order to preserve what remains of the wetland and riparian flora of south-central Kentucky.

ACKNOWLEDGMENTS

Support for this study was provided by the Marcia Athey Fund of the Kentucky Academy of Science. Thanks are extended to to Dr. William Martin and Dr. Branley Branson for serving on the thesis committee, and to Dr. Ralph Thompson for help with plant identifications. The assistance of Barbara Jeffries and Frances Carter in locating wetland sites in the region was greatly appreciated.

LITERATURE CITED

1. Mitsch, W. J. and J. G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold, New York.

2. Dahl, T. E. 1990. Wetlands losses in the United States 1780s to 1980s. U.S. Dept. of the Interior, Fish and Wildl. Serv., Washington, D.C.

3. Hannan, R. R., W. L. Fisher, and R. R. Cicerello. 1986. Wetlands protection strategies for Kentucky. Tech. Rep. Kentucky Nature Preserves Commission.

4. Murphy, G. W. 1970. A preliminary survey of the flora of Casey County, Kentucky. Castanea 35:118–131.

5. Meijer, W., J. J. N. Campbell, H. Setser, and L. E. Meade. 1981. Swamp forests on high terrace deposits in the Bluegrass and Knobs regions of Kentucky. Castanea 46:122–135.

6. Beal, E. O. and J. W. Thieret. 1986. Aquatic and wetland plants of Kentucky. Kentucky Nature Preserves Commission Scientific and Technical Series No. 5.

7. Hannan, R. R. and J. S. Lassetter. 1982. The vascular flora of the Broadhead Swamp forest, Rockcastle County, Kentucky. Trans. Ky. Acad. Sci. 43:43–49.

8. Homoya, M. 1983. The upland sinkhole swamps and ponds of Harrison County, Indiana. Proc. Indiana Acad. Sci. 92:383–387.

9. Ellis, W. H. and E. W. Chester. 1989. Upland swamps of the Highland Rim of Tennessee. J. Tenn. Acad. Sci. 64:97–101.

10. Johnson, G. 1980. A floristic survey of the vascular plants of Barren County, Kentucky. M.S. Thesis. Western Kentucky University, Bowling Green, Kentucky.

11. Cranfill, R. 1991. Flora of Hardin County, Kentucky. Castanea 56:228–267.

12. Carpenter, J. S. and E. W. Chester. 1987. Vascular flora of the Bear Creek Natural Area, Stewart County, Tennessee. Castanea 52:112–128.

13. Souza, K. and R. Kral. 1990. The vascular flora of Dickson County, Tennessee. J. Tenn. Acad. Sci. 65:91–100.

14. McKinney, L. 1989. Vegetation of the Eastern Highland Rim of Tennessee. J. Tenn. Acad. Sci. 64:145–147.

15. Smalley, G. W. 1979. Classification and evaluation of forest sites on the Eastern Highland Rim and Pennyroyal. U.S. Dept of Agric. For. Serv., Washington, D.C.

16. Bryant, W. S. 1978. An unusual forest type, hydromesophytic, for the Inner Bluegrass region of Kentucky. Castanea 43:129–137.

17. Meijer, W. 1976. Notes on the flora of the Sinking Creek System and Elkhorn source areas in the Inner Blue Grass Region of Kentucky. Trans. Ky. Acad. Sci. 37:77–84.

18. Harker, D. F., Jr., R. R. Hannan, M. L. Warren, Jr., L. R. Phillippe, K. E. Camburn, R. S. Caldwell, S. M. Call, G. J. Fallo, and D. VanNorman. 1980. Western Kentucky Coal Field: preliminary investigations of natural features and cultural resources. Introduction and ecology and ecological features of the western Kentucky coals field. Vol. I (Parts I and II). Technical Report, Kentucky Nature Preserves Commission, Frankfort, Kentucky.

19. Wharton, M. E. 1945. Floristics and vegetation of the Devonian-Mississippian Black-shale region of Kentucky. Ph.D. Dissertation. University of Michigan, Ann Arbor, Michigan.

20. Harker, D. F., Jr., R. R. Hannan, R. R. Cicerello, W. C. Houtcooper, L. R. Phillippe, and D. Van Norman.

1981. Preliminary assessment of the ecology and ecological features of the Kentucky "Knobs" oil shale region. Vol. 1. Technical Report, Kentucky Nature Preserves Commission, Frankfort, Kentucky.

21. Hoagland, B. 1990. Wetland flora and vegetation of the Upper Green River Basin, south-central Kentucky. M.S. Thesis. Eastern Kentucky University, Richmond, Kentucky.

22. Arms, F. S., D. S. Henry, A. S. Johnson, W. E. Partin, T. G. Sparks, and O. Whitaker. 1961. Soil survey of Adair County, Kentucky. U.S. Dept. of Agriculture, Soil Conservation Service.

23. Quarterman, E. and R. L. Powell. 1978. Potential ecological/ecological natural landmarks of the Interior Low Plateaus. U.S. Department of the Interior, Washington, D.C.

24. Weir, G. W. 1972. Geologic map of the Hall's Gap quadrangle, Lincoln County, Kentucky. Dept. of Interior, U.S. Geologic Survey.

25. Braun, E. L. 1950. Deciduous forests of eastern North America. Hafner Pub., Co., New York.

26. Kartesz, J. T. and R. Kartesz. 1980. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. University of North Carolina Press, Chapel Hill.

27. Cranfill, R. The ferns and fern allies of Kentucky. Kentucky State Nature Preserves Commission, Frankfort, Kentucky.

28. Cowardin, L. W., V. Carter, F. C. Colet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, FWS/OBS-79/31.

29. Gleason, H. and A. Cronquist. 1963. Manual of vascular plants of northeastern United States and adjacent Canada. D. Van Nostrand Company, Inc., New York.

30. Godfrey, R. K. and J. W. Wooten. 1979. Aquatic and wetland plants of southeastern United States: monocotyledons. The University of Georgia Press, Athens, Georgia.

31. Godfrey, R. K. and J. W. Wooten. 1981. Aquatic and wetland plants of southeastern United States: dicotyledons. The University of Georgia Press, Athens, Georgia.

32. Little, E. L. 1971. Atlas of United States trees, Vol. 1. Conifers and important hardwoods. U.S. Dept. Agri. Misc. Publ. No. 1146.

33. Warren, M. L., W. H. Davis, R. R. Hannan, M. Evans, D. L. Batch, B. D. Anderson, B. Palmer-Ball, Jr., J. R. MacGregor, R. R. Cicerello, R. Athey, B. A. Branson, G. J. Fallo, B. M. Burrs, M. E. Medley, and J. M. Baskin. 1986. Endangered, threatened, and rare plants and animals of Kentucky. Trans. Ky. Acad. Sci. 47:85–98.

34. Braun, E. L. 1943. An annotated catalog of spermatophytes of Kentucky. John S. Swift Co., Inc., Cincinnati, Ohio.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 154–161

Characterization of a Freshwater Mussel (Unionidae) Community Immediately Downriver of Kentucky Lock and Dam in the Tennessee River

ANDREW C. MILLER AND BARRY S. PAYNE

Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station
Vicksburg, Mississippi 39180-6199

AND

RICHARD TIPPIT

U.S. Army Engineer District, Nashville, P.O. Box 1070, Nashville, Tennessee 37202-1070

ABSTRACT

Data on community characteristics, density, recruitment rates, presence of endangered species, and population demography of dominant species of freshwater mussels (Family Unionidae) were obtained at selected sites between RM 22.2 and 21.2 at a mussel bed immediately downriver of Kentucky Lock and Dam (RM 22.4) in the lower Tennessee River. The unionid fauna was dominated by 2 thick-shelled species, *Amblema plicata plicata* (Say, 1817) (39.43%) and *Fusconaia ebena* (I. Lea, 1831) (39.41%). Six species each comprised 1 to 5% of the collection and 15 species each made up less than 1% of the collection. No federally listed endangered species was found. The similarity of size structure of *A. p. plicata* and *F. ebena* suggested interspecific similarity in temporal variation in recruitment. Species diversity ($\log_{2.3026}$, 1.54–1.87) and evenness (0.629–0.811) were moderate at 6 sites where 10 quantitative 0.25-sq m samples were taken. Mean unionid density ranged from 9.2–128.0 individuals/sq m (overall average was 63.0/sq m). The minimum density required to sustain a reproductively viable population of an uncommon species is probably 2–3 individuals/100 sq m. Mean density of *Corbicula fluminea* (Muller, 1774) ranged from 6.0–26.4 individuals/sq m, which was considerably less than values reported by Williams (1), who collected at a series of sites between Kentucky Lock and Dam and the mouth of the Tennessee River in the mid 1960s.

INTRODUCTION

A rich, dense, and commercially harvestable assemblage of freshwater mussels (Family Unionidae) occurs downriver of Kentucky Lock and Dam in the lower Tennessee River (1, 2, 3). Commercial fishermen consider the bed to extend from the dam at RM 22.4 to RM 11.0, although mussel distribution in this reach is patchy (3). Thirty six species of unionids, including 2 federally listed endangered species, have been collected at this bed (3). This reach of the lower Tennessee River has stable sand and gravel substratum that is kept free of sediment by continuous flow from Kentucky Dam. Kentucky Lock and Dam is a multiple-purpose project that was completed in September 1944.

From August 31 to September 3, 1990, a survey was conducted to obtain data on community characteristics, density, recruitment rates, presence of endangered species, and population demography of dominant species of freshwater mussels between RM 22.2 and 21.2, a dense section of the bed located immediately downriver of the dam. The survey was conducted at the request of the U.S. Army Engineer District, Nashville as part of environmental studies necessary before completion of a second lock at Kentucky Lock and Dam. Construction of the lower approach for this new lock would require removal of about 59,000 cu yd (45,000 cu m) of sand and gravel, which would eliminate some live bivalves and their habitat. When commercial traffic enters and exists this new lock they will pass closer to valuable portions of the mussel bed than they have in the past.

STUDY AREA

The Tennessee River originates at the junction of French Broad and Holston Rivers near Knoxville, Tennessee and flows southwest into Alabama, then north through Tennessee and Kentucky to Paducah, Kentucky where it enters the Ohio River at RM 933. The river is

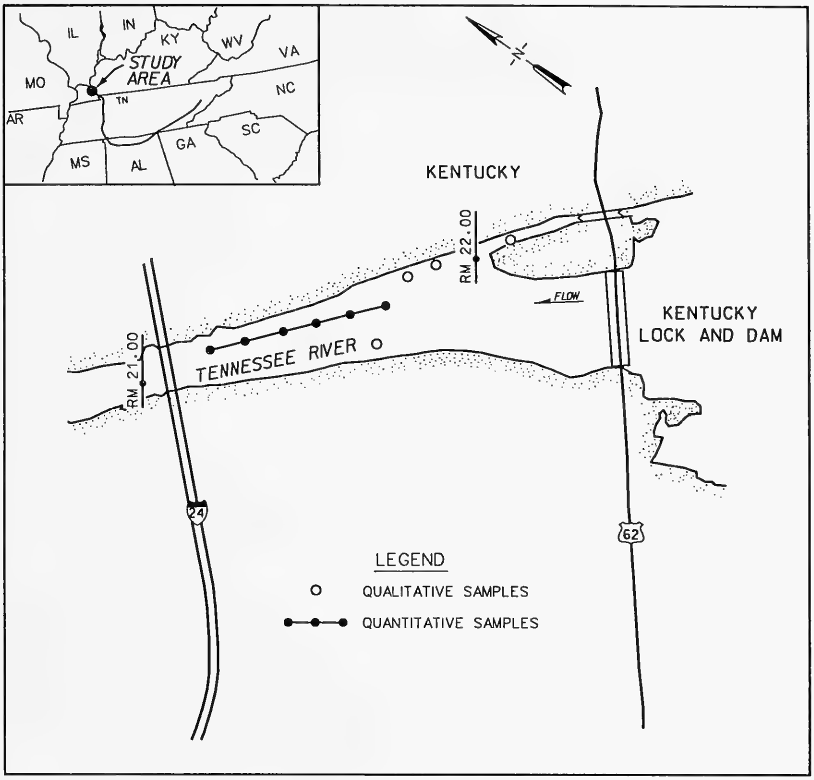


FIG. 1. Study areas on the lower Tennessee River.

1,050 km long with an average discharge of 1,834 cu m/s at Paducah (66 years of records (4)). Much of the river consists of a series of run-of-the-river reservoirs for navigation and hydroelectric power. Kentucky Lock and Dam is the last dam on the Tennessee River before its confluence with the Ohio River.

Quantitative and qualitative samples were obtained between RM 22.2 and RM 21.2, mainly along the right descending bank (Fig. 1). Sediment at sites where quantitative samples were collected consisted mainly of gravel (60.4–83.3%) with lesser amounts of sand (15.9–38.9%) and fines (0.2–1.1%). Percentage organic matter ranged from 0.62–4.90% by weight. Mussels were uncommon along the left descending bank in the study area, and virtually no mussels were found in the main channel. Sites were chosen to characterize areas that were likely to be affected by proposed construction of the second lock and movement of commercial vessels. Our study area contained one of the densest concentrations of mussels in this river reach (3). The study area is within a state mussel sanctuary located between RM 17.8 and 22.4 where commercial shell harvesting is prohibited.

METHODS

All sampling was accomplished by a dive crew equipped with surface air supply and communication equipment. Qualitative samples were obtained by three divers working simultaneously. Each diver placed a specific number of live mussels in each of four nylon bags; five mussels were placed in the first bag and 20 mussels were placed in each of three other bags. Each diver collected approximately 65 live mussels (some shells and rocks were inadvertently taken) for a total of about 185 mussels per site. Divers attempted to exclude the Asian clam, *Corbicula fluminea* (Muller, 1774), from qualitative samples. If *C. fluminea* was inadvertently collected, it was later eliminated from the sample. All mussels were brought to the surface, counted, and identified.

TABLE 1. Summary of relative species abundance and frequency of occurrence for freshwater mussels collected using qualitative techniques at five study areas upriver of the I-24 Bridge (see Fig. 1) in the lower Tennessee River, 1990.

Species	Total mussels	%	Total sites	%	Species rank
Amblema p. plicata (Say, 1817)	1,880	39.43	274	95.47	1
Fusconaia ebena (I. Lea, 1831)	1,879	39.41	259	90.24	2
Quadrula p. pustulosa (I. Lea, 1831)	241	5.05	141	49.13	3
Quadrula quadrula (Rafinesque, 1820)	175	3.67	113	39.37	4
Obliquaria reflexa Rafinesque, 1820	165	3.46	82	28.57	5
Megalonaias nervosa (Rafinesque, 1820)	73	1.53	58	20.21	6
Cyclonaias tuberculata (Rafinesque, 1820)	59	1.24	51	17.77	7
Elliptio crassidens (Lamarck, 1819)	57	1.20	47	16.38	8
Elliptio dilatata (Rafinesque, 1820)	35	0.73	31	10.80	9
Ellipsaria lineolata (Rafinesque, 1820)	30	0.63	27	9.41	10.5
Truncilla truncata Rafinesque, 1820	30	0.63	26	9.06	10.5
Potamilus alatus (Say, 1817)	27	0.57	23	8.01	12
Truncilla donaciformis (I. Lea, 1828)	26	0.55	22	7.67	13
Quadrula nodulata (Rafinesque, 1820)	18	0.38	18	6.27	14
Leptodea fragilis (Rafinesque, 1820)	17	0.36	17	5.92	15
Tritogonia verrucosa (Rafinesque, 1820)	16	0.34	15	5.23	16
Pleurobema cordatum (Rafinesque, 1820)	12	0.25	9	3.14	17
Ligumia recta (Lamarck, 1819)	9	0.19	9	3.14	18
Lampsilis teres (Rafinesque, 1820)	7	0.15	6	2.09	19
Anodonta imbecillis (Say, 1829)	4	0.08	4	1.39	20
Quadrula metanevra (Rafinesque, 1820)	3	0.06	3	1.05	21.5
Anodonta grandis Say, 1829	3	0.06	3	1.05	21.5
Lasmigona c. complanata (Barnes, 1823)	2	0.04	2	0.70	23
Total samples 287					
Total mussels 4,768					
Total species 23					

Ten quantitative samples (that included *C. fluminea*) were obtained at each of 6 sites 100 m apart (upriver to downriver in the center of the bed) in the area that would be dredged for lock construction. At each site ten 0.25-sq m quadrats were positioned approximately 1 m apart and arranged in a 2 by 5 matrix. A diver excavated all substratum to a depth of 10–15 cm. Material was sent to the surface in a 20 L bucket and transported to shore. Sediment was screened through a sieve series (finest screen with apertures of 6.4 mm). All live bivalves were picked from the sediment and placed in zipper-lock bags. Each bivalve was identified and total shell length (SL) was measured to the nearest 0.1 mm with a dial caliper.

RESULTS

Twenty three species and 4,768 freshwater mussels were obtained in 287 qualitative collections (Table 1). The fauna was dominated by 2 thick-shelled species, *Amblema plicata plicata* (Say, 1817) and *Fusconaia ebena* (I. Lea, 1831), which represented 39.43 and 39.41% of the fauna and were taken in 95.47 and 90.24% of the samples, respectively. Six species each comprised from 1 to 5% of the collection, and 15 species each comprised less than 1% of the collection. With the exception of *A. p. plicata* and *F. ebena*, all other unionids were taken in less than 50% of the samples; 14 species were found in less than 10% of the samples. Thin- and moderately thick-shelled species, *Anodonta grandis* Say, 1829, *Anodonta imbecillis* (Say, 1829), *Lampsilis teres* (Rafinesque, 1820) and *Leptodea fragilis* (Rafinesque 1820), usually associated with fine sand or silt, were uncommon and together comprised 0.65% of the assemblage. No live specimens of two endangered species, *Lampsilis abrupta* (Say, 1831) and *Plethobasus cooperianus* (I. Lea, 1834), previously collected in this river reach (3) were found.

A plot of cumulative species versus cumulative individuals illustrates the relationship between sampling effort and the ability to find uncommon species. Although a total of 4,768 individuals and 23 species were taken (Table 1), after 1,200 individuals had been found, all 23 species were identified (Fig. 2). This figure

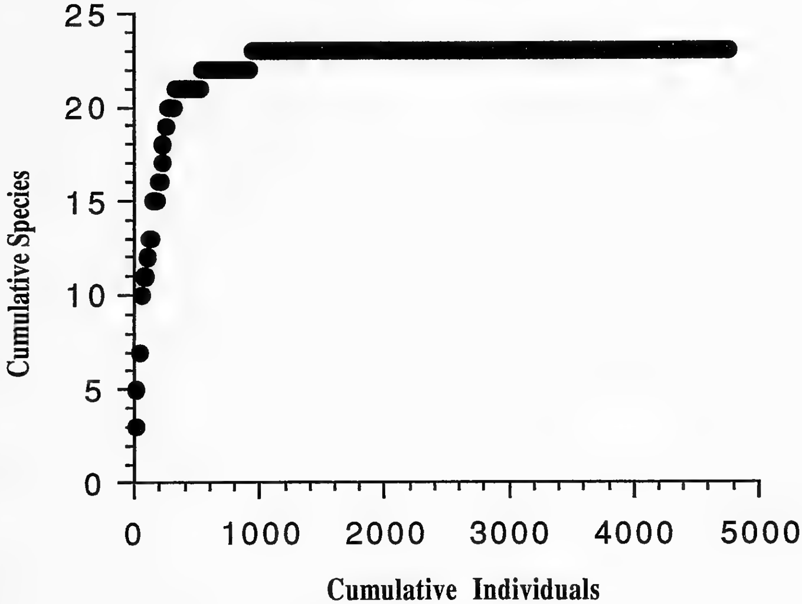


FIG. 2. The relationship between cumulative species and cumulative individuals for qualitative samples.

suggests that finding additional species with more sampling would be unlikely. If species were present and not collected, they would comprise less than 0.02% of the assemblage.

Mean unionid density at six sites ranged from 9.2 to 128.0 individuals/sq m (overall average was 63.0 individuals/sq m). Mean density of *C. fluminea* ranged from 6.0 to 26.4 individuals/sq m (Figure 3). Species diversity ($\log_{2.3026}$) ranged from 1.54 to 1.87, and evenness ranged from 0.629 to 0.811.

The *A. p. plicata* population ranged between 6 to 126 mm total SL (Fig. 4). The most abundant mussels occurred in 2 size classes: 10

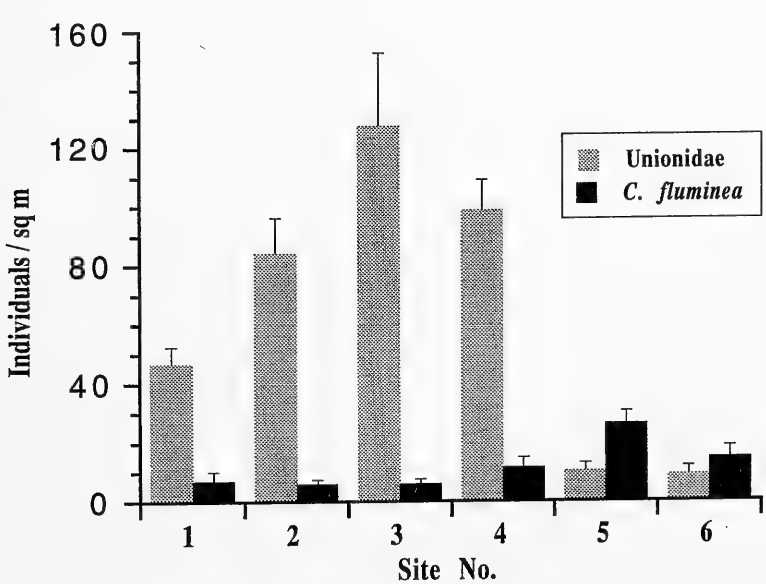


FIG. 3. Total density (individuals/sq m) of unionids and *Corbicula fluminea*.

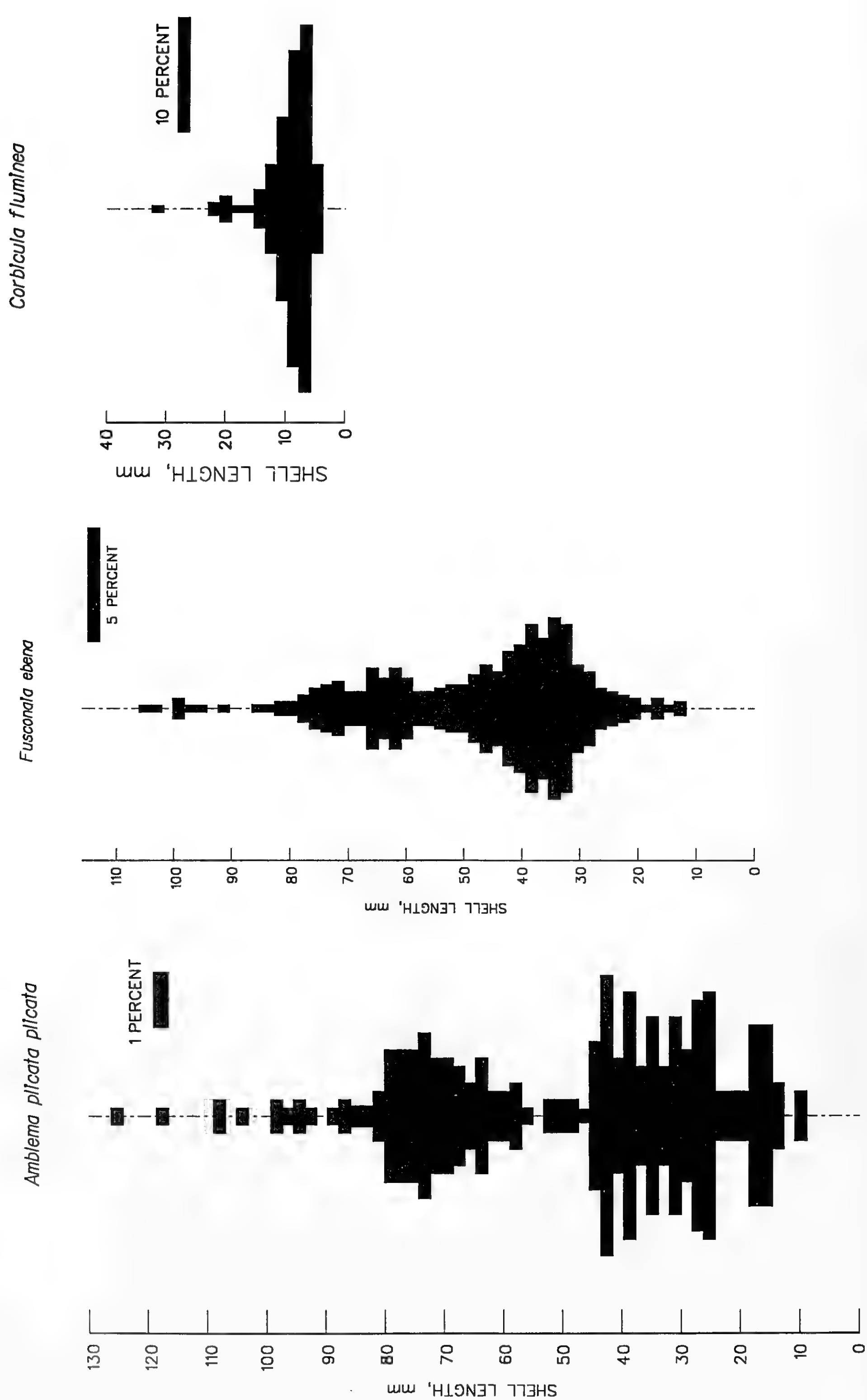


FIG. 4. Shell-length frequency histograms for *A. plicata*, *F. ebena*, and *C. fluminea*.

to 50 mm (62% of the population) and 54 to 88 mm (33% of the population). Several overlapping cohorts were included within each of these two SL ranges. A recently recruited cohort (probably the 1989 year class) had an average SL of 14–18 mm. Mussels ranging from 20 to 46 mm SL probably represented 3 largely overlapping cohorts. Two relatively abundant cohorts were centered at 22–26 mm and 36–44 mm SL, and an intermediate and less abundant cohort was between 28 and 34 mm. Individual cohorts could not be distinguished among the moderately large mussels ranging from 54 to 88 mm. The relative paucity of mussels between 46 and 56 mm is probably the consequence of 1 or 2 consecutive years of poor recruitment. Individuals greater than 100 mm comprised less than 2% of the total population. Although *A. p. plicata* can exceed 100 mm total SL, few individuals appeared to survive long enough to attain this size. Because the study area is within a mussel sanctuary, population structure should be unaffected by commercial harvest.

The size structure of *F. ebena* was similar to that of *A. p. plicata* (Fig. 4). *Fusconaia ebena* was characterized by two relatively abundant and broad size classes, and each consisted of multiple but indistinct cohorts. The smaller of these 2 groups included mussels ranging between 12 and 56 mm and comprised 72% of the population (compared to 62% in the 10- to 50-mm range of *A. p. plicata*). Mussels between 56 and 86 mm accounted for 28% of the total collection (compared to 31% in the 56 to 86 mm range of *A. p. plicata*). Individuals greater than 92 mm accounted for only 2% of the population.

The similarity of size structure among the 2 most abundant species populations may reflect interspecific similarity in temporal variation in recruitment. The paucity of mussels from 50 to 60 mm (relative to abundant size classes above and below this size range) for both populations could correspond to an interspecific simultaneity of one or more poor years of recruitment.

The low-density population of *C. fluminea* consisted almost entirely of small individuals between 4 to 13 mm, which probably represent spring recruits (Fig. 4). *Corbicula fluminea* usually exhibits spring and fall peaks of recruitment (5) unlike native unionids that have a single recruitment each year. Larger *C. fluminea* (18 to 24 mm) probably represent recruitment from the fall of 1989. Stable and thriving populations of *C. fluminea* sampled during the late summer usually show 3 to 5 cohorts, including many individuals from 20 to 35 mm (5, and references cited therein). The lack of complex size structure and large individuals plus low density indicates a population supported by low recruitment with subsequent poor survival.

DISCUSSION

The mussel assemblage in the reach of the Tennessee River immediately downriver of Kentucky Lock and Dam consisted almost entirely of thick-shelled species such as *A. p. plicata*, *F. ebena*, and *Quadrula* spp., and lesser numbers of *Elliptio* spp., *Megalonaias nervosa* (Rafinesque 1820), and *Pleurobema cordatum* (Rafinesque 1820). Thin- and moderately thick-shelled species (*L. fragilis*, *Potamilus alatus* (Say, 1817), and *Anodonta* spp.) together comprised only 0.65% of the qualitative collection. Within their range these thin-shelled species are found in appropriate substratum in large rivers (6, 7, 8). Each has multiple fish hosts (9) and would be more common in this reach if more suitable substratum and flow existed for them. However, gravel and erosive flows at high discharge stress thin-shelled species. If present, few would reach adult size. There would probably be more thin-shelled species immediately downriver of the lock and dam if maximum water velocities were less.

Our sampling was concentrated only in the portion of the bed immediately downriver of the lock and dam. Results of previous studies (1, 2, 3, 10, 11) included samples taken downriver of our study area. In 1985, Sickle (3) reported collecting 36 species (34 living) at 51 sites between RM 22.4 and the mouth of the Tennessee River. Species absent from our study area that have been collected by ourselves and others farther downriver include fairly common species such as *Arcidens confragosus* (Say, 1829) and *Fusconaia flava* (Rafinesque, 1820). The slightly reduced richness immediately downriver of the lock and dam (23 species), compared with results of previously conducted studies that included sites located farther downriver, does not necessarily indicate a change in richness through time. The slightly more erosional characteristic of substratum closer to the dam has probably greatly reduced or eliminated some species. An examination of data collected by the earlier workers (summarized by Sickel, 3) indicates that community composition at the mussel bed (RM 22.4 to 11.0) has remained relatively stable through time regardless of completion of major hydropower dams in the watershed.

Total species richness in the study area is similar to that at other mussel beds in large rivers. At a mussel bed in the lower Ohio River near Olmsted, Illinois, 23 species of freshwater mussels were collected (12). In a survey of the upper Mississippi River, Miller et al. (13) collected over 15,000 bivalves in 667 qualitative samples at 58 locations and identified 34 species. However, total species richness at any one location was usually between 15 and 25.

Mean unionid density at the 6 sites sampled (9.2–128.0 individuals/sq m with an overall average of 63.0 individuals/sq m) is within the range of density data from other large river mussel beds. In a survey of the upper Mississippi River, Miller et al. (13) reported that total mussel density ranged from 5.2 to 333.2 individuals/sq m at 16 sites (10 quantitative samples were taken at each). At half of those sites total density was greater than 50 individuals/sq m and at four sites it was greater than 100 individuals/sq m. At an inshore and offshore site sampled in 1986 at RM 18.6 in the lower Tennessee River (32 quantitative samples were collected at each), total mussel density was 187.7 and 79.7 individuals/sq m, respectively (14).

This bed is within the reported range of the following federally listed endangered freshwater mussel species: *Pleurobema plenum* (I. Lea, 1840), *P. cooperianus*, *L. abrupta*, *Obovaria retusa* (Lamarck, 1819), *Potamilus capax* (Green, 1832), *Plethobasus cicatricosus* (Say, 1829), *Cyprogenia stegaria* (=*irrorata*) (Rafinesque, 1820), and *Epioblasma torulosa torulosa* (Rafinesque, 1820) (15). Two of these species, *P. cooperianus* and *L. abrupta*, have been collected in the lower Tennessee River. Sickel (3) collected a single *Plethobasus cooperianus* at RM 20.6 and two at RM 20.7 (just downriver of our study area) in 1985. This species was found near the mouth of the river at Paducah, Kentucky in 1931 by Ellis (as reported by van der Schalie, 11). Sickel (3) reported 2 specimens of *L. abrupta* at RM 14.75 and 1 at RM 21.36 (16) (just within our study area). In the latter survey a total of 9,367 mussels were collected between RM 21.1 and 21.5. This species was also collected by personnel of the Tennessee Valley Authority in 1978 at RM 22.0 (within our study area) as reported by Sickel (3).

Between RM 22.2 and 21.2 in the lower Tennessee River, *P. cooperianus* and *L. abrupta* are either absent or extremely uncommon (i.e., less than one individual per 5,000 unionids). The relationship between cumulative species and cumulative individuals (Fig. 2) illustrates that it would be unlikely (although probably not impossible) to find either of these species in the study area. If individuals of these species are present, they are probably not part of a viable population. Miller et al. (17) found what appears to be a viable population of *P. cooperianus* at a mussel bed in the lower Ohio River near Olmsted, Illinois. In the fall of 1990 they obtained 2 live specimens in 3 samples of 200 individuals each. *Plethobasus cooperianus* continues to exist in certain reaches of large rivers in densities high enough to be easily collected.

Based on our qualitative samples, the least common species, *Lasmigona complanata complanata* (Barnes, 1823), comprised 0.04 percent of the fauna. With an average of 63 mussles/sq m, the density of this uncommon species would be 0.0252 individuals/sq m. A density of 2–3 individuals per 100 sq meters could be considered the minimum necessary to sustain a reproductively viable population of an uncommon unionid. Two uncommon federally listed species, *P. cooperianus* and *L. abrupta*, were collected previously in our study area (3). However, these species are so uncommon in this river reach that they probably can not sustain themselves.

Williams (1) sampled the lower Tennessee River between Kentucky Lock and Dam and the Ohio River in the mid 1960s with an 8-ft brail and a Peterson dredge. He estimated that *C. fluminea* comprised 99.41% of the bivalve community; densities ranged from 17 to 1,147 individuals/sq yd (20.3 to 1,372 individuals/sq m). In the present survey, density of Asian Clams ranged from 6.0 to 26.4 individuals/sq m. Although quantitative data on *C. fluminea* were not collected throughout the lower Tennessee River, it appears that its densities in the study area have diminished considerably since the survey conducted by Williams (1). Physical conditions in this river reach have not changed since that survey (i.e., Kentucky Lock and Dam was operational in September 1944). It is likely that *C. fluminea* densities are now declining to equilibrium conditions as suggested earlier by Morton (18).

Turbulence, increased suspended sediments, and benthic scour caused by passage of commercial vessels entering and exiting the new lock could negatively affect freshwater mussels and their habitat (19). Results of additional study after the second lock has been completed will provide data on long-term trends in the bivalve fauna, as well as effects of construction and operation of the second lock.

ACKNOWLEDGMENTS

Studies were funded by the U.S. Army Engineer District, Nashville. Divers were Larry Neill, Brad Bole, Robert Warden, and Dennis Baxter from the Tennessee Valley Authority (TVA). Assistance in the field was provided by Dr. John Jenkinson, TVA, and Dr. Jim Sickel, Murray State University, Murray, Kentucky. The authors appreciate constructive comments by anonymous reviewers. Permission was granted by the Chief of Engineers to publish this information.

LITERATURE CITED

1. Williams, J. C. 1969. Mussel fishery investigations, Tennessee, Ohio and Green Rivers. Project Completion Report for Investigations Projects Conducted Under the Commercial Fisheries Research and Development Act of 1964. U.S. Fish and Wildlife Service and Kentucky Department of Fish and Wildlife Resources.

2. Isom, B. G. 1969. The mussel resource of the Tennessee River. Malacologia 7:397–425.

3. Sickel, J. B. 1985. Biological assessment of the freshwater mussels in the Kentucky Dam Tailwaters of the Tennessee River. Contract Report to Kentucky Division of Water.

4. Tom, S. G., C. J. Sholar, and D. D. Zettwoch. 1986. Water resources data for Kentucky, water year 1986. U.S. Geol. Surv. Water Data Ret. KY-86-1.

5. McMahon, R. F. 1983. Ecology of an invasive pest bivalve, *Corbicula*. Pp. 505–561. In W. D. Russell-Hunter, (ed.) The mollusca (Volume 6): ecology. Academic Press, Orlando, Florida.

6. Murry, H. D. and A. B. Leonard. 1962. Handbook of Unionid Mussels in Kansas. Museum of Natural History, University of Kansas, Lawrence, Kansas.

7. Parmalee, P. W. 1967. The fresh-water mussels of Illinois. Illinois State Museum Popular Science Series 8:1–108.

8. Starrett, W. C. 1971. A survey of the mussels (Unionidae) of the Illinois River: a polluted stream. Ill. Nat. Hist. Sur. Bull. 30:266–403.

9. Fuller, S. L. H. 1974. Clams and mussels (Mollusca: Bivalvia). Pp. 215–273. In C. W. Hart, Jr., and S. L. H. Fuller (eds.) Pollution ecology of freshwater invertebrates. Academic Press, New York.

10. Ortmann, A. E. 1925. The Naiad-fauna of the Tennessee River System below Walden Gorge. Amer. Midl. Nat. 9:321–371.

11. van der Schalie. 1939. Additional notes on the naiades (fresh-water mussels) of the lower Tennessee River. Amer. Midl. Nat. 22:452–457.

12. Payne, B. S. and A. C. Miller. 1989. Growth and survival of recent recruits to a population of *Fusconaia ebena* (Bivalvia: Unionidae) in the lower Ohio River. Amer. Midl. Nat. 121:99–104.

13. Miller, A. C., Payne, B. S., Hornbach, D. J., and D. V. Ragland. 1990. Physical effects of increased commercial navigation traffic in the Upper Mississippi River: phase I studies. Technical Report EL-90-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

14. Way, C. M., Miller, A. C., and B. S. Payne. 1989. The influence of physical factors on the distribution and abundance of freshwater mussels (Bivalvia: Unionidae) in the lower Tennessee River. Nautilus 103:96–98.

15. U.S. Fish and Wildlife Service. 1991. Endangered and threatened wildlife and plants. 50 CFR 17.11 & 17.12 (July 15, 1991). Office of Endangered Species, U.S. Fish and Wildlife Service, Washington, D.C. 20240.

16. Sickel, J. B. 1987. Survey of freshwater mussels in the Kentucky Dam Tailwater at the site of the proposed Reed Crushed Stone Barge Facility. Prepared for Reed Crushed Stone Company, Inc., Gilbertsville, KY 42044.

17. Miller, A. C., Payne, B. S., and T. S. Siemsen. 1986. Description of habitat of the endangered mussel *Plethobasus cooperianus*. Nautilus 100:14–18.

18. Morton, B. 1979. Freshwater fouling bivalves. *In* Proceedings, First International Corbicula Symposium, Texas Christian Univ. Res. Found. :1–14.

19. Rasmussen, J. L. 1983. A summary of known navigation effects and a priority list of data gaps for the biological effects of navigation on the upper Mississippi River. Prepared for the U.S. Army Engineer District, Rock Island, by US Fish and Wildlife Service. Contract NCR-LO-83-C9, Rock Island, IL.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 162–164

A Note on Derivations and Modules of Quotients

PAUL E. BLAND[1]

Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

Let τ be a hereditary torsion theory on Mod-R. If M is a right R-module with derivation δ, then δ has a unique extension to the module of quotients of M if and only if the torsion submodule of M is a δ-module. Moreover, if R is a differntial ring, the ring of quotients of R is a differential ring if and only if the torsion ideal of R is a δ-ideal.

INTRODUCTION

In (5), Lambek indicated that if d: R → R is a derivation on a ring R, d can be extended uniquely to a derivation D: Q(R), → Q(R), where Q(R) is the complete ring of quotients of R. Tewari (8) showed previously that this could be accomplished when R is a commutative ring. The purpose of this note is to show that this result holds in the more general setting of a hereditary torsion theory on Mod-R. More specifically, if τ is a hereditary torsion theory on Mod-R and M is a module with derivation δ, then δ has a unique extension to the module of quotients of M if and only if the torsion submodule of M is a δ-module. From this it follows that if R is a differential ring, then the ring of quotients of R with respect to τ is a differential ring if and only if the torsion ideal of R is a δ-ideal. We also show that if the filter of right ideals of R associated with τ is a δ-filter, then any derivation δ on a right R-module M has a unique extension to the module of quotients M.

Throughout this note, R denotes an associative ring with identity and our attention will be confined to a hereditary torsion τ on Mod-R, the category of unital right R-modules. If τ is such a torsion theory on Mod-R, the topologizing and idempotent filter of right ideals associated with τ is denoted by F(R). The reader can consult (3) or (7) for the general results and terminology on torsion theory and recent results on derivations can be found in (1), (2) and (6).

DISCUSSION

If τ is a hereditary torsion theory on a Mod-R, the module of quotients of M is given by $Q_\tau(M) = \varinjlim_{k \in F(R)} \mathrm{Hom}_R(K, M/T(M))$, where T(M) denotes the torsion submodule of M. Elements of $Q_\tau(M)$ are equivalence classes [f] of R-linear mappings where 2 mappings are equivalent if they agree on some $K \in F(R)$. There is a canonical R-linear mapping ϕ:M → $Q_\tau(M)$ which is the canonical map η:M → M/T(M) followed by the injective mapping k:M/T(M) → $Q_\tau(M)$ defined by $k(x) = [f_x]$ where f_x:R → M/T(M):r → xr.

An additive mapping δ:R → R such that $\delta(rs) = \delta(r)s + r\delta(s)$ for all r, s ∈ R is said to be a *derivation*[2] on R and a ring with such a derivation is said to be a *differential ring.* If M is a right R-module and R is a differential ring with derivation δ, then an additive mapping δ':M → M such that $\delta'(mr) = \delta'(m)r + m\delta(r)$ for all m ∈ M and all r ∈ R is said to be a derivation on M. To simplify notation we will use δ to denote both a derivation on R and a derivation on a module M. The context of the discussion should make it clear which is being considered and should cause no confusion. If M is a right R-module with derivation δ, then a submodule of N of M is said to be a δ-module if $\delta(N) \subseteq N$.

Let τ be a torsion theory on Mod-R and suppose that R is a differential ring with derivation δ. If M is a right R-module with derivation δ, then δ is said to extend uniquely to $Q_\tau(M)$ if there exists a unique derivation δ^*: $Q_\tau(M) \to Q_\tau(M)$ such that $\delta^* \circ \phi = \eta \circ \delta$. Now

[1] This work was supported by Eastern Kentucky University's released-time program.

[2] The motivation for the definition of a derivation on a ring R comes from the differentiation formulas for the sum and product of two functions. If R is an integral domain with derivation δ, then the complete ring of quotients of R, is the field of fractions of R. In this case, the unique existence of δ to Q(R) referred to by Lambek in [5] is given by $\delta\left(\frac{a}{b}\right) = \frac{\delta(a)b - a\delta(b)}{b^2}$.

suppose $\delta^*:Q_\tau(M) \to Q_\tau(M)$ is such an extension of $\delta:M \to M$. Since $\ker \phi = T(M)$, $0 = \delta^* \circ \phi(T(M)) = \phi \circ \delta(T(M))$ and so $k \circ \eta \circ \delta(T(M)) = 0$. Hence $\eta(\delta(T(M))) = 0$ and so $\delta(T(M)) \subseteq \ker \eta = T(M)$. Thus, T(M) being a δ-module is necessary for such an extension to exist. The following shows this condition is also sufficient.

Lemma 1.—Let τ be a hereditary torsion theory on Mod-R and suppose that R is a differential ring with derivation δ. If M is a right R-module with derivation δ, there is at most one derivation $\delta^*:Q_\tau(M) \to Q_\tau(M)$ such that $\delta^* \circ \phi = \phi \circ \delta$.

Proof.—Let δ_1^* and δ_2^* be derivations on $Q_\tau(M)$ such that $\delta_1^* \circ \phi = \delta_2^* \circ \phi = \phi \circ \delta$. If $\delta_1^* \neq \delta_2^*$, there is a $q \in Q_\tau(M)$ for which $(\delta_1^* - \delta_2^*)(q) \neq 0$ and so suppose $k \in (\phi(M):q)$[3] $\in F(R)$. Since $\delta_1^* - \delta_2^*:Q_\tau(M) \to Q_\tau(M)$ is an R-linear mapping, if $m \in M$ is such that $\phi(m) = qk$, then $(\delta_1^* - \delta_2^*)(q)k = (\delta_1^* - \delta_2^*)(qk) = (\delta_1^* - \delta_2^*)(\phi(m)) = 0$. Hence $(\delta_1^* - \delta_2^*)(q)K = 0$ and so $(\delta_1^* - \delta_2^*)(q)$ is a non-zero torsion element of $Q_\tau(M)$. But $Q_\tau(M)$ is torsion free and so it must be the case that $\delta_1^* = \delta_2^*$.

Lemma 2.—Suppose τ is a hereditary torsion theory on Mod-R and let R be a differential ring with derivation δ. Suppose also that M is a right R-module with derivation δ such that T(M) is a δ-module. If $q \in Q_\tau(M)$ and $K = (\phi(M), q)$, then the mapping $\beta_q:K \to Q_\tau(M)$ defined by $\beta_q(r) = \phi \circ \delta(m) - q\delta(r)$ is a well defined R-linear mapping, where $m \in M$ is such that $\phi(m) = qr$.

Proof.—Let $r, s \in K$ and suppose $m, m_r, m_s \in M$ are such that $\phi(m) = q(r + s)$, $\phi(m_r) = qr$ and $\phi(m_s) = qs$. Then $m - m_r - m_s \in \ker \phi = T(M)$ and so since T(M) is a δ-module, $\phi \circ \delta(m) = \phi \circ \delta(m_r) + \phi \circ \delta(m_s)$. Thus $\beta_q(r + s) = \phi \circ \delta(m) - q\delta(r + s) = \phi \circ \delta(m_r) + \phi \circ \delta(m_s) - q\delta(r) - q\delta(s) = \beta_q(r) + \beta_q(s)$. Finally if $r \in K$ and $s \in R$, let $m, n \in M$ be such that $\phi(m) = qrs$ and $\phi(n) = qr$. Since $\phi(m) = \phi(ns)$, it follows that $\phi \circ \delta(m) = \phi \circ \delta(ns)$. Hence $\beta_q(rs) = \phi \circ \delta(m) - q\delta(rs) = \phi \circ \delta(ns) - q\delta(rs) = \phi(\delta(n)s + n\delta(s)) - q(\delta(r)s + r\delta(s)) = (\phi \circ \delta(n) + q\delta(r))s = \beta_q(r)s$.

Theorem 1.—Let τ be a hereditary torsion theory on Mod-R and suppose R is a differential ring with derivation δ. If M is a right R-module with derivation δ such that T(M) is a δ-module, then δ can be extended uniquely to $Q_\tau(M)$.

Proof.—If $q \in Q_\tau(M)$, then $K = (\phi(M) : q) \in F(R)$ and so β_q as defined in Lemma 2, determines an equivalence class $\delta^*(q) = [\beta_q]$ in $Q_\tau(Q_\tau(M)) \cong Q_\tau(M)$. (We will identify elements of $Q_\tau Q_\tau(M))$ with those of $Q_\tau(M)$ because of this isomorphism.) We claim that δ^* is a derivation which uniquely extends δ to $Q_\tau(M)$.

First, let's show that $\delta^* \circ \phi = \phi \circ \delta$. If $m \in M$, then $\delta^* \circ \phi(m) = [\beta_{\phi(m)}]$. Thus if $r \in R$, $\beta_{\phi(m)}(r) = \phi \circ \delta(mr) - \phi(m)\delta(r) = \phi(\delta(m)r + m\delta(r)) - \phi(m)\delta(r) = \phi \circ \delta(m)r$. Hence it follows that $[\beta_{\phi(m)}] = \phi \circ \delta(m)$ and so $\delta^* \circ \phi = \phi \circ \delta$.

Finally, let's show that δ^* is a derivation on $Q_\tau(M)$. If $q_1, q_2 \in Q_\tau(M)$, then $\delta^*(q_1 + q_2) = [\beta_{q1 + q2}]$ and so let $K_1 = (\phi(M) : q_1)$ and $K_2 = (\phi(M) : q_2)$. If $r \in K_1 \cap K_2 \in F(R)$, then $\beta_{q1 + q2}(r) = \phi \circ \delta(m) - (q_1 + q_2)\delta(r)$ where $\phi(m) = (q_1 + q_2)r$. Next suppose that $m_1, m_2 \in M$ are such that $\phi(m_1) = q_1r$ and $\phi(m_2) = q_2r$. Then because T(M) is a δ-module, $\phi \circ \delta(m) = \phi \circ \delta(m_1) + \phi \circ \delta(m^2)$. Hence $\beta_{q1 + q2}(r) = \phi \circ \delta(m_1) - q_1\delta(r) + \phi \circ \delta(m_2) - q_2\delta(r) = \beta_{q1}(r) + \beta_{q2}(r)$. Consequently, $\delta^*(q_1 + q_2) = \delta^*(q_1) + \delta^*(q_2)$. Next let $q \in Q_\tau(M)$ and $r \in R$. If $s \in K = ((\phi(M) : q) : r) \in F(R)$, $\beta_{qr}(s) = \phi \circ \delta(m) - qr\delta(s)$ where $\phi(m) = qrs$. Hence $\beta_{qr}(s) = \phi \circ \delta(m) - q\delta(rs) + q\delta(rs) - qr\delta(s) = \beta_q(rs) + q(\delta(r)s + r\delta(s)) - qr\delta(s) = \beta_q(rs) - q\delta(r)s = (\beta_q(r) + q\delta(r))s$. Therefore $\beta_{qr} = \beta_{qr} + q\delta(r)$ on K and so $\delta^*(qr) = \delta^*(q)r + q\delta(r)$. Lemma 1 shows uniqueness and so the proof is complete.

Corollary 1.—If M is a torsion free right R-module with derivation δ, then δ has a unique extension of $Q_\tau(M)$.

Proof.—$T(M) = 0$ is a δ-module.

Corollary 2.—If R is a differential ring with derivation δ, then $Q_\tau(R)$ is a differential ring with derivation extending that of R if and only if T(R) is a δ-ideal.

Proof.—When R is viewed as an R-module, Theorem 1 shows that R has a differential module of quotients $Q_\tau(R)$ with derivation δ^*. If $q \in Q_\tau(R)$ and $r \in R$, then $\delta^*(qr) = \delta^*(q)r + q\delta(r)$. We must show that if $q_1, q_2 \in Q_\tau(R)$, then $\delta^*(q_1q_2) = \delta^*(q_1)q_2 + q_1\delta^*(q_2)$. If $q_1, q_2 \in Q_\tau(R)$ and $r \in (\phi(R) : q_1q_2) \cap (\phi(R) : q_2) \in F(R)$, then $\beta_{q1q2}(r) = \phi \circ \delta(s) - q_1q_2\delta(r)$ where $\phi(s) = q_1q_2r$. But $\phi \circ \delta(s) = \delta^* \circ \phi(s) = \delta^*(q_1q_2r)$ and so $\beta_{q1q2}(r)$

[3] If N is a submodule of a right R-module M and $x \in M$, then $(N : x) = \{r \in R \mid xr \in N\}$.

$= \delta^*(q_1q_2r) - q_1q_2\delta(r) = \delta^*(q_1)q_2r + q_1\delta^*(q_2r) - q_1q_2\delta(r) = \delta(q_1)q_2r + q_1(\delta^*(q_2)r + q_2\delta(r)) - q_1q_2\delta(r) = (\delta^*(q_1)q_2 + q_1\delta^*(q_2))r$. Thus $\delta^*(q_1q_2) = \delta^*(q_1)q_2 + q_1\delta^*(q_2)$ and so $Q_\tau(R)$ is a differential ring.

If R is a differential ring with derivation δ, then F(R) is said to be a *δ-filter* if every right ideal K of F(R) is such that $\delta(K) \subseteq K$. The result of the next theorem allows one to look within the ring itself to investigate the possibility of extending a derivation δ on a module M to its module of quotients.

Theorem 2.—Let τ be a hereditary torsion theory on Mod-R and suppose that R is a differential ring with derivation δ. If F(R) is a δ-filter, then every derivation on a right R-module has a unique extension to its modules of quotients.

Proof.—In view of Theorem 1, it suffices to show that if M is a right R-module with derivation δ, then T(M) is a δ-module. Let $m \in T(M)$ and suppose that $K \in F(R)$ is such that $mK = 0$. If $k \in K$, then $0 = \delta(mk)\ \delta(m)k + m\delta(k)$. But $\delta(k) \in K$ and so $m\delta(k) = 0$. Therefore $\delta(m)k = 0$ and so it follows that $\delta(m)K = 0$. Hence $\delta(m) \in T(M)$.

A hereditary torsion theory τ with torsion class $\mathcal{T}$ is said to be a TTF theory if $\mathcal{T}$ is closed under direct products. In this case $\mathcal{T}$ is also a torsion free class for a hereditary torsion theory μ. It is well known that if τ is a TTF theory, there exists an idempotent ideal I in R such that $\mathcal{T} = \{K \mid K \supseteq I$, K a right ideal of R$\}$. (See (4) for details.) For example, if R is a left perfect ring, the Lambek torsion theory τ whose torsion class is given by $\mathcal{T} = \{M \mid Hom_r(M, E(R)) = 0\}$ is a TTF theory where E(R) denotes the injective hull of R.

The following theorem shows that if τ is a TTF theory, then unique extensions of derivations to modules of quotients always exist.

Theorem 3.—Let R be a differential ring with derivation δ. If τ is a TTF theory and M is a module with derivation δ, then δ can be extended uniquely to the module of quotients of M.

Proof.—Let I be the idempotent ideal of R such that $F(R) = \{K \mid K \supseteq I$, K a right ideal of R$\}$ and $\mathcal{T} = \{M \mid MI = 0\}$. If $r \in I = I^2$, then $r = \sum_{i=1}^{n} s_it_i$ where $s_i,t_i \in I$ for $i = 1, 2, \ldots, n$ and so $\delta(r) = \delta(\sum_{i=1}^{n} s_it_i) = \sum_{i=1}^{n} \delta(s_it_i) = \sum_{i=1}^{n} [\delta(s_i)t_i + s_i\delta(t_i)] \in I$. Hence I is a δ-ideal. If M is a module with derivation δ, then $T(M)I = 0$. Now suppose $m \in T(M)$ and $r \in I$. Then $0 = \delta(mr) = \delta(m)r + m\delta(r)$ and so $\delta(m)r = 0$ because $\delta(r) \in I$. Hence it follows that $\delta(m)I = 0$. But $I \in F(R)$ and so $\delta(m) \in T(M)$. Thus $\delta(T(M)) \subseteq T(M)$ and the result follows from Theorem 1.

As a final observation, let R be a Boolean ring with derivation δ and suppose that τ is a torsion theory on Mod R. If K is an ideal of R and $r \in K$, then $r = r^2 \in K^2$ and so $K \subseteq K^2$. Hence, $K = K^2$ and so every ideal of R is idempotent. Thus, as we have seen in the proof on Theorem 3, $\delta(K) \subseteq K$. Hence the filter F(R) is a δ-filter and so by Theorem 2, any derivation δ on a module M can be extended uniquely to its module of quotients.

LITERATURE CITED

1. Bresar, M. and J. Vukman. 1990. On left derivations and related mappings. Proc. Amer. Math. Soc. 110:7–16.

2. Chaung, C. 1990. On compositions of derivations of prime rings. Proc. Amer. Math. Soc. 108:647–652.

3. Golan, J. 1986. Torsion theories. Longman Scientific and Technical. copublished with John Wiley and Sons, Inc., New York.

4. Jans, J. 1965. Some aspects of torsion. Pacific J. of Math. 15:1249–1259.

5. Lambek, J. 1966. Lectures on rings and modules. Blaisdell Publishing Company, Toronto and London.

6. Nowicki, A. 1989. Derivations satisfying polynomial identities. Colloq. Math 57:35–43.

7. Stenstrom, B. 1975. Rings of quotients. Springer-Verlag, New York, Berlin.

8. Tewari, K. 1960. Complexes over complete algebra of quotients. Can. J. Math. 17:40–47.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 165–169

FORUM

Woundfins

BRANLEY ALLAN BRANSON

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Sand is nothing if not a harbinger of magical memories. The slightest gnash of it beneath the feet, as this afternoon in a child's playbox next to my house, causes me to pause in watchful reflection. A cholla forest may emerge unnoticed in the night. I know that deserts are on the march, relentlessly, they say, snuffing out rosebeds and wheatfields as they move. I wonder about those conclusions, however, for I do not believe that I shall live long enough to witness the invasion of Kentucky by the sand dunes of Phoenix. Yet, desert things have ways of conspiring to distil reason. Shadowy forms emerge into the daylight where they are seen for what they really are.

Most men live, perhaps, their entire lives without being smitten even once by magical instants, instants that carry the mind away from its confining bone deep into the wellsprings of glistening water and the rise of mountain ranges. The desert plays tricks like that, even on minds that are ever watchful lest miracles pass without being noted. Like beauty in a multitude of eyes, eliciting a different picture for each nerve, the scenes that waft from desertscapes make for wary, uncertain watchers. There is, I am certain, a reason for that: the vast lack of water. But vastness is relative. Water is everywhere evident; it subtends the great boles of chollas and saguaros; it slides down the hoary mountains and percolates into the sand; and it comes to the surface as springs, pools, and streams. Sometimes it falls from the air. Its cycles are all pervading, inexorable.

During many summers of various scientific excursions in American deserts, I have been served up a number of magical instants, some of them too personal to even contemplate outside the confines of my head. Other instants, precisely of the type at which I have been hinting, have been so unique that the reader will probably never be able to experience them, since I am certain that most readers would never imagine themselves in the body of another animal, least of all a small desert fish.

"And in that heaven of all their wish," says the poet Rupert Brooke, "there shall be no more land, say fish." He had desert fishes in mind, all right, and if he had extended his thinking a little more, desert-loving biologists, too, for they, like poets, are an alembic of survivorship, and although others may have had similar experiences they will never be the same. And sentience expressed at public gatherings by poets will not, by necessity, elicit the same response when given in private by scientists hardened by experimental design. To compound all that, I am hyperthyroid, causing me to suffer more than most desert travelers. Yet, as I think back on many of my experiences in the aridlands, perhaps it is my physiological condition that heightened the relationship between the desert and I. I am sure of that when I think back to the Virgin River.

Exactly what constitutes a river is a moot question in the desert. Sometimes, when the mountain storms send torrents cascading downward, they are raging personifications of destruction, carrying everything before them. At other times they whimper inches deep over the cast sand, flotsam from those same mountains. In its passage to the lowlands, insinuating its way through the tulmultousness of Zion Canyon before making a crook to dive into Arizona and Lake Mead, the Virgin river is a true paradox. As hot as bath water through much of the year, in winter its pools often freeze to the bottom. Bridges span its channel, and people despoil its waters. Yet, in spite of all that, the Virgin is a last refuge for a certain desert fish, the three-inch woundfin minnow.

Exactly why we were intent on driving 2,000 miles to meet this little creature is of no great importance to this essay. During many years, our scientific ventures have carried us to all parts of the American deserts, and we have had reason to become acquainted with nearly all the fishes that continue their struggle for existence, and even some that have since succumbed to the environmental blunders of men.

On the particular day that we eased out of Utah through Arizona and into Nevada, the milky-looking streamlet, nearly parched out of existence by the overbearing sun and attending drought startled us by way of its spareness. We decided to wade all the way to Lake Mead.

Why the idea germinated in my head, I am uncertain. I recall becoming momentarily dizzy, nearly faint, because of the hyperthyroidism and the extreme heat. As I lay supine beneath a bridge while my wife bathed my face with water, I fancied myself a fish floundering in a sun-struck pool, and the notion just popped into my head. To the seasoned world traveler, a wading trip down a sand-clogged stream of hot water will not seem a vast journey; it may even seem like a looking-glass journey, full of stuff and nonsense. But to us, who had to march the return eleven miles we convered in going in mid-July, it was not nonsense. Previous discoveries of mummified bodies along Southwestern rivers had graphically impressed us. Beside the fact that I dehydrate easily, the Virgin River does not make a beeline journey to the lake. Instead, it twists and turns like a reptile, and straight-line distances are often misleading. Heat death along such rivers is not exactly uncommon. Like most stretches of aquatic byways in the Southwest, sparsely clothed by tamarisk and scattered cottonwoods, rivers are not for vehicular traffic. Heat stroke might carry a man away long before an ambulance can arrive.

My redheaded wife mentioned these things with dark-eyed anxiety in the shade of the bridge, her toes wriggling in the shallow water. We had what we needed from the endangered woundfins. We tied our shoes to our belts, left the pickup where it was parked, and turned our faces south and set off. The dry hills mocked us. As the minutes passed, I fancied myself caught up in inexorable change, as if giant glaciers were melting to the north, sending their silvered waters sluicing into hidden basins. But I also felt the innervating heat bearing down, pulling me toward underground caverns beneath the sand. My head swam and the land danced. Make no doubt about it, this was an ancient battleground, rich in unwritten human history, richer still in earth history, witness to mountain building, the transformation of forests to desert. We were walking where three-toed horses had gamboled; I breathed the air of centuries, smelled the sulfureous volcanoes that exploded into oblivion, and my head swam. The woundfins touched their busy mouths to our skins, and I traced the multicolored layers of time through the loess.

We came upon a Model T frame projecting from a bank of sediments; we found a box that proclaimed "Dynamite" and a black-and-yellow centipede. In the shallows, the multi-colored particles rolled slowly downstream, remnants of old mountains streaming slowly downstream that would be retarded in their trip by Boulder and other dams—retarded, not stopped. I felt like a sand pebble myself, moving inexorably toward the mother sea, for everything eventually returns to whence it came. Man's architecture has the appearance of eternity, but it, too, will follow the mountains, the dams will erode away, release their hoard of sand, and the cities, when will the cities erode? We build on granite but it is water that makes the desert tolerable, and it is water that carries it away. The Anasazi and the People of the Morning Star and the swift runners of the old forest—and we of the latest attempt—all learned that water is something that cannot be abused in a land under the control of sun and wind. There is defiance, but in the end those elements are in command, and as I finally dizzily dropped to my knees, my brain reeling as from a peyote-induced vision, I lifted up my eyes to the sky, and raised my arms. I knew at once what the ancients knew, that we can not trap desert water forever, that the desert was not meant to be an Eden for man, and for all our ingenuity of pipes and well-oiled gears that whirr in the megaliths blocking the way, sand is not the mother of living things, nor shall it ever be; there is nothing suspicious respiring in its depths.

But what had we learned, as living concretions of water and, yes, even traces of sand that move so godlike through the wastelands of earth, what had we intended to learn in our long escape from the confines of gills? I, in my hoarded wisdom of many years, was certainly a moving desert parching slowly in the sun, giving admonitions to the kingdom of my own control. The sand upon which I knelt, grinding into the living flesh, reminded me that mountains fall, a minuscule expansion of the cosmos that send meteors crashing and which, upon inspiration, draw them back again.

William Blake, contemplating the pale facade of innocence in the 18th century, thought he could discern the world in a grain of sand and, during a moment of weird understanding, find heaven hiding in the petals of flowers. There is deeper insight in those poetics than Blake realized, the cyclical punctuation of mountains reared up by the expenditure of enormous energy to grains of sand and the subsidence of those in the sea, the partitioning of the parts in snail shells and the slithering of eels, and the return to mountains again. The poet may have seen in those crystalline planes the spruce casting needles to the wind that end up rolling in the waters of the Virgin. Whatever his thoughts, Blake's mind may have traveled enormously with his grain of sand, feeling the heavy foot of the great reptiles and the smothering of Cretaceous skies. In the rise of mountains and the drying out of the heartlands of America, sand became the common currency of the environment. The day of the forest was over, replaced by spiny water tanks that awaited the coming of man.

Years later, we camped on the banks of the same Virgin River we had hiked, in Zion, with snow frosting the highlands above us. We were alone, my wife and I, encased in down jackets and mittens. The cold river had a peculiar greenness to it, the kind of color dissolved iron gives water, and the leafless trees produced a swishingly musical sound in the crisp air. Our boots crunched the hoarfrost on the ground. In a tiny embayment, where the currents had dropped a load of brown, decaying leaves, whirligig beetles made slow circles on the surface and brilliant silver flashes exposed themselves against the stark bottom. We knew them for what they were.

Resting there with their clear fins spread as if for aerial flight, the males' nuptial colors already beginning to show, was a congress of familiar slender forms. They were woundfins, of course, experts of the narrow, shallow channels, that had nibbled our toes on the long trek south. We could tell by the pink blotches at the base of the fins that colorless spherules, coded for life in an antilife place, were now swelling and maturing within their delicate bodies. The chemical messengers, interacting with the lengthening of days, were racing through them, preparing the fish for one exuberance of sex, and they were simply biding their time until the day when the temperature was right. Fishes are slaves to temperature.

As scientists, we wondered aloud if the males would develop their bridesgroom colors if we artificially warmed them, or was it that the spring festivals were running in internal rivers? We decided it was experimentation—all scientists call up that term when they control things—and netted a dozen or so of the minnows and put them in a gallon jar. We did not expect instantaneous results, of course. We expected to see some changes during a week's time, perhaps, or ten days. We placed them, river water and all, in the back of our trailer. Then we sat down to a meal of—paradoxically—frozen perch lorn so far from the sea. Connections are tenuous, but the web includes us all.

Thus, because of our hunger and thirst, we did not pay proper attention to our captives. The overhead lamps cast light into the jar and the propane heater soon had us cozy enough to remove our jackets. One brief inspection demonstrated that the fish were hovering midway up in the water column. Sleep overtook us.

I do not know why I awakened so early the next morning. It was predawn. The light outside was preternatural, without substance. I heard flipping, liquid sounds in the rear of the trailer and got up to inspect those environs. The males had brilliant red patches now, and they were chasing the females around the circular container, flicking the surface with their tails. I sat down to watch. The fish ignored me. "Life," they whispered. These were not gold fish born in a tank. These were citizens of the sandstorm, ancient respondents to drought and interminable heat. They were end products and descendents of the Ice Ages, wafted about by giant waters, and partitioned, finally, by their genetics and adaptations to this particular river basin. The stamp of time was upon them.

"I'm not here to interfere," I said.

They executed to perfection their ancient drives while I watched. Quivering tail to tail and eye to eye, the clouds of milt and golden, magical spherules falling away like living rain. In their finely tuned brains and pituitary glands, the environment of the trailer had paralleled nature, and they felt—well, perhaps they didn't think about it at all. I watched the tiny amorphous eggs fall to the bottom, undulating gently back and forth from the currents set up by the parents. They had made their brave attempt to keep the species going, even if in a vitreous world with narrow boundaries. In a proper habitat, most of the eggs would never give rise to schools of adults; native waters are full of tooth and claw, and fungus lurks everywhere. But a billion years had gone into the perfection of those living bubbles, and the unbroken chain of feathered and furry things that came up with them.

"It's time to be on your own," I told the adults as I carried the jar back to the river. "This is a good place to weather the centuries until the next ice ages."

With fresh water, we kept the eggs with us for the next five days. They held for us the kind of history that spells out what earth is all about. We were, fish and humans, all cousins that share in the same glorious, unbroken code. In fish and soaring golden eagles riding the high thermals, and on the breakfast plate before me, I contemplated myself in an unrisen form, a form that still paddles in the oxygenless swamps of the netherlands waiting, perhaps, to emerge when my ilk has finished. Often I have felt the wrath of developers and dam builders when I have written about conservation and endangered fishes. Representatives of powerful interests have scorned my name for helping to hold up projects to protect three-inch fishes. Those interests fail to consider, it seems, anything but green-tinted paper in which are embedded multicolored fibers. They would eliminate these rare creatures and their magical spheres and replace them with more trustworthy species, like catfish and bass, to insure that they do not, by some nebulous miracle, perhaps, change their form into something that challenges engineers directly—a tetrapod, perhaps, capable of emerging again from the water to devour what we have wrought. We believe in life, though, and having been on such intimate terms with the woundfins in our youth, we felt obliged to return the eggs—dark eyes now whirling within the transparent casements—to the flowing river. I felt a little contrite with myself—more contrite than the engineers who had erected the great dam in the coils of the desert.

In the summer, on the glassy surface of Lake Mead, we hear the roar of motors and the shrill laughter of bronzed young Americans, sounds that are altogether reminescent of great cities to the east. They are, of course, mobile cities. Self assured. When seen from high places, man's gatherings seem like schools of fishes gathering for some stereotyped behavior that may or may not carry on into the future. The voices, those of the mechanical things, I mean, are irritants. Even the cars searching through the campgrounds at night are irritants, probably also to the tiny woundfins we released into the Virgin.

The sound of silence is like music to the ear of skilled biologists sojourning in the desert, easily distinguished from the silence of great cities and buildings, like poetry in the rustlings of unseen things in the undergrowth and wingbeats of moths in from the night, and they take them in with their breathing without marking in their consciousness. But there is no silence quite so profound as that encountered at airports, when nothing singing in the trees or splashing in the algal ridden shallows is discernible. In the dark of night, a single jet screams beneath the stars, paying out a long, white, whispy tail that gradually dissipates in the long, red rays of the morning star. Up there, we know, is a true desert, forever fishless.

At those times, when those people-deserts crowd oppressively in upon my small space, I think back to our river stroll. We talk of the omnipotent heat, the nibbling woundfins, and the endless desert sand driven by the hot wind. And as we speed through the uninhabited high places, peering down like senseless ascetics from a snowy mountain, the desert lifts its spiny arms upward imploringly.

They say more dams are planned to prevent the escape of water, to allow the growth of already overgrown cities like Phoenix and Tempe. They will grow, it is true, but there is a limit to growth—Chaco Canyon and its great, silent kivas attest to that, and so do the potshard pieces excavated and carried upward into the sun by ants. That man has tried to conquer the desert is obvious. Yet, those attempts were not couched in the same terminology, nor predestined in the same well-oiled machinery as we now encounter. Like a plague, these new attempts level mountains to ground level or excavate lake basins where none have been before. Those same thoughts, I believe in my heart, must have occured before the simplest engines evolved.

The wind is coming up in the west. The

serene, clear air has vanished before the onslaught of scarifying clouds of sand like the breath of a furnace in a prodigious mill. In the trailer, we find, sand has sifted through the tightly closed windows. The buildings in the cities must take note of that, must enter it into the calculations. Mountains have simply given up a little more of their form and stature to reappear in another guise. The sun has not so far to rise to clear the surface, nor we so far to go to slide down the other side. Sand is the final explanation of all that has risen or will ever rise in the desert. It will eventually clasp us all—men and water, and woundfin minnows—in the deep embrace that makes for the exuberance of life that will surely follow.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 170–171

NOTES

Host occurrence of *Phoradendron leucarpum* in the Lexington-Blue Grass Army Depot, Blue Grass Facility, Madison County, Kentucky.—The Lexington-Blue Grass Army Depot (LBAD), Blue Grass Facility, near Richmond, Kentucky, is bordered on the west by U.S. 421-25, on the north by Ky. 52, on the east by Ky. 374, and on the south by Ky. 499. The LBAD, Blue Grass Facility constitutes a significant area to inventory for the presence of American mistletoe (*Phoradendron leucarpum*) as part of a continuing survey of mistletoe-infested host trees in Madison County, Kentucky. Security clearance and permission from the land manager were necessary to gain entrance to the highly restricted LBAD, Blue Grass Facility.

This survey represents the first in-depth documentation and collection of mistletoe for a specific area in Kentucky, although individual mistletoe site occurrences have been reported for Kentucky counties (Garman, Woody Plants of Kentucky, Bull. Ky. Agri. Stat. 169:3–62, 1913; Braun, Annotated Catalog of Spermatophytes of Kentucky, 1942; Reed and Reed, Castanea 16:7–15, 1951; Wharton and Barbour, Trees & Shrubs of Kentucky, The University Press of Kentucky, 1973). All host tree species with visible signs of mistletoe parasitism, i.e., cankers, branch swellings, die-back, and clumps, were recorded from March 26–April 5, 1988. A representative mistletoe voucher with a twig from each host species was collected and deposited in the Berea College Herbarium (BEREA).

Phoradendron leucarpum (Raf.) Rev. & M. C. Johnston (Viscaceae) became the correct nomenclatural combination for American mistletoe in 1988 after a vote by the Committee for Spermatophyta (Reveal and Johnston, Taxon 38:107–108, 1989). Prior combinations used in state and regional manuals, *P. flavescens* (Pursh) Nutt. and *P. serotinum* (Raf.) M.C. Johnston, should be treated as synonyms. American mistletoe is a woody, evergreen, dioecious, obligate hemiparasite on various deciduous shrubs and trees. The distributional range extends eastward from New Mexico, Texas, Oklahoma, and Arkansas through the southeastern states to Florida and northward to southern New Jersey, southeastern Pennsylvania and extreme southern Ohio, Indiana, Illinois, and Missouri (Wiens, Brittonia 16: 11–54, 1964; Mohlenbrock, The Illustrated Flora of Illinois: Flowering Plants Nightshades to Mistletoe, Southern Illinois University Press, 1990).

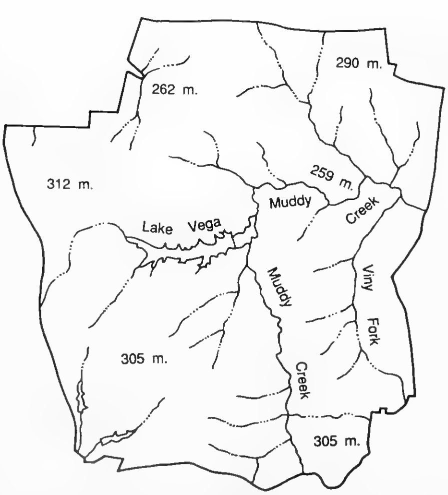


FIG. 1. Lexington-Blue Grass Army Depot, Blue Grass Facility, Madison County (Adapted from McDowell, Grabowski, Jr., and Moore, Geologic Map of Kentucky, U.S. Geological Survey, Washington, D.C.).

The LBAD, Blue Grass Facility was initially constructed as the U.S. Military Reservation Blue Grass Ordnance Depot in April 1942 and began official operations in October 1942. It serves primarily as a storage and maintenance depot for chemical weapons and conventional ammunition and as a multiple land use area for agricultural grazing, forestry, and wildlife resources. The LBAD, Blue Grass Facility consists of 5,907 ha with 4,856 ha in 16 tracts of varying sizes, which are leased for livestock grazing and limited hay production through the Agricultural Outleasing Program. Lake Vega, a 54.6 ha reservoir, supplies water for the depot and is a part of the Fish and Wildlife Management Program (Anonymous, Public Affairs Office, LBAD, Lexington, 1987).

The LBAD, Blue Grass Facility is situated in the Outer Bluegrass Physiographic Region, 1 of 6 sections of the Western Mesophytic Forest Region of Braun (Deciduous Forests of Eastern North America, Hafner Press, 1950). The forest at the depot may be classified as the sugar maple-black walnut type on moist sites, the oak-hickory type and oak-ash type on dry sites, and the red cedar-black locust on drier sites based on upland forest types and environmental relationships of moisture, pH, topography, and slope aspect from Campbell (Gradients of Tree Composition in the Central Hardwood Region, Proceedings, Central Hardwood Forest Conference VI, p. 325–346, 1987). Total scattered oak-hickory-ash-red cedar woodland approximates 175 ha with 100 ha of wildlife wooded areas, and 75 ha of small woodlots with 10 ha reforested (Anonymous, Forest Management Plan, Lexington-Blue Grass Depot, Blue Grass Facility, 1970).

Elevations within the LBAD, Blue Grass Facility range from 259 m in the Muddy Creek and Viny Fork system to 312 m on ridgetops (Fig. 1). The topography consists of rolling hill terrain with 2–12% slopes and broad ridges of Upper Ordovician limestones, dolomitic limestones, and calcitic shales of the Drake and Ashlock Formations. A small area in the extreme southeastern portion near Speedwell consists of Lower Silurian calcitic dolomites and mudstones of Brassfield Dolomite of Lower Silurian age and Middle Devonian dolomites and dolomitic limestones (Greene, Richmond South Quadrangle, Kentucky, GQ-479, 1966; Greene, Moberly Quadrangle, Kentucky, GQ-664, 1968). Four general forest soils mapped within the

TABLE 1. Host occurrence of American mistletoe (*Phoradendron leucarpum*) at the Lexington-Blue Grass Army Depot, Blue Grass Facility, Madison County, Kentucky.

Tree species	Total	Percentage
Prunus serotina	903	49.15
Juglans nigra	321	17.47
Ulmus americana	246	13.39
Fraxinus americana	124	6.75
Gleditsia triacanthos	95	5.17
Robinia pseudoacacia	79	4.30
Celtis occidentalis	19	1.03
Acer saccharum	18	0.98
Carya ovata	14	0.76
Maclura pomifera	11	0.60
Acer rubrum	4	0.22
Quercus muehlenbergii	1	0.06
Aesculus glabra	1	0.06
Acer saccharinum	1	0.06
Totals: 14	1837	100.00

LBAD, Blue Grass Facility are the Lawrence-Mercer-Robertsville Association of broad flats and alluvial drainageways, the Beasley-Brassfield-Otway Association of narrow ridges and side slopes, the Shelbyville-Mercer-Nicholson Association of level and wide ridgetops and slopes, and the Lowell-Faywood-Cynthiana-Rock Outcrop Association of wide ridgetops and moderate side slopes (Newton, McDonald, Preston, Richardson, and Sims, Soil Survey of Madison County, Kentucky, USDA, Soil Conservation Service, 1973).

Most mistletoe-infested trees occurred in pastures and fields, woodlands, fencerows, woodlot edges, and bunker areas in open terrain on ridges, rolling hills, and upper slopes. A total of 1837 mistletoe-infested trees were documented from 14 host-tree species at the LBAD, Blue Grass Facility. *Prunus serotina, Juglans nigra,* and *Ulmus americana* accounted for over 80 percent of all host trees (Table 1). *Aesculus glabra* was documented as a host tree for the first time in Kentucky.

Appreciation is extended to Billye M. Haslett, Land Manager, LBAD, Blue Grass Facility, for permission to conduct this study and for providing depot literature references. Thanks are given to Security Personnel, Charles Abney and Gary Langford, for transportation, and special thanks to Mack Harrison for transportation and his keen eyes for sighting even the smallest mistletoe clusters.—
Ralph L. Thompson, Biology Department, Berea College Herbarium, Berea, Kentucky 40404.

Occurrence of the Northern Studfish, *Fundulus catenatus* (Storer), in Northeastern Kentucky.—Kentucky populations of the northern studfish, *Fundulus catenatus*, are mainly found in several drainages in south-central Kentucky. Specimens are known from the upper Barren, upper Green, middle Cumberland, Dix and Salt rivers. However, this species is also known from the Licking and Big Sandy river drainages (Burr and Warren, Ky. Nat. Pres. Comm. Sci. Tech. Ser. 4, 1986). Burr and Warren (1986) reported specimens from Rockhouse Fork (Magoffin County), Licking River and Cave Run Lake (Rowan County), and Middle Creek (Floyd County). Their Rowan County specimens were collected by students in my ichthyology class at MSU; these specimens were found in Warix Run, Cave Run Lake and in the Licking River at US 60, near Farmers. Additional records in the MSU Vertebrate Collection are for specimens from the Licking River at Moores Ferry (Bath County), Grassy Creek (Morgan County), Payton Fork, ca. 1 mi S of Grassy Creek (Morgan County), and Abbott Creek at KY 1428 (Floyd County). Specimens from Bath, Rowan and Morgan Counties frequent the Licking River Drainage; those from Abbott Creek are in the Big Sandy Drainage. Perhaps this species was introduced by bait-bucket transfer, or perhaps it occurs in this region as a group of relict populations.—
Les Meade, Department of Biological and Environmental Sciences, Morehead State University, Morehead, Kentucky 40351.

NEWS AND COMMENTS

Annual Meetings

The 78th meeting of the Kentucky Academy of Science will be held at the Ashland Community College, Ashland, Kentucky, October 29–31, 1992. The 79th meeting is scheduled for Georgetown College, October 22–24, 1993, and will sponsored jointly by Georgetown College and the Toyota Motor Corporation.

Important Publication

Browne, Edward T. and Raymond Athey. 1992. *Vascular Plants of Kentucky. An Annotated Checklist.* University Press of Kentucky, Lexington, 180 pages ($20.00). The publication of this important book unfortunately did not occur until Mr. Athey's demise. Since the work lists over 3,000 plant species and varieties, providing geographic distribution by physiographic region for each form, the book should be of great interest to anybody interested in the flora of Kentucky, from systematists to flower lovers. Raymond Athey was, of course, a great benefactor of the Kentucky Academy of Science, and he will be missed by the scientific community.

Westinghouse Science Talent Search Scholarships for 1992

In the 51st Westinghouse Science Talent Search, only one Kentucky student—Nandini Nagarajin from Ballard High School—made it to the semifinalist level, and none appeared on the finalist list. The 40 finalists will share in a $205,000 scholarship pool: one $40,000, one $30,000, one $20,000, three $15,000, four $10,000 awards, and 30 $1,000 awards. Above and beyond the financial assistance, however, these are very prestigious awards. Five former winers have won the Nobel Prize, and countless others have made outstanding contributions to various areas of science.

Scientists in Kentucky are, perhaps, remiss in not directing more attention to high school students. It is embarrassing that only one of our students made it as far as the semifinals. We need to do more to encourage our budding scientific minds into a competitive mode of thinking, to reward imaginative and creative minds with assistance (personal, institutional, financial) in developing legitimate research projects at their high schools. We should follow the progress of individual students all the way to fruition of their efforts. I personally would like to see more Kentucky kids in those semifinalist and finalist lists, and perhaps a winner or two upon the podium. We have nothing to lose and everything to gain for our efforts.

Information concerning the Westinghouse Science Scholarships can be obtained from Science Service, 1719 N Street NW, Washington, D.C. 20036.

Trans. Ky. Acad. Sci., 53(3–4), 1992, 173–180

INDEX TO VOLUME 53

Instructions for Contributors

Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

Manuscripts may be submitted at any time to the Editor. Each manuscript will be reviewed by one or more persons prior to its acceptance for publication, and once accepted, an attempt will be made to publish papers in the order of acceptance. Manuscripts should be typed double spaced throughout on good quality white paper 8½ × 11 inches. NOTE: For format of feature articles and notes see Volume 43(3–4) 1982. The original and one copy should be sent to the Editor and the author should retain a copy for use in correcting proof. Metric and Celsius units shall be used for all measurements. The basic pattern of presentation will be consistent for all manuscripts. The Style Manual of the Council of Biological Editors (CBE Style Manual), the Handbook for Authors of the American Institute of Physics, Webster's Third New International Dictionary, and a Manual of Style (Chicago University Press) are most useful guides in matters of style, form, and spelling. Only those words intended to be italicized in the final publication should be underlined. All authors must be members of the Academy.

The sequence of material in feature-length manuscripts should be: title page, abstract, body of the manuscript, acknowledgments, literature cited, tables with table headings, and figure legends and figures.

1. The title page should include the title of the paper, the authors' names and addresses, and any footnote material concerning credits, changes of address, and so forth.

2. The abstract should be concise and descriptive of the information contained in the paper. It should be complete in itself without reference to the paper.

3. The body of the manuscript should include the following sections: Introduction, Materials and Methods, Results, Discussion, Summary, Acknowledgments, and Literature Cited. All tables and figures, as well as all literature cited, must be referred to in the text.

4. All references in the Literature Cited must be typewritten, double spaced, and should provide complete information on the material referred to. See Volume 43(3–4) 1982 for style.

5. For style of abstract preparation for papers presented at annual meetings, see Volume 43(3–4) 1982.

6. Each table, together with its heading, must be double spaced, numbered in Arabic numerals, and set on a separate page. The heading of the table should be informative of its contents.

Each figure should be reproduced as a glossy print either 5 × 7 or 8 × 10 inches. Line drawings in India ink on white paper are acceptable, but should be no larger than 8½ × 11 inches. Photographs should have good contrast so they can be reproduced satisfactorily. All figures should be numbered in Arabic numerals and should be accompanied by an appropriate legend. It is strongly suggested that all contributors follow the guidelines of Allen's (1977) "Steps Toward Better Scientific Illustrations" published by the Allen Press, Inc., Lawrence, Kansas 66044.

The author is responsible for correcting galley proofs. He is also responsible for checking all literature cited to make certain that each article or book is cited correctly. Extensive alterations on the galley proofs are expensive and costs will be borne by the author. Reprints are to be ordered when the galley proofs are returned by the Editor.

CONTENTS

TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

Volume 54
Numbers 1–2
March 1993

Official Publication of the Academy

The Kentucky Academy of Science

Founded 8 May 1914

All manuscripts and correspondence concerning manuscripts should be addressed to the Editor. Authors must be members of the Academy.

The TRANSACTIONS are indexed in the Science Citation Index. Coden TKASAT. ISSN No. 0023-0081.

Membership in the Academy is open to interested persons upon nomination, payment of dues, and election. Application forms for membership may be obtained from the Secretary. The TRANSACTIONS are sent free to all members in good standing.

Annual dues are $25.00 for Active Members; $15.00 for Student Members; $35.00 for Family; $350.00 for Life Members. Subscription rates for nonmembers are: domestic, $45.00; foreign $50.00; back issues are $30.00 per volume.

The TRANSACTIONS are issued semiannually in March and September. Four numbers comprise a volume.

Correspondence concerning memberships or subscriptions should be addressed to the Secretary. Exchanges and correspondence relating to exchanges should be addressed to the Librarian, University of Louisville, Louisville, Kentucky 40292, the exchange agent for the Academy.

THIS PUBLICATION IS PRINTED ON ACID-FREE PAPER.

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

March 1993
Volume 54
Numbers 1–2

Trans. Ky. Acad. Sci., 54(1–2), 1993, 1–6

Reproduction, Age and Growth Analysis of Paddlefish, *Polyodon spathula*, in the Falls of the Ohio National Wildlife Conservation Area

Deke T. Gundersen

Department of Fisheries and Wildlife, Oak Creek Laboratory of Biology, Oregon State University, Corvallis, Oregon 97330

and

William D. Pearson

Water Resources Laboratory, University of Louisville, Louisville, Kentucky 40292

Abstract

The status of paddlefish populations at the Falls of the Ohio River near Louisville, Kentucky is in question. This is due to habitat alteration, commercial fishing and high levels of PCBs being detected in the reproductive tissues of paddlefish from this area. Information on age, growth and sex of paddlefish collected from the Falls area was obtained between May 1988 and October 1989, to better evaluate the status of these populations. Paddlefish were captured with large mesh gill nets. Stranded paddlefish (54% of total) were also captured by hand and with dip nets shortly after the closing of McAlpine Dam. All fish were sexed and measured for total lengths, and the dentary bone of each fish was removed for age determinations. A total of 33 paddlefish were collected (20 males and 13 females). Most of the fish collected (70%) were between the ages of 6 and 12. The rate of growth of paddlefish appeared to be rapid for the first 3 years since lengths of 90 cm were possible by the third year. Only 3 of the females collected had ovaries with large egg masses. Additional measures may be needed to ensure the continued survival and well-being of paddlefish populations in this area.

Introduction

The paddlefish (*Polyodon spathula*) is a primitive chondrostean which is found primarily in large rivers of the Mississippi River drainage and a few rivers that run directly into the Gulf of Mexico (1). It is of particular interest to ichthyologists because of its great age, and the existence of just 2 living species (the second, *Psephurus gladius* in China) and 2 known fossil species in the family Polyodontidae. Within the last 100 years, paddlefish have undergone restrictions in range and there have been substantial declines in populations in some major river systems (1, 2, 3). It appears that habitat alteration and destruction, and commercial fishing pressure have played a big part in causing the decline of this species in many large rivers (1, 4, 5, 6, 7, 8).

The main stem of the Ohio River extends 981 miles from its source in Pittsburgh, Pennsylvania to its confluence with the Mississippi River, and the Falls of the Ohio is the only area along the mainstem which has a riffle-run habitat since establishment of navigation pools (9). This area harbors an abundant and diverse fish community (10) and may be a refuge for many fish which are either threatened or of special concern, including the paddlefish (11). The status of paddlefish in this area is questionable due to a number of factors, one of

TABLE 1. Dates, sex, total lengths and age of paddlefish collected from the Falls of the Ohio River near Louisville, Kentucky.

Date collected	Sex	Total length (cm)	Age (yrs)
5/5/88	M	111.0	6
	M	124.5	9
	F	117.0	11
5/6/88	M	126.0	12
	M	116.0	17
	F	127.0	12
	F	132.0	16
5/10/88	F	113.0	7
5/11/88	M	100.0	7
5/31/88	M	104.0	6
	M	105.0	6
	M	110.0	8
	M	111.0	8
	M	125.0	15
	F	131.0	10
	F	130.0	16
6/3/89	M	106.0	7
	F	131.5	13
	F	134.0	17
	F	139.0	17
7/3/89	F	90.0	3
8/3/89	M	100.0	6
	M	105.5	7
	M	103.0	9
	M	122.0	10
	M	101.0	11
	M	120.0	11
	M	129.0	18
	F	103.0	7
	F	101.0	9
	F	119.0	9
	F	124.0	12
10/13/89	M	50.0	2

which is illegal harvesting of paddlefish from this area by commercial fishermen in order to obtain the highly sought roe of females that is used to produce american caviar. In the early 1980s trade limitations with Iran reduced imports of Caspian Sea caviar and increased the demand for paddlefish roe which brought fishermen as much as $65/kg (5). Other factors affecting paddlefish populations in this area are hydroelectric power generation, flood control, maintenance of the 9-foot navigation depth and low-flow augmentation which have modified natural flow regimes, periodically causing fluctuations in flow and water levels. These fluctuations in flow and water levels have trapped fish and their eggs in isolated pools and stranded them on the exposed streambed and shoreline areas (9). High levels of PCBs have also been detected in the reproductive tissues of paddlefish collected from this area (12, 13), raising questions about the reproductive success of the species.

METHODS

Paddlefish were collected from the Falls of the Ohio River, near Louisville, Kentucky during May through September 1988 and May through September, 1989 between Ohio River miles 604.6 and 606.5. Paddlefish were captured with gill nets (30–60 m in length, 1.8 m deep, and 5–13 cm bar measure mesh). Both multi- and monofilament nets were used. Stranded paddlefish were also captured by hand, and with dip nets shortly after the closing of McAlpine Dam, which usually occurs during summer and fall months. A total of 16 paddlefish were collected in 1988 (Table 1). Using gill nets, 3 paddlefish were captured on May 5, 4 on May 6, 1 on May 10 and 1 on May 11. Following a dam closure, 7 paddlefish were collected on May 31. A total of 17 paddlefish were collected in 1989. Using gill nets 4 paddlefish were collected on June 3 and one on July 3. Following a dam closure on August 3, 11 paddlefish were collected. On October 10, 1 paddlefish was collected from McAlpine Lock, during a lockchamber rotenone collection.

Immediately after capture, all fish were measured (total lengths) and fillets and gonads were removed for determination of PCB concentrations (13). The dentary bone was also removed for later age determinations. Age determinations using dentary bones were carried out in a manner similar to the procedure described by Adams (14). Skin and excess tissue were removed from all dentary bones, and the bones were allowed to dry before any further preparations. Approximately 15 sections were made from each dentary bone at the point where it bends toward the middle. Sections were cut with a Dremel rotary cutting tool and an abrasive cutoff disk. They were then mounted on glass slides with epoxy resin. Sections were ground with various polishing stones, until growth rings could be seen clearly. Sections were examined under a dissection microscope with xylene added to each section to enhance the definition of growth rings.

RESULTS

A total of 33 paddlefish were collected from the Falls of the Ohio River near Louisville, Kentucky, with 20 (61%) being males and 13

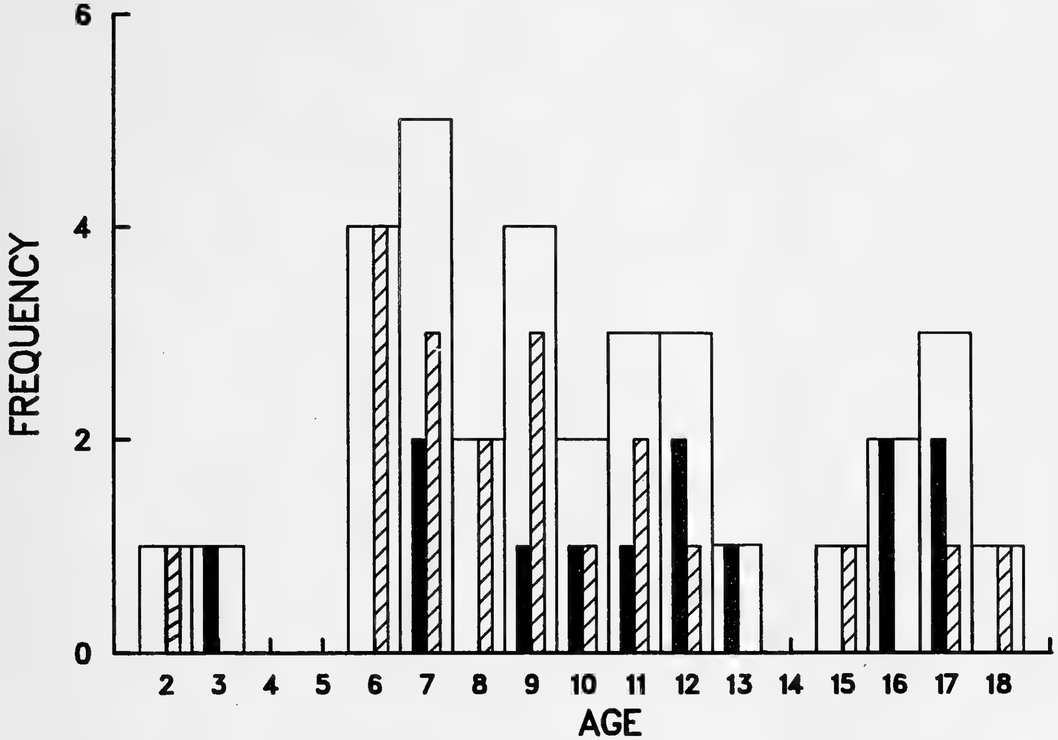


FIG. 1. Age frequency plot of all paddlefish collected from the Falls of the Ohio River near Louisville, Kentucky (represented by clear bars), including the frequency of males (striped bars), and females (solid bars).

(39%) females (Table 1). The range in total length for all fish collected was from 50.0 cm to 139.0 cm, with a mean total length of 113.9 cm.

Figure 1 shows the frequency of paddlefish collected in each age class. All fish collected were between the ages of 2 and 18 years with none being collected at 4, 5 or 14 years of age. The majority of fish collected (70%) were between the ages of 6 and 12. The youngest male and female were 2 and 3 years old, respectively. There were 3 males older than 12, with the oldest being 18 years of age. In comparison, there were 5 females older than 12, with the oldest two being 17 years.

The rate of growth for paddlefish collected from the Falls of the Ohio River (Fig. 2) appears to be rapid for the first 3 years since the fish attain lengths of 50.0 cm in the first 2 years of growth, and 90.0 cm in the third year. Fish examined in the 129.0 cm to 134.0 cm lengths were in their sixteenth to eighteenth year, indicating that growth from 90.0 cm to approximately 130.0 cm required about 13–15 years. In age classes where both females and males were collected, females tended to be larger than males (Fig. 3).

Female paddlefish have generally been reported to reach sexual maturity at 10–12 years and males at 7–9 years (1), although Hoffnagle and Timmons (15) reported earlier maturation ages of 8 and 6 years in Kentucky Lake. Based on these numbers and observations of reproductive tissue, 70% of the males and 69% of the females collected were sexually mature. Large egg masses were found in 3 of the females collected and one had ovaries in which eggs were in the early stages of development. All other females had immature ovaries which were associated with large fat bodies. The testes of males collected were also associated with dense fat bodies.

DISCUSSION

More than half of the paddlefish (54%) were collected after being stranded in shallow pools following the closing of McAlpine Dam (31 May 1988 and 3 August 1989). New operation

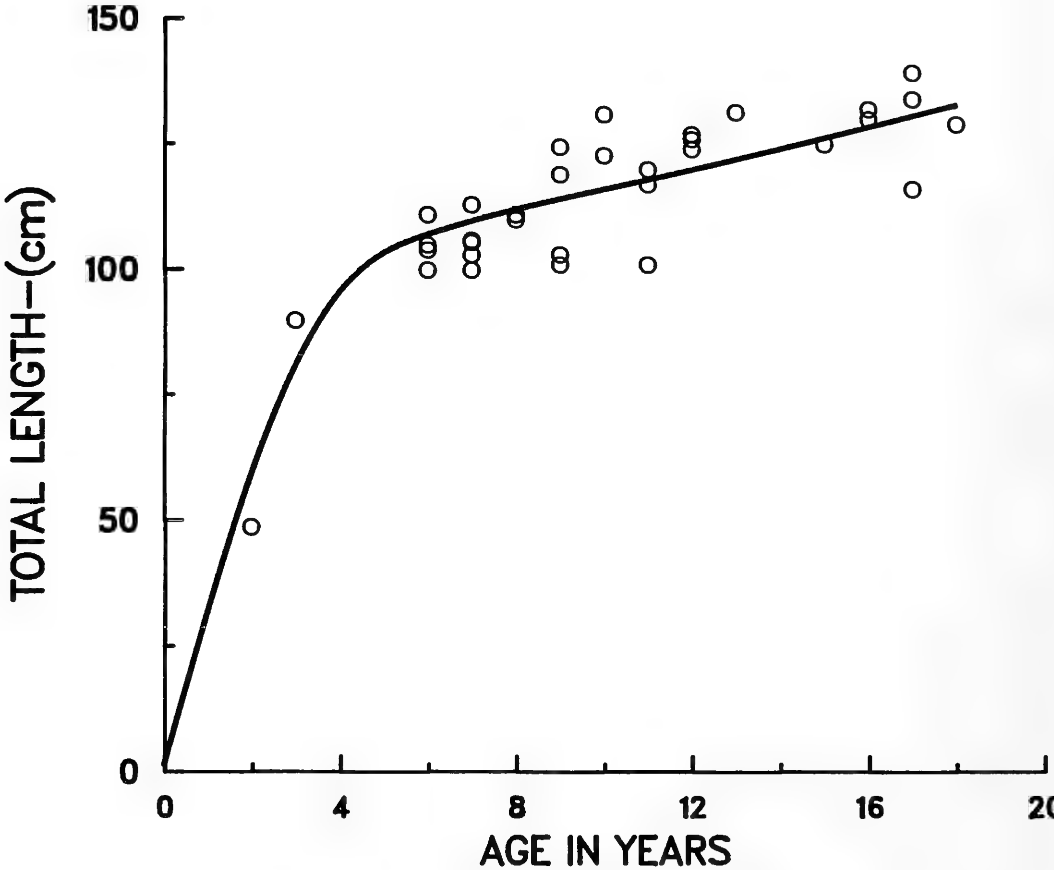


FIG. 2. Age length plot of paddlefish collected from the Falls of the Ohio River near Louisville, Kentucky.

procedures for McAlpine Locks and Dam have been put into effect by the U.S. Army Corps of Engineers in order to minimize fish stranding (9). It appears that these measures have reduced the number of smaller fishes being stranded, but larger fishes, like the paddlefish are still susceptible to being stranded. Additional measures may be needed to reduce the numbers of large fish being stranded. Adult paddlefish are due special consideration as fish of special concern (11) and as the ones contributing to reproduction in the population (5).

Adams (14) reported that otoliths and dentary bones were best suited for aging younger paddlefish and that age determinations of older fish were subject to more variability. Variability in total length for each age class of paddlefish collected from the Falls of the Ohio River was greatest in fish that exceeded 8 years of age. Age determinations became progressively difficult as annuli on sections of dentary bones of older paddlefish became crowded and difficult to distinguish from neighboring bands. The majority of paddlefish collected from the Ohio River were between the ages of 6 and 12, which appears to be somewhat low compared to other studies. Russell (1) reported that where paddlefish populations are sustained by sexually mature adults, most fish collected range from 7–18 years of age. Bronte and Johnson (5) and Hoffnagle and Timmons (15) also reported a high frequency of younger fish being collected from Kentucky Lake and Lake Barkley, in Kentucky, suggesting that through commercial and sports fishing, many individuals are harvested before being able to contribute to reproduction. This could certainly be the case for paddlefish populations at the Falls of the Ohio River, where commercial fishermen have been observed fishing for paddlefish with large mesh gill nets. In addition to this, many paddlefish and their eggs are stranded by dam

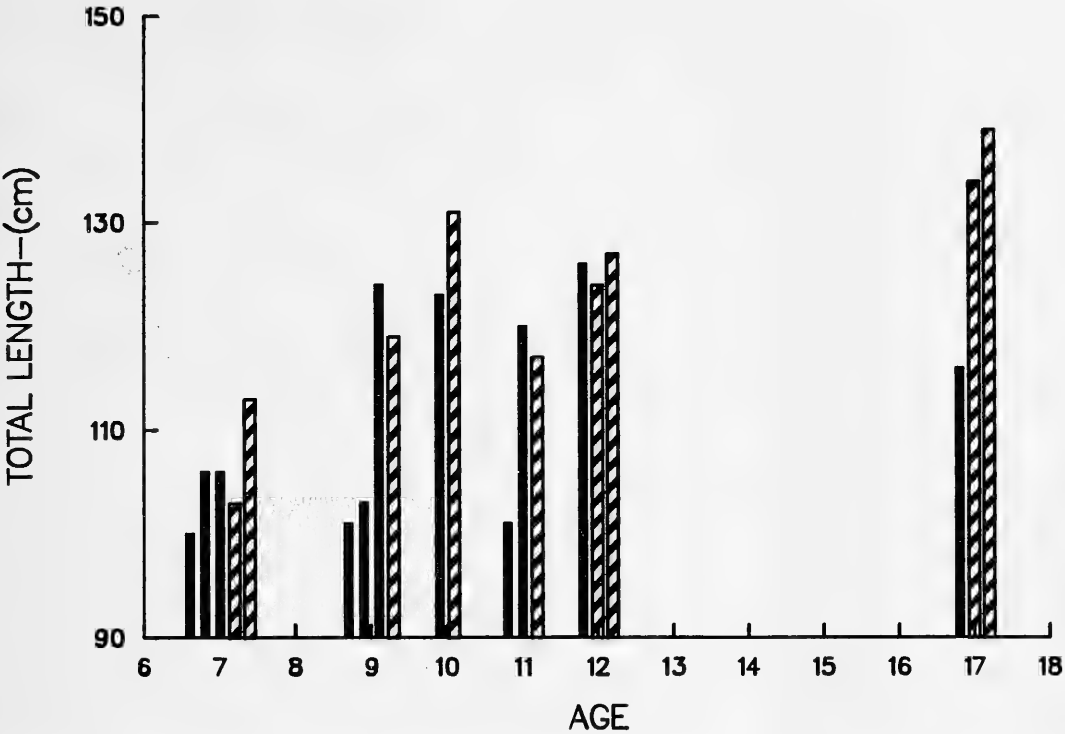


FIG. 3. Bar graph showing total lengths of male (solid bars) and female (striped bars) paddlefish collected from the Falls of the Ohio River near Louisville, Kentucky, in which both sexes were collected at each age class.

closures, particularly when these closures occur during the spawning season (9).

Length and age determinations of paddlefish from the Falls of the Ohio River indicated that total lengths of 90.0 cm were possible in the first 3 years of growth. This is consistent with the findings of Adams (14) who reported the rate of growth for paddlefish to be rapid for the first 3 years. Russell (1) reported values of mean total lengths from various studies on paddlefish, ranging from 71.0 cm to 94.0 cm. Growth rates for paddlefish from the Falls of the Ohio River were at the upper end of the range reported by Russell, which might indicate that a plentiful food supply exists for younger paddlefish at the Falls. This early rapid growth rate may be misleading, however, since only 1 individual was collected in year class III, and one at year class II. The low number of younger paddlefish collected was probably due to the use of large mesh gill nets (5–13 cm bar measure mesh), and it is possible that only the fastest growing members of age class II and III were collected.

Only 3 of the females collected from the Falls of the Ohio River contained mature ovaries. According to Houser and Bross (16), Purkett (3), and Bronte and Johnson (5), it is not unusual to observe few or no gravid females in samples containing sexually mature fish. This is indicative of present theories suggesting that paddlefish do not spawn every year (1, 14). Purkett (3), suggested that warming water temperatures (50°F), and a rise in river levels, may be necessary to promote spawning. All 3 gravid females were collected in May of 1988. In the spring of 1988, warming water temperatures were accompanied by an initial rise in river levels, providing the above suggested spawning conditions. In the spring of 1989 water levels in the Ohio River were high and stayed that way until mid summer, suggesting that both water temperature and falling high river levels may be necessary to facilitate spawning of Ohio River paddlefish. The high percentage of sexually mature paddlefish collected suggests that a suitable number of individuals exist that can contribute to reproduction in the population. Bronte and Johnson (5) found that few paddlefish caught by commercial fishermen in Kentucky Lake and Lake Barkley were sexually mature. They suggested that this was due to commercial fishing removing individuals before they were able to contribute to reproduction. Hoffnagle and Timmons (15) also considered the paddlefish population of Kentucky Lake to be overexploited. We have observed commercial fishermen in the area using large mesh gill nets (13–15 cm bar measure mesh) and this large mesh size may be capturing only the older members of local paddlefish populations.

The U.S. Congress has designated 566.6 ha of the Falls area of the Ohio River as a Wildlife Conservation Area (WCA). Within this area paddlefish are supposed to be protected reflecting on their questionable status in this area (9). Pearson and Pearson (4) suggest that although paddlefish populations in the Ohio River appear to have increased since 1970, the persistence of a fishery for the roe of female paddlefish may be slowing or even reversing the recovery of local populations. Our results suggest that an adequate food supply exists for paddlefish in this area based on their initial rapid growth rates. A total of 33 fish collected appears to be a low number based on numerous attempts to capture paddlefish over a 16-month period. This may be partially attributed to the location and/or time of year selected for sampling. High concentrations of PCBs have been detected in the roe of these paddlefish and it is possible that this is affecting their reproductive success (12). Additional information is needed in this area along with information on movements and distribution of paddlefish populations in the Ohio River.

LITERATURE CITED

1. Russell, T. R. 1986. Biology and life history of the paddlefish—a review. Pp. 2–21. In J. G. Dillard, L. K. Graham, and T. R. Russell (eds.) The paddlefish: status, management and propagation. North Central Division American Fisheries Society Special Publication No. 7.

2. Larimore, R. W. 1950. Gametogenesis of *Polyodon spathula* (Walbaum): a basis for regulation of the fishery. Copeia 1950:116–124.

3. Purkett, C. A. 1961. Reproduction and early development of the paddlefish. Trans. Amer. Fish. Soc. 90: 125–129.

4. Pearson, W. D. and B. J. Pearson. 1989. Fishes of the Ohio River. Ohio J. Sci. 89:181–187.

5. Bronte, C. R. and D. W. Johnson. 1985. Growth of paddlefish in two main stream reservoirs with reference to commercial harvest. Trans. Ky. Acad. Sci. 46:28–32.

6. Carlson, D. M. and P. S. Bonislawsky. 1981. The paddlefish (*Polyodon spathula*) fisheries of the Midwestern United States. Fisheries 6(2):17–27.

7. Pasch, R. W. and C. M. Alexander. 1986. Effects of commercial fishing on paddlefish populations. Pp. 46–53. In J. G. Dillard, L. K. Graham, and T. R. Russell (eds.) The paddlefish: status, management and propagation. North Central Division American Fisheries Society Special Publication No. 7.

8. Sparrowe, R. D. 1986. Threats to paddlefish habitat. Pp. 36–45. In J. G. Dillard, L. K. Graham, and T. R. Russell (eds.) The paddlefish: status, management and propagation. North Central Division American Fisheries Society Special Publication No. 7.

9. Pearson, W. D. and M. A. Froedge. 1989. Stranding of fishes below McAlpine Dam on the Ohio River. Trans. Ky. Acad. Sci. 50:183–201.

10. Pearson W. D. and L. A. Krumholz. 1984. Distribution and status of Ohio River fishes. ORNL/Sub/79-7831/1. Oak Ridge, Tennessee. 401 pp.

11. Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and J. E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern. Fisheries 14:2–20.

12. Gundersen, D. T. 1990. Partitioning of polychlorinated biphenyls (PCBs) in muscle and reproductive tissues of paddlefish at the Falls of the Ohio River. Unpubl. M.S. Thesis. University of Louisville, Kentucky.

13. Gundersen, D. T. and W. D. Pearson. 1992. Partitioning of PCBs in the muscle and reproductive tissues of paddlefish, *Polyodon spathula*, at the Falls of the Ohio River. Bull. Environm. Contam. & Toxicol. 49(3):455–462.

14. Adams, L. A. 1942. Age determination and rate of growth in *Polyodon spathula*, by means of the growth rings of the otoliths and dentary bone. Amer. Midl. Nat. 28:617–630.

15. Hoffnagle, T. L. and T. J. Timmons. 1989. Age, growth and catch analysis of the commercially exploited paddlefish population in Kentucky Lake, Kentucky-Tennessee. N.A.J. Fish. Mgmt. 9(3):316–326.

16. Houser, A. and M. G. Bross. 1959. Observations on the growth and reproduction of the paddlefish. Trans. Amer. Fish. Soc. 88:50–52.

Trans. Ky. Acad. Sci., 54(1–2), 1993, 7–12

Applications of Thermal Analysis in the Physical Chemistry Laboratory[1]

WEI-PING PAN, JEFF TIMMONS, AND ANGELA F. ARNOLD

Department of Chemistry, Western Kentucky University, Bowling Green, KY 42101

ABSTRACT

Thermal Analysis, the principal study of Western Kentucky University's Physical Chemistry Laboratory, encompasses several facets of research which familiarize the student with its importance within the industrial setting as well as throughout other fields of science. Through the utilization of today's most advanced equipment, hands-on experimentation, and lecture feedback, the student performs 3 laboratory procedures involving the thermal decomposition of calcium oxalate, the phase transitions of ammonium nitrates, and the enthalpies of combustion by calorimetry. These experiments are designed to demonstrate fundamental laws of thermodynamics which coincide with lecture material. The course thus provides valuable pre-professional experience which will be beneficial to future career placement.

INTRODUCTION

Thermal analysis involves studying the changes in energy content, mass, and related changes in entropy when a substance is subjected to temperature change (1). Many industrial firms study the thermal properties of such substances as: metals (2), tobacco (3), polymers (4), and coal (5). Since thermal analysis is used in industry it is important that it be included in academic curricula (6). Besides physical chemistry, methods of thermal analysis can be beneficial in engineering, biology, mineralogy and environmental science courses (7). This paper includes the application of thermal analysis in a senior-level physical chemistry laboratory course, as well as a review of the experiments performed.

DISCUSSION

The Western Kentucky University physical chemistry lab contains the following instruments for thermal analysis: a thermogravimetric analyzer, a high temperature differential scanning calorimeter, a high pressure differential scanning calorimeter, an adiabatic bomb calorimeter, and an isoperibol bomb calorimeter. Over the course of a semester, 3 experiments involving thermal analysis were carried out. They were designed to demonstrate fundamental laws of thermodynamics which are central to the lecture segment of the course. Each experiment required approximately 5 hours of laboratory work. The 3 experiments are:

Thermal Decomposition of Calcium Oxalate

The thermal decomposition of calcium oxalate monohydrate ($CaC_2O_4 \cdot H_2O$) was monitored using a DuPont 951 thermogravimetric analyzer as well as additional data obtained from a Stanton-Redcroft DSC 1500 high temperature differential scanning calorimeter. For both analysis methods, the decomposition was monitored using 3 different dynamic atmospheres (nitrogen, air, and carbon dioxide). When calcium oxalate (approximately 20 mg) was heated from 25°C to 1,000°C at a rate of 20°C/min, 3 sequential (decomposition) reactions were observed (1):

$$CaC_2O_4H_2O_{(s)} \rightleftharpoons CaC_2O_{4(s)} + H_2O_{(g)} \quad (1)$$

$$CaC_2O_{4(s)} \rightarrow CaCO_{3(s)} + CO_{(g)} \quad (2)$$

$$CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)} \quad (3)$$

In all atmospheres, the dehydration reaction (eq. 1) occurred at relatively the same temperatures (80°C) and was accompanied by the same weight loss (approx. 12%) (Fig. 1). Reactions involving the decomposition of $CaC_2O_{4(s)}$ to $CaCO_{3(s)}$ and $CO_{(g)}$ were unaffected by the nitrogen, air, and the carbon dioxide atmospheres. A portion of the TG curve (in air) is nonuniform, indicating a secondary oxidation reaction. This is due to the oxygen in the air converting the carbon monoxide released to carbon dioxide (1). This secondary oxidation reaction releases heat into the sur-

[1] Part of this work was presented at the 17th NATAS Annual Conference, October 1988.

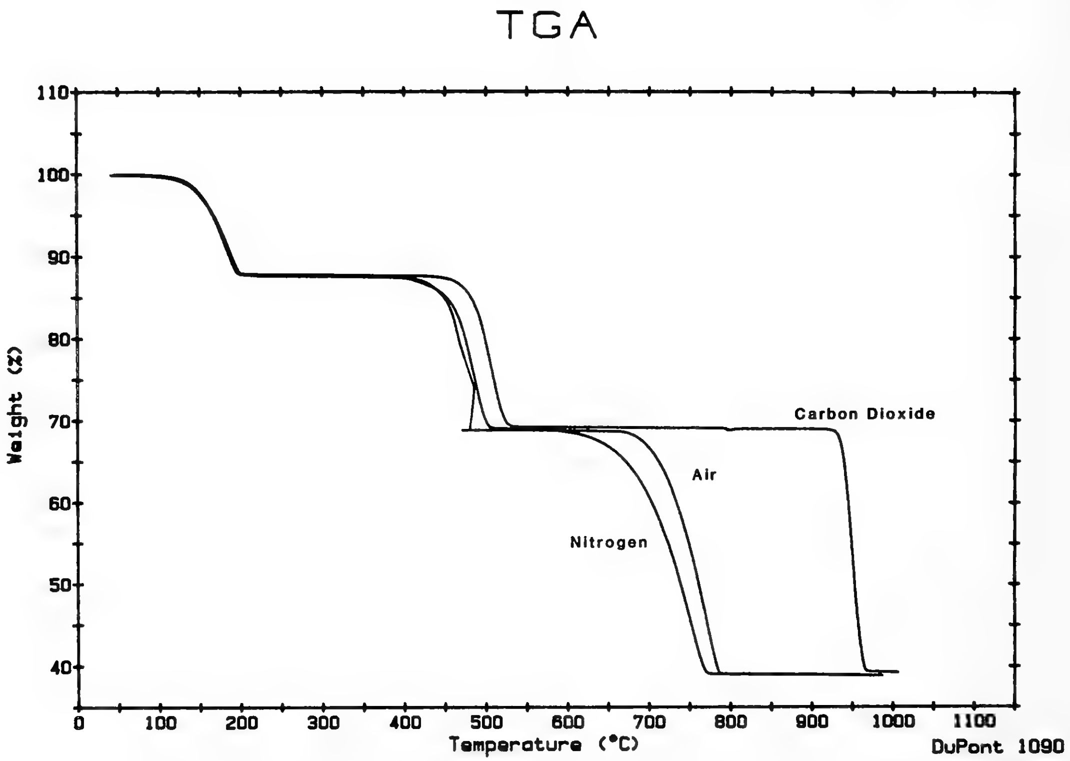


FIG. 1. TG heating curves for calcium oxalate in nitrogen, air and carbon dioxide.

roundings, which increases sample temperature rapidly while the furnace temperature continues to increase at a constant heating rate (20°C/min). When the secondary reaction is complete, the sample cools to the temperature of the furnace and the decomposition continues to completion.

The release of carbon dioxide in equation 3 occurs at a similar temperature in nitrogen and air, 751°C and 770°C, respectively (the difference may be due to the fact that the air contains approximately 325 ppm of carbon dioxide). Yet, in the presence of a carbon dioxide atmosphere this reaction did not occur until the temperature reached 951°C. Based on Le Chatelier's principle, it can be postulated that the carbon dioxide in the atmosphere will shift the equilibrium toward the left until the temperature is high enough to overcome the stress (an excess of CO_2) on the system (1). This difference in reaction temperatures is due to the fact that the release of carbon dioxide is a reversible reaction (eq. 3).

The percent weight lost corresponding to each reaction along the decomposition profile is also obtained. These percentages remained relatively constant regardless of the composition of the reaction atmosphere. It is also possible to determine that the reactions occur at a one-to-one mole ratio. The stoichiometry of each reaction can then be used to obtain the amount of reaction products. For example: the experimental data revealed a 12.28% (2.440 mg) weight loss for the first reaction. The theoretical values of 2.447 mg of water compared to 12.33% weight loss are in excellent agreement, having a difference of less than one-half per cent. Thus, this experiment is an excellent example of the application of stoichiometry, Le Chatelier's principle, and the thermodynamics of chemical reactions.

Further information on the decomposition of calcium oxalate is obtained from the DSC curve, under similar conditions. A DSC curve will show if a reaction is endothermic or exothermic and determines the enthalpy change (ΔH). For this system, in each atmosphere, the loss of water is endothermic and has approx-

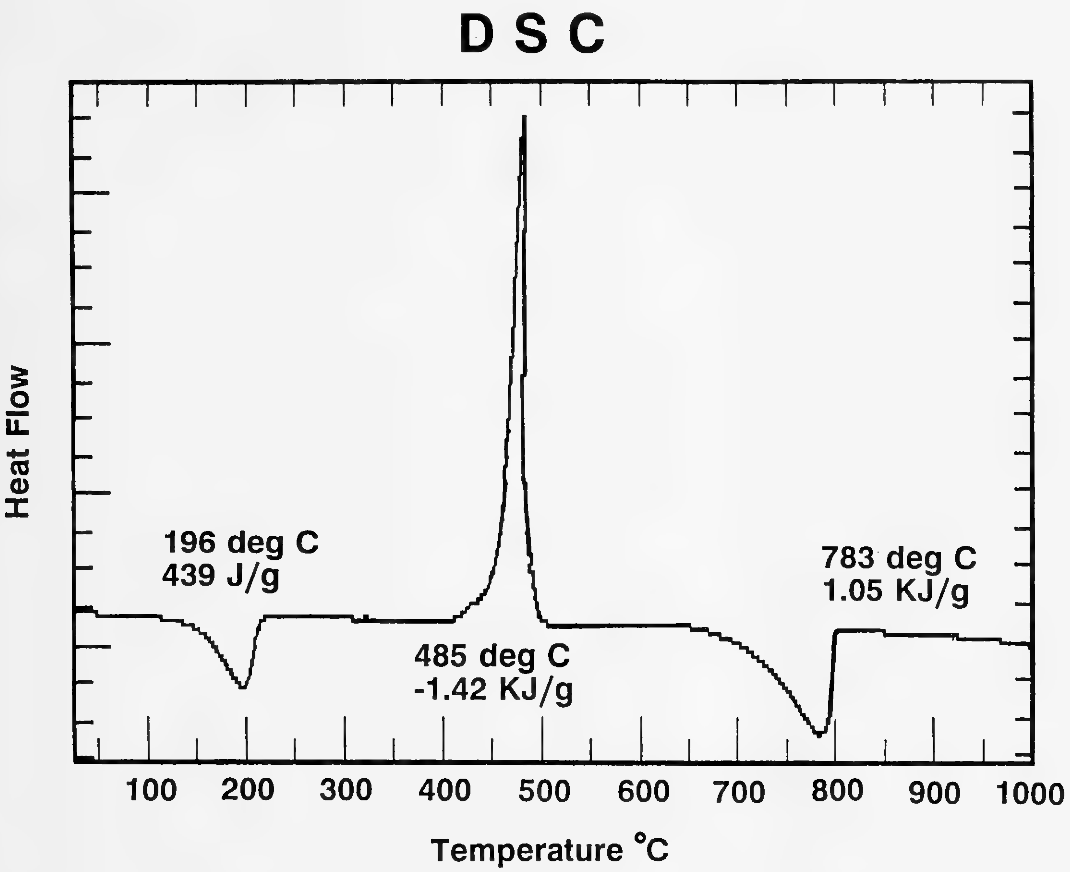


FIG. 2. DSC heating curve for calcium oxalate in air.

imately the same enthalpy change (approx. 439 J/g). A change in enthalpy (−1.42 KJ) occurred during loss of carbon monoxide (eq. 2) in the atmosphere containing air. The reaction is also endothermic under both nitrogen and carbon dioxide atmospheres: the ΔH values are 230 J/g and 238 J/g, respectively. However, in air we obtained a ΔH of −1.42 kJ/g, indicating an exothermic reaction (Fig. 2).

The energy produced during the secondary oxidation of CO discussed earlier is actually the product of the endothermic reaction from the loss of carbon monoxide combined with the exothermic reaction between the carbon monoxide and oxygen. Yet, because the exothermic reaction occurs so quickly and produces so much more heat than the endothermic reaction consumes, the DSC only records the net heat value. This is an example of the importance of using combined techniques, in this case comparing the TGA curve with the DSC curve, to determine information about the reactions that can only be determined from the DSC. The energy, 1.00 ± 0.04 kJ/g, associated with the formation of carbon dioxide in equation 3 shows little variation no matter which atmosphere is used.

Phase Transitions of Ammonium Nitrates

The phase transitions of ammonium nitrate crystals (analytical reagent, Mallinckrodt, Inc.) were studied using the DuPont 910 DSC in a nitrogen atmosphere. Approximately 15 mg of ammonium nitrate were placed in the aluminum sample dish which was then sealed. An empty sealed aluminum dish was used as a reference. The ammonium nitrate was heated (5°C/min) from 25°C to 160°C and then cooled (1°C/min) back to ambient temperature. The flow rate of nitrogen gas was 50 ml/min during the entire run including heating and cooling processes. The DSC curve for ammonium ni-

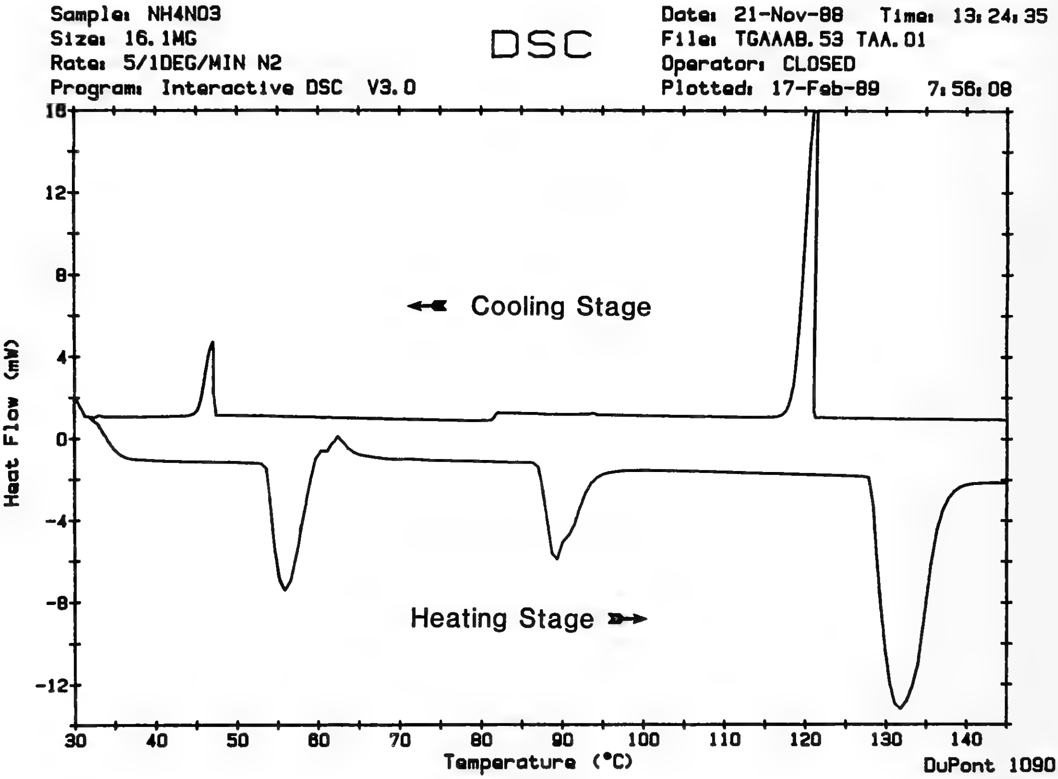


FIG. 3. DSC heating and cooling curves for ammonium nitrate in nitrogen.

trate contains a total of 5 peaks, 3 heating and 2 cooling peaks (Fig. 3). The 3 endothermic peaks have maxima at 55.9°C, 89.4°C, and 131.8°C, respectively. According to Mathews, Pareonagr and Straveley, the first peak involves the transition of the orthorhombic 2 (phase 4) to the orthorhombic 1 (phase 3) configuration (8, 9). It is proposed by Griffith, Sharma and Roy that this transition may shift from 55°C to 32°C, in a wet sample, depending upon the amount of water in the sample (10, 11). It was also observed that the baseline shifted during heating after the first phase transition. This suggests that the specific heat of the sample had possibly been altered by the formation of a metastable phase 3 (12, 13). The phase transition of phase 3 to phase 2 took place at the second endothermic peak and is due to the transition of the orthorhombic 1 form to the tetragonal form. It should be pointed out that whether the 4 → 3 → 2 transformation or the 4 → 2 transformation takes place has not been completely determined (10, 11, 12, 13, 14). In this experiment no attempt was made to justify which transformation actually occurred. The third endothermic peak corresponds to the 2 → 1 phase transition and is due to the transition of the tetragonal form to the cubic form. Upon cooling, 2 exothermic peaks were observed in the DSC curve. There was no indication of any exothermic process accompanying the 3 → 4 transition. Phase 2 apparently transforms directly to phase 4. This behavior correlates to the large difference in specific volume between phase 2 (4) and phase 3 (10).

This experiment demonstrates that as heat is added, the transitions which occur in ammonium nitrate crystals arise from an orientational disorder (8, 9). For example, the crystals began in an orthorhombic configuration which is highly specific (8, 9). The crystals then change to a tetragonal form which has 2 completely different orientations (8, 9). These 2 orientations allow more freedom of movement within the lattice compared to the orthorhom-

TABLE 1. Transition temperature, enthalpies and entropies of ammonium nitrate.

Transition	Temp. (°C)	ΔH (J/g)	ΔS (J/mol K)
4 → 3	55.9	22.0	5.1
3 → 2	89.6	15.3	3.4
2 → 1	131.89	51.2	10.21
1 → 2	121.39	−50.0	—
2 → 4	47.0	−20.1	—

bic form and also allow the molecule to become more ordered. Ammonium nitrate has, in fact, 12 different orientations in its cubic form and more degrees of transitional freedom than any of the other forms observed (8, 9).

The change in entropy (ΔS) is calculated using the formula: $\Delta S = \Delta H/T$, at constant pressure conditions. Entropy is defined as a measure of the randomness that exists in a system. The cubic system requires the most energy; therefore, the greatest extent of disorder is reflected in peak 3 (which is the formation of the cubic structure). The ΔS for this transition was equal to 10.2 J/mol K, compared to 5.16 J/mol K and 3.4 J/mol K for peak 1 and 2, respectively. The transition enthalpies, entropies and reaction temperatures found from the TGA and DSC curves for ammonium nitrate have been compiled in Table 1.

A TGA curve for ammonium nitrate was also given to students in this experiment to allow them to use combined techniques, TGA and DSC when interpreting data. From the TGA data, it was concluded that no thermal decomposition (as in calcium oxalate) was observed before the melting point (169°C). The results from the TG curve provided evidence that phase transitions are occurring rather than thermal decomposition.

Enthalpies of Combustion by Calorimetry

This experiment involved the determination of heat content for a set of coal samples of different rank by means of calorimetry. Three different calorimeters were used which required the application of 2 different measuring principles (14). To measure the energy exchanged, 3 experimental modes of operation were employed: isoperibol, adiabatic, and

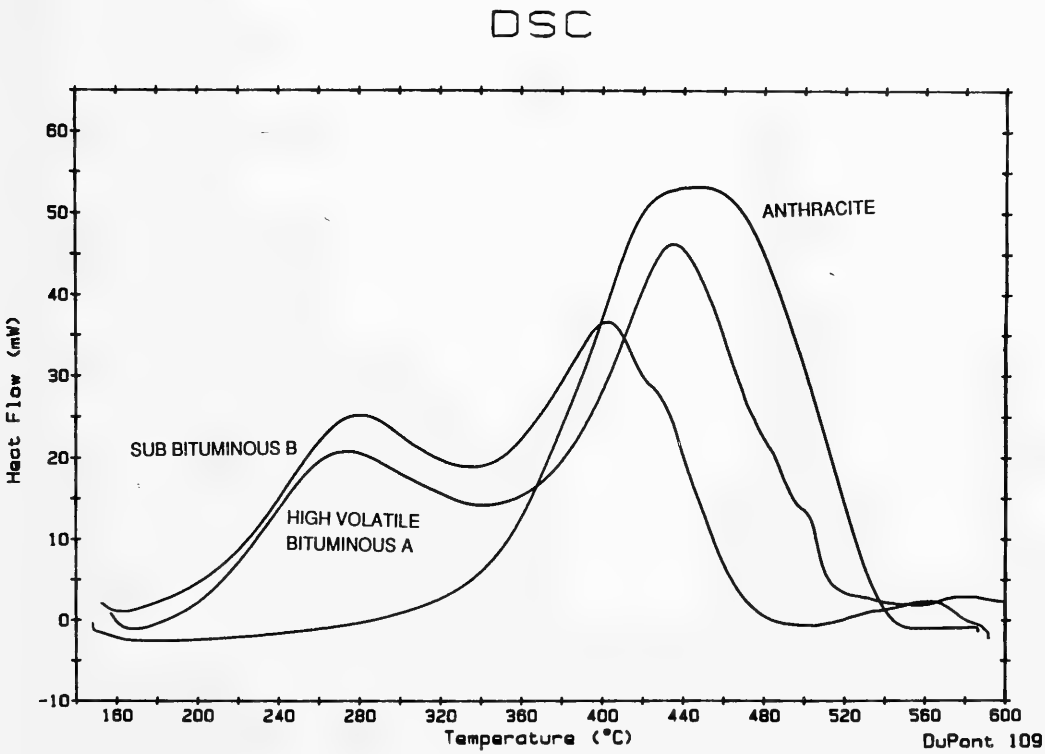


FIG. 4. DSC heating curves for anthracite subbituminous B and high volatile bituminous coal in oxygen.

scanning of the surroundings (15). The calorimeters used were the Parr 1241 and the Leco AC-300 calorimeters (adiabatic and isoperibol mode, respectively) which monitor time-dependent temperature differences, and the DuPont 910 HPDSC (the scanning mode), which monitors only a local temperature difference (14). The experimental procedures and sample preparation for using an adiabatic bomb calorimeter, an isoperibol bomb calorimeter, and a HPDSC are specified in ASTM method D2015, D3286 and in Hassel's paper (16).

The different modes of operation are characterized by the relationships between the temperature of the measuring system, T_M, and the temperature of the surroundings, T_F (15). In the isoperibol mode (15), the temperature of the measuring system changes by heat exchange with the surroundings until an equilibrium is established. T_M is a function of time and T_F is maintained at a constant value by an external source. In the adiabatic mode (15), no heat exchange occurs between the measuring system and the surroundings. In the scanning mode, a twin calorimeter was used (in contrast to the single calorimeter of both the isoperibol and adiabatic operations). In such cases, the temperature of the surroundings remains constant whereas the measuring system, actually composed of 2 separate measuring systems, is heated linearly with time (15). Each of the 2 separate measuring systems has a controlled heater which brings it to a temperature identical to that of the other measuring system. The desired heat measurement is obtained from the difference in energy inputs into the 2 systems. The HPDSC also enables the operator to investigate the nature of the substance being analyzed by providing the thermal history of the sample. In the case of coal analysis, the 2 peaks seen on the thermalgram (Fig. 4) correspond to the heat loss associated with the combustion of aliphatic (the first peak) and aromatic (the second peak) portions of the coal. The data gave some indication of the relative structure of the coal (aliphatic versus aromatic).

Overall, Western Kentucky University's Physical Chemistry laboratory offers an indepth and challenging approach to the study of thermal analysis. By providing the necessary equipment for appropriate comparative studies, students are provided with hands-on experience that is invaluable educationally, and later, professionally. The experimental design of the laboratory described gives each student an excellent experience with up-to-date equipment, as well as investigating theoretical laws and properties that have previously been discussed in lecture. Exposure, challenge, and insight are the educational advantages and the student will reap the benefits.

LITERATURE CITED

1. Wendlandt, W. W. 1986. Thermal Methods of Analysis, 3rd ed. Wiley, New York.

2. Winberly, J. W., A. B. Carel, and D. K. Cabbiness. 1982. Automated method for measuring the thermal degradation of Polyvinyl Chloride. Anal. Lett. 15:89–100.

3. Baker, R. R. 1984. Use of evolved gas analysis in studying tobacco pyrolysis. Anal. Proc. 21:12–13.

4. Turi, E. A. 1981. Thermal characterization of polymeric materials. Academic Press, New York.

5. Serageldin, M. A. and W. P. Pan. 1983. Coal analysis using thermogravimetry. Thermochim. Acta. 17:1–14.

6. Turi, E. A. 1988. The future of thermal analysis. Thermochim. Acta. 135:11–17.

7. Earnest, C. M. 1978. Experiments involving thermal methods of analysis for undergraduate chemistry laboratories. J. Chem. Educ. 55:331–335.

8. Mathews, G. P. 1985. Experimental physical chemistry. Charendon Press, Oxford.

9. Parsonage, N. B. and L. A. K. Straveley. 1978. Disorder in crystals. Charendon Press, Oxford.

10. Griffith, E. J. 1963. Phase transitions of the ammonium nitrate-magnesium nitrate system. J. Chem. and Eng. Data. 8:22–25.

11. Sharma, S. K. and H. Roy. 1967. Effect of inorganic additives on the phase transition (IV ⇋ III) of ammonium nitrate. Technology 4:3–6.

12. Langfelderova, H. 1982. Study of the influence of experimental conditions on the DSC curve of ammonium nitrate (20–140°C). Thermochim. Acta. 56:358–359.

13. Konkoly-Thege, I. 1977. Phase transformation of ammonium nitrate by thermal factors and inoculation. J. Therm. Anal. 12:197–205.

14. Dellien, I. 1982. DSC study of the phase transformations of ammonium nitrate. Thermochim. Acta. 55: 181–191.

15. Hemmington, W. G. and E. Hohne. 1984. Calorimetry: fundamentals and practice. Weinheim, Dearfield Beach, Florida.

16. Hassel, R. L. 1973. Heat content of coal. DuPont thermal analysis application brief. TA-55.

Trans. Ky. Acad. Sci., 54(1–2), 1993, 13–16

Factors Affecting Amphibian Use of Road-rut Ponds in Daniel Boone National Forest

MICHAEL D. ADAM AND MICHAEL J. LACKI

Department of Forestry, University of Kentucky, Lexington, Kentucky 40546

ABSTRACT

Road-rut ponds are being established throughout much of Daniel Boone National Forest (DBNF), Kentucky, to promote breeding habitat for forest-dwelling amphibians. However, quantitative data are lacking on species use and habitat features associated with ponds preferred as breeding sites. We surveyed 106 road-rut ponds in DBNF, April 1992. Eight amphibian species were observed using ponds. Discriminant function analysis (DFA) demonstrated pond selection by amphibians to be significantly different from random ($P < 0.0001$). Pond use was positively related to surface area and depth, with surface area loading as the most important variable. The DFA model assigned ponds into use categories significantly better than chance ($P < 0.005$), but was less effective with an independent data set ($P > 0.05$). Road-rut ponds are potentially important habitat for forest-dwelling amphibians.

INTRODUCTION

Many species of amphibians use woodland ponds for breeding, feeding, and residing. Historically, amphibians in eastern Kentucky probably utilized natural ponds created by large uprooted trees or by the damming of tributaries by large fallen trees (J. R. MacGregor, U.S. For. Serv., Daniel Boone Natl. For., pers. comm.). With large trees uprooting less frequently in mature woodlands, particularly on public lands managed under multiple-use systems, amphibians must find alternative sources of water to complete their reproductive cycles. Road-rut ponds are common throughout Daniel Boone National Forest (DBNF), Kentucky, due to old dirt or gravel roads left behind following completion of timber harvests. Ruts left by vehicle traffic become filled with water, producing both temporary and semi-permanent bodies of water.

Data bases identifying habitat requirements of amphibians have been slow to develop (1). This is especially disconcerting given the apparent decline in amphibian populations worldwide (2, 3, 4). To date, only one study has examined the use of road-rut ponds by forest-dwelling amphibians (5). Because these ponds may be potentially important in maintaining viable populations of some amphibian species, and amphibians are now looked upon as important biological indicators (6), an assessment of road-rut pond use by amphibians should aid in the identification of important habitat features provided by this forest resource. By examining a suite of habitat variables for a number of road-rut ponds, we tested the null hypothesis that pond preference by amphibians was independent of pond dimensions and properties.

STUDY AREA AND METHODS

The study area was located in the Stanton Ranger District of DBNF in Lee and Wolfe counties, Kentucky. The DBNF encompasses over 271,000 ha and is located adjacent to the Cumberland Escarpment, within the Cumberland Plateau physiographic region (7). Mixed mesophytic forest covers much of DBNF (8), with timber management implemented throughout the forest (9).

Road-rut ponds were surveyed from 8 to 21 April 1992. Data were collected on 106 ponds, with the data partitioned into 70 (Wolfe County) and 36 (Lee County) ponds for model development and validation, respectively. All ponds were located on old logging roads which received little vehicular traffic. A series of habitat variables was measured at each pond, including: length (m), width (m), depth (m), distance to other ponds (<5 m, 5–10 m, >10 m), detrital coverage of pond subsurface (%), and water clarity (1 = clear, 2 = cloudy, 3 = murky). Length and width were used to calculate pond surface area (m^2).

All amphibian species within a pond were recorded, with use determined by the presence of egg masses, larvae, or adults. Ponds were assigned to 1 of 3 use categories for analysis: (1) no species present, (2) only 1 species present, and (3) multiple ($\geq$2) species present. Each

TABLE 1. Frequency of occurrence for amphibian species found in road-rut ponds in DBNF, Kentucky, 1992.

Species	Frequency of occurrence (No. ponds)	
	Wolfe County	Lee County
Spotted salamander *Ambystoma maculatum*	41	14
Four-toed salamander *Hemidactylium scutatum*	4	0
Red-spotted newt *Notophthalmus viridescens*	17	6
American toad *Bufo americanus*	1	0
Fowler's toad *Bufo woodhousei fowleri*	0	1
Mountain chorus frog *Pseudacris brachyphona*	25	13
Pickerel frog *Rana palustris*	0	1
Wood frog *Rana sylvatica*	28	11

pond was a separate location and no pond was surveyed more than once to assess use.

One-way analysis of variance (ANOVA) and principal component analysis (PCA) were used initially to identify important habitat variables. The PCA was run on the correlation matrix because of the different units of measure among the variables examined (10). Natural log transformations were applied to variables where homogeneity of variance assumptions were not met. Detrital coverage was arcsine transformed to correct for departures from normality. Multicollinearity effects were examined using regression analysis, with a variance inflation factor (VIF) of ≤ 3 required to retain variables for model development.

Discriminant function analysis (DFA) was used to construct and evaluate the model predicting amphibian pond use from among the categories of use delineated above. The assumption of homogeneity of covariance matrices was tested (11). Standardized canonical coefficients were obtained for variables using canonical discriminant analysis. Classification outcomes were generated with DFA and tested using Cohen's kappa statistic (12). The model was validated using the independent data set from Lee County, by producing classification outcomes of the independent data and evaluating these with a kappa statistic test. All statistical analyses were run on PC SAS programs (13).

RESULTS

Eight species of amphibians used road-rut ponds with *Ambystoma maculatum, Rana sylvatica, Pseudacris brachyphona*, and *Notophthalmus viridescens* occurring most frequently (Table 1). Differentiation between egg masses of the Jefferson salamander (*A. jeffersonianum*) and the spotted salamander (*A. maculatum*) was not possible in the field, so these species were pooled into *A. maculatum* since it is the more common species in eastern Kentucky (J. R. MacGregor, U.S. For. Serv., DBNF, pers. comm.). For Wolfe County, ponds inhabited by multiple species were most common (54%), with single species (23%) and empty ponds (23%) observed less frequently. Data for Lee County showed a more equitable distribution among groups, with multiple-species ponds still most common (44%) and single species (22%) and empty ponds (33%) present to a lesser extent.

Significant variation among road-rut pond use categories was found with ANOVA for the variables surface area, depth, and detrital coverage (Table 2). Four variables loaded heavily on the first principal component, including the above 3 and water clarity. This component accounted for 41.7% of the variation present in the data set. No variable was found with a VIF ≥ 3, indicating multicollinearity to be absent.

TABLE 2. Univariate significance level, PCA loading, variance inflation factor (VIF), and standardized canonical coefficient (SC) for variables used in discriminating road-rut pond use groups, DBNF, Kentucky, 1992.

Variable	*P*-value	PCA loading	VIF	SC
Surface area	0.0001	0.546	1.54	1.039
Depth	0.0005	0.554	1.56	0.538
Detrital coverage	0.0548	−0.413	1.16	−0.152
Water clarity	0.4514	0.441	1.26	−0.806

The DFA model showed road-rut pond use by amphibians to be significantly different from random (Wilk's Lambda = 0.54, $F = 5.83$, $P < 0.0001$), with group means on the canonical axis demonstrating multispecies ponds (0.79) to be separate from single species (−0.85) and empty ponds (−1.03). Size of standardized canonical coefficients suggested surface area to be the most significant variable for distinguishing among road-rut pond use groups, with depth and water clarity also contributing to group separation (Table 2). Use of road-rut ponds was positively related with surface area, depth, and water clarity, and negatively associated with detrital coverage (Table 3). Water clarity and detrital coverage exhibited inconsistent patterns, being significant for some procedures but not others (Table 2), restricting interpretations based on these 2 variables.

The test of homogeneity of within covariance matrices was not significant ($\chi^2 = 13.5$, $P > 0.05$), so a pooled matrix was used for classification of observations among pond use groups. Classification outcomes for the observations used to develop the model demonstrated an assignment to road-rut pond use groups significantly better than chance ($K = 0.32$, $Z = 3.02$, $P < 0.005$). However, when validated with the independent data from Lee County, the model was unable to provide a significant improvement in classification ($K = 0.07$, $Z = 0.50$, $P > 0.05$). The most efficient assignments of observations occurred for the multiple-species use group with both data sets (Table 4).

DISCUSSION

Surface area, depth and, to a lesser degree, water clarity were important features for the selection of road-rut ponds by amphibians in DBNF. In general, ponds in which multiple species were found were larger in area, deeper, and had better water clarity than ponds not used, or used by only 1 species. Area appeared to be the most important factor in pond usage. This pattern makes intuitive sense, as larger, deeper ponds would be expected to support more individuals and species. Further, larger ponds are also less likely to dry up before egg maturation, increasing the likelihood of successful reproduction (14). Shallower ponds were probably used when availability of larger ponds was limited in relation to the spatial distribution of species.

TABLE 3. Means and standard deviations (SD) for variables used in discriminating road-rut pond use groups, DBNF, Kentucky, 1992. Units of measure for variables are outlined in the text. Sample sizes are in parentheses.

Pond-use group	Variable	Mean	SD
No species (n = 16)	Surface area	4.66	10.0
	Depth	0.10	0.04
	Detrital coverage	0.65	0.26
	Clarity	1.88	0.81
Single species (n = 16)	Surface area	2.42	2.81
	Depth	0.09	0.03
	Detrital coverage	0.75	0.18
	Clarity	1.56	0.63
≥2 species (n = 38)	Surface area	11.6	13.9
	Depth	0.13	0.04
	Detrital coverage	0.62	0.18
	Clarity	1.60	0.68

These data suggest that road-rut ponds were an important habitat component for amphibians in DBNF. Isolated ponds have been found to be important for sustaining amphibians in other ecosystems (14, 15, 16, 17). Continued maintenance and/or development of road-rut ponds in DBNF is recommended, although better information is needed on the importance of spatial distribution among ponds, and the link between pond use and actual reproductive success, e.g., eggs tracked to adult amphibians, needs to be verified. Limiting the volume of vehicular traffic on these roads in DBNF during late winter-early spring should improve the chance of success for spring-breeding amphibians in these localities.

ACKNOWLEDGMENTS

We thank J. R. MacGregor, U. S. For. Serv., DBNF, for logistic advice and assistance with the identification of egg masses. This study was funded by the Department of Forestry, Uni-

TABLE 4. Road-rut pond classification outcomes for DFA model determining amphibian use of road-rut ponds, DBNF, Kentucky, 1992.

Data set	Assigned correctly (%)		
	No species	Single species	≥2 species
Model development (n = 70)	31.3	25.0	89.5
Model validation (n = 36)	33.3	0.0	75.0

versity of Kentucky. This investigation (No. 92-8-136) is connected with a project of the Kentucky Agricultural Experiment Station and is published with the approval of the Director.

LITERATURE CITED

1. Gibbons, J. W. 1988. The management of amphibians, reptiles, and small mammals in North America: the need for an environmental attitude adjustment. Pp. 4-10. In R. C. Szaro, K. E. Severson, and D. R. Patton (eds.) Management of amphibians, reptiles, and small mammals in North America. Proc. of the Symposium, USDA For. Serv., Tech. Rep. RM-166.

2. Barinaga, M. 1990. Where have all the froggies gone? Science 247:1033–1034.

3. Phillips, K. 1990. Where have all the frogs and toads gone? BioScience 40:422–424.

4. Wyman, R. L. 1990. What's happening to the amphibians? Conserv. Biol. 4:350–352.

5. MacGregor, J. R. 1992. Species of amphibians (and a few other taxa) found using road rut ponds on DBNF. Daniel Boone National Forest, USDA For. Serv., Berea, Kentucky.

6. Beiswenger, R. E. 1988. Integrating anuran amphibian species into environmental assessment programs. Pp. 159–165. In R. C. Szaro, K. E. Severson, and D. R. Patton (eds.) Management of amphibians, reptiles, and small mammals in North America. Proc. of the Symposium, USDA For. Serv., Tech. Rep. RM-166.

7. McGrain, P. 1983. The geologic story of Kentucky. Kentucky Geol. Survey, Univ. Kentucky, Lexington, Special Publ. 8, Series XI.

8. Braun, E. L. 1950. Deciduous forests of eastern North America. Hafner, New York, New York.

9. Daniel Boone National Forest. 1991. The Daniel Boone National Forest Kentucky. Gen. Rep. to the Public for 1990, Southern Region, USDA For. Serv., Winchester, Kentucky.

10. Rexstad, E. A., D. D. Miller, C. H. Flather, E. M. Anderson, J. W. Hupp, and D. R. Anderson. 1988. Questionable multivariate statistical inference in wildlife habitat and community studies. J. Wildl. Manage. 52:794–798.

11. Morrison, D. F. 1976. Multivariate statistical methods. McGraw-Hill, New York, New York.

12. Titus, K. J., A. Mosher, and B. K. Williams. 1984. Chance-corrected classification for use in discriminant analysis: ecological applications. Amer. Midl. Nat. 111:1–7.

13. SAS Institute Inc. 1988. SAS/STAT User's Guide, Release 6.03 Edition. Cary, North Carolina.

14. Semlitsch, R. D. 1987. Relationship of pond drying to the reproductive success of the salamander *Ambystoma talpoideum*. Copeia 1987:61–69.

15. Sexton, O. J., and C. Phillips. 1986. A qualitative study of fish-amphibian interactions in 3 Missouri ponds. Trans. Missouri Acad. Sci. 20:25–35.

16. Dodd, C. K., Jr. and B. G. Charest. 1988. The herpetofaunal community of temporary ponds in North Florida Sandhills: species composition, temporal use, and management implications. Pp. 87–97. In R. C. Szaro, K. E. Severson, and D. R. Patton (eds.) Management of amphibians, reptiles, and small mammals in North America. Proc. of the Symposium, USDA For. Serv., Tech. Rep. RM-166.

17. Moler, P. E., and R. Franz. 1988. Wildlife values of small, isolated wetlands in the southeastern coastal plain. Pp. 234–241. In R. R. Odom, K. A. Riddleberger, and J. C. Ozier (eds.) Proceedings of the third southeastern nongame and endangered wildlife symposium. Georgia Dept. Nat. Resour., Athens, Georgia.

Trans. Ky. Acad. Sci., 54(1–2), 1993, 17–21

A Simple Method for Isolating Soybean (*Glycine max* L. Merr.) cv. Fayette Regenerates of Parental Genotypes

M. M. Rahman

Plant & Soil Science, Community Research Services, Kentucky State University, Frankfort, Kentucky 40601

Abstract

Immature embryos of soybean (*Glycine max* (L.) Merr.) cv. Fayette were used with the objective of isolating regenerates of parental genotypes from embryogenic calli cultures. Immature embryos of field-grown soybeans were placed onto a basic medium supplemented with various concentrations of 6-benzylaminopurine, indole-3-butyric acid, α-naphthaleneacetic acid, kinetin and indole-3-acetic acid. All media induced organogenesis with varying degree. Fully developed plantlets were planted in the field and their mature seeds were harvested. Cytological examination of the progenies of regenerates had varying number of chromosomes. Morphologically, there were no observable differences between the control plants and the surviving progenies of the regenerates.

Introduction

Much effort has been devoted to soybean (*Glycine max* (L.) Merr.) tissue culture to achieve *in vitro* plant regeneration (1). There are recent reports of *in vitro* plant regeneration in which multi-media manipulations, in conjunction with various growth hormones, were needed for shoot and root development (1, 2, 3).

Although both somatic and embryogenic plant cells contain identical genetic information, genetic instability is normal in plants generated *in vitro* (4, 5). With 1 or 2 exceptions (6, 7), these variabilities are neither novel nor useful for agricultural crops (8).

Unlike *Datura stramonium* L. (9) and *Nicotiana sylvestris* L. (10), the trisomic, double trisomic, etc. plants in soybean are morphologically indistinguishable from their disomic sibs (11, 12). Therefore, cytological examination of the chromosomes is needed to differentiate between euploidy and aneuploidy regenerates of soybean.

This study describes a simple procedure to regenerate a large number of soybean plants of parental genotype from immature embryos without multi-media manipulation.

Materials and Methods

Media.—A basic medium (13) supplemented with 1.0–5.0 mg liter^{-1} 6-benzylaminopurine (BAP), 0.2–1.0 mg liter^{-1} indole-3-butyric acid (IBA), 0.5–1.0 mg liter^{-1} indole-3-acetic acid (IAA), 0.2–1.0 mg liter^{-1} kinetin (Kn), and 0.5–1.0 mg liter^{-1} α-naphthaleneacetic acid (NAA) in various combinations was used. The pH was adjusted to 5.8 before autoclaving for 15 minutes at 1 kg cm^{-2}. Twentyfive ml of media were poured into 20 × 100 mm sterilized plastic Petri dishes.

Plant Materials.—About 4–5 mm long, immature soybean embryos of cv. Fayette were extracted from surface sterilized pods of field-grown plants and transferred to the Petri dishes containing various culture media. For each treatment there were 25 Petri dishes. Each Petri dish contained 2 immature embryos.

After 6 to 7 weeks calli obtained from these immature embryos were transferred to the same respective media. The cultures were incubated at 26 ± 1°C with 16 h of light (68 μMol s^{-1} m^{-2} PAR) supplied with Vitalite (Dura Test Corporation) and 8h of darkness. This experiment was repeated 3 times.

Regenerates. After 6 weeks in the freshly prepared media (14), the calli began to show signs of organogenesis. The number of plantlets differentiated from those calli varied from 1 to 11 (Fig. 1). When the plantlets were approximately 2 cm tall, they were carefully separated from the calli and transferred to separate plastic culture vessels containing 50 ml of fresh identical medium. After reaching about 8–10 cm in length, the regenerates were transferred to plastic pots containing regular greenhouse potting mixture (Promix). The plantlets were covered with transparent plastic bags to

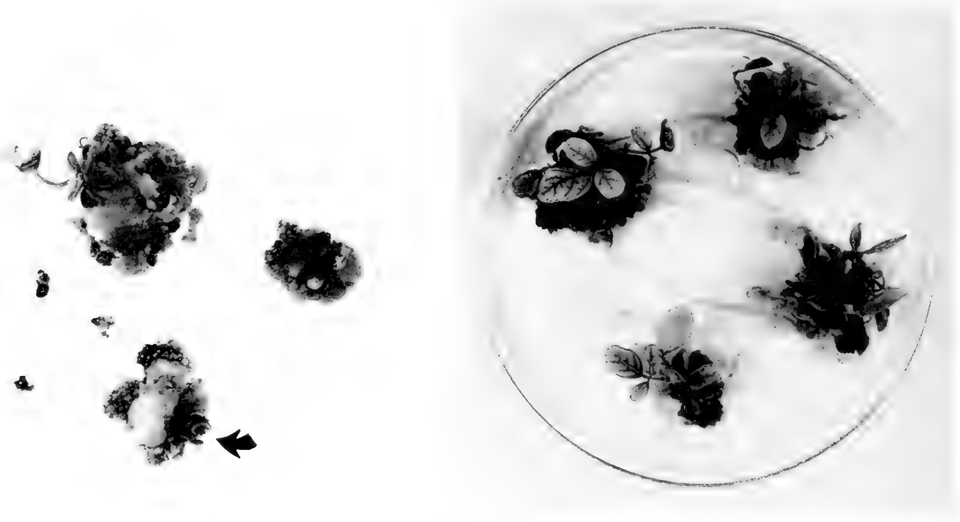


FIG. 1. Root and shoot differentiation from soybean calli. Embryoid marked with arrow.

maintain high humidity. The plantlets were grown in growth chambers under the same temperature and light conditions as that of immature embryo culture, and watered as needed. After 3 weeks, the plastic bags were removed. After 4 weeks the regenerates were transplanted to the field (mid July). The plants were spaced 20 cm apart with 60 cm between rows. The plantlets were grown to maturity, and the resulting seeds were collected from individual plants for next year's plantings.

Cytogenetics.—Fifteen seeds from each of 3 randomly selected regenerates from each treatment were used to study the changes in number and/or aberration of chromosomes in the harvested plants. The seeds were germinated, and roots were fixed, squashed and stained (15). Three to 4 cells from each root sample were examined microscopically.

RESULTS AND DISCUSSION

The results presented here include means of the pooled data of 3 experiments.

Table 1 summarizes the percentage of shoot and root differentiation from calli cultured in media supplemented with various combinations and concentrations of plant growth hormones. It has been reported that various concentrations of BAP stimulated shoot differentiation (15) and IBA alone induced rooting (2). In the present study, the BAP and IBA combination was found to be superior in inducing shoot as well as root differentiation. Regardless of the concentration of IBA, the calli in the media containing 5.0 mg^{-1} BAP did not show any response (Table 1), and began to degenerate within 2–3 weeks. This suggested toxicity of BAP at this concentration.

In a previous study, high concentrations of NAA (21.4 μM–60.0 μM) stimulated embryogenesis (16). In the present study, however, NAA, in combination with Kn, induced shoot and root differentiation (Table 1). The auxin, IAA, is known to cause embryogenesis (16) and induce shoot development (17). The auxin, IAA and Kn in all concentrations induced root and shoot differentiation, but the extent was quite limited (Table 1).

The number of chromosomes counted in the progenies of regenerates is presented in Table 2. Thirty six per cent of the mitotic cells had varying number of chromosomes, ranging from

→

FIG. 2. Mitotic chromosomes of soybean seedlings. (a) Normal chromosome complement: (control) 2n = 40 (× 1,800). Chromosome number of regenerates: (b) Normal chromosome number, 40 (× 1,800); (c) Irregular chromosome number, 36 (× 1,800); (d) Irregular chromosome number, 27 (× 1,800); (e) Irregular chromosome number, 19 (× 1,800).


a
b
c
d
e

TABLE 1. Root and shoot differentiation from immature embryos of soybean (*Glycine max* (L.) Merr.) cv. Fayette calli.

Treatments (mg^{-1})		Percent calli with root only	Percent calli with shoot only	Percent calli with root & shoot	Mean number shoots & roots/callus & SE
BAP	IBA				
1.0	0.2	32.00	48.67	19.33	3.69 ± 0.43 c*
1.0	0.5	26.66	22.00	48.67	6.37 ± 0.31 b
1.0	1.0	19.33	27.33	53.33	8.16 ± 0.14 a
2.0	0.2	38.00	45.33	16.67	6.32 ± 0.46 b
2.0	0.5	31.33	46.67	24.00	4.17 ± 0.22 c
2.0	1.0	32.67	48.00	19.33	4.28 ± 0.41 c
5.0	0.2	0	0	0	0
5.0	0.5	0	0	0	0
5.0	1.0	0	0	0	0
NAA	Kn				
0.5	1.0	15.33	14.00	0	0
1.0	1.0	20.67	12.67	0	0
IAA	Kn				
0.5	0.2	45.33	38.67	15.33	3.69 ± 0.41 c
0.5	0.5	65.33	17.33	16.00	3.67 ± 0.31 c
0.5	1.0	59.33	26.67	14.00	3.62 ± 0.49 c
1.0	0.2	36.67	44.00	12.67	4.09 ± 0.44 c
1.0	0.5	36.67	36.67	12.00	3.89 ± 0.39 c
1.0	1.0	44.00	32.67	14.00	3.62 ± 0.49 c

* According to Duncan's Multiple Range Test means with same letters are not significantly different among themselves.

19 to 37, and 64 per cent of the cells underwent normal meiosis (2n = 40) (Fig. 2). In vitro regenerates display genetic instability (5) and these are exhibited by the progenies (8). Since regenerates with chromosomal irregularities would not reach maturity (8), these chromosomal aberrations were of no consequence.

Moreover, in 2 years of field trials no noticeable morphological differences between the control plants and regenerates were oberved (unpublished data). The soybean is an obligately self-pollinated crop. Therefore, any gross morphological mutations would be expressed within the progeny. Since there were no observable morphological differences, these regenerates may be assumed to be of parental genotypes.

The method outlined here is a simple procedure which may be used to obtain a large number of regenerates of parental genotypes without multi-media manipulation.

TABLE 2. Number of chromosomes observed in the root tips of the progenies of soybean (cv. Fayette) regenerates.

Treatments (mg^{-1})	Number of chromosomes					Number of cells observed
	10–20	21–25	26–39	40–40	>40	
BAP + IBA						
1.0 + 0.2	3	45	2	95	0	145
1.0 + 0.5	5	17	4	113	0	139
1.0 + 1.0	5	3	1	175	0	184
2.0 + 0.2	7	8	7	132	0	154
2.0 + 0.5	11	16	8	117	0	153
2.0 + 1.0	16	19	21	132	0	188
IAA + Kn						
0.5 + 0.2	29	32	29	73	0	163
0.5 + 0.5	19	30	27	79	0	155
0.5 + 1.0	27	23	18	73	0	141
1.0 + 0.2	19	37	16	78	0	152
1.0 + 0.5	40	39	18	60	0	157
1.0 + 1.0	27	31	16	79	0	153
Total	208	300	167	1,206	0	1,881

ACKNOWLEDGEMENT

This research was supported by the USDA Cooperative State Research Service grant to Kentucky State University under agreement KYX10-90-12P. Administrative support of Drs. H. R. Benson and R. J. Barney is thankfully acknowledged. Mention of a trade name does not constitute a guarantee or warranty of the product by Kentucky State University and USDA/CSRS and does not imply approval to the exclusion of other products that may also be suitable.

LITERATURE CITED

1. Hildebrand, D. F., G. C. Phillips, and G. B. Collins. 1985. Soybean (*Glycine max* L. Merr.). Pp. 283–308. In Y. P. S. Bajaj (ed.) Biotechnology in agriculture and forestry 2. Crop I. Springer-Verlag, Berlin.

2. Mante, S., R. Scorza, and J. Cordts. 1989. A simple, rapid protocol for adventitious shoot development from mature cotyledons of *Glycine max* cv. Bragg. In Vitro Cell Develop. Biol. 25:385–388.

3. Wright, M. S., S. M. Koehler, M. A. Hinchee, and M. G. Carnes. 1986. Plant regeneration by organogenesis in *Glycine max*. Plant Cell Rep. 5:150–154.

4. Bennici, A. and F. D'Amato. 1978. *In vitro* regeneration of *Durum* wheat plants 1. Chromosome numbers of regenerated plantlets. Z. Pflanzenzuchtg. 81:305–311.

5. D'Amato, F. 1985. Cytogenetics of plant cell and tissue cultures and their regenerates. CRC Crit. Rev. Plant Sci. 3:73–112.

6. Scowcraft, W. R. and P. J. Larkin. 1982. Somaclonal variation: a new option for plant improvement. Pp. 159–178. In I. K. Vasil, W. R. Scowcraft, and K. J. Frey (eds.) Plant improvement and somatic cell genetics. Academic Press, New York.

7. Krishnamurthi, M. 1982. Disease resistance in sug-

arcane developed through tissue culture. Pp. 160–168. In A. Fujiwara (ed.) Plant tissue culture. Jap. Assoc. Plant Tissue Culture. Tokyo.

8. Vasil, I. K. 1988. Progress in the regeneration and genetic manipulation of cereal crops. Biotech. 6:397–402.

9. Blakeslee, A. F. 1922. Variation in *Datura* due to changes in chromosome number. Am. Nat. 56:16–31.

10. Goodspeed, T. H. and P. Avery. 1939. Trisomic and other types in *Nicotiana sylvestris*. Genetics. 36:381–458.

11. Palmer, R. G. 1976. Chromosome transmission and morphology of three primary trisomics of soybean (*Glycine max*). Canadian J. Genetics. 18:131–140.

12. Gwyn, J. J. and R. G. Palmer. 1989. Morphological discrimination among some aneuploids of soybean (*Glycine max* (L.) Merr.): 2. Double trisomics, tetrasomics. J. Hered. 80:209–213.

13. Phillips, G. C. and G. B. Collins. 1980. Somatic embryogenesis from cell suspension cultures of red clover. Crop Sci. 19:323–326.

14. Palmer, R. G. and H. Heer. 1973. A root tip squash technique for soybean chromosomes. Crop Sci. 13:389–391.

15. Wright, M. S., D. V. Ward, M. A. Honchee, M. G. Barnes, and R. J. Kaufmann. 1987. Regeneration of soybean (*Glycine max* L. Merr.) primary leaf tissue. Plant Cell Rept. 6:83–89.

16. Barwale, U. B., H. R. Kerns, and J. M. Widholm. 1986. Plant regeneration from callus of several soybean genotypes via embryogenesis and organogenesis. Planta 167:473–481.

17. Widholm, J. M. and S. Rick. 1983. Shoot regeneration from *Glycine canescens* tissue cultures. Plant Cell Rep. 2:19–20.

Trans. Ky. Acad. Sci., 54(1–2), 1993, 22–27

Seasonal Changes in Abundance of Kentucky Cottontails

William M. Giuliano[1] and Charles L. Elliott

Wildlife Program, Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

and

Jeffery D. Sole

Upland Game Program, Kentucky Department of Fish and Wildlife Resources Frankfort, Kentucky 40601

Abstract

The pellet-plot technique and spotlight surveys were employed to estimate seasonal changes in cottontail rabbit (*Sylvilagus floridanus*) abundance on 5 wildlife management areas in Kentucky, from 20 November 1988 to 20 November 1989. Rabbit populations ranged from 0.2 to 6.0 rabbits per hectare, and fluctuated seasonally, possibly due to dispersal and changes in reproductive performance. Local rabbit populations may be limited by the amount of preferred rabbit habitat available, frequency of harassment, and the effects of an endophyte-infected tall fescue (*Festuca arundinacea*) diet.

Introduction

In Kentucky, as well as much of the rest of North America, the eastern cottontail (*Sylvilagus floridanus*) is pursued by thousands of sportsmen each year (1, 2, 3). However, cottontail numbers appear to be declining throughout a large part of their range (1, 4, 5), including Kentucky (6). These declines appear to be due to changes in land-use. However, other human related activities may also be important (5, 7).

The objective of this study was to determine and compare the seasonal changes in abundance of cottontail rabbits on 5 wildlife management areas (WMAs) in Kentucky.

Methods

The study was conducted on 5 WMAs operated by the Kentucky Department of Fish and Wildlife Resources: Central Kentucky WMA (CKWMA; Madison County), Clay WMA (CWMA; Nicholas County), Yellowbanks WMA (YWMA; Breckinridge County), Taylorsville Lake WMA (TLWMA; Spencer County), and Lloyd WMA (LWMA; Grant County). The WMAs consisted of a mosaic of hardwood forests, agricultural fields typically planted in corn (*Zea mays*) or sunflowers (*Helianthus* spp.), fencerows, and fields of various plant successional stages (7).

Population levels at each WMA were determined using the pellet-plot technique (8) in conjunction with an average daily cottontail rabbit defecation rate of 350 ± 4.5 pellets/rabbit/day (9). Two hundred, 1 m^2 plots, marked with wooden surveyors stakes, were placed 10 m apart along randomly located transects running through all major habitat types (forests, agricultural fields, fencerows, and regenerating fields) at each WMA. Fecal pellets were counted and removed from plots every 4-to-8 weeks between 20 November 1988 and 20 November 1989, to determine seasonal changes in population levels at each WMA.

Roadside spotlight surveys (10, 11) were conducted every 4-to-8 weeks at each WMA to determine relative abundance of rabbits among seasons and WMAs. These surveys were conducted by driving a set route through each WMA starting approximately ½ hour after sunset, and counting the number of rabbits seen per km driven.

Results

Cottontail rabbit density estimates, based on pellet-plot analysis, were determined for each WMA from January to November 1989. These values were combined to determine mean densities for all WMAs over the same period (Fig.

[1] Present address: Department of Range and Wildlife Management, Texas Tech University, Lubbock, Texas 79409.

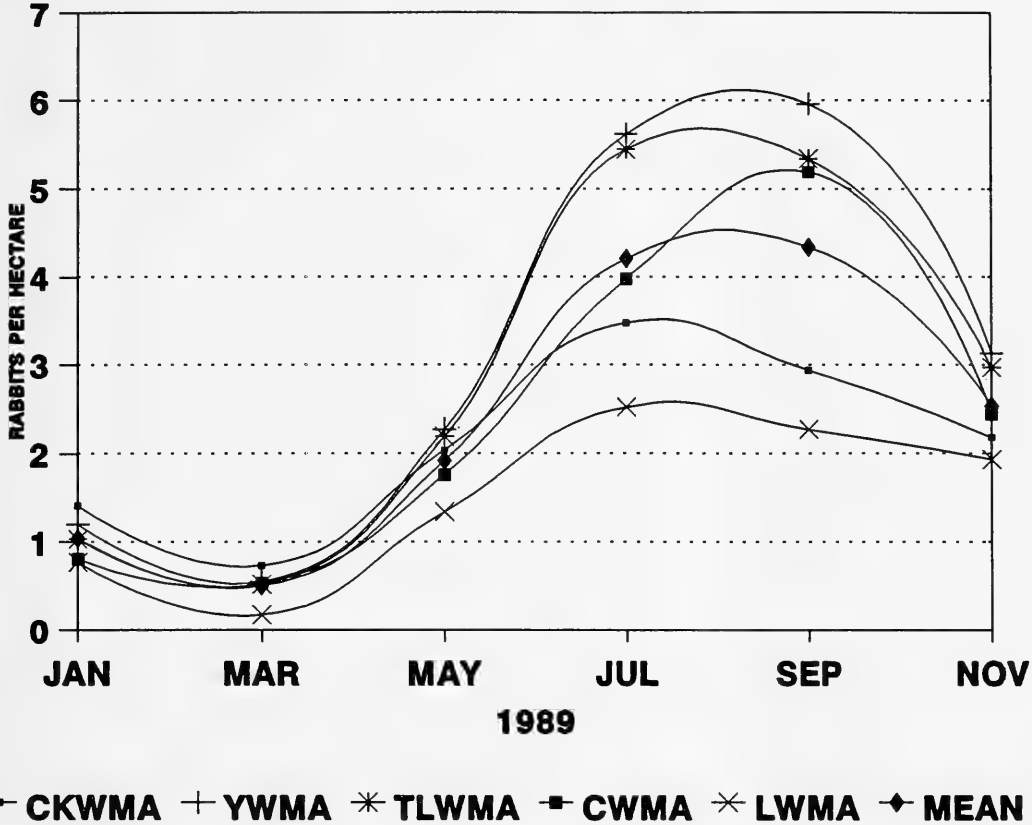


FIG. 1. Seasonal changes in cottontail rabbit density on Central Kentucky Wildlife Management Area (CKWMA), Clay (CWMA), Yellowbanks (YWMA), Taylorsville Lake (TLWMA), and Lloyd Wildlife Management Areas (LWMA), and mean based on pellet-plot surveys.

1). Wide seasonal fluctuations in density were observed. Average annual rabbit densities (±range) were: CKWMA = 2.13 ± 0.03; CWMA = 2.45 ± 0.03; YWMA = 3.12 ± 0.04; TLWMA = 2.92 ± 0.04; LWMA = 1.50 ± 0.02; and mean = 2.42 ± 0.04 rabbits/ha, respectively.

Based on the Friedman Rank Sums Test (12), Lloyd WMA had a significantly lower mean annual rabbit density ($P < 0.01$) than both YWMA and TLWMA. Differences in rabbit densities were not significant ($P > 0.05$) between other WMAs.

Seasonal indices of rabbit abundance were determined at each WMA using spotlight surveys from January to November 1989. These values were combined to generate a mean index for all WMAs (Fig. 2). Wide fluctuations in abundance were observed among seasons at all WMAs. Average annual rabbit indices (rabbits seen per km ± SD) were: CKWMA = 0.40 ± 0.34; CWMA = 0.38 ± 0.32; YWMA = 0.66 ± 0.38; TLWMA = 0.30 ± 0.35; LWMA = 0.21 ± 0.26; and mean = 0.39 ± 0.21.

Comparing the 2 methods, similar seasonal trends in rabbit abundance were observed using both the pellet plot (Fig. 1) and spotlight survey (Fig. 2) data.

DISCUSSION

Rabbit densities in the study areas ranged from 0.2 to 6.0 rabbits per ha; seasonal fluctuations in abundance were evident from both the pellet plot and spotlight survey data (Figs. 1, 2). Both techniques indicated a low in rabbit populations during February–March, increasing to a peak in July–September. Based upon the life-history of cottontails, this trend was expected. Cottontail populations on the WMAs were generally lowest in late-winter, the season

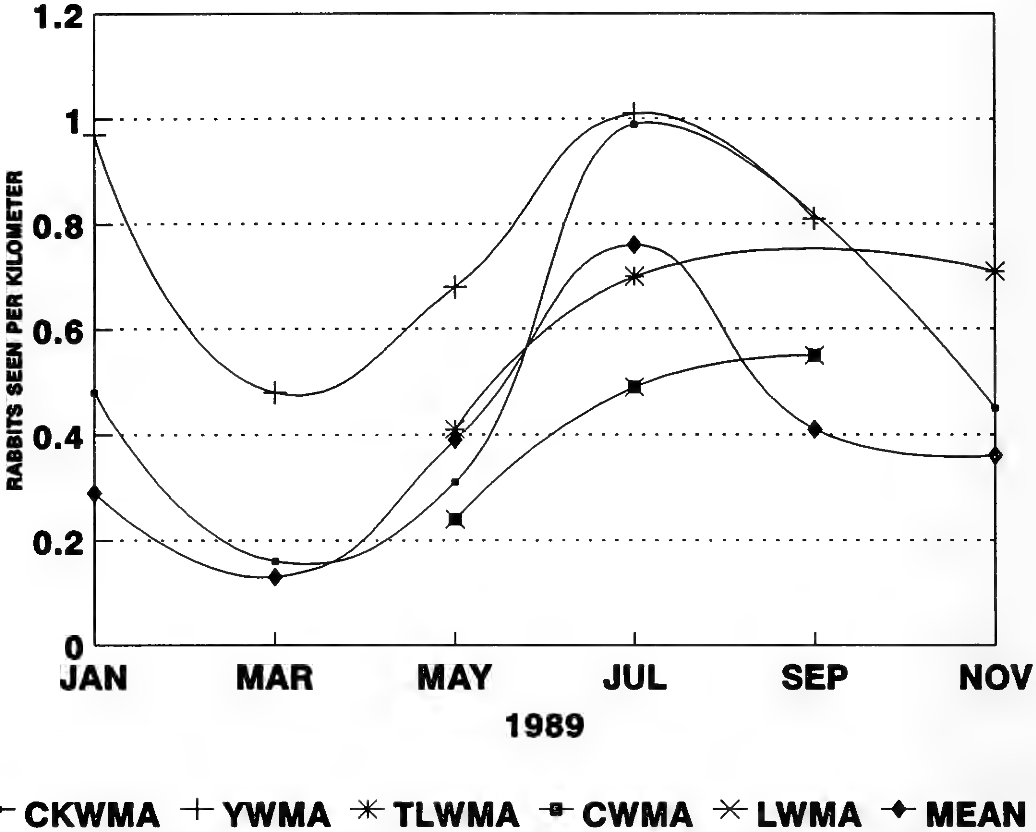


FIG. 2. Relative cottontail rabbit abundance on Central Kentucky Wildlife Management Area (CKWMA), Clay (CWMA), Yellowbanks (YWMA), Taylorsville Lake (TLWMA), and Lloyd Wildlife Management Areas (LWMA), and mean based on spotlight surveys.

when rabbits exhibit high mortality rates. Mortality in cottontail populations at this time appears to be primarily due to harvest, predation, and exposure to adverse climatic conditions (1). This mortality, coupled with a lack of reproductive activity (13), generally leaves the population at its lowest annual level. From March–July, populations on all WMAs increased sharply. This was the result of the onset of reproductive activity and more favorable climatic conditions (1, 7, 13).

The cottontail populations peaked in July–September on the study areas, and then began to decline. This may have been due to a variety of factors. While cottontails in the southeast will breed through October or November (14), the number of litters produced per female and the number of offspring per litter begin to decline after July–August (13, 15, 16). Bittner and Chapman (17) concluded that reproductive performance in cottontails was a function of density, i.e., as population levels increase reproductive performance declines. Dispersal by young animals also appears to be an important factor regulating population levels (1, 18, 19), as is the availability of succulent vegetation (20).

McWherter (21) reported densities of 1.68 rabbits per ha during March; 2.08 rabbits per ha in August; and 2.64 rabbits per ha in December at Land Between the Lakes in Stewart County, Tennessee, just a few km south of the Kentucky border. Chapman et al. (1), in a review of published cottontail research, reported rabbit densities as high as 20 per hectare, although densities were typically lower. Density estimates from this study (Fig. 1) fall within the range described by Chapman et al. (1). Comparisons to other studies in Kentucky were not possible because of a lack of comparable density data.

The spotlight surveys (Fig. 2) and the pellet-plot technique (Fig. 2) showed similar seasonal trends in population levels. However, there were inconsistencies in density estimates obtained. These differences were postulated to be due to problems associated with each technique.

Problems associated with the pellet-plot technique are typically due to fecal pellets degrading or being lost, and, thus, not counted (22). Degradation and loss of pellets is facilitated by rain, humidity (23, 24), and destruction by invertebrates (25). Other pellet-plot problems arise from clumped distributions of pellets and variable defecation rates (26). Because of these potential sources of error, the density estimates obtained using the pellet-plot technique were probably conservative.

The variability in population estimates based on spotlight surveys is primarily due to weather (27). Newman (11) found that increased wind and moonlight reduced the number of rabbits observed during roadside counts. Precipitation and temperature also appear to affect roadside counts (28).

Seasonal fluctuations in rabbit abundance at each WMA followed similar trends. However, there were differences in the degree of fluctuation between WMAs.

In March, CKWMA had the highest relative rabbit density (Fig. 1), but by July its population ranked next to last. The population had only increased five-fold, as compared to the rabbit populations at the other WMAs, which increased at least ten-fold. This did not appear to be related to habitat quality. Preferred rabbit habitat (i.e., old fields and edge) were abundant at Central Kentucky WMA compared to the other WMAs (7). The change in rabbit density at the CKWMA may have been the result of frequent disturbance by dog-training activities associated with hunting clubs utilizing the area from late-spring through fall.

Data indicated that LWMA had a significantly lower rabbit density ($P < 0.01$) than both YWMA and TLWMA (Fig. 1). This may have been related to the relative amounts of preferred habitat (i.e., old field and edge) available at each WMA. Only 13.5% of LWMA was composed of preferred rabbit habitat (7), while both YWMA and TLWMA consisted of at least 35.3% preferred habitat. The amount of endophyte-infected tall fescue (*Festuca arundinacea*), a common pasture grass at LWMA as well as at all other WMAs, may also have been impacting (lowering) rabbit population levels.

The fungal endophyte (*Acremonium ceonophialum*), which infects much of the tall fescue within Kentucky (29), has been shown to reduce survival and reproductive rates in cottontails as well as many other species (30, 31, 32). Tall fescue comprised approximately 69% of the food items identified in Kentucky rabbit diets (7). Frequent dog-training activities may also be limiting rabbit numbers at LWMA.

Current management practices at each WMA vary greatly, but all are based on the multiple use/species concept. Management practices used on the WMAs include: selective cutting, prescribed burning, disking, mowing, food plots, brushpile construction, and limited hunter harvest. These practices are used to maintain or increase habitat types and to regulate wildlife densities.

Based on habitat availability and current management practices, rabbit populations should thrive on the CKWMA. However, population levels remain moderate and may begin to decline if the rabbits continue to be frequently disturbed by dog-training activities, particularly during the breeding season.

Increased urbanization and more intensive agricultural practices can reduce the availability of suitable rabbit habitat through destruction and fragmentation (1, 5). Based on mail-carrier roadside rabbit counts, Sole (6) reported that the cottontail population in Kentucky has been declining since 1969. This decline may be due to changes in land-use, as they relate to rabbit habitat quality. Urban land in Kentucky has increased 6.0% since 1982 (33). Similar long-term declines have been reported in Illinois (4, 5). These declines appear to be related to land-use. Urban lands typically support few rabbits (1, 5) and an increase in this type of land-use may be detrimental to rabbit populations in Kentucky. A 1.1% increase in pasturelands, a preferred rabbit habitat, and a decrease of 1.2% in forestlands and 1.9% in croplands (33), generally unfavorable rabbit habitats, may offset some of the detrimental land-use changes occurring within Kentucky (7).

The data from this one-year study cannot be related to these findings. A longer-term study is needed to relate population levels to habitat availability.

In summary, Kentucky rabbit populations

on 5 WMAs ranged from 0.2 to 6.0 rabbits per ha, fluctuating seasonally apparently due to dispersal and changes in reproductive performance. Local rabbit populations may be limited by the amount of preferred habitat (i.e., old fields and edge) available and the frequency of harassment. YWMA and TLWMA exhibited relatively high rabbit densities, and under current management schemes should continue to favor cottontails. CWMA and CKWMA had relatively moderate densities. Both of these WMAs should continue to support populations at current levels. However, due to dog-related harassment problems there is the potential for a rabbit population decline at the CKWMA. LWMA exhibited the lowest relative rabbit density, and under the current habitat management plan should remain unfavorable to rabbits.

ACKNOWLEDGMENTS

This study was funded by Pittman-Robertson Federal Aid in Wildlife Restoration monies in cooperation with the Kentucky Department of Fish and Wildlife Resources, P-R Project W-45-21, and the Wildlife Program, Department of Biological Sciences, Eastern Kentucky University. We thank Steve Bonney, Buford Clark, Mark Cramer, Jimmy May, Steve McMillen, Dewey Mullins, Billy Pointer, Paul Rose, and Marcia Schroder of the Kentucky Department of Fish and Wildlife Resources, and Sonny Milby and Gary Roloff of Eastern Kentucky University for help with data collection.

LITERATURE CITED

1. Chapman, J. A., J. G. Hockman, and W. R. Edwards. 1982. Cottontails. Pages 83–123. In J. A. Chapman and G. A. Feldhamer (eds.) Wild mammals of North America. Johns Hopkins Univ. Press, Baltimore, Maryland.

2. Alabama Game and Fish Division. 1987. Comparison of the sixteen member states of the Southeastern Association of Fish and Wildlife Agencies: hunting seasons, bag limits, harvest totals and man-days of hunting pressure. Unpubl. Report.

3. Schaaf, L. E., J. D. Sole, T. Edwards, J. Phillips, M. Price, and E. Schneider. 1990. Hunter/harvest survey and deer hunter survey 1989. Kentucky Dept. Fish and Wildl. Resourc. and Urban Res. Inst. Louisville, Kentucky.

4. Bailey, J. A. 1968. Regionwide fluctuations in the abundance of cottontails. Trans. N. Am. Wildl. Nat. Resourc. Conf. 33:265–277.

5. Edwards, W. R., S. P. Havera, R. F. Labisky, J. A. Ellis, and R. E. Warner. 1981. The abundance of cottontails in relation to agricultural land use in Illinois (U.S.A.) 1956–1978, with comments on mechanism of regulation. Proc. World Lagomorph Conf. 1:761–789.

6. Sole, J. D. 1990. Quail and rabbit roadside survey. P-R Proj. W-45-22. Kentucky Dept. Fish and Wildl. Res.

7. Giuliano, W. M. 1990. Food habits, habitat utilization, and abundance of the eastern cottontail rabbit in Kentucky. M.S. Thesis. Eastern Kentucky Univ., Richmond.

8. White, G. C. and L. E. Eberhardt. 1980. Statistical analysis of deer and elk pellet-group data. J. Wildl. Manage. 44:121–131.

9. Cochran, G. A. and H. J. Stains. 1961. Deposition and decomposition of fecal pellets by cottontails. J. Wildl. Manage. 25:432–435.

10. Hendrickson, G. O. 1939. Inventory methods for Mearns cottontail. Trans. N. Am. Wildl. Conf. 4:209–215.

11. Newman, D. E. 1959. Factors influencing the winter roadside count of cottontails. J. Wildl. Manage. 23: 290–294.

12. Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, New Jersey.

13. Chapman, J. A., A. L. Harman, and D. E. Samuel. 1977. Reproductive and physiological cycles in the cottontail complex in western Maryland and nearby West Virginia. Wildl. Monogr. 56:1–73.

14. Pelton, M. R. and E. E. Provost. 1972. Onset of breeding and breeding synchrony by Georgia cottontails. J. Wildl. Manage. 36:544–549.

15. Pelton, M. R. and J. H. Jenkins. 1971. Productivity of Georgia cottontails. Proc. Ann. Conf. Southeastern Assoc. Game Fish Comm. 25:261–268.

16. Johnson, L. W. 1973. A model for the synchronous breeding of the cottontail. M.S. Thesis. Univ. Illinois, Urbana.

17. Bittner, S. L. and J. A. Chapman. 1981. Reproductive and physiological cycles in an island population of *Sylvilagus floridanus*. Proc. World Lagomorph Conf. 1:182–203.

18. Howard, W. E. 1960. Innate and environmental dispersal of individual vertebrates. Am. Midl. Nat. 63:152–161.

19. Gibb, J. A. 1977. Factors affecting population density in the wild rabbit, *Oryctolagus cuniculus* (L.), and their relevance to small mammals. Pages 33–46. In B. Stonehouse and C. Perrins (eds.) Evolutionary ecology. Univ. Park Press, Baltimore, Maryland.

20. Ecke, D. H. 1955. The reproductive cycle of the Mearns cottontail in Illinois. Am. Midl. Nat. 53:294–311.

21. McWherter, G. R. 1991. Estimating abundance of cottontail rabbits using live trapping and visual surveys. M.S. Thesis. Univ. Tennessee, Knoxville.

22. Flinders, J. T. and J. A. Crawford. 1977. Composition and degradation of jackrabbit and cottontail fecal pellets, Texas High Plains. J. Range Manage. 30:217–220.

23. Robinette, W. L., R. B. Ferguson, and J. S. Gashwiler. 1958. Problems involved in the use of deer pellet group counts. Trans. N. Am. Wildl. Conf. 23:411–425.

24. Wallmo, O. C., A. W. Jackson, T. L. Hailey, and R. L. Carlisle. 1962. Influence of rain on the count of deer pellet groups. J. Wildl. Manage. 26:50–55.

25. Lord, R. D. 1963. The cottontail rabbit in Illinois. Illinois Dept. Conserv. Tech. Bull. 3:1–94.

26. Neff, D. J. 1968. The pellet-group count technique for big game trend, census, and distribution: a review. J. Wildl. Manage. 32:597–614.

27. Greathouse, T. E. 1950. Evaluation of census methods for cottontail rabbits. M.S. Thesis. Univ. Michigan, Ann Arbor.

28. Fafarman, K. R. and R. J. Whyte. 1979. Factors influencing nighttime roadside counts of cottontail rabbits. J. Wildl. Manage. 43:765–767.

29. Siegel, M. R., M. C. Johnson, D. R. Varney, W. C. Nesmith, R. C. Buckner, L. P. Bush, P. B. Burrus, T. A. Jones, and J. A. Boling. 1984. A fungal endophyte in tall fescue: incidence and dissemination. Phytopathology 74: 932–936.

30. Sadler, K. C. 1980. Of rabbits and habitat: a long term look. Pennsylvania Game News 51:4–7.

31. Varney, D. R., M. Ndefru, S. L. Jones, R. Newsome, M. R. Siegel, and P. M. Zavos. 1987. The effect of feeding endophyte infected tall fescue seed on reproductive performance in female rats. Comp. Biochem. Physiol. 87C: 171–175.

32. Zavos, P. M., D. R. Varney, J. A. Jackson, M. R. Siegel, L. P. Bush, and R. W. Hemken. 1987. Effect of feeding fungal endophyte (*Acremonium ceonophialum*)-infected tall fescue seed on reproductive performance in CD-1 mice through continuous breeding. Theriogenology 27:549–559.

33. SCS (Soil Conservation Service). 1990. Kentucky fact sheet—National Resources Inventory (NRI). U.S.D.A. Soil Conserv. Serv., Lexington, Kentucky.

Trans. Ky. Acad. Sci., 54(1–2), 1993, 28–29

Note on the Lorentz Transformation

P. L. Corio

Department of Chemistry, University of Kentucky, Lexington, Kentucky 40506

Abstract

A simple derivation of the Lorentz transformation is presented. The derivation shows explicitly that the invariance of the velocity of light is a consequence of the fact that velocities transform projectively.

There have been many derivations of the Lorentz transformation at various levels of sophistication (1, 2, 3, 4, 5, 6, 7). The following demonstration is based on similar assumptions, but differs sufficiently in certain details that it may be of interest.

Consider 2 right-handed coordinate systems (xyz) and (x′y′z′) with their axes parallel, moving relative to each other in the positive x-direction with uniform velocity v. We shall assume that the units of measure are the same in the 2 systems, and that the origins O, O′ coincide at $t = t' = 0$, when a spherical light pulse emanates from their common origin. Since the speed of light is the same in all reference systems, the equations of the wave fronts in the 2 systems at subsequent times are

$$x^2 + y^2 + z^2 - c^2t^2 = 0, \quad (1)$$

$$x'^2 + y'^2 + z'^2 - c^2t'^2 = 0. \quad (2)$$

Assuming that the transformation relating the primed and unprimed variables is linear, it follows that the quadratic form in the left-member of equation (1) is proportional to the quadratic form in the left-member of equation (2). A straightforward argument (3) shows that the proportionality factor is +1, so that

$$x^2 + y^2 + z^2 - c^2t^2 = x'^2 + y'^2 + z'^2 - c^2t'^2. \quad (3)$$

The axes traverse to the velocity are not in relative motion, so that (3) $y = y'$, $z = z'$. Substituting into equation (3) and rearranging, we obtain

$$x^2 + c^2t'^2 = x'^2 + c^2t^2. \quad (4)$$

This equation admits a simple geometrical interpretation if we consider 2 points, $P = (x', ct)$, $Q = (x, ct')$ in a real, 2-dimensional euclidean space, and imagine that P is transformed into Q. Equation (4) then states that the squares of the distances of P and Q from the origin are equal. Such a transformation must be real and orthogonal, so that the coordinates of Q can be related to those of P by the equations

$$x = x'\cos\theta - ct\sin\theta,$$
$$ct' = x'\sin\theta + ct\cos\theta, \quad (5)$$

where θ is an angle to be determined presently.

Equations (5) can be solved for x′ and t′, provided $\cos\theta \neq 0$:

$$x' = \frac{x}{\cos\theta} + ct\tan\theta,$$
$$t' = \frac{x}{c}\tan\theta + \frac{t}{\cos\theta}. \quad (6)$$

We shall see that the condition $\cos\theta \neq 0$ corresponds to the fact that v cannot equal +c or −c.

To determine θ, we first note that

$$\frac{dx'}{dt'} = \frac{dx'/dt}{dt'/dt} = \frac{(\partial x'/\partial x)(dx/dt) + \partial x'/\partial t}{(\partial t'/\partial x)(dx/dt) + \partial t'/\partial t}. \quad (7)$$

Using equations (6), we find that

$$\dot{x}' = \frac{\dot{x} + c\sin\theta}{(\dot{x}/c)\sin\theta + 1}, \quad (8)$$

where $\dot{x} = dx/dt$, $\dot{x}' = dx'/dt'$. Relative to the primed system, O′ is at rest, so that $\dot{x}' = 0$, whereas relative to the unprimed system its velocity is $\dot{x} = v$. Substituting into equation (8) we get $\sin\theta = -v/c$, so that $\cos\theta = \pm(1 - v^2/c^2)^{1/2} = \pm\sqrt{1 - \beta^2}$. We take the plus sign from the consideration that with $v = 0$ and the axes coincident, equations (6) must reduce to $x = x'$, $t = t'$. Therefore,

$$x' = \frac{x - vt}{(1 - \beta^2)^{1/2}}, \quad (9)$$

$$t' = \frac{t - xv/c^2}{(1 - \beta^2)^{1/2}}, \tag{10}$$

$$\dot{x}' = \frac{\dot{x} - v}{1 - \dot{x}v/c^2}. \tag{11}$$

Some interesting results can be deduced from equation (8) irrespective of θ, so long as $\cos\theta \neq 0$. Firstly, equation (8) shows that velocities transform projectively, whereas the coordinates transform linearly. In fact, it is the projective transformation (8) that ensures the invariance of the velocity of light. For if we set $\dot{x} = +c$ or $-c$, then $\dot{x}' = +c$ or $-c$, and conversely. Finally, if we set $\dot{x}' = \dot{x}$, and solve the resulting quadratic equation, we find that $+c$ and $-c$ are the only projective invariants.

The preceding derivation produces no new result, but it seems simpler in some respects than others, and has the advantage of focusing attention upon the transformation of the velocities, the heart of the principle of invariance.

LITERATURE CITED

1. Sears, F. W. and R. W. Brehme. 1968. Introduction to the theory of relativity. Addison-Wesley, Reading.

2. Lieber, L. R. 1936. The Einstein theory of relativity. Rinehart, New York.

3. Møller, C. 1952. The theory of relativity. Oxford, London.

4. Jackson, J. D. 1962. Classical electrodynamics. Wiley, New York.

5. Resnick, R. 1968. Introduction to special relativity. Wiley, New York.

6. Einstein, A. 1905. Annal. der Phys., 17:891. A translation of this article is available in The principle of relativity (Methuen, London, 1923), which has been reprinted by Dover Publications, New York.

7. Pauli, W. 1958. Theory of relativity. Pergamon, New York.

Trans. Ky. Acad. Sci., 54(1–2), 1993, 30–31

NOTE

Persimmon (*Diospyros virginiana*, Ebenaceae) and Mayapple (*Podophyllum peltatum*, Berberidaceae): Proximate Analysis of Their Fruits.—We give here a proximate analysis (Table 1) of two of the best-known indigenous, fleshy fruits of eastern United States, the American persimmon (*Diospyros virginiana*) (Fig. 1) and the mayapple (*Podophyllum peltatum*) (Fig. 2). We collected ripe persimmons and mayapples in Campbell County, Kentucky, in summer and fall 1991.

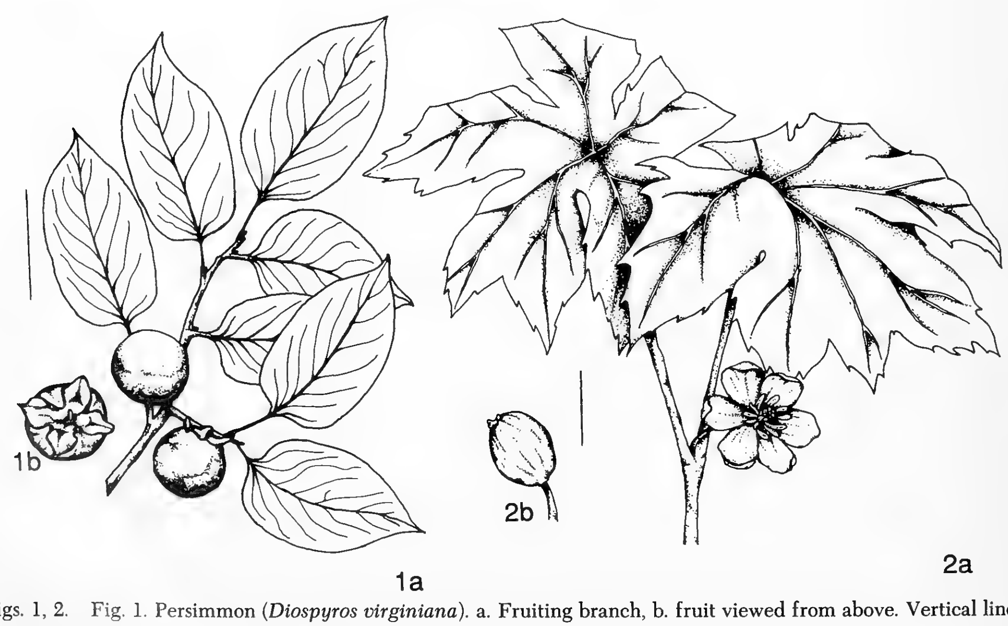
The first of these, the persimmon (Fig. 1), is a member of the largely tropical ebony family (Ebenaceae); its genus is of commercial importance primarily for a prized, Old World wood, ebony, and for a widely cultivated fruit tree, Japanese persimmon (*D. kaki*). Our species, although usually a small to medium-sized deciduous tree, can attain a height of 125 feet and a trunk diameter of 30 inches. Found in fencerows, old fields, and woods, *Diospyros virginiana* ranges from Connecticut to Iowa, south to Florida and Texas (Little, 1971, U.S.D.A. Misc. Publ. 1146; Skallerup, 1953, Ann. Missouri Bot. Gard. 40:211–224).

Persimmon fruits, more or less globose or somewhat oblate (ca. 2.5–7.5 cm in diameter), are orange to red-purple or even dark red when ripe and usually contain several flattened, brown seeds. In our collection (n = 13) the average fruit weight was 11.1 g, with 1–8 seeds per fruit (ave. = 4). The seeds constituted ca. 43% of the total fruit wet weight.

Although folk wisdom dictates that persimmons must be frosted or frozen to remove the intensely puckery quality (caused by tannins), such is not necessarily the case, some trees ripening their saccharine fruits as early as mid-August. Various birds and mammals—including humans—feed upon the fruits, which may be eaten out of hand or made into pudding, syrup, vinegar, or preserves (Fletcher, 1915, U.S.D.A. Farm. Bull. 685; Gibbons, 1962, Stalking the Wild Asparagus, David McKay Co., New York). According to Church and Church (1989, Food Values of Portions Commonly Used, 15th ed., Lippincott, Philadelphia), the "persimmon" (probably the Japanese species, although this is not specified) has an unusually high carbohydrate content, 33.6%. In our study, the fruits of the American species had an average carbohydrate content of 26.0%. This high value is uncommon in fruit, but comparable to passion fruit (23.3%), custard-apples (25.2%), bananas (23.4%), and sapotes (33.8%) (Church and Church, op. cit., 1989). A high sugar content may account for the reportedly long length of preservability of the fruit (Gibbons, op. cit., 1962).

The mayapple (Fig. 2), an unmistakable, herbaceous and rhizomatous species of the barberry family (Berberidaceae), grows, often in large clones, in woods and meadows from Quebec to Minnesota, south to Florida and Texas. Although the rhizomes and other parts of the plant, including the green fruits, are poisonous, the ripe fruits are considered edible (Ernst, 1964, J. Arnold Arb. 45:1–35).

Mayapple fruits, green-yellow to yellow when ripe (mid- to late summer), are many-seeded and about the size and shape of a hen's egg. Our collection (n = 48) had an average weight of 13.4 g per fruit, with 34.3% of the total weight being made up of seeds and attached arils. Though de-



Figs. 1, 2. Fig. 1. Persimmon (*Diospyros virginiana*). a. Fruiting branch, b. fruit viewed from above. Vertical line = 4 cm. Fig. 2. Mayapple (*Podophyllum peltatum*). a. Distal portion of plant in flower, b. fruit. Vertical line = 5 cm.

TABLE 1. Proximate analyses of fruits of persimmon (*Diospyros virginiana*) and mayapple (*Podophyllum peltatum*); figures are averages.

	Persimmon	Mayapple	Persimmon[b]
Fruit weight (g)	11.1 ± 0.71[a] (n = 13)	13.4 ± 0.8[a] (n = 48)	25
% water	71.1 ± 0.43[a] (n = 11)	94.7 ± 0.2[a] (n = 1)	64.4
% lipid	1.67 ± 0.16[a] (n = 3)	0.03 ± 0.01[a] (n = 6)	0.4
% ash	0.64 ± 0.04[a] (n = 8)	0.34 ± 0.04[a] (n = 6)	0.4
% protein	0.60 ± 0.08[a] (n = 5)	0.88 ± 0.17[a] (n = 5)	0.8
% carbohydrate (calculated)	26.0	4.0	33.6

[a] SEM.
[b] Values are those given in Church, C. F., and H. N. Church. 1989. Food Values of Portions Commonly Used, 15th ed. Lippincott, Philadelphia. Species was unidentified.

scribed by Asa Gray as "mawkish, eaten by pigs and boys," they may be used raw or for excellent preserves, especially a "luscious" marmalade (Fernald and Kinsey, 1958, Edible Wild Plants of Eastern North America, Harper, New York). We found mayapples to have an extremely high water content, higher even than watermelon (92%), grapefruit (91%), "melons" (90%), or papayas (89%). However, several vegetables have comparably high water contents, e.g., cucumber (96%), summer squash (94%), and sweet green peppers (92%) (Church and Church, op. cit., 1989).

In our laboratory, proximate analyses were performed on freshly collected ripe persimmons and mayapples, unpeeled and with seeds removed. Water content was calculated as a percent difference from fresh weight after drying at 100°C for 24 hr. Percent lipid was determined by ether extraction of the dried samples. Protein analysis was done using micro-kjeldahl methodology and a nitrogen conversion factor of 6.25. For mineral content, samples were ashed at 600°C in a muffle furnace. Carbohydrate content was estimated by subtraction of water, lipid, and mineral content from original net weights.—**Debra K. Pearce** and **John W. Thieret**, Department of Biological Sciences, Northern Kentucky University, Highland Heights, Kentucky 41099.

Trans. Ky. Acad. Sci., 54(1–2), 1993, 32–35

ACADEMY AFFAIRS

The Seventy-Eighth Annual Business Meeting of the Kentucky Academy of Science

Ashland Community College
Ashland, Kentucky
29–31 October 1992

Minutes of the Governing Board Meeting Kentucky Academy of Science 29 October 1992

Present: Presiding—Douglas L. Dahlman, J. G. Rodriguez, Charles Boehms, Blaine Ferrell, Val Dunham, Larry Elliott, Jim Gotsick, Blaine Early, David Hartman, Estel Hobbs, and William P. Hettinger. Ben Harmon and George Livingston, Ashland Community College—members of the Local Arrangement Committee.

President Dahlman called the meeting to order at 1:05 p.m. in a meeting room at the Ashland Plaza Hotel. The Minutes of the August 29, 1992, meeting were approved.

President's Report

- Local Arrangement Representatives Ben Harmon and George Livingston reported on details concerning display boards, refreshments near the vending area and the commercial exhibit area.
- About 150 banquet places are expected.
- A spouse tour program was announced, as was an Ashland refinery tour and an Ashland Oil traveling exhibit.

Awards

Larry Elliott announced the winners for the 4 KAS awards. They were:

- Distinguished Scientist—Marcus T. McEllistrem, University of Kentucky
- Industrial Scientist—Karl Russ, United Catalysts Inc., Louisville
- Outstanding College-University Science Teacher—Curtis C. Wilkins, Western Kentucky University
- Outstanding Secondary Science Teacher—Andrea L. Warren, Franklin-Simpson High School, and Samuel Thomas Hunt, Montgomery County High School, were co-recipients

Future Meetings

Discussion of each site was as noted.

- 1993: 22–23 October, Georgetown College with Toyota as co-hosts—Charles Boehms
- 1994: Paducah Community College—Blaine Early; Jim Meeks is contact
- 1995 or 1996: Bowling Green—KAS/Tenn. Academy—Charles Boehms
- 1999: Lexington—Blaine Early and Planning Committee

Program 1992

There are 191 papers, 53 from undergraduates and 36 poster displays.

Treasurer's Report

- Membership dues income showed a significant drop. Discussion followed on the need to invoice on yearly basis. KAS may have to operate in a deficit situation.
- See Treasurer's Report—Appendix A.

Cash Advances

The Executive Secretary discussed the need for cash advance required by Blue Grass Mailing Service and to Executive Secretary to pay for postage. The Governing Board approved the motion to issue a total of $1,000 for both of these expenses (details to be worked out by the Treasurer and the Executive Secretary).

Mentor Program

The Executive Secretary stated it was prudent to set up a separate bank account for the Mentor Program. Motion passed.

Secretarial Services

Gwyn Ison petitioned for an increase of $1.00 per hour for a total of $8.50 per hour. Motion passed. New rate to begin January 1, 1993.

Commercial Vendors and Museum Exhibit

The Executive Secretary expressed concern that only seven vendors would exhibit (see Appendix B). In addition we invited Donald Chestnut, University of Kentucky Geologist and Paleontologist, to display his exhibit and proposal for the Kentucky Museum of Natural History.

Hettinger Award Winners

The annual AAAS awards for the Kentucky Junior Academy of Science winners will be known as the KAS–William P. Hettinger Award. Bill Hettinger expressed his appreciation for naming the program after him.

Appendix A: Treasurer's Report

Kentucky Academy of Science
1992

Starting Balance (January 1, 1992)		$72,175.28
Income (below)	+27,033.08	

Expenses (on page 2)	−20,922.24	
Ending Balance (September 30, 1992)		$78,286.12

Income—1992

Membership Dues		$5,082.00
Regular	$5,082.00	
Life (61) 1992		
Institutional Memberships		6,400.00
Corporate Memberships		5,950.00
Library Subscriptions		1,963.60
Page Charges and Abstracts		3,120.00
Annual Meeting—1992		1,959.00
Exhibits	770.00	
Registration and Banquet	1,189.00	
Interest Income		2,552.43
Bank	1,193.07	
CD	1,359.36	
Griffith Memorial Trust—1992 ($133.83)		0.00
Endowment Fund Gifts		0.00
Life Membership		0.00
Mentor Program		0.00
Miscellaneous		6.05
Total		$27,033.08

Expenses—1992

KJAS		$ 2,500.00
KJAS-AAAS—1992		1,774.42
NAAS—dues		120.00
Printing		10,477.53
Transactions	$8,978.56	
Newsletter (Secr.)	1,425.96	
Other (Exec. Secr.)	73.01	
Mentor	0.00	
Professional Services (CPA)		575.00
Annual Meeting 1991		2,613.22
C. Nelson	2,055.18	
Printing	495.00	
Executive Inn	63.04	
Annual Meeting 1992		116.72
Badges	116.72	
Transfer to Endowment Fund		0.00
Gifts	0.00	
New Life Member	0.00	
Griffith Awards		0.00
Refunds		0.00
Editor		61.48
Treasurer		23.20
Postage	23.20	
Vice President		105.17
Postage and Print	105.17	
Executive Secretary		2,246.84
Postage	1,258.97	
Secretarial Services	692.90	
Phone	230.10	
Office Supplies	64.87	
Meetings, Executive and Board)		193.80
Miscellaneous		114.86
Corp. Fees	8.00	
Bond	106.50	
Bank Service Charge	0.36	
Total		$20,922.24

Kentucky Academy of Science Foundation
Endowment Fund—1992

Starting Balance (January 1, 1992)		$25,846.23
Life Memberships (61)	$21,350.00	
Endowment	4,496.23	
Income		+1,076.68
Transfer from KAS		
Life Member Increase	0.00	
Gifts	0.00	
Direct Gifts to Endowment	0.00	
Life Memberships	0.00	
Interest		
Bank Account	170.44	
CD	906.24	
Expenses		0.00
Transfer to KAS for Life Memberships (61) 1992		
Ending Balance (September 30, 1992)		$26,922.91
Life Memberships (61)	$21,350.00	
Endowment	5,572.91	

Botany Fund—1992

Starting Balance (January 1, 1992)		$15,695.73
(Principal—$13,488.42; Interest—$2,207.31)		
Income		+594.45
Interest		
Bank Account	$141.33	
CD	453.12	
Donation	0.00	
Expenses		−1,615.00
Grant—M. D. Delong	1,615.00	
Ending Balance (September 30, 1992)		$14,675.18
(Principal—$13,488.42; Interest—$1,186.76)		

Marcia Athey Fund—1992

Starting Balance (January 1, 1992)		$58,120.51
(Principal—$54,572.79; Interest—$3,547.72)		
Income		+2,506.28
Interest		
Bank Account	$195.37	
CD	2,310.91	
Expenses		–3,241.00
Grants		
M. Stinson	$ 391.00	
M. Fuller	2,850.00	
Ending Balance (September 30, 1992)		$57,385.79
(Principal—$54,572.79; Interest—$2,813.00)		

Corporate Affiliates—1992

	Date paid	1991	Amount
DataStream Imaging Systems, Inc.			
Dow Corning Corporation			
The BFGoodrich Company			
Brown and Williamson Tobacco Corporation	3/30/92		$ 1,000.00
All-Rite Pest Control	4/24/92		100.00
Alltech Biotechnology Center	3/25/92		250.00
First Security Banks		$100.00	
Corhart Refractories Corporation	3/30/92		250.00
Kentucky Electric Steel Corporation			
Group Financial Partners, Inc.		100.00	
Ashland Oil, Inc.	8/5/92		2,000.00
E. I. Du Pont de Nemours & Company Wurtland KY Plant			
Estron Chemical, Inc.			
The Rexroth Corporation Pneumatics Division			
Westvâco	5/8/92		200.00
GAF Chemicals Corporation		250.00	
Hoechst Celanese Corporation Engineering Plastics Division			
International Business Machines Corp.	8/11/92		100.00
The Humana Foundation Inc.		200.00	
Citizens Fidelity Bank & Trust Company			
Air Products & Chemicals, Inc.	3/25/92		500.00
Rohm and Haas Kentucky Inc.			
United Catalysts Inc.	4/7/92		250.00
Wood Hudson Cancer Research Laboratory, Inc.	3/25/92		100.00
Island Creek Corporation			
Litton Industrial Automation		250.00	
MPD, Inc.	6/27/92		250.00
C & I Engineering, Inc.		250.00	
Proctor & Gamble	3/30/92		100.00
DataBeam Corporation	4/14/92		250.00
3M	4/20/92		100.00
ISP Chemicals	4/7/92		500.00

Contributions from Colleges and Universities—1992

	Date paid	1991	Amount
Kentucky Wesleyan College	3/9/92		$100.00
Georgetown College	3/17/92		500.00
Bellarmine College		$250.00	
Berea College	1/30/92		100.00
Brescia College	3/2/92		100.00
Campbellsville College	3/9/92		250.00
Kentucky State University	4/7/92		500.00
Transylvania University	3/2/92		100.00
Midway College	3/17/92		100.00
Sue Bennett College	3/2/92		100.00
University of Kentucky	3/2/92		1,000.00
Murray State University	4/14/92		500.00
Centre College	9/16/92		100.00
Lees College		50.00 (1990)	
Morehead State University	3/9/92		500.00
Eastern Kentucky University	7/8/92		500.00
Northern Kentucky University	3/2/92		500.00
Alice Lloyd College		50.00 (1990)	
Western Kentucky University	5/15/92		500.00
University of Louisville	3/17/92		500.00
Thomas More College	3/9/92		100.00
Spalding University	5/22/92		100.00
Cumberland College	3/9/92		250.00
Union College		100.00	

APPENDIX B: COMMERCIAL EXHIBITORS

- Miami Computer Supply, Inc., Dayton, OH
- MPD, Inc., Owensboro, KY
- Parco Scientific Co., Vienna, OH
- Swift, Cincinnati, OH
- Preiser Scientific, Louisville, KY
- Fisher Scientific, Cincinnati, OH
- B&B Microscopes, Ltd., Warrendale, PA

Raymond Athey Estate Trust

The Executive Secretary reported on the status of the trust. The Paducah business was expected to sell by mid-October. The property in Decatur, Illinois, has not sold, being hindered by a large mortgage (see Appendix C).

KJAS Report

- Dr. Val Dunham, Director, represented KJAS at the annual meeting of the Kentucky Science Teachers Association (KSTA), 22–24 October 1992. Dr. Dunham made a presentation to the KSTA board concerning KJAS including: a. benefits for teachers and students and b. possible cooperative efforts with KSTA and Kentucky Science Olympiad (KSO).

- Discussion is needed by the KAS board on the possibilities of having the annual KJAS Symposium in conjunction with KSO after 1993. Current KSO events include lab skills. KJAS would maintain research presentations (oral presentations and posters) and Science Bowl, if desired. The KSO will be meeting next year at Male High School in Louisville during April.
- The 1993 KJAS annual meeting will be in April at Western Kentucky University.

Election

The results of the election of officers were announced as follows:

- Candidates for Vice-President—Robert Creek won over Marcus T. McEllistrem.
- Candidates for Representative-at-Large—Valena Hurt won over Vincent A. DiNoto.
- Candidates for Representative from the Division of Social Sciences and Science Education—David E. Hogan won over Jim Murray Walker.
- Candidates for Representative from the Division of Physical, Mathematical and Computer Sciences—Patricia K. Doolin and Jerry D. Cook tied. (The Governing Board voted to break the tie and Patricia Doolin was elected.)
- Candidates for Treasurer—Julia H. Carter won over Angela R. Keith.

Governing Board Meeting October 1992

President Dahlman presided. The meeting was called to order at 12:10 p.m.

New Editor

An invitation will be extended to Vince DiNoto to become the new *Newsletter* Editor for the year 1993. The expectation to be expressed to him is that he attend all Governing Board meetings.

Format of Newsletter

To increase readability, the cover page should highlight the Contents.

Membership Dues

A discussion led by the Executive Secretary on membership dues expressed the concern that confusion exists relative to billing of dues. The motion was made and approved as follows:

1. Two general types of memberships will exist: Annual and Life.
2. Dues are payable by January 1 for that year. Dues paid after February 1 will not receive the *Transactions* because the number ordered from the publisher is precontracted by that date.

Trans. Ky. Acad. Sci., 54(1–2), 1993, 36–59

PROGRAM, ANNUAL MEETING

Kentucky Academy of Science
The Seventy-Eighth Annual Meeting

Ashland Community College
Ashland, Kentucky
29–31 October 1992

Governing Board

Executive Committee

President	Douglas L. Dahlman, University of Kentucky
President Elect	Charles N. Boehms, Georgetown College
Past President	W. Blaine Early, III, Cumberland College
Vice-President	Larry P. Elliott, Western Kentucky University
Secretary	Peter X. Armendarez, Brescia College
Treasurer	David R. Hartman, Western Kentucky University
Executive Secretary	J. G. Rodriguez, University of Kentucky
Editor, *Transactions*	Branley A. Branson, Eastern Kentucky University
Editor, *Newsletter*	Varley E. Wiedeman, University of Louisville

Division Representatives and At Large Members

Estel M. Hobbs (1992)	Ashland Petroleum Company
Bruce A. Mattingly (1992)	Morehead State University
Lee T. Todd (1992)	DataBeam Corporation
Burtron H. Davis (1993)	Center for Applied Energy Research
Ray K. Hammond (1993)	Centre College
James E. Gotsick (1994)	Morehead State University
Kimberly Ward Anderson (1995)	University of Kentucky
Blaine R. Ferrell (1995)	Western Kentucky University
AAAS/NAAS Representative William P. Hettinger, Jr. (1995)	Russell, KY
Chairperson, KJAS Valgene L. Dunham (1994)	Western Kentucky University

Local Arrangement Committee

Ashland Community College
Ben Harman, Co-Chairman
George Livingston, Co-Chairman
Charles Dassance
Charles Howes
Tony Newberry

Hossein Mohebbian
Ted Shields

Ashland Oil Incorporated
Estel M. Hobbs

KENTUCKY ACADEMY OF SCIENCE
78TH ANNUAL MEETING

Ashland, Kentucky

PROGRAM SUMMARY

Thursday Evening Activities at the
Ashland Plaza Hotel

Thursday, 29 October 1992

1:00–4:00 p.m.
Executive Board Meeting, Hotel Conf. Rm.

2:00–7:00 p.m.
Registration, Hotel Lobby

6:00–7:00 p.m.
Interest Sessions
Legacy of Jesse Stuart, Dr. James M. Gifford, Ballroom A; Kentucky Museum of Natural History, Dr. Donald R. Chestnut, Jr., Ballroom C

7:00–9:00 p.m.
Reception, Ballroom B

Friday, 30 October 1992

All portions of the meeting except the
banquet will be held in the
Ashland Community College Main Building

7:30 a.m.–6:00 p.m.
Registration, Main Bldg. Lobby

8:00 a.m.–5:30 p.m.
Poster Exhibits, Room A106

8:00 a.m.–5:30 p.m.
Vendor Exhibits, Student Lounge

10:00 a.m.–10:30 a.m.
Comm. Coll. Science Faculty, Room 305

10:30 a.m.–12:00 noon
Comm. Coll. Biology Faculty, Room 303

10:30 a.m.–12:00 noon
Comm. Coll. Chemistry Faculty, Room 304

10:30 a.m.–12:00 noon
Comm. Coll. Physics Faculty, Room 305

8:00 a.m.–12:00 noon
Sectional Meetings
Section C—Chemistry, Room L275; Section G—Physiology and Biophysics, Room 205; Section H—Science Education, Room 204; Section K—Zoology and Entomology, Room 302; Section Q—Agriculture, Room A222

9:00 a.m.–9:30 a.m.
Refreshments, Student Lounge

12:00 noon–1:00 p.m.
Lunch, On your own

1:00 p.m.–2:15 p.m.
Plenary Session, Auditorium—A231
Presiding: Douglas L. Dahlman—President, Kentucky Academy of Science
Welcome: Dr. Charles Dassance, President, Ashland Community College
Announcements: Dr. George Livingston, Chairman, Local Arrangement Committee
Plenary Presentation: *The Research University in the 1990's: Partnerships with K–12 Education, Businesses, and Government*
Dr. Lee Magid, Vice President for Research and Graduate Studies, University of Kentucky

2:15 p.m.–2:45 p.m.
Refreshments, Student Lounge

2:45 p.m.–5:00 p.m.
Sectional Meetings
Section B—Botany and Microbiology, Room 301; Section C—Chemistry, Room L275; Section D—Geography, Room 222; Section E—Geology, Room 221; Section G—Physiology and Biophysics, Room 205; Section H—Science Education, Room 204; Section I—Psychology, Room 321; Section K—Zoology and Entomology, Room 302; Section Q—Agricultural Science, Room A222; Section R—Industrial Science, Room L269

6:30 p.m.–7:15 p.m.
Presidents' Reception (Hosted by Ashland Oil Corp.), Ashland Oil

7:15 p.m.–9:00 p.m.
Annual Awards Banquet, Ashland Oil
Darwinism in American Politics: What Goes Around Comes Around—Dr. Gene Krisky, College of Mt. St. Joseph

Saturday, 31 October 1992

8:00 a.m.–1:00 p.m.
Registration, Main Lobby

8:00 a.m.–2:00 p.m.
Scientific Posters, Room A106

8:00 a.m.–2:00 p.m.
Vendor Exhibits, Student Lounge

8:00 a.m.–9:30 a.m.
Sectional Meetings
Section A—Anthropology, Room 219; Section B—Botany and Microbiology, Room 301; Section C—Chemistry, Room L275; Section F—Physics, Room 220; Section I—Psychology, Room 321; Section K—Zoology and Entomology, Room 302; Section N—Engineering, Room L269; Section Q—Agricultural Science, Room A222

9:30 a.m.–10:00 a.m.
Refreshments, Student Lounge

10:00 a.m.–11:00 a.m.
Annual Business Meeting, Auditorium

11:00 a.m.–11:15 a.m.
Science Olympiad Performance, Bell County High School, Auditorium

11:15 a.m.–12:00 a.m.
Sectional Meetings, Rooms same as above

12:00 noon–1:00 p.m.
Lunch, On your own

1:15 p.m.–end
Sectional Meetings, Rooms same as above

Note: KJAS

Each spring the Kentucky Junior Academy of Science holds an Annual Spring Symposium. The 58th Symposium was held at Eastern Kentucky University on April 24–25, 1992. Activities at this meeting included the presentation of Science Projects by KJAS members, Science Bowl competition and Lab Skills competition. The winners of each division of the Science Projects presentations are invited to present their work at the annual meeting of the Kentucky Academy of Science. A KJAS precedes the title of each of the papers given by these young scientists.

SESSION—COMMUNITY COLLEGES

Community Colleges Science Faculty
Room 305

Friday, 30 October 1992

10:00 a.m.
General Session, Room 305

10:30 a.m.
Break-out Sessions
Biology, Room 303; Chemistry, Room 304; Physics, Room 305

SECTION A—ANTHROPOLOGY SECTION

James F. Hopgood—Chairman
Jim Murray Walker—Secretary
Room 219

Saturday, 31 October 1992
Jim Murray Walker—Presiding

8:00 a.m.
Parsees and Gabars: Racial Mixing or Plasticity?
Jim Murray Walker—Eastern Kentucky University

8:15 a.m.
The Rhetoric of Myth in Ritual Space at a Complex Rock Art Site in Chaco Canyon
Robert Vallier—University of Tennessee at Chattanooga

8:30 a.m.
Early Christian Celtic Artwork
Iain Barksdale—Madisonville Community College and Henderson Community College

8:45 a.m.
An Analysis of Selected Artifacts Recovered from the Battlefield at Cumberland Church, Virginia, 1865
Doug Rigsby—Ashland Community College

9:00 a.m.
Chaos, Entropy, and Social Construct: The Use of Physics to Help Explain Some Human Institutions
Rex McDonald—Eastern Kentucky University

9:15 a.m.
Researching an American Iconic Movement: An Update
James F. Hopgood—Northern Kentucky University

9:30 a.m.
Refreshments, Student Lounge

10:00 a.m.
Annual Business Meeting, Auditorium

11:30 a.m.
Library Research is Easier Than Fieldwork?
Cara E. Richards—Transylvania University

11:45 a.m.
A New Slant on Acculturation
Mary Carol Hopkins—Northern Kentucky University

12:00 noon
Network Strategies and Economic Change on an English Speaking Caribbean Island
Gina Meyer (Undergraduate)—Northern Kentucky University; sponsored by James Hopgood

12:15 p.m.
Shawnee Indian Ethnicity
Sharlotte Neely—Northern Kentucky University

12:30 p.m.
The Vertical Economy of a Mexican Peasant Community: A Model for Understanding Persistence and Change
T. D. Murphy—Northern Kentucky University

12:45 p.m.
Anthropology Section Business Meeting

SECTION B—BOTANY AND MICROBIOLOGY SECTION

David Taylor—Chairperson
Landon McKinney—Secretary
Room 301

Friday, 30 October 1992
Landon McKinney—Presiding

2:30 p.m.
KJAS
The Effects of Acid Rain on Lolium Perenne
Jonathan Ashby—Warren Central High School; sponsored by Ronica Shuffitt

2:45 p.m.
KJAS
The Effectiveness of Various Toilet Bowl Cleaners on *E. coli*
Joanna Durham—Warren Central High School; sponsored by Ronica Shuffitt

3:00 p.m.
Influence of Pesticide Treatment on Mycoflora Populations in High Moisture Bin Stored Shelled Corn
Bryan D. Price, John D. Sedlack, and Paul A. Weston—Kentucky State University

3:15 p.m.
Polytaenia nuttalii (Parsley: Apiaceae) in Kentucky and Tennessee
Edward W. Chester—Austin Peay State University and Eugene Wooford—University of Tennessee at Knoxville

3:30 p.m.
Inhibitory Effects of Acidic Minesoil on the Sericea Lespedeza/Bradyrhizobium Symbiotic Relationship
G. R. Cline and Z. Ngewoh Senwo—Kentucky State University

3:45 p.m.
Comparison of Flagellar Motion in Selected Euglenoid Algae (Euglenophyceae)
Nancy Dawson, Amy Baker, Brad Weaver, and David Pittman—Western Kentucky University

4:00 p.m.
Tissue Culture Studies of *Castanea dentata*
Larry A. Giesmann—Northern Kentucky University

4:15 p.m.
Flora of Kentucky Projects—Can There Be Order Out of Chaos?
Ronald Jones—Eastern Kentucky University

4:30 p.m.
Flora of Kentucky Discussion

Saturday, 31 October 1992
Landon McKinney—Presiding

8:00 a.m.
A Floristic Study of the Only Known Site for *Drosera brevifolia* in Kentucky
J. Richard Abbott (Undergraduate) and R. L. Thompson—Berea College

8:15 a.m.
Botanical Survey of the Redbird Purchase Unit, Daniel Boone National Forest
Julian Campbell—The Nature Conservancy and Allen Risk—University of Tennessee

8:30 a.m.
The Kentucky Natural Areas Inventory, 1988–1992
Tom Bloom and Marc Evans—Kentucky State Nature Preserves Commission

8:45 a.m.
Somatic Embryogenesis in Tissue Cultures of *Pinus strobus*
L. Catherine Mahl and K. Kaul—Kentucky State University

9:00 a.m.
Natural Areas Inventory of the Jackson Purchase
Marc Evans and Landon McKinney—Kentucky State Nature Preserves Commission

9:15 a.m.
Botany and Microbiology Section Meeting

9:30 a.m.
Refreshments, Student Lounge

10:00 a.m.
Annual Business Meeting, Auditorium

11:30 a.m.
Effects of Light Environment on Growth and Yield of Field-Grown Okra
Edith Greer and K. Kaul—Kentucky State University and M. J. Kasperbauer—USDA/ARS

11:45 a.m.
Niche Partitioning between Gap-colonizing Bryophytes
Craig C. Young (Undergraduate) and Robin W. Kimmerer—Centre College

12:00 noon
Ecological Consequences of Asexual Reproduction in the Forest Floor Bryophyte, *Dicranum flagellave*
Robin W. Kimmerer—Centre College

12:15 a.m.
Rare Plant Inventory of the Jackson Purchase
Landon E. McKinney and Marc Evans—Kentucky State Nature Preserves Commission

12:30 a.m.
Comparative Sulfur Levels of *Juniperus virginiana* in Respect to Leaf Tissues and Geographic Location
Joe E. Winstead—Western Kentucky University

SECTION C—CHEMISTRY

Nancy Flachskam—Chairperson
Ted Shields—Secretary
Room L275

Friday, 30 October 1992
Ted Shields—Presiding

8:30 a.m.
Synthesis and Analysis of Sulfonium Salts
Robert C. Molloy and Tom Green—Western Kentucky University

9:00 a.m.
Refreshments, Student Lounge

9:15 a.m.
Behavior of Fuel Blends Containing Limestone

T. C. Roth, J. T. Riley, and W. P. Pan—Western Kentucky University

9:30 a.m.
Application of the Determination of Total Aromatics in Petroleum Products by SFC
Paula C. Wiseman—Ashland Petroleum

9:45 a.m.
Determination of Chlorine Release Profile from Coal Combustion and Pyrolysis by TG/1C Technique
Tony D. Shao and Wei-Ping Pan—Western Kentucky University

10:00 a.m.
Analysis of Sulfur Compounds in Petroleum via Sulfonium Salts and NMR
Jo Ann Wood, Ben Harris, and Tom Green—Western Kentucky University

10:15 a.m.
Rapid Analysis of Moisture in Coal
Stuart Burris and John T. Riley—Western Kentucky University

10:30 a.m.
A Study of Coal Sulfur Forms Using Thermal Analytical Techniques
BuCheng Wang and John T. Riley—Western Kentucky University and DeXiang Zhang—Huainan Mining Institution (P.R.O.C.)

10:45 a.m.
Characterization of Aliphatic Sulfur in Coal
John T. Riley, BuCheng Wang, Mingshe Zhu, and L. Michelle Lewis—Western Kentucky University

11:00 a.m.
Thermal Analysis of Polymer Composite by TG-F7ZR
Or Zhang and Wei-Ping Pan—Western Kentucky University

11:15 a.m.
DSC and DTA Comparisons to the AOCS Titer Method
Erik Hutchinson and Wei-Ping Pan—Western Kentucky University

11:30 a.m.
Hydrogen Bond Directed Molecular Recognition in Organic Crystals
Dan Adsmond and Margaret Etter—Morehead State University

11:45 a.m.
Determination of Nitrates in Consumer Beverages by Ion Chromatography
Beverly Campbell and Wei-Ping Pan—Western Kentucky University

12:00 noon
Lunch, On your own

1:00 p.m.
Plenary Session, Auditorium

2:15 p.m.
Refreshments, Student Lounge

2:45 p.m.
On the Cobalt (1120) Surface as a Template for Hydrocarbon Chain Formation in Fischer Tropsch Synthesis
Yon-Tae Je(x) and Audrey L. Companion—University of Kentucky

3:00 p.m.
Acid Insoluble Ash as a Marker in Nutrient Digestibility Studies
Jeff Stidam, Joe L. Werth (Undergraduates), Charles Anderson, and John T. Riley—Western Kentucky University

3:15 p.m.
Mineral Analysis in Animal Digestibility Studies
L. Michelle Lewis, Joe L. Werth, Stuart Burris, Tawana Woods (Undergraduates), Charles Anderson, and John T. Riley—Western Kentucky University

3:30 p.m.
Soot Analysis in Southeast Kentucky
Howard C. Van Woert, Jr., and Timothy J. Bailey (Undergraduate)—Southeast Community College

Saturday, 31 October 1992
Ted Shields—Presiding

10:00 a.m.
Annual Business Meeting, Auditorium

11:30 a.m.
Analysis of First-Order Kinetic Data by a Differential Technique
Li Jing Sun, Koorosh Zaerpoor (Undergraduates), and Lee Roecker—Berea College

11:45 a.m.
Azide Trapping During the Base Hydrolysis of the Pentammine-Dimethylsulfidecobalt(III) Ion—Evidence for a Dissociative Mechanism
Regina Hicks (Undergraduate) and Lee Roecker—Berea College

12:00 noon
Synthesis and Reactivity of Cobalt(III) Complexes Coordinated by Monodentate and Bidentate Thioether Ligands
Lee Roecker—Berea College

12:15 p.m.
Development of HPLC-EC Methodology to be Used in the Determination of the Daily Pattern of Brain Octopamine Levels in *Leucophaea maderae*
Maya Siddiqui, Chris Pergrem (Undergraduate), Laura Lee Wilson (Undergraduate), Darwin B. Dahl, and Blaine R. Ferrell—Western Kentucky University

3:45 p.m.
Determination of Fat Oxidation Products by FTNMR
De Chen, David Hartman, and Tom Green—Western Kentucky University

4:00 p.m.
Kinetic Controls on Limestone Dissolution During Early Stages of Karst Aquifer Development

Christopher Groves—Western Kentucky University and Alan D. Howard—University of Virginia

4:15 p.m.

Thermal Analysis of Montomorillonite/Pyrrole During Pyrolysis and Combustion

Terri Brown (Undergraduate), Qi Zhang, Mingzu Zhang, and Pei Gu—Western Kentucky University

4:30 p.m.

Video/Workbook Modules for the Metric and Apothecary Systems

Joanne Kendall and James Newton—Prestonburg Community College

Saturday, 31 October 1992

Nancy Flachskam—Presiding

8:30 a.m.

Transition Metal Catalyzed Peptide Formation—Preliminary Results

Richard Reznik, G. Ferrell Long (Undergraduate), and Dewey Mortan III (Undergraduate)—Ashbury College and Sam Riffell—Baylor University

8:45 a.m.

Lithium, Boron, and Fluorine Proton-Induced Gamma-Ray Emission Analysis of Separated Micas

J. David Robertson—University of Kentucky, M. Darby Dyar—University of Oregon, and Eric S. Meadows (Undergraduate)—Western Virginia Wesleyan

9:00 a.m.

Electron Reactivity of the Elements

Howard C. Van Woert, Jr., and Timothy J. Bailey (Undergraduate)—Southeast Community College

9:15 a.m.

Synthesis, Characterization, and Reactivity of a Urea Derivative Coordinated to Cobalt(III)

Billy Helton (Undergraduate) and Lee Roecker—Berea College and Anthony C. Willis and Alan M. Sargeson—Australian National

9:30 a.m.

Refreshments, Student Lounge

SECTION D—GEOGRAPHY

Adrian A. Wasserman—Chairperson
James M. Bingham—Secretary
Room 222

Friday, 30 October 1992

Adrian A. Wasserman—Presiding

1:00 p.m.

Plenary Session, Auditorium

2:15 p.m.

Refreshments, Student Lounge

2:45 p.m.

Downtown Isn't There Anymore: Change and Abandonment in Covington's Central Business District

Edwin T. Weiss, Jr.—Northern Kentucky University

3:00 p.m.

The Parke County, Indiana, Covered Bridge Festival: A Geographical Analysis

James L. Davis—Western Kentucky University

3:15 p.m.

Toward Automated Adaptive Estimation of Dynamic Spatial Models

Stuart A. Foster—Western Kentucky University

3:30 p.m.

Alternative Methods for Controlling Travel Demand: Glasgow, Kentucky

Melanie Neuber—Western Kentucky University

3:45 p.m.

An Analysis of Traffic Congestion in Tompkinsville, Kentucky

Keirsten Jaggers—Western Kentucky University

4:00 p.m.

Regional Wind Patterns in the Contiguous United States

Conrad T. Moore and Celia Campbell—Western Kentucky University

SECTION E—GEOLOGY

Thomas R. Lierman—Chairman
Graham Hunt—Secretary
Room 221

Friday, 30 October 1992

Graham Hunt—Presiding

1:00 p.m.

Plenary Session, Auditorium

2:15 p.m.

Refreshments, Student Lounge

2:30 p.m.

Business Meeting of Geology Section

2:45 p.m.

Interpretive Center, Falls of the Ohio State Park, Indiana

Graham Hunt—University of Louisville and Troy McCormick—Falls of the Ohio State Park

3:00 p.m.

Chronostratigraphy of the Big Eddy Section, Mile 605, Ohio River

Graham Hunt—University of Louisville

3:15 p.m.

Louisville/Jeffersonville Formations in the Crescent Hill Area, Louisville, Kentucky

Graham Hunt and Tom Flood—University of Louisville

3:30 p.m.

Fracture Traces and Ground Water Occurrences in the Inner Blue Grass Region in Central Kentucky

C. Taylor—U.S. Geological Survey

3:45 p.m.

Sedimentary Record of Quaternary Sea-Level Fluctuations in San Salvador, Bahamas

Deborah W. Kuehn—Western Kentucky University

4:00 p.m.
Changes in Coal Composition during Cleaning by Oil Agglomeration
Kenneth W. Kuehn—Western Kentucky University

4:15 p.m.
Vertebrate Fossil Collection of the Owensboro Area Museum
Malcolm T. Sadler (Undergraduate) and James X. Corgan—Austin Peay State University and Kathy H. Olson—Owensboro Area Museum

4:30 p.m.
Field Trip

SECTION F—PHYSICS

John Christopher—Chairman
Vincent DiNoto—Secretary
Room 220

Saturday, 31 October 1992
John Christopher—Presiding

9:00 a.m.
Learning at a Distance: Astronomy As A Lab Science
Raymond C. McNeil—Northern Kentucky University

9:15 a.m.
Dropping Cow Magnets Down Conducting Tubes
F. Dudley Bryant—Western Kentucky University and D. Ray Carpenter—Virginia Military Institute

9:30 a.m.
Detecting Low-Amplitude Periodic Signals by Additive Sampling
Chris Graney—Jefferson Community College–Southwest and Joel Gwinn—University of Louisville

9:45 a.m.
The Kentucky Space Grant Consortium—Space for Kentucky in the Space Age
T. Bohuski, R. Hackney, K. Hackney, C. Kupchella, and R. Scott—Western Kentucky University

10:00 a.m.
Two-Year College Physics Faculty Development Workshops
L. Stamper—Owensboro Community College

10:15 a.m.
Break

10:30 a.m.
Application of Polarization in Biophysics and Astrophysics
Jason E. McCoy, B. Wieb Van Der Meer, and Richard L. Hackney—Western Kentucky University

10:45 a.m.
Computer-Assisted Laboratory Exercises For College Physics
Linda S. Stamper—Owensboro Community College and Richard L. Hackney and Karen R. Hackney—Western Kentucky University

11:00 a.m.
Sputtering Rate of Copper From Sparsely Coated Silicon
Islamshah Amlani and Doug Harper—Western Kentucky University and Jim Arps and Robert Weller—Vanderbilt University

11:15 a.m.
Physics Section Business Meeting

Saturday, 31 October 1992
Vincent DiNoto—Presiding

11:30 a.m.
Consortium of Physics Alliances

12:00 noon
Lunch, on your own

1:00 p.m.
Demonstration of the Physics Infomall CD-ROM
Vincent DiNoto—Jefferson Community College–Southeast

1:15 p.m.
Formation of Excimers of Fluorescein Dyes
Ajay K. Mukhopadhyay—Southeast Community College

1:30 p.m.
Are All 486 Computers and Operating Systems the Same?
James L. Meeks and Larry Bigham—Paducah Community College

1:45 p.m.
Noise Effects in Photometric Measurements Using CCDs
M. Lowry, B. Peters, M. Pentecost (Undergraduates), R. Scott, R. Hackney, K. Hackney, and M. Binion—Western Kentucky University

2:00 p.m.
Chaotic Dynamics—Personal Computer Investigations of Features in the Bifurcation Diagrams of Simple Non-Linear Oscillators
T. Nordmeyer, M. Troutman, J. Travelstead (Undergraduates), R. Hackney, K. Hackney, and J. Chamberlin—Western Kentucky University

2:15 p.m.
MAP—A Program to Explore the Logistic Map
Sean Molley (Undergraduate), Richard Hackney, and John Chamberlin—Western Kentucky University

2:30 p.m.
Astronomy as a Role Model Promoting Student Involvement in General Studies Science Classes
R. Scott, K. Hackney, R. Hackney, P. Campbell, and T. Bohuski—Western Kentucky University

2:45 p.m.
Making the Oscilloscope Work in the Introductory Physics Laboratory
M. Robinson, K. Hackney, R. Hackney, R. Scott, and S. Boddeker (Undergraduate)—Western Kentucky University

3:00 p.m.
PHOTON—A Program for Monte-Carlo Simulation of Diffraction Patterns as a Sequence of Photon Events
M. Pentecost (Undergraduate), R. Hackney, K. Hackney, D. Bryant, and D. Harper—Western Kentucky University

SECTION G—PHYSIOLOGY, BIOPHYSICS, AND PHARMACOLOGY

William W. Farrar—Chairperson
Dexter Speck—Secretary
Room 205

Friday, 30 October 1992
William W. Farrar—Presiding

10:15 a.m.
KJAS
A Comparative Analysis of the Teratogenic Effects of Increased Amounts of Ethyl Alcohol vs. "Near Beer" on the Embryonic Development of Chicken Embryos
Meuay Oulay—Warren Central High School; sponsored by Ronica Shuffitt

10:30 a.m.
KJAS
A Comparative Analysis of the Teratogenic Effects of an Aqueous Nicotine Solution vs. an "Aqueous Cigarette" Solution on the Embryonic Development of Chicken Embryos
Kristy Hixson—Warren Central High School; sponsored by Ronica Shuffitt

11:00 a.m.
Effects of Cyclic Energy Restriction on Body Weight Reduction in Oophorohysterectomized Fisher 344 Rats
C. Wang, C. J. Lee, and A. Babalmoradi—Kentucky State University

12:00 noon
Lunch, On your own

1:00 p.m.
Plenary Session, Auditorium

2:15 p.m.
Refreshments, Student Lounge

2:45 p.m.
Hybridization of Animal DNA Polymerase Probes to a Soybean cDNA Library
Valgene L. Dunham and Hope L. Guenthner—Western Kentucky University

3:00 p.m.
Non-NMDA Neurotransmission in the Medial Nucleus Tractus Solitarius (mNTS) is Not Involved in All Afferent-Evoked Inspiratory Termination Reflexes
Diane R. Karius, Dexter F. Speck, and Liming Ling—University of Kentucky

3:15 p.m.
KJAS
A Chemical Analysis of the Enzyme Catalase
Jenny Burnette—Paris High School—KJAS Winner; sponsored by Randall Sale

3:30 p.m.
KJAS
The Combined Effects of Acid Rain and Heavy Metal Pollution on *Artemia Salinas*
Caryn Birchard—Paris High School—KJAS First Place; sponsored by Randall Sale

3:45 p.m.
The Effect of Weightlessness (Zero-Gravity) on Cardiac Function
Thomas E. Bennett and Thomas A. Schurfranz (Undergraduate)—Bellarmine College and George M. Pantalos—University of Utah

4:00 p.m.
Effect of Angular and Spectral Distribution of Light on the Computation of Aquatic Primary Production
Elaine Young (Undergraduate), B. R. Anderson, and H. R. Kobraei—Murray State University

4:15 p.m.
Computation of Aquatic Primary Production in Kentucky Lake
Tiffany Taunton (Undergraduate), H. R. Kobraei, and B. R. Anderson—Murray State University

4:30 p.m.
Cell Wall-degrading Enzyme Activities and Pathogenicity of *Fusarium solani* on Soybeans
Kristine DeStefano (Undergraduate) and Margaret G. Richey—Centre College

4:45 p.m.
The Bdelloida Rotifer as a Model of Aging: An Inexpensive Investigative Screening Test for Exploratory Aging Research
William P. Hettinger, Jr.—Russell, KY

5:00 p.m.
Investigation of the Programmed Aging Hypothesis: The Effect of Several RNA and Protein Synthesis Inhibitors on the Life Span of the Rotifer
William P. Hettinger, Jr—Russell, KY

SECTION H—SCIENCE EDUCATION

Zexia K. Barnes—Chairperson
Ben Malphrus—Secretary
Room 204

Friday, 30 October 1992
Zexia K. Barnes—Presiding

9:00 a.m.
Refreshments, Student Lounge

9:30 a.m.
Fast Plant Physiology—Experimental Classroom Applications for the "Wisconsin Fast Plants," *Brassica rapa*
Robert Creek and Kim Alexander—Eastern Kentucky University

9:45 a.m.
A Revolutionary Classroom Tool: Historical Perspectives on the "Wisconsin Fast Plants"
Kim Alexander and Robert Creek—Eastern Kentucky University

10:00 a.m.
Remembrance of Things Past: College Student's Memories of Elementary School Science
Robert Boram, Lola Aagaard, and Zexia Barnes—Morehead State University

1:00 p.m.
Plenary Session, Auditorium

2:15 p.m.
Refreshments, Student Lounge

2:45 p.m.
Kentucky UV-B Monitoring Network: Opportunities for Student Research
John Guyton—Murray State University and Benjamin K. Malphrus—Morehead State University

3:00 p.m.
Chemistry Labs for Nursing Students: Developing Classification and Scientific Method Process Skills
Zexia Barnes, Richard Hunt, and H. Wade Cain—Morehead State University

3:15 p.m.
A New Approach to Teaching Chemical Information at Morehead State University
Wade Cain—Morehead State University

3:30 p.m.
Assessing Group Problem Solving
Joyce Saxon—Morehead State University

3:45 p.m.
Development of an Advanced Topics Science Course at the Secondary School Level
Robert Forsythe—Warren East High School

4:00 p.m.
KJAS
The Effects of Environment on the Biodegradability of Trash Bags, Newspapers, and Paper Sacks
Nathan Stocke—Henderson South Junior High School; sponsored by Susan Mueller

4:15 p.m.
Using Bio Sci II and LinkWay in an Introductory Biology Course
Dan Rogers—Somerset Community College

4:30 p.m.
A Homemade Video of Acid-Base Titration
Kelly Boggs, Norman W. Hunter, and Curtis C. Wilkins—Western Kentucky University

5:00 p.m.
Investigation of the Programmed Aging Hypothesis: The Effect of Several RNA and Protein Synthesis Inhibitors on the Life Span of the Rotifer
William P. Hettinger, Jr.—Russell, KY

SECTION I—PSYCHOLOGY

David Hogan—Chairperson
Jeff Smith—Secretary
Room 321

Friday, 30 October 1992
David Hogan—Presiding

2:45 p.m.
Personality Factors and Verbal Hallucinations in Normals
Terry R. Barrett—Murray State University

3:00 p.m.
Psychological Effects of Dance
Tracy Adams (Undergraduate)—Murray State University

3:15 p.m.
Gender Differences and Stress
Leisa Capo (Undergraduate)—Murray State University

3:30 p.m.
The Effects of Weather on Mood
Anthony Collins (Undergraduate)—Murray State University

3:45 p.m.
Task Influences on Time Perception
Dwayne Coon (Undergraduate)—Murray State University.

4:00 p.m.
Personality Types, Exercise Habits, and Anxiety
Susan Hart (Undergraduate)—Murray State University

4:15 p.m.
The Relation Between Self Esteem and Partner Selection
Lisa Holland (Undergraduate)—Murray State University

4:30 p.m.
Fantasy Process, Dissociation and Child Abuse
Tammie Jones (Undergraduate)—Murray State University

4:45 p.m.
Psychopathic Personality in Headaches: Cause or Consequence?
Mari Littlefield (Undergraduate)—Murray State University

5:00 p.m.
The Effects of Leadership Styles on University Professors
Christina Moore (Undergraduate)—Murray State University

Saturday, 31 October 1992
David Hogan—Presiding

8:00 a.m.
The Effects of Color on Arousal and Recall
Reginald Schultz (Undergraduate)—Murray State University

8:15 a.m.
Discrimination in the Employment Interview
Adrey Vaughan (Undergraduate)—Murray State University

8:30 a.m.
Characteristics of a Coupon User
Lisa Webb (Undergraduate)—Murray State University

8:45 a.m.
Drug Abuse, STDs, and Birth Control—A Community College Survey
J. G. Shiber and N. V. Anosike—Prestonsburg Community College

9:00 a.m.
Evaluation of an Instrument for Measuring Howard Gardner's Multiple Intelligences Concept
Francis H. Osborne, Brian E. Newton, and Alan Smith—Morehead State University

9:15 a.m.
KJAS
The Effects of Flueoxitine Hydrochloride on Inner Group Aggression and Memory Retention in *Mus Musculus*
Phonesavane Lianekhammy—Warren Central High School; sponsored by Ronica Shuffitt—Moss Middle School

9:30 a.m.
Refreshments, Student Lounge

10:00 a.m.
Annual Business Meeting, Auditorium

11:15 a.m.
A Comparison of Measures of Anxiety to Predict Achievement
Robert E. Simpson—Western Kentucky University

11:30 a.m.
Goal Setting in Sports
Mark Whitaker (Undergraduate)—Murray State University

11:45 a.m.
Depression Reduction and Imagery Vividness Training
Susan Wilkins (Undergraduate)—Murray State University

12:00 noon
Lunch, On your own

1:30 p.m.
Acquisition of Stimulus Equivalence through Instructional Feedback
Derek Kren and Tim Wolery—Asbury College

1:45 p.m.
Role of Dopamine D1-D2 Receptor Interactions in the Development of Behavioral Sensitization
Karen Lim, Don Matthews, and Bruce Mattingly—Morehead State University

2:00 p.m.
Behavioral and Biochemical Effects of Dopamine D2 Receptor Stimulation
Tamara Hart, Tracey Ellison (Undergraduate), and Bruce Mattingly—Morehead State University and James Rowlett and Mike Bardo—University of Kentucky

2:15 p.m.
Cocaine-Induced Behavioral Sensitization: Effects of D1 Receptor Blockade
Carmen Perkins, Kristin Rase (Undergraduate), and Bruce Mattingly—Morehead State University

2:30 p.m.
Relationship Between Field Dependence/Independence, Personality Style, and Science Grades
Jennifer Curran and Deborah Schember—Asbury College

2:45 p.m.
Relationship Between Learning Style and Performance in an Introductory Psychology Course
Mini Mamak, Allison K. Gould, and Francis H. Osborne—Morehead State University

3:00 p.m.
Sexual Attitudes and Religiosity
Larry Wayne Reid and Nobuyori Ohshima—Asbury College

3:15 p.m.
Taste Expectancies
Deanna Simpson—Asbury College

3:30 p.m.
Incubation and Writing: Are Interruptions in the Writing Process Productive?
Paul Marchbanks (Undergraduate) and Don Brown—Centre College

3:45 p.m.
Classroom Ecology and Academic Performance
Sarah Bishop and Don Brown—Centre College

SECTION K—ZOOLOGY AND ENTOMOLOGY

Matthew Byers—Chairperson
Monte Johnson—Secretary
Room 302

Friday, 30 October 1992
Matthew Byers—Presiding

9:45 a.m.
KJAS
The Effect of Varying Concentrations of Sulphuric Acid on the Population and Developmental Stages of *Drosophila melanogaster*
Ben Campbell—Warren Central High School; sponsored by Ronica Shuffitt—Moss Middle School

10:00 a.m.
Clock Control of Circadian Changes in Ommatidial Structure in the Cockroach, *Leucophaea maderae*
Zhuming Zhang and Blaine R. Ferrell—Western Kentucky University

10:15 a.m.
Distribution and Status of Amphibians in the Northern Tier Counties of Kentucky
Paul J. Krusling—Cincinnati Museum and John W. Ferner—Thomas More College

10:30 a.m.
Growth, Body Composition, and Organoleptic Evaluation of Channel Catfish Fed Diets Containing Various Percentages of Distillers Grains with Solubles
Laura S. Goodgame, James H. Tidwell, and Carl D. Webster—Kentucky State University and Peter B. Johnson—USDA

10:45 a.m.
Steatitis in Snapping Turtles, *Chealydra serpentina*
Russell E. Moore (Undergraduate) and Paul V. Cupp—Eastern Kentucky University

11:00 a.m.
Factors Affecting the Investigatory Behavior of the Northern Water Snake, *Nerodia sipedon*
Eric Pridemore (Undergraduate) and Roy Scudder-Davis—Berea College

12:00 noon
Lunch, On your own

1:00 p.m.
Plenary Session, Auditorium

2:15 p.m.
Refreshments, Student Lounge

2:30 p.m.
Sense Organ Recruitment in Early Behavior Formation of Larval Fathead Minnows
Robert Hoyt and Hanan Abdul-Rahim—Western Kentucky University

2:45 p.m.
Impact of Potential Competitors on Shelter Preferences in Madtour Catfishes
Ashley Walton (Undergraduate) and Michael Barton—Centre College

3:00 p.m.
Zoology and Entomology Business Meeting

3:15 p.m.
Break

3:30 p.m.
Insect Populations on Potatoes as Influenced by Different Colored Plastic Mulches
Patti L. Rattlingourd, John D. Sedlacek, Bryan D. Price, and Dietra N. Draper (Undergraduate)—Kentucky State University and Monica M. Williams—Western Hills High School

3:45 p.m.
Insect Populations on Okra as Influenced by Different Colored Plastic Mulches
Monica M. Williams—Western Hills High School and John D. Sedlacek, Patti L. Rattlingourd, Bryan D. Price, and Dietra N. Draper (Undergraduate)—Kentucky State University

4:00 p.m.
Insect Populations on Sweet Potatoes as Influenced by Different Colored Plastic Mulches
Dietra N. Draper (Undergraduate), John D. Sedlacek, Patty L. Rattlingourd, and Bryan D. Price—Kentucky State University and Monica M. Williams—Western Hills High School

4:15 p.m.
Ovipositional Stimuli of Angoumois Grain Moth, A Lepidopteran Pest of Stored Grains
Paul A. Weston, Jacqualine Perkins (High School), and Patti L. Rattlingourd—Kentucky State University

4:30 p.m.
Pesticide Impact on Populations of Insects in Stored Shelled Corn
John D. Sedlacek, Paul A. Weston, Bryan D. Price, and Patti L. Rattlingourd—Kentucky State University

4:45 p.m.
Kentucky Pesticide User Practices and Alternatives 1990
Monte P. Johnson—University of Kentucky

Saturday, 31 October 1992
Matthew Byers—Presiding

8:15 a.m.
The Dragonflies and Damselflies (Insecta: Odonata) of Buck Creek, Pulaski County, Kentucky, with Ecological Observations
Randall G. Payne and Guenter A. Schuster—Eastern Kentucky University

8:30 a.m.
A Two-Year Biomonitoring Study of a Constructed Wetland Treating Acid Mine Drainage
B. A. Ramey—Eastern Kentucky University and H. G. Halverson—USDA Forest Service

8:45 a.m.
A Preliminary Study of Digenetic Trematode Cercariae From the Snail, *Helisoma trivolvis*, at Owsley Fork Reservoir
Jose M. Ilagan, Marichelle Asuncion, Jessica K. Starnes, and Audrey d'Souza (Undergraduates)—Berea College

9:00 a.m.
In vitro Culture of *Microplitis croceipes* Teratocytes and the Production of Teratocyte Secretory Products
Eric Schepers, D. Dahlman, and Deqing Zhang—University of Kentucky

9:15 a.m.
Microplitis croceipes Teratocytes Regulate Protein Synthesis in *Heliothis virescens* Larvae
Deqing Zhang—University of Kentucky and D. L. Dahlman

9:30 a.m.
Refreshments, Student Lounge

10:00 a.m.
Annual Business Meeting, Auditorium

11:30 a.m.
Gene Expression in *Drosophila melanogaster*: Right-left Correlation of Wing Venation
Lynn A. Ebersole—Northern Kentucky University

11:45 a.m.
Behavioral and Physiological Stress Responses of Fathead Minnows and Northern Studfish to a Predator
Judith Johnson, James Martin (Undergraduates), and Christine Barton—Centre College

12:00 noon
Behavioral Responses of Northern Studfish to Visual and Chemical Cues From a Bass
Caroline Sinex (Undergraduate) and Christine Barton—Centre College

SECTIONS L AND M—COMPUTER SCIENCE AND MATHEMATICS

Richard A. Rink—Chairman of Computer Science
Russel M. Brengelman—Chairman of Mathematics
Art Shindhelm—Secretary of Mathematics
Room L284

Saturday, 31 October 1992
Russel M. Brengelman—Presiding

1:00 p.m.
Plenary Session, Auditorium

2:15 p.m.
Refreshments, Student Lounge

3:00 p.m.
The Tangram—A Manipulative of Geometric Interest
Carroll G. Wells—Western Kentucky University

3:15 p.m.
The Numerical Solution of a Nonlinear Schrödinger Equation Using a Finite Element Method
Mark P. Robinson—Western Kentucky University and Graeme Fairweather—University of Kentucky

3:30 p.m.
Object-Oriented Simulation—An Overview
John Crenshaw—Western Kentucky University

3:45 p.m.
Teaching Fuzzy Logic—Why? When? Where?
Art Shindhelm—Western Kentucky University

Section N—Engineering

Keith Rouch—Chairman
Issam Harik—Secretary
Room L269

Saturday, 31 October 1992
Keith Rouch—Presiding

9:00 a.m.
Gold - Silicon Eutectic Die Bonding in Micro-Electronic Components
Alan A. Johnson—University of Louisville

9:15 a.m.
The Brent-Spence Bridge: Will it Survive the Big Earthquake?
Issam E. Harik, Meiwen Guo, and David L. Allen—University of Kentucky

9:30 a.m.
Refreshments, Student Lounge

10:00 a.m.
Annual Business Meeting, Auditorium

11:15 a.m.
Stress Evaluation of Welded Steel Bridges on Coal-Haul Routes
Keith J. Hogan, Issam E. Harik, and Theodore Hopwood II—University of Kentucky

11:30 a.m.
Unattented High-Resolution Earthquake Data Collector
Robert J. Dugan—University of Kentucky

11:45 a.m.
Torsional Analysis Procedures for Drive System Vibration
John R. Baker and Keith Rouch—University of Kentucky

Section Q—Agricultural Sciences

Robert J. Barney—Chairperson
Room A222

Friday, 30 October 1992
Robert J. Barney—Presiding

10:30 a.m.
The London Planetree—Origins and Nomenclature
James M. Martin—Western Kentucky University

10:45 a.m.
Herbicide Leaching in Vegetable Culture
M. E. Byers, G. F. Antonious, T. Baker (Undergraduate), and D. L. Tyess (Undergraduate)—Kentucky State University

11:00 a.m.
Herbicide Runoff Losses in Vegetable Culture
M. E. Byers, G. F. Antonious, and D. L. Tyess (Undergraduate)—Kentucky State University

11:15 a.m.
Soil and Water Conservation in Vegetable Culture Under Three Management Regimes
M. E. Byers, G. F. Antonious, D. Hilborn, and R. Calhoun—Kentucky State University

11:30 a.m.
Sustainable Management Practices in Vegetable Culture: Influence on Yield
M. E. Byers, G. F. Antonious, R. Calhoun, and D. Hilborn—Kentucky State University

11:45 a.m.
KJAS
Can Corn Yields Be Increased By Sidedressing Sulfur Fertilizer?
Lisa Powell—South Henderson Jr. High School; sponsored by Susan Mueller

1:00 p.m.
Plenary Session, Auditorium

2:15 p.m.
Refreshments, Student Lounge

2:45 p.m.
A Simple Method for Isolating Uniform Soybean (Glycine max (L.) Merr.) cv. Fayette
M. M. Rahman—Kentucky State University

3:00 p.m.
Factors Affecting the Performance of Stocker Cattle During the First 30 Days of a Receiving Program
B. R. Pratt, D. G. Britt, and M. Judge—Eastern Kentucky University

3:15 p.m.
Leaching Rates of Three Soil Medias in a Floating Hydroponic System
G. L. Janicke, T. M. Hughes, and D. G. Barkley—Eastern Kentucky University

Saturday, 31 October 1992

8:00 a.m.
Repeatabilities of Pelvic Area Measurements Between and Within Technicians With Varying Levels of Experience
Gordon F. Jones and Steven B. Fitzner—Western Kentucky University

8:15 a.m.
Swine Breed Differences in Agglutination Titers Following Vaccination With Sheep Red Blood Cells and Pasteurella Multocida (Serotype A)
Gordon F. Jones, Ken J. Stalder, and Cheryl D. Davis—Western Kentucky University

8:30 a.m.
Equidistant Plant Spacings and Yield Components of Bush Snap Beans
Jac Widodo, Timothy P. Hafner, and Elmer Gray—Western Kentucky University

8:45 a.m.
Effects of Planting Date, Mulch Application, Seeds/Hill, and Hill Spacings on Seedling Emergence and Plant Survival of Bush Snap Beans
Elmer Gray and Naysa M. Call (Undergraduate)—Western Kentucky University

9:00 a.m.
Use of Soybean Meal, Raw Soybeans, and Heat-Treated Soybeans As Protein Supplements With and Without Niacin for Dairy Cows in Early Lactation
James L. Pierce (Undergraduate), Daniel E. Aguilar, Jodie A. Pennington, and David R. Hartman—Western Kentucky University

9:30 a.m.
Refreshments, Student Lounge

10:00 a.m.
Annual Business Meeting, Auditorium

11:15 a.m.
Study of Soy Protein Products in Milk Replacers and Early Weaning Diets for Pre-ruminant Calves
Mark C. Barrow and David A. Stiles—Western Kentucky University

11:30 a.m.
Evaluation of Early Weaning Diets for Baby Pigs
David A. Stiles, Mark C. Barrow, and Ken Stalder—Western Kentucky University

11:45 p.m.
Composting Fractions of Municipal Solid Waste
L. B. Hughes and R. M. Schneider—Western Kentucky University

SECTION R—INDUSTRIAL SCIENCES

Estel M. Hobbs—Chairperson
Burtron H. Davis—Secretary
Room L269

Friday, 30 October 1992
Estel Hobbs—Presiding

1:00 p.m.
Plenary Session, Auditorium

2:15 p.m.
Refreshments, Student Lounge

2:45 p.m.
Auto/Oil Air Quality Improvement Research Program Results
Estel M. Hobbs—Ashland Petroleum Company

3:00 p.m.
Meeting 1995 Specifications for Reformulated Gasolines
Jamie M. Kersey, Charles Allen Johnson, Howard F. Moore, and Maurice M. Mitchell, Jr.—Ashland Petroleum Company

3:15 p.m.
Oxygenates in Gasoline by Near-Infrared Spectroscopy
Brian K. Wilt and Steven M. Maggard—Ashland Oil

POSTER PRESENTATIONS

1. Formation of Mixed Crystals from p-Methylbenzoic Acid and p-Methoxybenzoic Acid
   Polly J. Shrewsbury (Undergraduate)—Centre College and Carolyn P. Brock—University of Kentucky
2. Qualitative Organic Chemistry on Computers
   Ted C. Shields—Ashland Community College
3. Flacks, Hacks, and Quacks: Trends in Politicizing Science
   Ted C. Shields and Jon P. Shoemaker—Ashland Community College
4. The Allelopathic Effect of *Juglans nigra* and Synthetic Juglone on the Germination and Growth of *Solanum lycopersicum*
   Jonathan Fellows (High School)—duPont Manual High School
5. Survey of Animal Waste Management Practices in the Barren River Area
   Alvin Bedel, O. W. Dotson III, and David A. Stiles—Western Kentucky University and Ruthi Steff—Mammoth Dave RC & D
6. Development and Evaluation of Constructed Wetlands for the Waste Management of Large Scale Animal Production Units
   O. W. Dotson III, Ray Johnson, David Stiles, and Al Bedel—Western Kentucky University and Susan McPherson and Kenneth York—Soil Conservation Service
7. Factors Influencing Provision of Dental Services to the Homeless
   Arthur Van Stewart and Eric T. Veal—University of Louisville
8. Kentucky Survey of Nursing Home Administrators' Perceptions of Current Dental Service Programs
   Arthur Van Stewart and Bryan G. Harness—University of Louisville and Keith Knapp—LIFE SPAN/University of Louisville and Jackie Fischer—Price Counseling
9. Perceived vs. Actual Nutritional Status of Southern Rural Elders
   Martha Marlette, Susan Templeton, and Chung Ja Lee—Kentucky State University
10. The Combined Effects of Acid Rain and Heavy Metal Pollution on *Artemia salinas*
    Caryn Birchard (High School)—Paris High School
11. Do Anti-Estrogens have Anti-Angiogenic Activity?
    A. Gagliamdi, H. Hadd, and D. C. Collins—V.A. Medical Center
12. Anti-Angiogenic Activity of Suramin
    D. C. Collins and A. Gagliamdi—V.A. Medical Center
13. Agriculture in General Education
    Linda G. Brown and David M. Coffey—Western Kentucky University
14. Evaluation of Distillers Dried Grains with Soblules as

an Ingredient in Diets for Pond Culture of the Freshwater Shrimp *Macrobrachium rosenbergii*
J. H. Tidwell, D. C. Webster, and J. A. Clark—Kentucky State University and L. R. D'Abramo—Mississippi State University

15. Scanning Electron Microscopy (SEM) Method for Studies of Fungi on American Holly Roots, *Ilex opaca,* Using Microwave Silver Staining and Hexamethyldisilazane (HMDS) Drying
Beverly Giammara, Nancy Esarey (Undergraduate), Varley Wiedeman, and Marilyn Day—University of Louisville and Jacob Hanker—University of North Carolina
16. The Effect of an Income Compensated Price Change on Soft Drink Consumption in the Rat
Ngozi Kanu (Undergraduate), Amy Woeste (Undergraduate), Louis Noyd, and David E. Hogan—Northern Kentucky University

NSF Young Scholars Program
Western Kentucky University
Valgene Dunham, Director

17. Short-term Effects of Selenium on Rubisco Activity in *Nicotiana tabacum*
Emily Bellew—Fulton County High School
18. Negative Staining and Immunogold Labelling of Flagella of *Euglena gracilis*
Andrew Bentley—Lafayette High School
19. The Short-term Effects of Cadmium on Rubisco Activity in *Nicotiana tabacum*
Benjamin Campbell—Warren Central High School
20. Restriction Mapping of cDNA Inserts from *B. napus*
Carson Coatney—Hopkinsville High School
21. Ultrastructural Study of the Alga, *Euglena gracilis,* Revealed by Transmission Electron Microscopy
Jennifer Duball—Muhlenberg South High School
22. Screening for Spectrin and Tubulin Proteins in Euglenoid and Trypanosoma Cells and Flagella
Mark Fannin—Paintsville High School
23. Expressed Protein Differentiation in Regenerating Neuromasts of *Ambystoma mexicanum*
Jonathan Fellows—duPont Manual High School
24. Amino Acid Composition of the VPg Protein from Southern Bean Mosaic Virus
Joy Greer—Louisville Male Traditional High School
25. Protein Expression During Regeneration of the Tail of the Axolotl Salamander
Keri Hunter—Pikeville High School
26. The Short Term Effects of Selenium on Isocitrate Dehydrogenase Activity in *Nicotiana tabacum*
Robert Jennings—McLean County High School
27. Restriction Mapping of cDNA Clones from *B. napus*
Brock Jordan—Scott High School
28. Optimal Conditions of Gentamicin Treatment for Hair Cell Destruction in the Chick Cochlea
Rebecca Massie—Lewis County High School
29. Analytical Studies of Flagellar Motion in Selected Euglenoid Algae
Rachel Phillips—Metcalfe County High School
30. Isolation of the Paraflagellar Body from *Euglena gracilis*
Sarah Richter—Calloway County High School
31. Site-directed Mutagenesis of the Southern Bean Mosaic Virus Protease
Cammie Rinehart—Greenwood High School
32. Effects of Cadmium and Selenium on Tobacco Rubisco Levels Determined by Rocket Immunoelectrophoresis
Amy Turner—Monroe County High School
33. Effects of Cadmium on the Isocritrate Dehydrogenase Activity in the Tobacco Plant
Brian Vanhoose—Russell High School
34. A Comparison of the Effectiveness of Ethidium Bromide and H33258 (Hoescht fluorochrome) in Dot Quantitation Assay of DNA
Aaron Wenger—South Oldham High School
35. A Study of High Transformation Efficiency
Holly Willet—Union County High School
36. Optional Conditions for DNA Precipitation
K. T. Williams II—Webster County High School

ABSTRACTS OF SOME PAPERS PRESENTED AT THE ANNUAL MEETING, 1992

AGRICULTURAL SCIENCES

Agricultural composting of fractions of municipal solid waste. LUTHER B. HUGHES, JR.* and ROBERT M. SCHNEIDER, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

After 5 yr of study, an ongoing composting project in Bowling Green, KY, has demonstrated a successful method of reduction of an important fraction of municipal solid waste. Approximately 20,000 yd^3 of leaves have been processed annually on a well-drained site on the Western Kentucky University Farm. With grinding and regular "turning" of windrows of the composting leaves to insure good aeration and no offensive odors, a mulch-like product, well received by the public, has been produced. Analysis of the product showed that concentration of all heavy metals was well below established standards of concern. This project has clearly demonstrated that agriculture can play an important role in reducing the amount of municipal solid waste going into landfills and, by this process, can save a community of 50,000 people over $200,000 in disposal costs.

Agriculture in general education. L. G. BROWN* and D. M. COFFEY, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

The need for increased agricultural literacy in the United States has been recognized, even by the National Research Council. In an effort to improve agricultural literacy among college students, Western Kentucky University offers "The Science of Agriculture," a 3 credit-hour course that partially fulfills the university-wide general education requirement for at least 9 credit-hours of natural-science instruction. The wide cross-section of majors who enroll in this course are exposed to biological and chemical concepts that are fundamental to understanding agronomy, horticulture, and animal science. Additionally, world food supply, agriculture's history, and contemporary agricultural issues are presented. Course content, a profile of students recently enrolled in the course, course format, and student response are discussed in this paper.

Development and evaluation of constructed wetlands for waste management of large scale animal production units. O. W. DOTSON, III,* RAY JOHNSON, AL BEDEL,* and DAVID STILES, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101; SUSAN MCPHERSON and KENNETH YORK, USDA-SCS, Bowling Green, KY 42101.

A long-term monitoring study of constructed wetlands for the management of large-scale swine units (1,200 and 1,700 sows) was developed. This multi-disciplinary (WKU-Agriculture, Biology, and Chemistry; Kentucky Division of Conservation and Division of Water-NPS; and USDA-Soil Conservation Service) effort will attempt to monitor the adjacent streams, groundwater, and animal waste lagoons as well as the artificial wetlands for a baseline period of 1 yr and for the succeeding 5 yr. Biological review of the streams will include algae, invertebrate and vertebrate populations, and chemical analyses of water (N, P, K, solid, pH, BOD, coliform, and other mineral elements per USDA-SCS recommendation for wetlands). Wetland plant material and influent and effluent wastewater (as it moves from cell to cell) will be studied. Evaluation of these data will confirm the benefits of constructed wetlands for animal waste management. Data and observations should aid in construction and correct management of Kentucky's constructed wetlands.

Effects of planting dates and cultural practices on emergence and survival of bush snap beans (*Phaseolus vulgaris*). NEYSA M. CALL* and ELMER GRAY, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

Seedling emergence is a critical stage in the life cycle of beans. Emergence is influenced by soil moisture and temperature, by soil crusting and compaction, and by diseases and insects. In 1991 and 1992, experiments were conducted to compare the effects of planting dates (biweekly, 15 May–15 Jul), seeds per hill (1, 2, and 4), hill spacings (1, 2, 4, 8, and 16 in), and mulching (none vs. approximately 1 in leaf mulch) on the emergence and survival of 'Blue Lake 274' bush snap beans. Data were obtained on percentages of seedling emergence and plant survival at 4 wk after planting and at maturity. Although emergence in various treatments equaled or exceeded the reported germination (85%) for the seeds, average emergence percentages were variable and lower for the years and treatments. Emergence percentages were as follows: overall (52%); planting dates—15 May (65%), 1 Jun (51), 15 Jun (47), 1 Jul (58), and 15 Jul (44); seeds per hill—1 (54%), 2 (52), and 4 (51); hill spacings—1 in (55%), 2 in (54), 4 in (52), 8 in (50), and 16 in (52); and mulching—none (52%) and 1 in (52). Overall plant survival percentages were 48 at 4 wk and 46 at maturity. The treatment effects were not conclusive. Emergence and survival appeared to be slightly higher for early plantings, closer spacings, and single plants per hill. Planting date and mulch application appeared to influence other plant characteristics including pod yield. Soil moisture at planting and subsequent rainfall were critical to plant emergence.

Equidistant plant spacing and yield components of bush snap beans (*Phaseolus vulgaris*). WIDODO, TIMOTHY P. HAFNER, and ELMER GRAY,* Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

'Blue Lake 274' and 'Kentucky Wonder 125' bush snap beans were compared at four equidistant spacings (3, 6, 9, 12 in) in 1989 and 1990 at Bowling Green, KY. The total aboveground plant material was separated into vegetative and pod yields. Pods were further divided into hulls and seeds. Pods/plant, seeds/plant, and seeds/pod were counted. Performance was significantly higher for 'Kentucky Wonder 125' than for 'Blue Lake 274' for total yield and all of the components except vegetative yield and pods/plant. Spacing treatments differed significantly for total yield and for all components except seeds/pod. Likewise, the linear relationship between plant spacing and yield was positive and significant for total yield and for all components except seeds/pod. Total plant yield and all components, except vegetative yield, were significantly higher in 1989 than 1990. None of the years × spacings or cultivars × spacings interactions was significant; however, the cultivars × years interactions were significant for total yield and for several components. Contrary to previously reported research results, these two determinate cultivars exhibited significant plasticity in individual plant response to spacing. The premise for increasing yield through higher population densities is that determinate snap beans have little developmental plasticity.

Evaluation of early weaning diets for baby pigs. DAVID A. STILES,* MARK C. BARROW, and KEN STALDER, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

Eleven litters of crossbred pigs were offered one of three diets at 15 d of age while still nursing. The treatments were: high milk product prestarter (20% crude protein and 7% fat), high soy protein replacer (22% crude protein and 10% fat), and a commercial prestarter (M) (22% crude protein and 7% fat). In trial I, weights were recorded at days 15 and 29. The pigs were weaned at 29 d. Average daily gains and feed intake while nursing the sow were 259 and 72 g, 290 and 86 g, and 295 and 90 g, respectively, for milk product starter, soy protein starter, and commercial prestarter. No differences ($P > 0.05$) were observed. During the 7 d postweaning period (29–36), the following growth and feed intakes, respectively, were observed: 240 and 304 g (milk product starter); 182 and 259 g (soy protein starter); and 272 and 295 g (commercial prestarter). There were no significant differences ($P > 0.05$). In trial II, with fewer litters, pigs were weaned from the sow as early as 15 d. Growth appeared reduced on the soy protein diet. Pig health was good and normal growth was observed. High soy protein diets for baby pigs merit further study.

Herbicide leaching in vegetable culture. MATTHEW E. BYERS, GEORGE F. ANTONIOUS, TRACY L. BAKER,* and DEBBIE L. TYESS, Kentucky State University, Frankfort, KY 40601.

The use of herbicides to control weeds on erodible lands may reduce the need for tillage and help sustain the soil bank. However, herbicide leaching may affect groundwater quality. The purpose of this study was to determine if clomazone (2-(2-chlorophenyl)methyl-4,4-dimethyl-3-isoxazolidinone), a selective herbicide, was a threat to groundwater under the experimental conditions. Clomazone was applied at 1.1 kg/ha to plots (12.5 × 72 ft) on a 10% slope, with lowell silt loam soil, and to which pepper transplants were planted. Plots had either fescue strips, black plastic mulch, or no-mulch as soil treatments. Clomazone was monitored using tension lysimeters located at the top, middle, and bottom of each plot, and within each location were placed at three depths, 1, 2, and 5 ft. Samples were drawn monthly. Sampling followed rigorous QA/QC procedures. Extraction was liq/liq using hexane. Analysis was by GC-NPD and GC-MS. Clomazone was found in <2.0 ppb for 1 and 2 ft and <0.25 ppb for 5 ft during the July sampling (1st sampling post-application). All levels diminished to <0.25 ppb by September. Fescue strips reduced runoff but increased infiltration of clomazone relative to BP and NM. Although leaching occurred, concentrations were very low. Impact at such levels to exposed organisms is unknown.

Herbicide runoff losses in vegetable culture. MATTHEW E. BYERS, GEORGE F. ANTONIOUS, DEBRA L. TYESS,* and DEBRA HILBORNE, Kentucky State University, Frankfort, KY 40601.

The use of herbicides may be compatible with sustainable agriculture to reduce tillage and therefore erosion. But herbicide may be lost in runoff water. The purpose of this study was to determine if clomazone, (2-(2-chlorophenyl)methyl-4,4,dimethyl-3-isoxazolidinone), was lost in runoff water, under the experimental conditions, and at what levels. Clomazone was applied at 1.1 kg/ha to plots (12.5 × 72 ft) on a 10% slope, with lowell silt loam soil. Influence of two crops (peppers and pumpkins) and three soil treatments—fescue strips, black plastic mulch (BP), and no mulch (NM)—was determined by assigning treatments (2 × 3 factorial) to blocks (RCBD). The experiment was replicated three times. Runoff was caught and measured in tipping buckets and samples were collected within 12 hr of last rainfall event. Samples were extracted using hexane; analysis was by GC-NPD and GC-MS. In the field, losses decreased over time from 175.7, 2,380.7, and 4,100.3 mg/ha after the first rainfall after spraying in June, to 0, 0.183, and 2.267 mg/ha by September in the fescue, BP, and NM plots, respectively. Concentrations after spraying were 0.00595, 0.00805, and 0.329 μg/ml and by September were 0, 3.3×10^{-5}, and 0.000417 μg/ml for fescue, BP, and NM, respectively. NM plots consistently lost more clomazone to runoff; fescue strips reduced runoff. Impact at detected levels is unknown.

London planetree—origins and nomenclature. JAMES M. MARTIN, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

The London planetree (*Platanus* ×*acerifolia*), is a widely planted street tree in Europe and the U.S. However, its origins are obscure and its nomenclature is confused. Based on powerful circumstantial evidence, the most cogent theory is that it originated as a chance crossing of the sycamore (*P. occidentalis*) and the oriental planetree (*P. orientalis*) in the Oxford Botanic Garden about 1670. The specimen of the original London plane tree in the Sherard Herbarium at Oxford University has notes by Jacob Bobart Jr., curator of the Botanic Garden in the late 17th century, referring to the tree as *Platanus inter orientalem et occidentalem media* and describing characters somewhere between *P. occidentalis* and *P. orientalis*. This was the first mention of the tree. The original tree is no longer extant, but a 200-yr-old specimen propagated by a cutting from it is on the Magdalen Campus at Oxford. The type specimen is in the herbarium at the Berlin Botanic Garden. Willdenow named it *Platanus* ×*acerifolia* in 1805. Priority was denied to Brotero's *P* ×*hybrida* because of confusing identification of his type specimen. The use of the name *P.* ×*hispanica* by the Royal Botanic Garden at Kew is incorrect as this plant is considered a seedling of *P.* ×*acerifolia*.

Repeatabilities of cattle-pelvic-area measurements between and among technicians with various levels of experience. GORDON F. JONES* and STEVEN B. FITZNER, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

There has been some concern recently about the ability of technicians to accurately measure and rank prospective replacement heifers and herd bulls for pelvic area. Two studies were conducted to determine the repeatabilities between and among technicians with various levels of experience in measuring pelvic areas. In both studies, primiparous yearling heifers were measured for pelvic height and width to determine pelvic area. In each study, technicians included a veterinarian with several years experience in reproductive physiology practice and Western Kentucky University students with various levels of experience in rectal examinations. In the first study, the veterinarian used both the "Krautmann-Litton" pelvimeter and the "Rice" pelvimeter; in the second study, the veterinarian used only the "Krautmann-Litton" pelvimeter. In both studies, the students used a "Rice" pelvimeter. Coefficients of correlation and Spearman's coefficients of rank correlation were calculated to determine repeatabilities between and within technicians. In the first experiment, the correlations between technicians for pelvic area ranged from 0.66 to 0.92 and Spearman's rank correlations between technicians ranged from 0.65 to 0.92. In the second, the correlations between and among technicians for pelvic area ranged from 0.78 to 0.97 and Spearman's rank correlations between and among technicians ranged from 0.77 to 0.95. These results show clearly that cattle breeders can become proficient at measuring the pelvic area of heifers and bulls and in ranking them for selection purposes.

Soil and water conservation in vegetable culture under three soil management practices. D. HILBORN,* G. ANTONIOUS, M. BYERS, and R. CALHOUN, Kentucky State University, Frankfort, KY 40601.

Runoff and sediment yield during 1992 from an experimental area of 10% slope support results of earlier studies that concluded soil erosion is a serious problem. The present study involved testing three soil management systems including fescue strips, black plastic mulch (BP), and no-mulch (NM) in side-by-side comparisons to determine best management system in conserving soil and water. Pepper transplants or pumpkin seeds were planted in USLE std. plots (n=18). Runoff water and sediment were sampled using tipping buckets at the bottom of each plot. Runoff varied with rainfall amounts, which varied from 0.82 to 4.44 in rain per runoff event. No significant differences ($P = 0.05$) were observed between the amount of runoff water per average event in NM treatment (10,071 liter/ha) and BP (12,172 liter/ha); significant reduction in runoff (1,550 liter/ha) was clear in plots having fescue strips. Sediment yield was 2,833 in NM treated plots, 995 in BP, and 6-kg/ha in fescue plots. Pumpkin provided an apparently good ground cover (prostrate crop). During heavy rains, runoff below the canopy of pumpkin plants removed 9.92 kg sediment/ha in comparison to 69.43 kg sediment loss in pepper planted plots. A mulch treatment is recommended as a soil-bank stabilizing treatment for vegetable farming on erodible lands. Fescue strips are highly recommended.

Study of soy protein products in milk replacers and early weaning diets for pre-ruminant calves. MARK BARROW and DAVID STILES,* Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

Jersey and Holstein bull calves (5J and 2H/trt) were offered one of three treatments: treatment 1—all-milk product (M) milk replacer offered for 42 d; treatment 2—soy (S) based milk replacer (⅔ of protein from soy protein) also fed for 42 d; and treatment 3—a pelleted pre-starter (P). The treatment 3 group was fed the all-milk liquid replacer (at 10% of body weight per day) until 21 d, when they were weaned to the dry pellets (22% CP). Overall (56 d) average daily gains were not different ($P > 0.10$) with M—0.327 kg/d, S—0.277 kg/d, and P—0.295 kg/d. Overall feed intake was not different. The calves fed the pellets did gain more slowly ($P < 0.10$) for the period (21–42 d) when weaned from liquid replacer to pellets than the calves fed the all-milk product replacer. The high soy milk replacer diet and the pelleted prestarter appear to be viable alternatives for feeding dairy calves but need further study.

Survey of animal waste management practice in the Barren River area, Kentucky. ALVIN BEDEL,* O. W. DOTSON, III,* DAVID STILES, RAY JOHNSON, and RUTHIE STEFF, Department of Agriculture, Western Kentucky University, and RC&D-SCS USDA, Bowling Green, KY 42101.

The Barren River area with its karst topography has the potential for polluting ground water from animal waste disposal. A survey instrument was developed to collect information on waste disposal methods of livestock producers in Allen, Barren, Butler, Edmonson, Hart, Logan, Simpson, and Warren counties. An attempt was made to include all livestock producers in those counties. There were 360 survey instruments sent to producers (response rate, 33%); 86 farms had dairy animals, 22 farms a swine enterprise, and 39 farms a beef enterprise. Livestock numbers ranged from six cows per farm to 7,500 hogs per farm. The most common method of waste disposal was a lagoon (27%) and then hauling from a stack pad (21%). The most important single purpose of animal waste application was for improving soil fertility (42.1%), but a combination of emptying the facility and as a part of a fertility program was the most often cited (45.8%). Concentration of manure measured by animals per acre ranged from 0.58 on the beef and dairy farms to 2.68 on the beef farms. In addition, 59 responses (52%) agreed to allow us to visit their farms and take samples.

Sustainable management practices: influence on yield. RHONDA J. CALHOUN,* MATTHEW E. BYERS, GEORGE F. ANTONIOUS, and DEBRA J. HILBORN, Kentucky State University, Frankfort, KY 40601.

An acceptable vegetable yield, reduced soil erosion, and water conservation are determining factors used to qualify a specific procedure as the best management practice (BMP). The limited resource farmer must be able to obtain low-budget maintenance while producing acceptable vegetable yields. This research is part of a larger study including pesticide dissipation and conservation of soil and water to determine the BMP among tested systems. The yields of pumpkin and pepper as influenced by three soil treatment systems—black plastic mulch (BP), fescue strips, and no-mulch (NM)—were determined. Eighteen plots (72 × 12.5 ft) were located on a 10% slope. The experiment was replicated three times. Crops were harvested over a 3-yr period, weighed, and graded. An ANOVA was conducted and year, treatment, date, and row effects were noted. Overall mean yields of peppers were 5.0, 3.3, and 3.7 and pumpkin were 88.7, 42.7, and 57.9 kg/7.3 m row for BP, fescue, and NM treatments, respectively. In both pumpkin and pepper yield data, year 1 was affected by fescue competition. This problem was corrected by increasing row width from 24 to 48 in. It has been determined that BP produced the most acceptable yields of the three systems, but, relative to fescue, was not the best for soil or water conservation. Plastic and installation equipment is expensive and may not be considered an option with respect to limited resource farming operations.

Swine breed differences in agglutination titers following vaccination with sheep red blood cells and *Pasteurella multocida* (serotype A). GORDON F. JONES,* K. J. STALDER, and C. D. DAVIS, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

An investigation into genetic differences in the humoral immune response of swine following vaccination with a sheep red blood cell solution (SRBC) and a commercially prepared *Pasteurella multocida* (serotype A) bacterin in (PmA) was conducted on 150 pigs. This study also evaluated the humoral immune response of pigs to a non-pathogen (SRBC) and a known pathogen to swine (PmA). The pigs were from 10 litters born in spring and 6 litters born in summer 1991 consisting of crossbred Hampshire × Yorkshire (n = 91), purebred Yorkshire (n = 42), and Hampshire (n = 17). Individual pigs were vaccinated at 5 and 8 wk of age with 2 ml of a 5% SRBC solution and 1 ml of a killed PmA bacterin. At 11 wk 8 ml of blood was collected from each animal and serum prepared to determine antibody titer levels against the two antigens by agglutination methods. Results indicate that breed of pig affected the immune response against both PmA ($P < 0.01$) and SRBC ($P < 0.02$), with the Hampshire × Yorkshire crossbred pigs having higher titer levels against the PmA than either Hampshire or Yorkshire purebred pigs. The purebred Yorkshire pigs were not statistically different from either the purebred Hampshire or the Hampshire × Yorkshire crossbred pigs in their antibody response to SRBC; however, the Hampshire × Yorkshire crossbred pigs were higher than the Hampshire pigs. A low positive correlation of 0.27 was found between the pigs' antibody responses to PmA and SRBC. Results suggest that further studies into breed differences of the immune response in swine are warranted. Results also suggest that further studies are needed to evaluate sheep red blood cells as a suitable antigen when conducting research to analyze the immune response in swine.

Use of soybean meal, raw soybeans, and heat-treated soybeans as protein supplements for dairy cows in early lactation with and without niacin. JAMES L. PIERCE,* DANIEL E. AGUILAR, JODIE A. PENNINGTON, and DAVID R. HARTMAN, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

Fifty-six cows from day 10 to day 150 postpartum were utilized to measure the effects of soybean meal (SBM), raw soybeans (RS), and heat-treated soybeans (HTS) with niacin (+N) and without niacin (−N) on milk, 4% fat corrected milk (FCM), solid corrected milk (SCM), dry matter intake (DMI), % fat, % protein (% PRO), % lactose (% LAC), body weight (BWT), and body condition score (BCS) based on 1–100.

Overall, HTS and SBM yielded greater production and DMI than RS. Niacin improved both milk production and DMI in these early lactation cows.

	Milk	FCM (lbs/week)	SCM	DMI	% FAT	% PRO	% LAC	BWT lbs	BCS
SBM	444	412	408	371	3.63	3.00	5.01	1,315	46
RS	377	353	350	338	3.53	2.94	5.07	1,275	45
HTS	439	414	411	357	3.61	3.01	5.12	1,308	43
P	0.001	0.001	0.001	0.001	0.077	0.009	0.001	0.001	0.114
+N	435	411	407	367	3.60	2.99	5.12	1,309	45
−N	401	378	375	346	3.57	2.98	5.01	1,292	44
P	0.001	0.001	0.001	0.001	0.429	0.540	0.001	0.138	0.850

BOTANY AND MICROBIOLOGY

Comparison of flagellar motion in selected euglenoid algae (Euglenophyceae). NANCY S. DAWSON,* AMY BAKER, BRAD WEAVER, and DAVID PITTMAN, Department of Biology, Western Kentucky University, Bowling Green, KY 42101.

Selected taxa of euglenoid organisms were video-taped, utilizing video-enhanced Nomarski differential interference contrast microscopy, and were analyzed to determined characteristic flagellar movement. Patterns of flagellar wave propagation were determined primarily during cell swimming. Typically, phagotrophic species such as *Peranema* possess two emergent flagella, one projecting anteriorly and propagating asymmetric, helical, sinusoidal waves, and one directed posteriorly, remaining closely appressed to the cell body with no noticeable motion. Osmotrophic euglenoids such as *Distigma* propagate rapid helical waves along the anteriorly directed flagellum and slow, paddle-like planar waves in the shorter, recurved flagellum. Photosynthetic euglenoids such as *Euglena* have a single emergent flagellum, which appears to function like the anteriorly directed flagellum of phagotrophic and osmotrophic genera. Preliminary designations of functionally homologous flagella will be made, and details of the flagellar system and nature of heterodynamic motility in this group of algae will be presented.

Scanning electron microscopy (SEM) method for studies of fungi on roots of American holly (*Ilex opaca*) using microwave silver staining and hexamethyldisilazane (HMDS) drying. BEVERLY GIAMMARA, Graduate Programs and Research, NANCY ESAREY,* VARLEY WIEDEMAN, and MARILYN DAY, Department of Biology, University of Louisville, Louisville, KY 40292; and JACOB HANKER, Biomedical Engineering, University of North Carolina, Chapel Hill, NC 27599.

The determination of fungi, invasive or non-invasive, on American holly root is time-consuming and difficult. For this study, selected specimens were obtained from Bernheim Forest and fixed with 4% formaldehyde/1% glutaraldehyde on site. Since silver stains are known to stain fungi selectively, a newly developed microwave silver stain (Sigma Diagnostics HT100) was used. The specimens were further processed through a dehydration series, followed by HMDS drying to retain good structural integrity. This allowed fungal presence to be determined by light microscope followed by SEM using back-scattered electron imaging in the reverse polarity mode. Fungi was easily located on the same large specimen due to the Z contrast of the silver. These same areas of the root containing fungi were then cut under a light microscope and further embedded in Epon-Araldite. Quick polymerization was achieved by using 15 min microwave at 50 power level. Semi-thin sections (1 μm) and ultra-thin sections (70 nm) were obtained using ultramicrotomy and examined by SEM or Transmission Electron Microscopy (TEM). This new method allows determination of the presence of penetrating fungi and preservation of internal structure of both fungi and root.

CHEMISTRY

Analysis of Fat Oxidation by FT-NMR. DE CHEN,* DAVID HARTMAN, and JOHN REASONER, Department of Chemistry, Western Kentucky University, Bowling Green, KY 42101.

Fats and oils are a major source of calories in the American diet. Frying in fat or oil is a method of cooking commonly used for manufacture and preparation of foods. The fat serves as a heat transfer medium and as an important ingredient of the fried food, providing flavor, energy, and essential fatty acids. Edible oils are easily oxidized when used for frying. Oxidation originates with double bonds present in unsaturated fatty acids. High resolution fourier transform nuclear magnetic resonance (FT-NMR) spectroscopy has found increasing use in biochemistry. One pure fat, triolein, was heated at 160°C in the presence of air. Samples were taken for FT-NMR analysis at 4, 10, 20, 25, and 35 hr. Proton, carbon-13, and several types of two-dimensional FT-NMR spectra were obtained using a JEOL 270 Mhz instrument. The spectra suggests initial oxidation occurs by an allyl free radical mechanism facilitating the formation of epoxide and peroxide products.

Formation of mixed crystals from p-methylbenzoic acid and p-methoxybenzoic acid. POLLY J. SHREWSBURY* and CAROLYN P. BROCK, Department of Chemistry, University of Kentucky, Lexington, KY 40506.

Conditions for the formation of solid solutions of molecules were given by Kitaigorodskii (*Mixed crystals*, 1984): the molecules must be geometrically similar, and crystals of the pure compounds must have unit cells of the same symmetry and of similar dimensions. A series of para-substituted benzoic acids, R=H, CH_3, OCH_3, Cl, and Br were studied. X-ray powder diffraction patterns of the pure compounds were compared with patterns of crystals grown from 1:1 (molar basis) solutions in ethanol of the ten possible pairs of compounds. Two substances, p-methylbenzoic acid (toluic acid) and p-methoxybenzoic acid (anisic acid), were selected for further study. Toluic and anisic acids appear to form mixed crystals. The unit cell constants and the habit of crystals grown from toluic/anisic acid solutions are similar to, but not the same as, the cell constants and the habit of pure anisic acid. An NMR spectrum of crystals alike in shape and unlike crystals of pure anisic acid confirmed the presence of both toluic and anisic acids in a ratio of ca. 1:4. A solid solution is formed even though only one of Kitaigorodskii's three conditions is met. The toluic and anisic acid molecules differ by only one atom; presumably, the methyl group on the toluic acid, or guest, molecule substitutes for the slightly larger methoxy group on the anisic acid, or host, molecule. The dimensions and symmetries of the unit cells of the pure compounds, however, are not the same; the arrangements of the molecules in the two structures are very different.

The cobalt $(11\bar{2}0)$ surface as a template for hydrocarbon chain formation in Fischer-Tropsch synthesis. YON-TAE JE* and AUDREY L. COMPANION, Department of Chemistry, University of Kentucky, Lexington, KY 40506.

An explanation is proposed for the observations of Geerlings, Zonnevylle and de Groot (*Surface Science* 241: (1991) 302, 315. 1991) that longer hydrocarbon chains grow on the zigzag, grooved cobalt $(11\bar{2}0)$ surface during Fischer-Tropsch reactions, while on stepped $(10\bar{1}2)$ and smooth (0001) surfaces mainly C1 fragments are observed. Molecular orbital calculations show that the zigzag troughs on this surface may act as templates favoring CO dissociation and skeletal carbon chain formation, and that such events do not occur on stepped and smooth surfaces. Some speculations are offered on the nanotechnological design of "custom" templates for hydrocarbon synthesis.

ENGINEERING

Gold-silicon eutectic die bonding in microelectronic components. ALAN A. JOHNSON, Speed Scientific School, University of Louisville, Louisville, KY 40292.

The gold-silicon eutectic alloy (19.1 at % Si) is widely used for die bonding in microelectronics. When such an alloy is solidified using a cooling rate less than 5°C sec^{-1}, the resulting solid contains nearly pure Au and nearly pure Si. Higher cooling rates give a mixture of gold silicide (Au_3Si) and Au. The Au_3Si dissociates into Au and Si by a surface nucleated reaction accompanied by extensive cracking caused by a volume change. The reaction front moves at about 0.03 mm yr^{-1} at room temperature. A die bonding alloy frequently cools at a rate greater than 5°C sec^{-1}. Die bonds must therefore frequently contain Au_3Si. It is predicted that the Au_3Si dissociation reaction will be found to cause failure in such bonds after several years in service.

Stress evaluation of welded steel bridges on coal-haul routes in Kentucky. KEITH J. HOGAN,* Department of Civil Engineering, THEODORE HOPWOOD, II, Kentucky Transportation Center, and ISSAM E. HARIK, Department of Civil Engineering, University of Kentucky, Lexington, KY 40506.

Kentucky's transportation system as well as the coal industry rely heavily on highway bridges in order to link to their respective destinations. In Kentucky, coal haulers are permitted to carry overloads above the normal legal weight limits on specific roads designated as "extended-weight coal-haul routes." Many extended-weight coal-haul routes incorporate bridges of welded steel construction. Those bridges contain welded details (connections) that are prone to fatigue cracking if subjected to severe loading conditions. To determine whether the permitted overloads constitute a fatigue hazard to the bridges, live-load strain applications on those bridges are monitored at fatigue-prone welded connections. Strain applications are measured using strain gages attached adjacent to the connections of interest, typically those anticipated to be subjected to the highest live load stress. The strain gages are monitored using "set-and-forget" data loggers that monitor and classify the strain data unattended for periods of up to several weeks. The collected data are provided as stress histograms showing the number of load applications versus the occurring stress. Based on these stress measurements, extensive fatigue analyses and evaluation will be made in order to determine if the bridge superstructure has sustained significant fatigue damage. Consequently, this study will provide a greater assurance of structural integrity as well as an extended inspection period from 2–5 yr if the results can prove to be safe.

The Brent-Spence Bridge: will it survive the big earthquake? ISSAM E. HARIK* and MEIWEN GUO, Department of Civil Engineering, and DAVID L. ALLEN, Kentucky Transportation Center, University of Kentucky, Lexington, KY 40506.

The Brent-Spence Bridge, a double-decked bridge, is a key component on interstate I-75 over the Ohio River connecting Covington to Cincinnati. The bridge was built in the early 1960s prior to the implementation of stringent seismic design codes. The bridge has not yet been subjected to a big earthquake. After the Loma Prieta earthquake of 17 Oct 1992 and the collapse of the elevated double decked section of I-880 in Oakland, CA, The Federal Highway Administration commissioned the seismic evaluation of all double-decked bridges located in seismically active regions. The Brent-Spence Bridge is located in a region influenced by the seismically active New Madrid and the Wabash seismic zones. The development of detailed mathematical computer models of the Brent-Spence Bridge are presented, and the behavior of the various structural components is evaluated. The bridge model was subjected to ground motions under maximum credible earthquake conditions. The bridge will resist the maximum credible earthquake within the elastic range of the structural components without damage.

Unattended high-resolution earthquake-data collector. ROBERT J. DUGAN, College of Engineering, University of Kentucky, Lexington, KY 40506.

Earthquakes that stimulate earth motion sensors pose special problems in trying to analyze the signals produced. The event happens at a totally unpredictable time: daytime, nighttime, weekends, holidays. Event recorders are therefore slow ink tracings on paper strips. Analyzing such signals demands far greater resolution than is now commonly available. A data collection system is described that was designed to continuously monitor earth motion signals. The system operates completely unattended and collects data in digital form at a rate sufficiently rapid to recreate the original signal well enough for seismologists to analyze the real time waveform or the frequency spectrum via Fourier transform. Off-the-shelf hardware and "streaming" software are used. Unique system requirements and the custom control software are described. Special problems relating to unattended remote sites connected by modem to a master station are explored.

GEOLOGY

Chronostratigraphy of the Big Eddy Section, Mile 605, Ohio River. GRAHAM HUNT, Department of Geography and Geosciences, University of Louisville, Louisville, 40292.

Many detailed studies over the past few centuries have greatly extended our geologic data base of the well known Silurian/Devonian rocks exposed at the Falls of the Ohio, in Clarksville, Indiana. However, because of the recent drawdown of the water levels at the McAlpine Dam, there is new evidence for the disconformable contact of the lower Coral Zone of the Jeffersonville Limestone and the underlying Halysites beds of the Louisville Limestone of the Middle Silurian Age at Mile 605 of the Ohio River, herein, referred to as the Big Eddy section.

Some previous workers of the type locality of the Jeffersonville Limestone, Kindle and Butts of the Whirlpool section and Perkins of the Railroad Bridge section, have all pointed out the inability to examine the water covered disconformable contact of rocks of probable Ludlovian/Emsian Age, located near the Big Eddy section of this study.

At the base of the Big Eddy section, a 1 meter thick section of coarse grained, dolomitic limestone consists mainly of whole and broken coral—stromatoporoidal fossils in a very sharp contact with the Silurian/Devonian unconformity. Samples of in situ, upright and mound-like stromatoporoids were collected along with recumbent rugose corals for age determinations. Some recumbent and elongate coralla were oriented mainly in an east–west orientation indicating possible tidal activity in late Early Devonian time.

Some beds of the Jeffersonville Limestone are characterized by carbonaceous partings and flakes usually associated with vertical N 10 deg. E striking calcite infilled fractures. The Jeffersonville Limestone is petroliferous in recent cuts on the nearby highways. Structure contours suggest the location of a N 30 deg. E striking anticline of local extent, at Mile 605, Ohio River. At this location the strikes of vertical joint sets of N 10 deg. E, N 40 deg. W, and N 88 deg. W are found. Because there are structurally related fractures associated with specific structures such as faults and folds, the fractures associated with the faults will strike parallel to the faults.

Interpretive Center, Falls of the Ohio State Park, Indiana. GRAHAM HUNT, Department of Geography and Geosciences, University of Louisville, Louisville, KY 40292, and TROY McCORMICK, Indiana Department of Natural Resources, Falls of the Ohio State Park, New Albany, IN 47150.

The Falls of the Ohio State Park lies along the north shore of the Ohio River in Clarksville, Indiana. The park contains approximately 68 acres of land but lies within the Falls of the Ohio National Wildlife Conservation Area, which includes 1,404 acres of Federally protected land and water. The park was established in 1990, after several attempts to preserve and protect the area. As the 20th Indiana State Park, the Falls of the Ohio will specialize in natural interpretation and education. The focal point for both the Federal and State properties will be a 16,000 square foot interpretive center that is planned to open in 1993. Situated on the bluff, overlooking the Ohio River and Devonian fossil beds, the interpretive center will create a center for research, study, education, and understanding of the Falls of the Ohio and surrounding region.

As the only exposed bedrock along the 981 miles of the Ohio River, the rapids, called the Falls, proved to be a natural navigational hazard to explorers and early travelers. The "Falls" are actually a series of cascading rapids that drop twenty-six feet in elevation, in a two and one-half mile stretch of the river. The significance of the site to early scientists and researchers was clearly evident as the Falls still provides 220 acres of exposed Devonian fossil beds. More than 600 species of fossils have been identified at the Falls with two-thirds being "type" specimens described for the very first time. Recent drilling for the interpretive center has added new geologic data to our study.

Fossils from the Haney Limestone, (Mississippian) Christian County, Kentucky. MALINDA WASHER POWELL,* Murray State University, Murray, KY 42071, and JAMES X. CORGAN, Austin Peay State University, Clarksville, TN 37044.

The Haney Limestone, of Chesterian age, is well exposed along Forbes Creek in northeastern Christian County. Fossils, abundant in many horizons, include brachiopods, such as *Atrypa* and *Athyris,* that characterize Late Mississippian faunules everywhere. They also include rarer taxa referable to the trilobite genus *Palladin,* the blastoid genus *Pentremites,* and the bryozoan genus *Archimedes.* The trilobite is *Palladin chesterensis.* Tentative specific identifications of bryozoan and echinoderm taxa suggest that further study of the Haney Limestone will yield many new distributional records for southern Kentucky. At present, a lack of modern revisionary work precludes the easy identification of meaningful species-group taxa.

The Vertebrate Fossil Collection of the Owensboro Area Museum of Science and History, Owensboro, Kentucky. MALCOLM T. SADLER* and JAMES X. CORGAN, Austin Peay State University, Clarksville, TN 37044.

The Owensboro Area Museum of Science and History has a diverse collection of Quaternary vertebrate fossils from sites in north central Kentucky and adjacent Indiana. Well-documented specimens represent four Pleistocene and Recent localities. Two Pleistocene sites are under the waters of the Ohio River. One yields a mammoth tooth plus poorly preserved or difficult to identify remains of modern cattle. It is a mixed Pleistocene–Recent site. Another underwater site yields both mammoth and mastodon in abundance and is entirely Pleistocene. A young *Bison bison bison* bull is the only fossil from the third underwater site. This subspecies first appears about 4,000 years ago. Thus this site is Recent. It may predate modern populations. At the fourth site, river bluff sediments yield a poorly preserved elephantine tusk. Efforts to recollect or further document two additional pachyderm sites are on-going but vexing. The first is a spring site just south of Owensboro. We cannot gain access to the land. The second troublesome site, in Union County, was discovered by an amateur archaeologist. It is proving difficult to relocate this locality. In addition to these six sites for which some geographic data are available, the Owensboro Area Museum of Science and History has specimens from five other Pleistocene vertebrate sites that cannot be precisely located. All are pachyderms, either mastodons or mammoths. Specimens are useful for display but do not contribute to paleogeographic knowledge.

HEALTH SCIENCES

Effects of cyclic energy restriction on body weight reduction in oophorohysterectomized Fisher 344 rats. C. WANG,* C. J. LEE, and A. BABALMORADI, Human Nutrition Research, Community Research Service, Kentucky State University, Frankfort, NY 40601.

To study the effect of cyclic energy restriction on body weight reduction, oophorohysterectomized Fisher-344 female rats (13 mo old, 8/group) were assigned to consume for 4 mo a control diet freely (C4), 4 mo an energy-restricted diet at 60% of the average intake of C4 group (R4), 2 mo the restricted and 2 mo the control (R2C2), 2 mo the control and 2 mo the restricted (C2R2), 2 cycles of 1 mo the control and 1 mo the restricted (C1R1C1R1), or 2 cycles of 1 mo the restricted and 1 mo the control diet (R1C1R1C1). The control diet contained 50 g Ca, 40 g P, 5 g Mg, and 200 g protein per kg. The energy-restricted diet was formulated so that 60 g provided only 60% of the energy, but the same amounts of other nutrients except carbohydrate as 100 g of control diet. When switched from the restricted diet to the control diet, rats of R2C2, R1C1R1C1, and C1R1C1R1 consumed greater amounts of food than the R4 group. Weight loss during the second cycle was greater than for the first cycle for C1R1C1R1 and R1C1R1C1 groups, but weight loss of R1C1R1C1 group during the third month was similar to that of C2R2 (with no prior restriction) during the same month. Cyclic energy restriction caused similar reduction in body weight as first time energy restriction when animal age and experimental conditions were maintained the same. These suggest that weight loss does not necessarily get harder each time in individuals with repeated weight loss and regain.

Factors influencing provision of dental services to homeless persons in Kentucky. ARTHUR VAN STEWART and ERIC T. VEAL,* Department of Orthodontic, Pediatric, and Geriatric Dentistry, University of Louisville, Louisville, KY 40292.

Dental health indices for most Americans have improved significantly during the last 4 decades. Among the most underserved are the homeless, who represent an estimated 5–7% of the total population. The purpose of this research project was to examine factors associated with dental services for homeless persons as represented by 70 adults seen at an urban health care center. The study obtained data by means of patient interviews, dentist interviews, clinical observations, and review of the medical records during the period: 25 May 1992 to 31 Jul 1992. The study showed that only 114 of the 1,386 clients (8.2%) sought dental care. Other findings reveal that 34 (49%) presented with a chief complaint of oral/dental pain. The second most common chief complaint reported was a perceived need to have missing teeth replaced. Only three (4.3%) visited the dental clinic for "a routine dental checkup." Patient services most often included full diagnostic examination (62 individuals [90%]); 29 (44%) patients had dental extractions; 4 (6%) received "simple" restorations; and 18 (27%) were treated for partial or complete edentulism, while only one patient (>1%) received periodontal treatment. During the period studied, no endodontic or fixed prosthodontic procedures were undertaken. Data suggest that ca. 28 (41%) of the patients could have received additional treatment if (a) the patients could have been seen on a more regular basis, (b) additional dental equipment was available, (c) funds to cover laboratory fees could have been obtained, and/or (d) the volunteer dentists could extend their hours of service to the clinic.

Kentucky survey of nursing home administrators' perceptions of current dental service programs. ARTHUR VAN STEWART, BRYAN G. HARNESS,* KEITH KNAPP, and JACKIE FISCHER, Department of Orthodontic, Pediatric, and Geriatric Dentistry, University of Louisville, Louisville, KY 40292.

During 1990–1991 the ULSD Gerontological Studies Program conducted a comprehensive survey of dental consultants serving the Commonwealth's 300+ long-term care facilities (nursing homes). Results were reported at the 1991 KAS meeting in Owensboro, KY, and also at a number of national and international meetings. This year's project is a companion study that sought to examine the same series of problems and concerns as the 1990–1991 study but as seen from the perspective of the chief administrators of the nursing homes. The research design included the use of a panel of experts to help edit the survey instrument, the use of follow-up rounds of inquiry for those failing to respond to the initial request for information, and data management/interpretation techniques following procedures used in the earlier study. Using a cognitive dissidence approach, the study sought to reveal differences and similarities in professional perspective. A nine-page (42 item) questionnaire was sent to the top administrative leaders of all licensed nursing homes in Kentucky (ca. 1992). The findings represent the first organized research effort in the United States to examine the health care system for delivering oral health services to geriatric patients as seen from the perspective of the professional long-term health care administrator. This research was reported at the 1992 Health Sciences Center Research Day Program. Findings from the study also will be reported at selected national and international professional meetings and conferences in the coming months.

PHYSICS

MAP—A program to explore the logistic equation. SEAN MOLLEY,* RICHARD HACKNEY, and KAREN HACKNEY, Department of Physics and Astronomy, and JOHN CHAMBERLIN, Department of Chemistry, Western Kentucky University, Bowling Green, KY 42101.

The word "chaos" is defined as "extreme confusion or disorder." Classical Newtonian science has traditionally tended to deal with systems that can be modeled linearly or at least to avoid those which become chaotic. However, we are discovering that non-linear behavior pervades every branch of natural science and that the "friendly" more easily modeled linear systems are in fact the oddities. Furthermore, we are learning of a surprising order behind the facade of apparent randomness: order out of chaos. The mathematics of "chaos theory" or "non-linear dynamics" has become a common thread weaving many disciplines together. Many natural systems require the continuous expression provided by nonlinear differential equations, which can become extremely complicated. Graphical analysis and numerical integration with the aid of a microcomputer have made these systems tractable. In addition, it sometimes happens that the essential behavior of a differential system can be reduced to a one-dimensional mapping. "Single-humped" mappings have been shown by Feigenbaum to exhibit a universal type of behavior. Therefore, the careful study of such a mapping, besides having intrinsic mathematical worth in itself, aids in the understanding of more complex differential systems. The program MAP, written by Richard Hackney, is designed to allow the exploration of the most celebrated of these maps, the logistic equation: $X_{n+1} = mX_n(1 - X_n)$. Slight modifications in the program would allow similar study of any other one-dimensional map. Discussion will center on the capabilities of the program, such as production of "time" series, bifurcation plots and values, sequencing, and chaos.

PHYSIOLOGY, BIOPHYSICS, BIOCHEMISTRY, AND PHARMACOLOGY

The bdelloid rotifer as a model of aging. An inexpensive investigative screening test for exploratory aging research. W. P. HETTINGER, JR., Russell, KY 41169.

Many hypotheses of aging are presently under investigation, and exposure to biologically active molecules has been shown to affect life span. To accelerate such studies, an inexpensive, reliable, short-term aging screening test was developed. The bdelloid rotifer, a micro-aquatic animal, was selected for the test, based on many criteria, including the fact that it is a multi-cellular animal (1,000 cells), has a very short and reproducible life span (21 d at 31°C), and is of constant genetic character. The micro-aquatic factor was likewise considered most important, as it facilitated exposure of an animal to a well-controlled, but broadly variable environmental concentration of additives such as RNA and protein synthesis inhibitors. The fact that the animal is syncyial also served to enhance the likelihood of minimizing any internal concentration gradients. It also reduced the need for expensive treating molecules or those in short supply, and test equipment cost was very low. Six colonies (10 animals each) were always used as a reference standard, and similar numbers were used at each level of chemical concentration. In a typical case, an average increase of about 3.2 mean d in life span for the six colonies indicates a 95% probability that the treatment positively affected life span. Approximately 80 person hours are required to evaluate one chemical at four levels of concentration; e.g., 100, 10, 1.0, and 0.1 µg/ml. Usually 1 to 5 mg of chemical suffice for the study.

Investigation of the programmed aging hypothesis. The effect of several RNA and protein synthesis inhibitors on the life span of the rotifer. W. P. HETTINGER, JR., Russell, KY 41169.†

An accelerated aging test (21 days at 31°C) employing the rotifer, has been previously described. These micro-aquatic animals were then exposed to a number of DNA, RNA, and protein synthesis inhibitors over a broad concentration range. These inhibitors were chosen on the premise that if a program exists, it should be expressed by readout leading to specific RNA and protein syntheses. Retardation of the readout of DNA in RNA synthesis, and possibly protein synthesis should therefore increase life span.

It was recognized, however, that such inhibitors might adversely affect other vital life processes. Therefore at best, an optimum concentration range was to be anticipated.

Eukaryotic RNA and protein synthesis inhibitors included Actinomycin-D (Act-D), Acridine Orange (AO), Chromomycin-A3 (CA-3), Puromycin (PO), Cycloheximide (CHN), Tetracycline (TCY), and Streptomycin (SM). Non-inhibiting molecules, of related interest, Fluorodeoxyuridine, Colchicine, Carbenicillin, Chloramphenicol, Pyran, and Penicillin were also tested.

For some of the RNA inhibitors, life span increased, and then fell off as did egg laying and hatching with increasing concentration of inhibitor. Non-inhibitors did not affect life span, but DNA inhibitors Fluorodeoxyuridine and Colchicine as expected, did inhibit egg laying and hatching.

The equation proposed in terms of inhibitor concentration for the data observed where life span increased is as follows.

Δ life span observed (days increase in average life span)

= Δ life span increase due to inhibitor

− Δ life span loss due to inhibition of life support reactions in the presence of the inhibitor and as concentration increased.

$$= \Delta\ \max_A \cdot \frac{1}{K_A/X + 1} - \Delta\ \max_{Life} \cdot \frac{1}{K_L/X + 1}$$

appears to fit the data, where Δ obs. is the increase or decrease in life span observed compared to the standard colony in mean days as the concentration of inhibitor is varied, K_A is a proposed dissociation constant for inhibition or reduction related to readout of the aging program, K_L a similar const. for inhibiting other life functions, $\Delta\ \max_{Aging}$ the increase anticipated if the aging program is blocked, $\Delta\ \max_{Life}$ the negative mean life of other vital functions which are required to sustain life. In other words, $\Delta\ \max_{Life}$ relates to the amount of days that life is *cut short* because certain life-sustaining readouts are also inhibited. X is the concentration in mcg/ml of inhibitor.

For RNA synthesis inhibitors, a significant increase in life span at optimum concentration was observed for Strep-

† Research done at University of Miami, Coral Gables, FL, and Gerontology Research Center, Baltimore, MD.

tomycin (4.1 days, $P = 0.001$) at 1 mcg/ml; Acridine Orange (2.7 days, $P = 0.03$) 0.5 mcg/ml; Tetracycline (3.1 days, $P = 0.1$) mcg/ml; Actinomycin (2.2 days, $P = 0.1$) 0.06 mcg/ml; Acridine Orange *plus* Streptomycin (5.1 days, $P = 0.01$) 1 mcg/ml; Chromomycin-A3 (0.5 days) 1 mcg/ml; Cycloheximide (0.7 days) 1–10 mcg/ml; and Puromycin (0.0 days). For three inhibitors for which egg laying and hatching data was available, K_L and K_A could be estimated, and therefore Δ max_A could be determined by extrapolation to very large values of X. As a result based on data observed, it was estimated to be an increase of 13 to 15 days or an increased life span of 62% to 71%. The results lend good support to the hypothesis that aging is programmed.

SOCIOLOGY

Drug abuse, STDs, and birth control—a community college survey. J. G. SHIBER* and N. V. ANOSIKE, Divisions of Biological Sciences & Social Sciences, Prestonsburg Community College, Prestonsburg, KY 41653.

Biology students (n = 517) at Prestonsburg Community College were surveyed on drug abuse, sexually-transmitted diseases (STDs), and birth control to identify their educational needs and get an idea of knowledge and attitudes of the local population on these topics. Seventy-one per cent of the students have known someone addicted to a drug through intentional abuse, and 55% unintentionally, mainly via prescriptions; 41% were pressured to try drugs—about half "experimented"; and 90% believe a drug problem exists in eastern Kentucky, primarily with marijuana, alcohol, and stimulants. Sixty per cent of the respondents also believe there is a problem here with STDs, especially gonorrhea and genital herpes. Forty-one per cent have known people with STDs. Although 92% had some knowledge of STDs, mainly through school and reading, many had heard of neither lymphogranuloma venerum & chancroid (34%) nor granuloma inguinale (24%). Fifty per cent of "myths" related dwelled on AIDS transmission. Fifty-seven per cent of the students related availability of birth control measures to increased incidence of STDs, chiefly (1) people mistakenly think such measures effectively protect against STDs and (2) measures have lessened fear of pregnancy, thus encouraging increased sexual activity and promiscuity. Sixty-two per cent believe certain measures, especially condoms and abstinence, offer some protection; 46% would recommend condoms, alone or combined with other measures, to someone dear. The "Pill" rated most effective with 42%, followed by abstinence, sterilization, and condoms. Least effective choice(s) was coitus interruptus (withdrawal), then rhythm, spermicides, and condoms.

ZOOLOGY AND ENTOMOLOGY

Distribution and status of amphibians in the northern tier counties of Kentucky. PAUL J. KRUSLING,* of Cincinnati Museum of Natural History, Cincinnati, OH 45202, and JOHN W. FERNER, Department of Biology, Thomas More College, Crestview Hills, KY 41017.

Twenty-four species of amphibians have been recorded from Boone, Campbell, and Kenton counties in Kentucky. Although this region has traditionally been classified as part of the Outer Bluegrass physiographic province, the effects of glacial activity have contributed to the added diversity of species. In addition, the Ohio River is an effective barrier to northern and southern range expansion. The study extended from Aug 1991 to Aug 1992. Representative surveyed habitats included springs and ravines in the glaciated regions and an *Acer rubrum/Quercus palustris* flood plain depression forest. Significant new county records include *Ambystoma maculatum, A. jeffersonianum, Plethodon glutinosus,* and *Notophthalmus viridescens.* Comparison was made with historical and recent collections to determine any changes in status of amphibian populations.

Trans. Ky. Acad. Sci., 54(1–2), 1993, 60–62

DISTINGUISHED SCIENTIST AND OUTSTANDING TEACHER AWARDS, 1992

Distinguished College/University Scientist Award

Dr. Marcus T. McEllistrem, Professor of Physics and Astronomy at the University of Kentucky, is the recipient of the 1992 Distinguished College/University Scientist Award. Dr. McEllistrem received his B.A. degree from Saint Thomas College and Masters and Doctorate from the University of Wisconsin. In 1957, Dr. McEllistrem joined the faculty of the Physics and Astronomy Department at the University of Kentucky. During his illustrious career, Dr. McEllistrem has been given many awards and honors by his colleagues: University Research Professor at UK, Distinguished Professor of the College of Arts and Sciences of UK, Program Officer of the National Science Foundation, Chair of the University Senate at UK, Fellow of the American Physical Society, and Invited Lecturer at numerous international conferences. An outstanding servant for the cause of science, he has served as a member of Kentucky NSF/EPSCoR Committee and as Chair of the Kentucky Statewide Subcommittee for DOE/EPSCoR.

Dr. McEllistrem had a leading role in proposing, designing, and constructing the Van De Graaf Accelerator Laboratory at UK, and has been the principal investigator and director of the nuclear physics project which has been continuously funded by NSF grants since 1963. Dr. McEllistrem is recognized as a world leader in neutron scattering reactions and their interpretation. His work in nuclear astrophysics has provided new insight into the determination of the age of the universe. Dr. McEllistrem has encouraged many others to utilize the accelerator facility and has given freely of his time and efforts to develop other colleagues' research. These programs vary from the production of short-lived radionuclides for radiopharmaceuticals to his recent colloborative studies of methods for detecting narcotics and explosives. Currently, he is collaborating with Ann Arbor Nuclear Corporation by leading experimental research at UK's accelerator in the development of a neutron activated metal detector, which potentially could be used in airport detection systems.

While doing extensive research, Dr. McEllistrem always makes time for students. He has taught and advised students in physics at all levels. Student ratings have been uniformly high. He has advised several undergraduate students involved in the research program at the accelerator laboratory and has guided numerous graduate students through the Ph.D. degree in nuclear physics.

Dr. McEllistrem has spent much time contributing to the scientific and educational development of young scientists. It is this selfless attitude that has made him respected and admired by his colleagues. Most importantly he is a gentleman and a scholar. Professor McEllistrem has made great contributions to science and technology in Kentucky by being a gifted and dedicated teacher while compiling an impressive record in the area of service and research.

Industrial Scientist Award

The 1992 recipient of the Industrial Scientist Award is Mr. Karl Russ of Louisville. Mr. Russ is a leader in catalytic research. He has been involved in catalyst development and research at United Catalysts, Inc., where he is Vice-President and Manager of the Technical Department. Mr. Russ has led the successful implementation of the laboratory research effort, the pilot plant development work, and the introduction of the catalysts into the marketplace. He has been responsible for the research and development of a number of catalysts used in a wide variety of chemical processes, including hydrogenation of fats and fatty chemicals for margarine, shortening and steric acid; conversion of methane to hydrogen and ammonia for the refining and fertilizing industries; as well as other dehydrogenation processes.

Mr. Russ is a native of Louisville, Kentucky, and earned his bachelor's degree in Chemistry from Bellarmine College. He has actually been involved in catalyst development and research since 1960 at United Catalysts, Inc., when he first worked as a technician before completing his bachelor's degree in 1966. He has held positions of increasing responsibility since he joined the company. He became a group leader in the Development Department in 1966 and the manager of the Development Department in 1972. In 1973, he became manager of New Products Research and his responsibilities expanded in 1974 when he became manager of the Technical Department. He was promoted to his present position in 1979. Even though he is responsible for the activities of several hundred employees, Mr. Russ has remained active in research. A measure of this success is three patents he holds in catalyst manufacturing. He has worked closely with many companies such as pharmaceutical companies that have developed catalysts which are kept confidential. Mr. Russ is also responsible for solving problems encountered in the use of the catalysts supplied by his company to its many customers. The interactions with these customers, and his on-site visits to United Catalysts., located in several foreign countries (Japan, Germany, India, etc.), illustrate his true role as an international industrial scientist whose laboratory represents large multinational companies as well as numerous smaller ones.

Mr. Russ is a member of the American Institute of Chemical Engineers, the American Chemical Society, the Kentucky Academy of Science, and the Tri-State Catalysis Club. Not only is he a greater supporter of these scientific activities, he encourages members of his staff to also be active in these endeavors.

One nominator stated that "Mr. Russ is an impressive industrial researcher and administrator exemplified by the astounding growth of United Catalysts, Inc., particularly during the past 15 years." In the international arena of catalyst manufacturer and users, Mr. Russ is also a well known figure. Another nominator stated that "for this important Industrial Scientist Award to be bestowed on Mr. Russ, it is well deserved and well earned, and is a fitting example and inspiration to our young people seeking to develop careers in science in Kentucky."

OUTSTANDING COLLEGE UNIVERSITY SCIENCE TEACHER

The award for the Outstanding College University Science Teacher is presented to Dr. Curtis C. Wilkins, Professor of Chemistry at Western Kentucky University. Dr. Wilkins received his bachelor's degree from Wisconsin State College and his Ph.D. in Physical Chemistry from Michigan State University. He taught at West Virginia Wesleyan College before joining the Chemistry Department at Western Kentucky University in 1965. He has remained in that position except for 1982–1983 when he was a Visiting Professor of Chemistry at Texas A&M.

Although his credentials in teaching physical chemistry are excellent, he also excels at teaching general (freshman) chemistry. Dr. Wilkins teaches over 100 students each semester in both lecture and laboratory courses. These students' evaluations affirm that he is always well prepared, gives excellent examples, and is always considerate of his students. Even though his expectations for excellence from his students are high, he is well liked and appreciated by these students, especially when they realize how well prepared they are for the upper level chemistry courses. Professor Wilkins has developed computer programs and practice exams to aid students in understanding nomenclature. He has published a number of papers in the Journal of Chemical Education and given presentations at local, regional, and national meetings of the American Chemical Society. He is currently collaborating on the production of TV cassette tapes for pre-laboratory instruction. He has received external funding to particularly improve chemistry teaching. One of his nominators summed up the justification for his consideration for this prestigious award when he wrote, "If you are looking for someone who does an outstanding job of communication of information to students, does an outstanding job of building a rapport with his students, actively supports his profession and is respected by his students and colleagues alike, then Curtis is the best person to receive the award." Another supporter commented, "When she was reintroduced to chemistry by Dr. Wilkins to prepare her to do graduate work, she found a clear, thorough, rigorous course. Professor Wilkins exemplified every quality I admire in a professor—patience, a sense of humor, a strong love of his subject area, a willingness to work with students individually, and an enduring belief in fairness and equal opportunity. His labs are safe and effective in reinforcing abstract concepts from lectures; his tests are demanding, yet well-formed. How could any student not thrive in such an environment?"

OUTSTANDING SECONDARY SCHOOL SCIENCE TEACHER

Ms. Andrea L. Warren, Chairperson of the Science Department of Franklin-Simpson High School, is the co-recipient of the 1992 Outstanding Secondary School Science Teacher Award. Ms. Warren has been described as a "hands-on" teacher whose students participate in class because much is expected of them. Her classroom is a laboratory where updated equipment and resource material are available for the students.

Ms. Warren has an A.S. Degree from Broward Community College, a B.S. Degree from Barry University, and a Master's Degree in Education with emphasis in science. She keeps current in science education by attending meetings and workshops. Also, Ms. Warren has worked in the rain forests of Belize and participated in an exchange trip to Russia. Among her many memberships in scientific and/or educational organizations is her position on the Kentucky Department of Education Science Curriculum Development Committee and Kentucky/Department of Education Integrated Curriculum Development Committee. Because of her activities, she brings to her students an excitement for learning and the learning process that serves as an excellent example to younger faculty. Ms. Warren does not take the shortcuts available to the secondary teacher. She emphasizes writing and critical thinking in the classroom and is willing to "pay the price" in the evaluation time required to grade such student endeavors. This is evidenced by one of her student's comments who stated, "From beads and strings, to microscopes hooked up to the television, she found a way to help me understand even the toughest concepts. For high schoolers, going out into the middle of the hallway during class to join hands and form protein models was fun. In addition to reading assignments, our AP labs required time outside of class, weekly essays, field trips and 'a lab alive' project. Our field trips included a water analysis of our local water source and a week-long stay at Dauphin Island, Alabama, where we studied marine biology."

Ms. Warren emphasizes the need for good relationships between the school and the community. Several local industries have donated equipment to the school as a result of Ms. Warren's efforts. She is currently in the process of establishing an outdoor laboratory.

Ms. Warren's outstanding attribute is her ability to communicate excitement for her subject to her students both in and out of the classroom. A veteran biology teacher pays her the highest compliment by stating "she is one of the best examples of a dedicated teacher I have known."

OUTSTANDING SECONDARY SCHOOL SCIENCE TEACHER

Mr. Samuel Thomas Hunt, Science Department Chair of Montgomery County High School, is the co-recipient of the 1992 Outstanding Secondary School Science Teacher Award. Mr. Hunt received his Bachelor's Degree of Science in Biology from Morehead State University in 1973. That same year he joined the Montgomery County Junior High School staff as a science instructor. In 1977 he became a biology instructor in General Biology, Special Topic Biology, Advanced Placement Biology and a Photography instructor. During the 1990–1991 school year, he was promoted to his present position of chairman. His colleagues and students agree that he has developed into a master teacher.

His teaching includes "hands on" learning using individual and innovative team lab projects, suggestions for home projects with families, and group problem solving. Mr. Hunt was ahead of his time in the classroom as he was teaching with performance events in mind for students before it was included in the assessment process of KERA. He promotes collaboration with the vocational school by incorporating the work of chemistry, physics and electronics classes into its curriculum. Just recently, he initiated work with the health and physical education teachers to eliminate overlapping of subject matter being taught in health and biology.

Because Mr. Hunt attends state and national meetings for science teachers, as well as local and state workshops relative to his field, he has much to share with his students. With his proficient presentation skills and effective use of teaching aids/materials/equipment, he provides quantitative in-service activities for teachers. He has evaluated the science program K through 12 and has infused new enthusiasm for teaching science across all levels of the Montgomery County School System. He initiated a science newsletter allowing teachers to exchange ideas regarding teaching science. He encourages teachers to join professional science teaching organizations and attends the meetings faithfully himself.

"Mr. Hunt is an outstanding teacher, leader, organizer, and staff person who puts the interests of students first and covets little recognition" one nominator stated. Another nominator commented, "Mr. Hunt teaches self-discipline, goal setting, analytical thinking, team concepts, environmental concern and a sound foundation in the sciences." The committee was impressed by the comment of one of his students who paid him the ultimate compliment when she stated, "I'm considering going into the science field and wouldn't mind being a biology teacher like Mr. Hunt."

NEWS AND COMMENTS

Annual Meetings

The 79th meeting of the Kentucky Academy of Science will be at Georgetown College (co-host: Toyota), 23–24 October 1993. Future meetings are planned at Paducah Community College (1994) and Western Kentucky University (combined meeting with the Tennessee Academy) either in 1995 or 1996.

Noteworthy Publications

Schumann, Walter. 1993. Handbook of rocks, minerals, and gemstones. Houghton Mifflin, New York. $18.95 paper; $35.00 cloth. This beautiful little book, surfeited with color photographs (over 600) of each rock, mineral or gemstone, is an excellent contribution that will be thoroughly enjoyed by any rockhound.

Pasachoff, J. M. and Donald H. Menzel. 1992. Stars and planets. Houghton Mifflin, New York. $24.95. This is yet another welcome addition to the Peterson Field Guide series. It is heavily illustrated with sky charts and excellent color photographs, and a rather comprehensive overview of the solar system. The text is very informative for both novices and professionals.—Branley Allan Branson

Kentucky Advocates for Higher Education

Your editor was one of the finalists for the first Acorn Award. I guess you might say he was in the hunt with the rest of the squirrels but, alas, no acorn.

Guidelines for Preparation of Abstracts for the *Transactions* and Annual Meeting[1]

1. Abstracts must be 250 words or less.
2. Abstracts must be on white bond paper (8.5 × 11 inches) with black type. Abstracts must have margins of 1 inch top, bottom, left and right. Abstracts must not exceed one page.
3. The title, authorship, address, and text must be double spaced in ordinary type.
4. Use a short and specific title.
5. The address should contain the name of the author's department(s), the name of the university or company, the name of the city, the name of the state (use standard 2-letter abbreviations (e.g., IN, OH, KY, TN) and the zip code, all in ordinary type.
6. Use standard, well-known abbreviations when the use of abbreviations is necessary.
7. When using abbreviations for compounds, spell out the name in full at the first mention and follow with the abbreviation in parentheses; use the abbreviation thereafter. Do not abbreviate compounds in the title of the abstract.
8. Any special symbols, such as Greek letters, that are not on your typewriter or word processor must be carefully drawn by hand with black ink.
9. Scientific names should be underlined. Spell out generic names the first time they are used; afterwards, these names should be abbreviated to the first letter (+ period) when followed by a specific name (unless confusion results with another abbreviated generic name in the abstract).
10. In the upper right-hand corner of the abstract, type in capitals the names of the section to which your paper belongs:

AGRICULTURAL SCIENCES	PHYSIOLOGY, BIOPHYSICS
BOTANY AND MICROBIOLOGY	BIOCHEMISTRY AND PHARMACOLOGY
CHEMISTRY	PSYCHOLOGY
COMPUTER SCIENCE	PHYSICS
ENGINEERING	SCIENCE EDUCATION
GEOGRAPHY	SCIENTIFIC INFORMATION
GEOLOGY	SOCIOLOGY
HEALTH SCIENCES	ZOOLOGY AND ENTOMOLOGY
INDUSTRIAL SCIENCES	
MATHEMATICS	

11. Poor preparation of an abstract may result in the abstract not being published.
12. For publication in the *Transactions*, please submit the following to Dr. Robert F. C. Naczi, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41076: Abstract prepared as described above. A check for $15.00 made out to Kentucky Academy of Science (to cover publication costs).

[1] Some sections prepare abstracts to be distributed at the Section meetings. Contact the Section Secretary for guidelines.

Instructions for Contributors

Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

Manuscripts may be submitted at any time to the Editor. Each manuscript will be reviewed by one or more persons prior to its acceptance for publication, and once accepted, an attempt will be made to publish papers in the order of acceptance. Manuscripts should be typed double spaced throughout on good quality white paper 8½ × 11 inches. NOTE: For format of feature articles and notes see Volume 43(3–4) 1982. The original and one copy should be sent to the Editor and the author should retain a copy for use in correcting proof. Metric and Celsius units shall be used for all measurements. The basic pattern of presentation will be consistent for all manuscripts. The Style Manual of the Council of Biological Editors (CBE Style Manual), the Handbook for Authors of the American Institute of Physics, Webster's Third New International Dictionary, and a Manual of Style (Chicago University Press) are most useful guides in matters of style, form, and spelling. Only those words intended to be italicized in the final publication should be underlined. All authors must be members of the Academy.

The sequence of material in feature-length manuscripts should be: title page, abstract, body of the manuscript, acknowledgments, literature cited, tables with table headings, and figure legends and figures.

1. The title page should include the title of the paper, the authors' names and addresses, and any footnote material concerning credits, changes of address, and so forth.

2. The abstract should be concise and descriptive of the information contained in the paper. It should be complete in itself without reference to the paper.

3. The body of the manuscript should include the following sections: Introduction, Materials and Methods, Results, Discussion, Summary, Acknowledgments, and Literature Cited. All tables and figures, as well as all literature cited, must be referred to in the text.

4. All references in the Literature Cited must be typewritten, double spaced, and should provide complete information on the material referred to. See Volume 43(3–4) 1982 for style.

5. For style of abstract preparation for papers presented at annual meetings, see Volume 43(3–4) 1982.

6. Each table, together with its heading, must be double spaced, numbered in Arabic numerals, and set on a separate page. The heading of the table should be informative of its contents.

Each figure should be reproduced as a glossy print either 5 × 7 or 8 × 10 inches. Line drawings in India ink on white paper are acceptable, but should be no larger than 8½ × 11 inches. Photographs should have good contrast so they can be reproduced satisfactorily. All figures should be numbered in Arabic numerals and should be accompanied by an appropriate legend. It is strongly suggested that all contributors follow the guidelines of Allen's (1977) "Steps Toward Better Scientific Illustrations" published by the Allen Press, Inc., Lawrence, Kansas 66044.

The author is responsible for correcting galley proofs. He is also responsible for checking all literature cited to make certain that each article or book is cited correctly. Extensive alterations on the galley proofs are expensive and costs will be borne by the author. Reprints are to be ordered when the galley proofs are returned by the Editor.

CONTENTS

TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

Volume 54
Numbers 3–4
September 1993

Official Publication of the Academy

All manuscripts and correspondence concerning manuscripts should be addressed to the Editor. Authors must be members of the Academy.

The TRANSACTIONS are indexed in the Science Citation Index. Coden TKASAT. ISSN No. 0023–0081.

Membership in the Academy is open to interested persons upon nomination, payment of dues, and election. Application forms for membership may be obtained from the Secretary. The TRANSACTIONS are sent free to all members in good standing.

Annual dues are $25.00 for Active Members; $15.00 for Student Members; $35.00 for Family; $350.00 for Life Members. Subscription rates for nonmembers are: domestic, $45.00; foreign $50.00; back issues are $30.00 per volume.

The TRANSACTIONS are issued semiannually in March and September. Four numbers comprise a volume.

Correspondence concerning memberships or subscriptions should be addressed to the Secretary. Exchanges and correspondence relating to exchanges should be addressed to the Librarian, University of Louisville, Louisville, Kentucky 40292, the exchange agent for the Academy.

∞ This paper meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).

EDUCATIONAL AFFILIATES

Fellow

University of Kentucky

Sustaining Members

Eastern Kentucky University
Georgetown College
Kentucky State University
Morehead State University
Murray State University
Northern Kentucky University
University of Louisville
Western Kentucky University

Members

Campbellsville College
Cumberland College

Associate Members

Berea College
Brescia College
Centre College
Kentucky Wesleyan College
Midway College
Spalding University
Sue Bennett College
Thomas More College
Translvania University

INDUSTRIAL AFFILIATES

Associate Patron

Ashland Oil, Inc.

Fellow

Brown and Williamson Tobacco Corporation

Sustaining Members

Air Products & Chemicals, Inc.
ISP Chemicals Inc.

Members

Alltech Biotechnology Center
Corhart Refractories Corporation
DataBeam Corporation
MPB, Inc.
United Catalysts, Inc.

Associate Members

All-Rite Pest Control
3M Tape Manufacturing Division
(Cynthiana Plant)
The Proctor & Gamble Manufacturing Company
Westvaco
Wood Hudson Cancer Research Laboratory, Inc.

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

September 1993
Volume 54
Numbers 3–4

Trans. Ky. Acad. Sci., 54(3–4), 1993, 65–72

The Influence of Mulching Materials and Nitrogen Application Method on Growth and Yield of Yellow Crookneck Squash (*Cucurbita pepo* L.)

WENWEI JIA, WLODZIMIERZ BRES, LESLIE A. WESTON, AND ROSELEE HARMON

Department of Horticulture and Landscape Architecture, University of Kentucky, Lexington, Kentucky 40546-0091

ABSTRACT

The influence of nitrogen application method and selected mulching materials on the growth and yield of summer squash (*Cucurbita pepo* L. 'Dixie') was investigated in the summer and fall of 1990. Black plastic, clear plastic and latex spray mulch treatments were compared to bareground. Ammonium nitrate was applied to mulching treatments (1) as a single broadcast application (112 kg N/ha) at planting or (2) a 56 kg N/ha application broadcast at planting plus 56 kg N/ha applied through drip irrigation four weeks later. Total yields were greater for the late spring season crop compared to the fall crop due to increased mosaic viral disease incidence in the fall which resulted in smaller plants with reduced yields. Early and total yields were greatest for plants grown on black plastic mulch. Highest overall fruit numbers were obtained using black plastic mulch in the spring and black or clear plastic mulch in the fall. Fruit size was similar in all treatments. Latex spray mulch provided little residual ground coverage and resulted in no differences in yield or other observations when compared to the bareground control. Weed suppression was greatest with black or clear plastic mulch. Use of clear plastic mulch also resulted in decreased rate of incidence of mosaic viral disease 6 weeks after planting. Nitrogen application methods had no effects on yield or fruit number in either spring or fall experiments.

INTRODUCTION

Yellow crookneck squash (*Cucurbita pepo* L.) is a high-value spring- or summer-seeded crop with excellent potential for fresh market production in Kentucky. In Kentucky, squash is usually transplanted through plastic mulch or direct-seeded into bareground raised beds without plastic. Use of black or clear plastic mulch is becoming increasingly popular for cucurbit crop production since mulch use maximizes production and return per unit of land area (7). Reported benefits of plastic mulch use include alteration of soil temperature (4, 10, 19), conservation of soil moisture (18), modifications of growth environment (20, 25), and improved weed control (9, 19).

Latex spray mulch (LSM) is a relatively new development in which styrene–butadiene latex is applied as a black or white liquid spray using a CO_2-pressurized sprayer (1). A solid latex mulch layer is formed after the latex spray dries on the soil surface.

Trickle irrigation is often an important component of plasticulture technology for water and fertilizer application (13, 21). Recently, it has been shown that nitrogen (N) may be successfully applied to a crop through the trickle irrigation line (22, 23, 24), in a process known

---

The investigation reported in this paper (92-10-102) is in conjunction with a project of the Kentucky Agricultural Experiment Station and is published with approval of the director.

as fertigation. Some information is currently available regarding the effect of nitrogen application through fertigation upon zucchini growth and yield and suggests that increased plant growth and yields were associated with trickle irrigation and plastic mulch usage (22, 24).

Mosaic viral infection can be a severe problem limiting the production of summer squash in the southern United States (2, 12). Mosaic viruses affecting summer squash are commonly transmitted by aphids and sweet potato whitefly (16, 17). In the southern United States, whitefly has caused millions of dollars in losses to growers (16). It is extremely difficult to gain acceptable control of nonpersistent viruses using approved insecticide spray programs (5, 8). However, various mulching materials provide some level of deterrence to aphids thereby reducing the incidence of mosaic virus on yellow summer squash (6, 12).

Limited information is available regarding the influence of latex mulching material and fertigation on yellow crookneck squash growth. Therefore, the influence of two nitrogen application methods and selected mulching materials on summer squash growth and yield, weed suppression, and viral disease incidence was evaluated over two growth seasons in Kentucky.

MATERIALS AND METHODS

Experiments were conducted in the summer and fall of 1990 at the University of Kentucky, Horticulture Research Farm in Lexington, Kentucky. 'Dixie' crookneck squash was field seeded by hand on 21 June (late spring crop) and 15 August 1990, (fall crop), and upon emergence was thinned to one plant per 30 cm of row. Each plot contained 15 plants. Treatments were arranged as a 2 × 4 factorial within a randomized complete block design with 4 replications. Nitrogen treatments evaluated included (1) the recommended rate of 112 kg N/ha (ammonium nitrate) broadcast at planting and (2) a 56 kg N/ha application broadcast at planting plus 56 kg N/ha applied through trickle irrigation four weeks later. Trickle lines were 1.25 cm in width, 8 mil thickness and emitted up to 757 liter/min/ha. Mulching treatments were compared to a bareground control and included (1) clear polyethylene film, (2) black polyethylene film, and (3) black liquid latex spray mulch (LSM) (BASF Co., Raleigh, NC). All polyethylene mulches were established before direct seeding and were 120 cm wide by 32 μm thick except LSM, which was applied as recommended with a CO_2 pressurized sprayer at a rate of 118 ml per 900 cm^2 soil surface immediately after seeding. A standard herbicide (trifluralin) was applied at 1.12 kg/ha between beds before planting for preemergence weed control.

In each experiment, squash seedling emergence was estimated at 7 days after seeding by counting the number of seedlings emerged per plot in comparison to number of seeds planted. Squash seedling height was also measured for 5 plants randomly selected from each plot at 4, 5 and 6 weeks after seeding in the spring or 3, 4 and 5 weeks after seeding in the fall. Fruit set was monitored on a weekly basis, with the percentage of plants forming fruit recorded per plot. Weed suppression provided by mulches was visually evaluated for each treatment at three weeks after seeding in the spring crop. Percentage of ground covered by grass or broadleaf weeds was estimated in the space within the mulched area 60 cm to the left or right of the squash row in each plot.

During the fall, leaf area (LICOR, Model LI 6000) fresh weight and whitefly infestation (number of adult whiteflies per leaf) were evaluated 4 and 6 weeks after planting on the fourth youngest fully-expanded leaf collected from 5 plants randomly selected from each plot. At six weeks after planting, chlorophyll content was analyzed from 5 leaf discs per treatment using DMF extraction (11). In addition, viral incidence (percentage of infected plants based on 15 plants/plot) was determined. Viral severity (a visual rating of viral infection) was also determined for 5 plants per plot.

The summer crop was harvested 3 times weekly from 30 July to 16 August 1990. The fall crop was harvested twice weekly from 24 September to 11 October. Fruit number and weight were recorded for each plot. Data are presented as early (first week), midseason (second week) and total harvests for both experiments. Treatment effects on all measured parameters were tested using appropriate analysis of variance for factorial experiments and Bartlett's tests were performed to check for homogeneity of variance. Mean separations were performed where appropriate using Fisher's protected LSD tests. Data for spring and fall experiments are presented separately since seasonal effects did not allow for combination of data.

RESULTS AND DISCUSSION

Influence of Mulch or Nitrogen Treatment on Seedling Emergence.—The emergence of squash seedlings was influenced by mulching treatments. In the summer, seedling emergence under black and clear mulch at 7 days after seeding was 100% and 96%, respectively, whereas emergence of seedlings under LSM or in the control was delayed, with only 50% emergence by this date (data not presented, $P \geq 0.01$). Increased seedling emergence under plastic mulches was possibly due to altered soil temperature and moisture level encountered under plastic mulching materials (18, 19); but these features were not measured. The LSM mulch was applied at suggested rates and blackened the soil surface at the time of application but by one week after application ground coverage was sparse and non-uniform in both experiments, and effects upon soil temperature and moisture were probably minimal in comparison to the polyethylene mulching materials. Nitrogen treatment had no effect on seedling emergence at 7 days after planting (data not presented).

Influence of Mulch or Nitrogen Treatment on Plant Size and Fruit Set.—Squash seedlings over clear and black plastic mulch were taller than those grown under LSM or the bareground control in both spring and fall plantings (Fig. 1). Averaged over both N treatments, five-week-old seedlings under black mulch were approximately 22% taller than those under clear mulch, and 45% taller than those under LSM and control treatments in the late spring experiment. In the fall crop at four weeks after seeding, plants grown under black mulch were approximately 10% taller than those grown under clear mulch and 35% taller than those in both LSM and bareground treatments. In the fall, 93% of the plants exhibited fruit set in black mulch plots by 26 days after planting (data not presented). Within clear mulch plots, 78% of plants had fruit at this date, while 30% and 38% of plants had fruit in LSM and control plots, respectively. Nitrogen application methods had no effect on plant growth or fruit set in either experiment. In the fall experiment, mulching treatment had a significant impact on leaf size of the fourth youngest leaf evaluated in 4- and 6-week-old plants. Seedlings grown under polyethylene mulches exhibited up to 50% greater leaf area and 60% greater fresh leaf weight than those in LSM or control treatments (Table 1). In warm weather conditions, polyethylene mulches may provide a more suitable rooting environment, thus enhancing nutrient or water absorption, and improving overall plant growth (18). Nitrogen application method had no effect on seedling growth up to six weeks after planting (Table 1).

TABLE 1. Influence of mulching treatments averaged over N application method on leaf fresh weight and leaf area from squash four and six weeks after planting in August of 1990.[a]

	4 weeks		6 weeks	
Mulch type	Leaf fresh weight (g)	Leaf area (cm^2)	Leaf fresh weight (g)	Leaf area (cm^2)
Clear	10.5	203.7	26.1	642.7
Black	7.6	153.2	25.4	654.5
LSM	3.5	99.1	16.7	462.0
Control	3.1	90.7	16.4	459.1
LSD (0.05)	2.1	69.9	2.1	224.4
Significance:				
Mulch	**	***	**	*
Nitrogen	NS	NS	NS	NS
Mulch × Nitrogen	NS	NS	NS	NS

NS, *, **, *** Nonsignificant or significant at $P = 0.05$, 0.01, or 0.001, respectively.

[a] Fresh weight and leaf area means are based upon 20 samples collected per treatment. The fourth youngest fully expanded leaf was randomly selected from 5 plants per plot over four replications.

Mulching Effects on Weed Control.—Weed control among mulching treatments was significantly different as estimated by visual ratings 3 weeks after planting. The percentage of ground cover by annual grass weeds averaged 39% for the LSM and 45% for the bareground treatments, while broadleaf weeds covered approximately 0.5% of LSM plots and 2% of bareground plots (Table 2). In comparison, there were no weeds under black plastic mulch within 60 cm of the squash row at three weeks after planting. At this point in the season, clear plastic mulch provided excellent weed suppression, although some weed growth under the plastic occurred later in the season. These findings were not unexpected, since colored polyethylene mulching materials have proven to

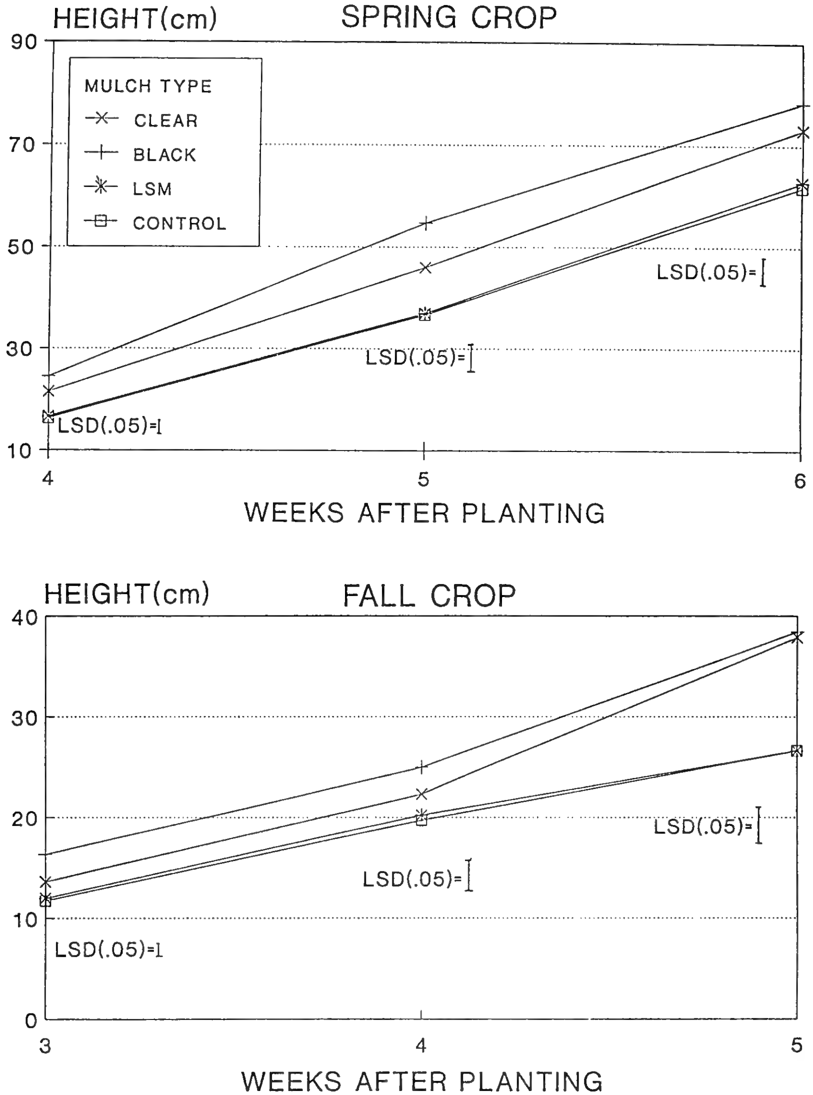


FIG. 1. The effect of mulching material averaged over nitrogen application method on squash seedling height in the spring and fall crops.

be highly effective in suppressing weed growth if the mulching material remains intact (9, 19). LSM provided poor ground coverage after application and effects upon weed suppression were minimal compared to the bareground treatment. Nitrogen application treatment had limited effects on grass weed growth within mulched plots three weeks after planting, with growth slightly increased in plots receiving a split application of N and fertigation versus a single broadcast application.

Incidence of Viral Disease.—Mosaic virus appeared late in the summer planting and infection was sporadic (data not presented). However, in the fall crop, mosaic viral infection was severe and the crop was seriously affected. Viral infection was due to a complex of mosaic viruses attacking the summer squash. Clear mulch treatments resulted in reduced viral incidence early in the fall growing season, with the control and LSM treatments exhibiting increased viral infection, as measured by visual ratings of viral incidence and viral severity (Table 3). Leaf chlorophyll content was

TABLE 2. Influence of mulching and nitrogen application method on the percentage of ground covered by weeds three weeks after planting summer squash in June 1990.

Nitrogen application (kg/ha)	Mulch type	Ground covered (%)	
		Grass[a]	Broadleaf[b]
112 Broadcast	Clear	0.0	0.0
	Black	0.0	0.0
	LSM	27.8	0.5
	Control	41.3	1.8
56 + 56 Broadcast plus Trickle	Clear	0.0	0.0
	Black	0.0	0.0
	LSM	49.3	0.5
	Control	48.0	1.8
	LSD (0.05)	13.5	1.4
Significance:			
Mulch		***	**
Nitrogen		*	NS
Mulch × Nitrogen		NS	NS

NS, *, **, *** Nonsignificant or significant at $P = 0.05$, 0.01, or 0.001, respectively.

[a] Grass weeds included giant foxtail, barnyardgrass and large crabgrass.

[b] Broadleaf weeds included common lambsquarters, redroot pigweed, ivy-leaf morning glory, galinsoga and prickly sida.

generally reduced in leaf samples collected from 6-week-old squash in LSM and control plots in comparison to clear polyethylene mulch treatments. Seedlings grown in polyethylene mulch treatments may have resisted viral infection more effectively due to their increased size and vigor as compared to unmulched controls. The clear plastic mulch may also exhibit some increased reflectivity, leading to reduced attractancy of whiteflies which are carriers of mosaic virus, to the mulching surface in comparison to black polyethylene or bareground. Lamont et al. (12) reported reduced viral incidence in plastic mulching materials with aluminum reflective strips. Interestingly, the number of whiteflies located on virally infected leaves in the control was up to three times greater than numbers observed on leaves of polyethylene grown plants (Table 3). This may be due to the attraction of whitefly to the color yellow (15) which was evident from reduced chlorophyll content in the control and LSM treatments. By seven weeks after planting, however, plants in all mulch treatments in the fall experiment were also severely infected with mosaic virus. Lamont et al. (12) also observed that various mulching treatments only delayed the onset of mosaic virus in summer squash.

Mulching and Nitrogen Treatment Effect on Fruit Number, Weight and Yield Response.—Total yield and fruit numbers were significantly greater ($P \geq 0.01$) in the summer season crop than in the fall crop (Figs. 2, 3). Although seasonal effects may have influenced yield, this was most likely due to increased viral disease incidence in the fall, which resulted in smaller plants (Fig. 1) with reduced yields. Mulching treatments had a significant effect on yields in both fall and late spring crops. Early, mid-season and total yields were greatest for plants grown on clear or black plastic mulches (Figs. 2, 3). Highest fruit numbers were also obtained using black plastic mulch. Yields produced with clear plastic were reduced compared to black plastic treatments, but significantly greater than those of LSM or bareground treatments. This is consistent with the findings of Bhella (3), Coffey and Ramsey (7), and Motsenbocker and Bonanno (14), who also reported increased yield and early production of other cucurbit crops when mulched with polyethylene materials. In both experiments, squash plants produced with plastic mulches were larger, flowered earlier and produced up to 50% greater overall yield. Fruit size was similar in all treatments. The modified growth environment and improved long term

TABLE 3. Influence of mulching treatments averaged over N application method on viral disease incidence in fall-grown summer squash six weeks after planting.

Mulch type	Chlorophyll content[a] (mg/g)	Number of whiteflies[a]/leaf	Viral incidence[b] (%)	Viral severity[c]
Clear	9.7	5.0	58.5	0.50
Black	9.3	3.3	90.0	0.53
LSM	6.1	6.0	95.0	0.60
Control	5.8	11.6	97.5	0.68
LSD (0.05)	3.6	8.0	22.0	0.16
Significance:				
Mulch	**	*	***	*
Nitrogen	NS	NS	NS	NS
Mulch × Nitrogen	NS	NS	NS	NS

[a] All measurements were taken from squash plants 6 weeks after planting. Leaf tissue for chlorophyll and whitefly analysis was collected from the fourth youngest fully expanded leaf from 5 plants per plot and the means presented were the averages of 20 samples.

[b] Viral incidence was calculated from visual ratings of 15 plants per plot and represents the percentage of infected plants in each plot.

[c] Viral severity was based on a 0 to 1 scale where 0 = no infection and 1 = complete infection. The index was calculated by obtaining a visual leaf rating (1–5 rating, 1 = slight infection and 5 = complete infection) × Number of affected leaves/Number of measured leaves × 5. Viral index ratings were calculated for five randomly selected plants per plot and means presented were the averages of 20 samples.

NS, *, **, *** Nonsignificant or significant at $P = 0.05$, 0.01, or 0.001, respectively.

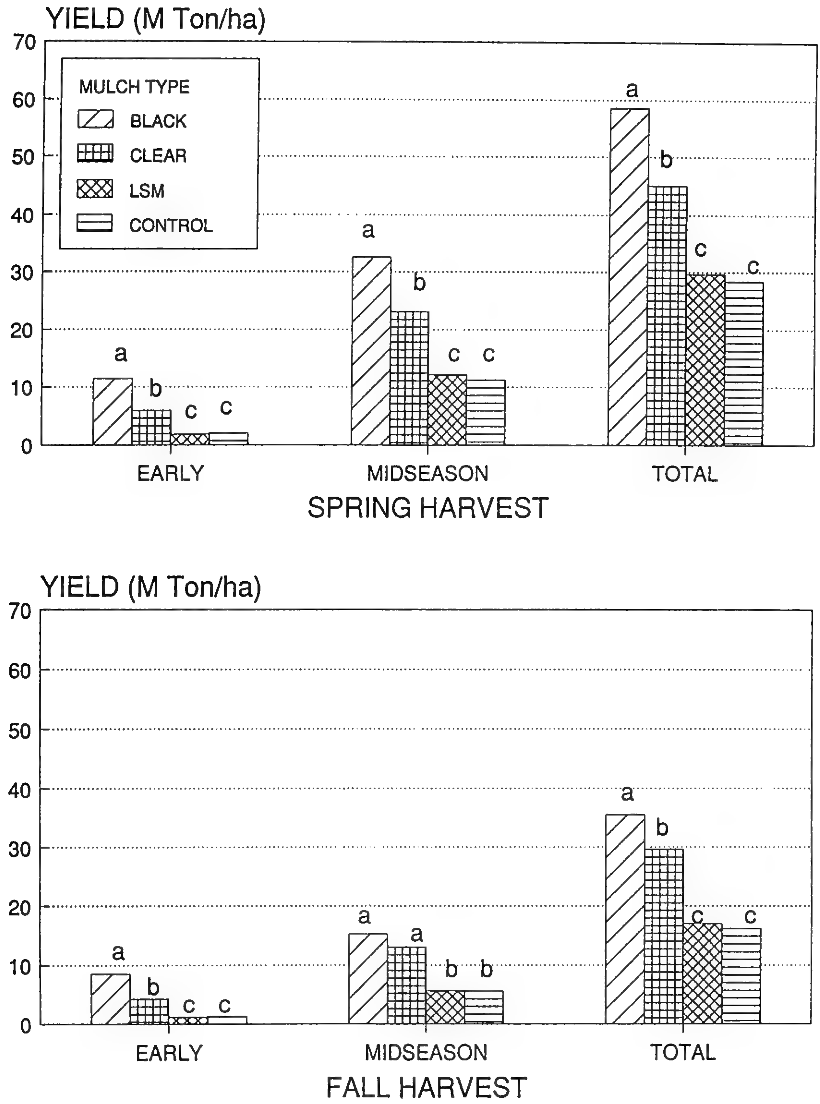


FIG. 2. The effect of mulching material averaged over nitrogen application method on squash yield in the spring and fall crops.

weed control provided by the presence of black polyethylene mulches most likely resulted in improved yield. Weed suppression was also greater in late season under black plastic mulches than clear (data not presented). The lack of extensive ground coverage provided by the suggested rate of LSM mulch and its deterioration over the course of the season likely accounted for the limited effect of this material on seedling growth or subsequent squash yields. Higher usage rates of LSM may be indicated. Split applications of nitrogen had no effect on seedling growth, yield or fruit number in either summer or fall plantings (data not presented). Preplant levels of soil N, along with N provided through broadcast application, were adequate to support squash growth and may account for the lack of observed N treatment effect. Depending upon early season market prices, the use of black polyethylene

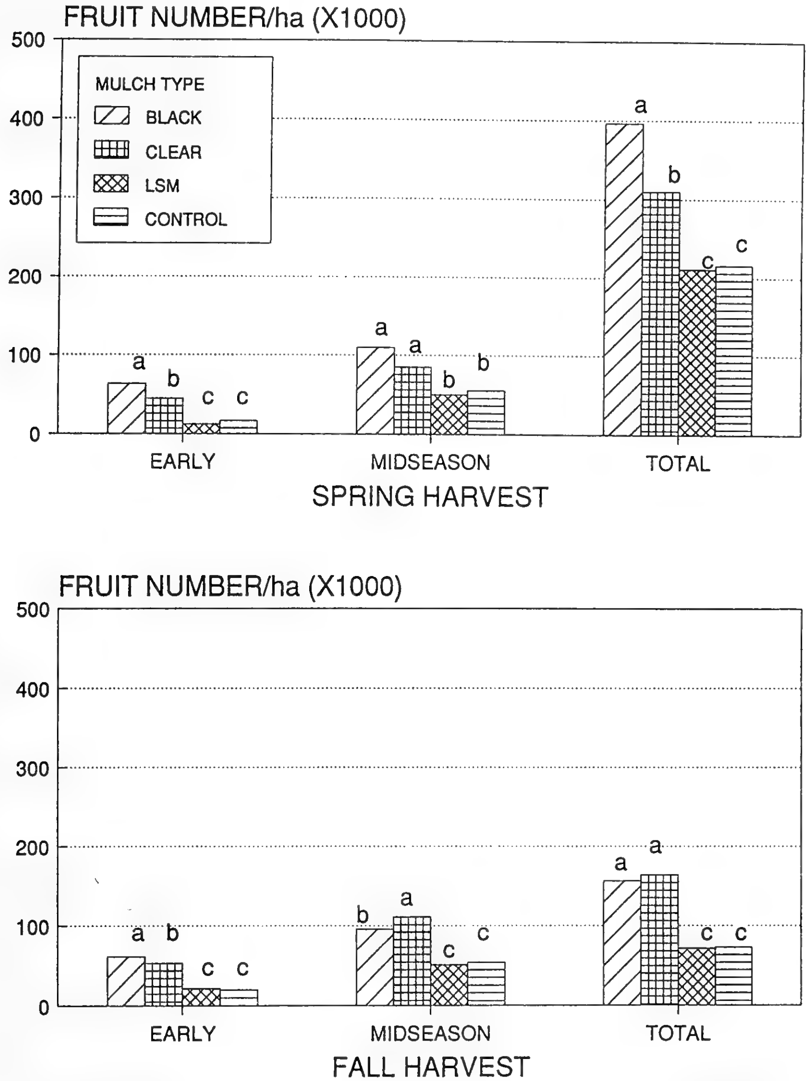


FIG. 3. The effect of mulching material averaged over nitrogen application method on squash fruit number in the spring and fall crops.

mulch may result in enhanced profitability in the summer or fall squash crop.

ACKNOWLEDGMENTS

This research was funded in part by U.S.D.A. Cooperative State Research Service Grant No. 86-CRSR-2864 and 88-34262-3419. Any findings, conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture. The authors would like to express their appreciation to Darrell B. Slone and Dean E. Knavel for their technical assistance.

LITERATURE CITED

1. Audette, J. L. and E. G. Pole. 1989. Latex spray mulch—available mulching system. Proc. Natl. Agr. Plastics Congr. 21:1–7.

2. Baldwin, R. E. 1989. Problems with summer squash. The Vegetable News Virginia 44:1–3.

3. Bhella, H. S. 1984. The effect of trickle irrigation and plastic mulch on zucchini. HortScience 19:410–411.

4. Bonanno, A. R. and W. J. Lamont. 1987. Effect of polyethylene mulches, irrigation method, and row covers on soil and air temperature and yield of muskmelon. J. Amer. Soc. Hort. Sci. 112:735–738.

5. Broadbent, L. 1957. Insecticidal control of the spread of plant viruses. Ann. Rev. Ent. 2:239–354.

6. Chalfant, R. B., C. A. Jaworski, A. W. Johnson, and D. R. Summer. 1977. Reflective film mulches, millet borers and pesticides: effects on watermelon mosaic virus, insects, nematodes, soil borne fungi and yield of yellow summer squash. J. Amer. Soc. Hort. Sci. 102:11–15.

7. Coffey, D. L. and P. W. Ramsey. 1987. Sequential cropping of vegetables on black plastic. Tennessee Farm and Home Science 144:19–21.

8. Duffus, G. E. and R. A. Flock. 1982. Whitefly-transmitted disease complex of the desert southwest. Calif. Agric. 36:4–6.

9. Hall, B. J. 1971. Perforated and non-perforated row covers for vegetables. Proc. Natl. Agr. Plastics Congr. 10: 131–143.

10. Hopen, H. J. 1965. Effects of black and transparent polyethylene mulches on soil temperature, sweet corn growth and maturity in a cool growing season. Proc. Amer. Soc. Hort. Sci. 86:415–420.

11. Inskeep, W. P. and P. R. Bloom. 1984. Extinction coefficients of chlorophyll *a* and *b* in N,N-dimethylformamide and 80% acetone. Plant Physiol. 77:483–485.

12. Lamont, W. J., K. A. Sorensen, and C. W. Averre. 1990. Painting aluminum strips on black plastic mulch reduces mosaic symptoms on summer squash. HortScience 25:1305.

13. Liss, H. and B. L. Pollack. 1975. A comparison of trickle and sprinkle irrigation of peppers on polyethylene mulch at different soil moisture regimes. Proc. Natl. Agr. Plastics Congr. 12:27–35.

14. Motsenbocker, C. E. and A. R. Bonnano. 1989. Row cover effects on air and soil temperatures and yield of muskmelon. HortScience 24:601–603.

15. Mound, L. A. 1962. Studies on the olfaction and color sensitivity of bemisia tabaci (Genn.) (Homoptera, Aleyrodidaee). Entomol. Exp. and Applic. 5:99–104.

16. Natwick, E. T. and D. Alfonso. 1985. Polyester covers protect vegetables from whitefly and virus disease. Calif. Agri. 4:21–22.

17. Price, J. F., D. J. Schuster, and D. E. Short. 1987. Recent advances in managing the sweet potato whitefly on poinsettia. Univ. of Florida, Bradenton, GCREC Research Report 21:1–5.

18. Schales, F. D. and R. Sheldrake. 1965. Mulch effects on soil conditions and musk-melon response. Proc. Amer. Soc. Hort. Sci. 88:425–480.

19. Shadbolt, C. A. and O. D. McCoy. 1960. Temperature and plant responses to paper and plastic protectors on cantaloupes. Hilgardia 30:247–266.

20. Sheldrake, R. 1967. Plastic mulches. Cornell Univ. Ext. Bull. 1180:1–8.

21. Shoji, G. 1977. Drip irrigation. Scientific Amer. 237:62–68.

22. Smittle, D. A. and E. D. Threadgill. 1982. Response of squash to irrigation, nitrogen fertilization and tillage systems. J. Amer. Soc. Hort. Sci. 10:437–440.

23. Stansell, J. R. and D. A. Smittle. 1980. Effects of irrigation regimes on yield and water use of snap bean (*Phaseolus vulgaris* L.). J. Amer. Soc. Hort. Sci. 105:869–873.

24. Stansell, J. R. and D. A. Smittle. 1989. Effect of irrigation regimes on yield and water use of summer squash. J. Amer. Soc. Hort. Sci. 114:196–199.

25. Waggoner, P. E., P. M. Miller, and H. C. De Roo. 1960. Plastic mulching, principles, and benefits. Conn. Agr. Expt. Sta. Reports 634:124–128.

Trans. Ky. Acad. Sci., 54(3–4), 1993, 73–75

Differential Filters

Paul E. Bland[1]

Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

If δ is a derivation on a ring R and $\mathfrak{R}$ is a topologizing filter of right ideals of R, then $\mathfrak{R}$ is said to be a differential filter if for every right ideal $K \in \mathfrak{R}$, there is a right ideal $I \in \mathfrak{R}$ such that $\delta(I) \subseteq K$. We show that if $\mathfrak{R}$ is a differential filter of right ideals in a ring R, then every derivation on a right R-module M has a unique extension to its module of quotients. The main purpose of this paper is to show that differential filters exist for rings which satisfy the descending chain condition on right ideals in $\mathfrak{R}$. This leaves open the more interesting question regarding the existence of differential filters for general associative rings with identity.

Introduction

A derivation[2] δ on a ring R is an additive mapping $\delta: R \to R$ such that $\delta(rs) = \delta(r)s + r\delta(s)$. A ring R together with a derivation is called a differential ring. If M is a right R-module, then an additive mapping $\delta': M \to M$ such that $\delta'(mr) = \delta'(m)r + m\delta(r)$ is said to be a derivation on the module M. δ will be used to denote both a derivation on a ring R and a derivation on a module M. The context of the discussion should make it clear which is being considered and should cause no confusion.

A filter $\mathfrak{R}$ of right ideals in a ring R is a nonempty collection of right ideals of R which satisfy the following two conditions:

1. If $K \in \mathfrak{R}$ and $x \in R$, then $(K : x)$[3] $\in \mathfrak{R}$.
2. If $K \in \mathfrak{R}$ and I is a right ideal of R such that $(I : x) \in \mathfrak{R}$ for each $x \in K$, then $I \in \mathfrak{R}$.

It is well known [6] that if $\mathfrak{R}$ is such a filter in R, then $\mathfrak{R}$ forms a fundamental system of neighborhoods for $0 \in R$ in a topology $\mathcal{T}$ on R which makes R into a topological ring. Moreover, conditions 1 and 2 can be shown to imply that:

3. If $I, K \in \mathfrak{R}$, then $I \cap K \in \mathfrak{R}$.
4. If $I \in \mathfrak{R}$ and $I \subseteq K$ where K is a right ideal of R, then $K \in \mathfrak{R}$.
5. If $I, K \in \mathfrak{R}$, then $IK \in \mathfrak{R}$.

Conditions 3 and 4 justify calling $\mathfrak{R}$ a filter of right ideals in R.

If τ is a hereditary torsion theory on Mod R, the category of right R-modules, and $\mathfrak{R}$ is the associated filter of right ideals of R, the module of quotients $Q_\tau(M)$ of a right R-module M is given by the direct limit

$$Q_\tau(M) = \varinjlim \mathrm{Hom}_R(K, M/T(M))$$

where $K \in \mathfrak{R}$ and T(M) is the torsion submodule of M. Each element of $Q_\tau(M)$ is an equivalence class of R-linear mappings where two mappings are equivalent if they agree on some $K \in \mathfrak{R}$. There is a canonical R-linear mapping $\varphi: M \to Q_\tau(M)$ which is the canonical surjection $\eta: M \to M/T(M)$ followed by the injective map $k: M/T(M) \to Q_\tau(M)$ which is defined by $k(x) = [f_x]$ where $f_x: K \to M/T(M): r \to xr$, $K \in \mathfrak{R}$. Now let R be a differential ring with derivation δ and suppose that $\delta: M \to M$ is a derivation on the right R-module M. A derivation $\delta^*: Q_\tau(M) \to Q_\tau(M)$ is said to extend the derivation $\delta: M \to M$ to $Q_\tau(M)$ if the diagram

$$\begin{array}{ccc} M & \xrightarrow{\varphi} & Q_\tau(M) \\ \delta\downarrow & & \downarrow\delta^* \\ M & \xrightarrow{\varphi} & Q_\tau(M) \end{array}$$

is commutative. We have shown in [1] that such a derivation δ on M has a unique extension to $Q_\tau(M)$ if and only if the torsion submodule T(M) of M is a δ-module, that is, if and only if $\delta(T(M)) \subseteq T(M)$. We now define a differential filter $\mathfrak{R}$ in a ring R with derivation δ to be a filter in R such that for each $K \in \mathfrak{R}$ there is an $I \in \mathfrak{R}$ such that $\delta(I) \subseteq K$. The reader can consult [4] or [6] for the standard results and terminology on torsion theory, while recent

[1] This work was supported by Eastern Kentucky's released time program.

[2] The motivation for the definition of a derivation on a ring R is the formula for the derivative of the sum of two functions and the formula for the derivative of the product of two functions.

[3] If K is a right ideal of R, then so is $(K : x) = \{r \in R \mid xr \in K\}$.

results on derivations can be found in [2], [3] and [5].

DISCUSSION

The following proposition shows that if $\mathfrak{R}$ is a differential filter in R, then every derivation on a module has a unique extension to its module of quotients.

Proposition 1.—Let R be a differential ring with derivation δ and suppose that $\mathfrak{R}$ is a differential filter in R. If δ is a derivation on a right R-module M, then δ has a unique extension to the module of quotients of M.

Proof.—We know from the remarks above that it suffices to show that $\delta(T(M)) \subseteq T(M)$. If $m \in T(M)$, there is a $K \in \mathfrak{R}$ such that $mK = 0$. Since $\mathfrak{R}$ is a differential filter, there is an $I \in \mathfrak{R}$ such that $\delta(I) \subseteq K$. But $I \cap K \in \mathfrak{R}$, and so if $k \in I \cap K$, then $0 = \delta(mk) = \delta(m)k + m\delta(k) = \delta(m)k$ since $m\delta(k) = 0$. Thus, $\delta(m)(I \cap K) = 0$ and so $\delta(m) \in T(M)$. Hence, $\delta(T(M)) \subseteq M$.

We now turn our attention to the existence question for differential filters. We show that under certain conditions, if $\mathfrak{R}$ is a filter in a ring R with derivation δ, then there exists a differential filter $\mathfrak{R}_\delta$ such that $\mathfrak{R}_\delta \subseteq \mathfrak{R}$. Consequently, by Proposition 1, we can conclude that every derivation on a module M can be extended uniquely to the module of quotients $Q_{\delta(\tau)}(M)$ of M where $\delta(\tau)$ is the hereditary torsion theory induced by $\mathfrak{R}_\delta$.

If n is a positive integer, δ^n will denote δ composed with itself n times while δ^0 will denote the identity mapping on R. δ^n is an additive mapping but not necessarily a derivation on R when $n \neq 1$.

Proposition 2.—Let R be a differential ring with derivation δ and suppose that I is a right ideal of R. If $x \in I$ and $r \in R$, then for each integer $n \geq 0$, $\delta^k(x)\delta^{n-k}(r) \in \Sigma_{j=0}^k \delta^j(I)$ for $k = 0, 1, 2, \ldots, n$.

Proof.—If $n = 0$, then $k = 0$ and so $\delta^k(x)\delta^{n-k}(r) = xr \in I = \Sigma_{j=0}^k \delta^j(I)$. Now make the induction hypothesis that the Proposition is true for $n = N$ and all k such that $0 \leq k \leq N$. Note that if $k = 0$, $\delta^k(x)\delta^{N+1-k}(r) = x\delta^{N+1}(r) \in I = \Sigma_{j=0}^k \delta^j(I)$. Hence, the Proposition holds for $n = N + 1$ and $k = 0$. Next suppose the Proposition holds for $n = N + 1$ and k where $0 \leq k \leq N$ and let's show that the Proposition holds for $n = N + 1$ and $k + 1$. Now if $0 \leq k \leq N$, then $\delta^k(x)\delta^{N-k}(r) \in \Sigma_{j=0}^k \delta^j(I)$ by our induction hypothesis. Thus, we see that $\delta(\delta^k(x)\delta^{N-k}(r)) \in \delta(\Sigma_{j=0}^k \delta^j(I)) \subseteq \Sigma_{j=0}^{k+1} \delta^j(I)$. But $\delta(\delta^k(x)\delta^{N-k}(r)) = \delta^{k+1}(x)\delta^{N-k}(r) + \delta^k(x)\delta^{N+1-k}(r)$ and $\delta^k(x)\delta^{N+1-k}(r) \in \Sigma_{j=0}^k \delta^j(I)$ since by assumption the Proposition is true for $n = N + 1$ and k where $0 \leq k \leq N$. Now $\Sigma_{j=0}^k \delta^j(I) \subseteq \Sigma_{j=0}^{k+1} \delta^j(I)$ and so $\delta^k(x)\delta^{N+1-k}(r) \in \Sigma_{j=0}^{k+1} \delta^j(I)$. Hence, it follows that $\delta^{k+1}(x)\delta^{N+1-(k+1)}(r) = \delta^{k+1}(x)\delta^{N-k}(r) \in \Sigma_{j=0}^{k+1} \delta^j(I)$. Thus, the Proposition is true for $n = N + 1$ and $k + 1$ where $0 \leq k \leq N$. Hence, it follows that the Proposition holds for $n = N + 1$ and $k = 0, 1, 2, \ldots, N + 1$. The Proposition now follows by induction.

Corollary 1.—If $x \in I$ and $r \in R$, then $\delta^n(x)r \in \Sigma_{j=0}^n \delta^j(I)$ for every integer $n \geq 0$.

Proof.—Let $k = n$ in Proposition 2.

Proposition 3.—Let R be a differential ring with derivation δ. If I is a right ideal of R, then so is $\Sigma_{j=0}^\infty \delta^j(I)$.

Proof.—This follows immediately from Corollary 1 and the fact that for any integer $n \geq 0$, δ^n is an additive mapping.

Proposition 4.—Let R be a differential ring with derivation δ. If I is a right ideal of R, then $\delta^n(\cap_{j=0}^n (I : \delta^j(x))) \subseteq (\Sigma_{j=0}^n \delta^j(I) : x)$ for each $x \in R$ and all integers $n \geq 0$.

Proof.—Using an inductive proof similar to that of Proposition 2, we can show that if I is a right ideal of R and $x \in R$, then for any integer $n \geq 0$, $r \in \cap_{j=0}^n (I : \delta^j(x))$ implies that $\delta^{n-k}(x)\delta^k(r) \in \Sigma_{j=0}^k \delta^j(I)$ for $k = 0, 1, 2, \ldots, n$. Thus, when $k = n$ we see that $r \in \cap_{j=0}^n (I : \delta^j(x))$ gives $x\delta^n(r) \in \Sigma_{j=0}^n \delta^n(I)$. Whence, $\delta^n(r) \in (\Sigma_{j=0}^n \delta^n(I) : x)$.

The following proposition is an analog of the well-known Leibniz formula for the nth derivative of the product of two functions.

Proposition 5.—If R is a differential ring with derivation δ and $x, y \in \mathfrak{R}$, then $\delta^n(xy) =$

$$\Sigma_{j=0}^k \binom{n}{k} \delta^{n-k}(x)\delta^k(y).$$

Proof.—The proof follows easily by induction and the fact that $\binom{n}{k} + \binom{n}{k-1} = \binom{n+1}{k}$ for any integer $n \geq 0$ and any integer k such that $0 \leq k \leq n$ where $\binom{n}{k} = \frac{n!}{k!(n-k)!}$.

We now assume that the right ideals in $\mathfrak{R}$ satisfy the descending chain condition. For example, if R is an Artinian ring, this condition holds.

Proposition 6.—Let R be a differential ring with derivation δ and suppose that the right ideals of a filter $\mathfrak{R}$ satisfy the descending chain condition. Then $\mathfrak{R}_\delta = \{K \in \mathfrak{R} \mid$ there is an $I \in \mathfrak{R}$ such that $\delta^n(I) \subseteq K$ for all integers $n \geq 0\}$ is a differential filter in R.

Proof.—First let's show that $\mathfrak{R}_\delta$ is a filter. Suppose $K \in \mathfrak{R}_\delta$ and that $x \in R$. If I is a right ideal in $\mathfrak{R}$ such that $\delta^n(I) \subseteq K$ for all $n \geq 0$, then $J \subseteq K$ where J is the right ideal $\Sigma_{j=0}^{\infty} \delta^j(I)$ given in Proposition 3. Now $(I : \delta^j(x)) \in \mathfrak{R}$ for each $j \geq 0$ and so since the right ideals in $\mathfrak{R}$ satisfy the descending chain condition, $\cap_{j=0}^{\infty}(I : \delta^j(x)) \in \mathfrak{R}$. By Proposition 4, $\delta^n(\cap_{j=0}^{n}(I : \delta^j(x))) \subseteq (\Sigma_{j=0}^{n} \delta^j(I) : x)$ and so if $S = \cap_{j=0}^{\infty}(I : \delta^j(x))$, $\delta^n(S) \subseteq \delta^n(\cap_{j=0}^{n}(I : \delta^j(x))) \subseteq (\Sigma_{j=0}^{n} \delta^j(I) : x) \subseteq (\Sigma_{j=0}^{\infty} \delta^j(I) : x) \subseteq (K : x)$ for all $n \geq 0$. Thus, we have found a right ideal S in $\mathfrak{R}$ such that $\delta^n(S) \subseteq (K : x)$ for all $n \geq 0$. Therefore, $(K : x) \in \mathfrak{R}_\delta$.

Next suppose that I is a right ideal of R and let $K \in \mathfrak{R}_\delta$ be such that $(I : x) \in \mathfrak{R}_\delta$ for all $x \in K$. We must show that $I \in \mathfrak{R}_\delta$. Since $(I : x) \in \mathfrak{R}_\delta$ for each $x \in K$ there is an $I_x \in \mathfrak{R}$ such that $\delta^n(I_x) \subseteq (I : x)$. Thus, $x\delta^n(I_x) \subseteq I$ for each $x \in K$ and all integers $n \geq 0$. If $B = \cap_{x \in K} I_x$, then B is in $\mathfrak{R}$ because the right ideals in $\mathfrak{R}$ satisfy the descending chain condition. Hence, $K\delta^n(B) \subseteq I$ for each $n \geq 0$. Since $K \in \mathfrak{R}_\delta$, there is a right ideal $A \in \mathfrak{R}$ such that $\delta^n(A) \subseteq K$ for each integer $n \geq 0$. Now $AB \in \mathfrak{R}$ and so if $xy \in AB$ where $x \in A$ and $y \in B$, then, by Proposition 5, $\delta^n(xy) = \Sigma_{k=0}^{n} \binom{n}{k} \delta^{n-k}(x)\delta^k(y)$. Now $\delta^{n-k}(x) \in \delta^{n-k}(A) \subseteq K$ and $\delta^k(y) \in \delta^k(B)$ where $k = 0, 1, 2, \ldots, n$. Hence, $\delta^{n-k}(x)\delta^k(y) \in K\delta^k(B) \subseteq I$ for each k such that $0 \leq k \leq n$. Thus, $\delta^n(xy) \in I$ and from this it follows easily that $\delta^n(AB) \subseteq I$ for each integer $n \geq 0$. Consequently, $I \in \mathfrak{R}_\delta$.

Finally, let's show that $\mathfrak{R}_\delta$ is a differential filter. If $K \in \mathfrak{R}_\delta$, there is an $I \in \mathfrak{R}$ such that $\delta^n(I) \subseteq K$ for all integers $n \geq 0$. Thus, if $J = \Sigma_{j=0}^{\infty} \delta^j(I)$, then $J \in \mathfrak{R}$ since $J \supseteq I$. Now by construction, $\delta^n(I) \subseteq J$ for each integer $n \geq 0$ and so $J \in \mathfrak{R}_\delta$. But $\delta(J) \subseteq K$ and so $\mathfrak{R}$ is a differential filter. Incidentally, $\mathfrak{R}_\delta \neq \varnothing$ since $J \in \mathfrak{R}_\delta$ and so the proof is complete.

LITERATURE CITED

1. Bland, P. 1992. A note on derivations and modules of quotients. Trans. Ky. Acad. of Sci. 53:162–164.

2. Bresar, M. and J. Vukman. 1990. On left derivations and related mappings. Proc. Amer. Math. Soc. 100:7–16.

3. Chaung, C. 1990. On compositions of derivations of prime rings. Proc. Amer. Math. Soc. 108:647–652.

4. Golan, J. 1986. Torsion theories. Longman Scientific and Technical. Copublished with John Wiley and Sons Inc., New York.

5. Nowicki, A. 1989. Derivations satisfying polynomial identities. Colloq. Math. 57:35–43.

6. Stenstrom, B. 1975. Rings of quotients. Springer-Verlag, New York, Berlin.

Trans. Ky. Acad. Sci., 54(3–4), 1993, 76–81

Comparison of the Preliminary Results of the Nationwide Urban Runoff Program with the Results of a Louisville, Kentucky Runoff Assessment

JENNIFER MCGEHEE MARSH

Biology Department, University of Louisville, Louisville, Kentucky

ABSTRACT

First flush (first 20 minutes) and composite (first 3 hours) samples of stormwater runoff were collected during a one year period (1991–1992) from 6 sites in the Louisville metropolitan area, Kentucky. Each collection was analyzed for organic and inorganic compounds, pesticides, nutrients, dissolved solids, dissolved oxygen, turbidity, alkalinity, conductivity, hardness, pH and temperature. The toxicity of the water was then determined by bioassay of fathead minnows (*Pimphales promelas* Rafinesque).

One of the objectives of the study was to compare the toxicity of Louisville's runoff with that of cities involved in the Nationwide Urban Runoff Program (NURP). The results of the NURP study showed that all 13 metals on the U.S. EPA's priority pollutant list were in the runoff samples. Louisville's runoff contained high levels of these metals, but none exceeded criteria. Organic priority pollutants were detected in Louisville's runoff less frequently and at lower concentrations than in the cities participating in the NURP study. However, it exceeded criteria in amounts of lindane, endrin, methoxychlor, 2,4-D, and in one collection, DDT. Coliform bacteria were present in high levels in both NURP and Louisville's runoff. Nutrient concentrations were higher in Louisville's runoff than in the NURP cities.

INTRODUCTION

Nonpoint sources of pollution (NPS) are probably the most important water-quality issue today (1, 2, 3, 4, 5, 6, 7, 8, 9). This is particularly true when the interrelationship between the management of hazardous wastes, groundwater contamination, and abandoned toxic waste dumps is considered.

Pollution in urban runoff includes air pollutants that have settled in streets, erosion from construction sites that is contaminated with construction chemicals such as pesticides, petroleum products, solvents, asphalt, acids, and salts, deicing chemicals, litter, and animal refuse (4). Increased amounts of impervious surfaces in urban areas also dramatically increase the amount and speed of urban runoff.

The effects of urban nonpoint sources of pollution are being felt and in some cases are pronounced (10). Nonpoint sources of pollution are degrading vulnerable waters where they have caused increased turbidity and algal growth, and are also suspected as a source of increased counts of fecal bacteria that are flowing into streams after storms (11). Estimations of as much as 90% of total suspended solids and 80% of Biological Oxygen Demand (BOD) are believed to have been generated by urban runoff at some locations (12). Results of the U.S. EPA's National Urban Runoff Program (13, 14) showed that lead, zinc, and copper were detected in 75% of all samples, and chromium and arsenic were found in over half of all runoff sampled.

New U.S. EPA regulations (15) are requiring that cities test to determine the magnitude of urban NPS problems and to develop plans to capture and treat stormwater runoff. These regulations require that nonpoint sources of pollution become point sources when they enter storm sewers. In addition, the U.S. EPA is requiring all cities with more than 100,000 people to obtain permits to discharge stormwater runoff to streams and lakes. Cities that carry out industrial activities, such as landfills, wastewater treatment plants, vehicle care and maintenance, and airports, must also obtain U.S. EPA permits. New construction sites of more than 5 acres will require permits as will industries which produce or process energy, chemicals, and metals, treat or store hazardous waste or have hazardous waste disposal sites, build ships, manufacture paper or lumber, and facilities that leave material exposed to stormwater.

Municipalities had to submit Part One applications to the U.S. EPA by the end of 1992. This application covers management strategies, such as developing wet-weather monitoring programs to quantify sources of pollutants during storm events, and generating site maps that can be used to locate illegal connections to storm sewers and stormwater outfalls. It also includes a summary of historical data on leaks and spills (15).

Within a year of completing the Part One application, cities will have to submit Part Two applications. The major aspects of this application are the assessment of pollution loadings through wet-weather sampling and computer modeling, and the development of strategies to manage runoff from residential and commercial areas, landfills and key industries, construction sites, and illegal discharge into storm sewers.

METHODS

A field monitoring program was designed and conducted during 1991 and 1992, to collect first-flush stormwater from 6 drainage basins within Jefferson County, Kentucky (Greater Louisville Area). The samples collected were of rainwater which had accumulated on surfaces and was delivered to a nearby storm drain. After these samples were analyzed for chemical composition (Table 1), bioassays were performed using fathead minnows (*Pimphales promelas* Rafinesque) in sequential dilutions of the sample water. Finally, an LC_{50}, or the concentration of runoff that was lethal to 50% of the test fish, was calculated for each sample using the Trimmed Spearman-Karber statistical method (16).

TABLE 1. Water quality constituents measured in first flush and composite samples. Dissolved oxygen, pH, and water temperature were also recorded daily throughout each bioassay.

Dissolved oxygen	pH
Water temperature	Air temperature
Specific conductance	Alkalinity
Hardness	Turbidity
Biochemical oxygen demand (BOD)	Chemical oxygen demand (COD)
Fecal coliform	Fecal streptococcus
Oil and grease	Surfactants
Nitrite	Nitrate
Organic nitrogen	Ammonia
Orthophosphorus	Total phosphorus
Total dissolved solids	Total suspended solids
Total volatile suspended solids	
Volatile organic carbon (VOC)	Organic carbon (TOC)
Phenol	Lindane
Endrin	Methoxychlor
Chlordane	Toxaphene
2,4-D	2,4,5-TP
Arsenic	Barium
Beryllium	Cadmium
Calcium	Chlorine, residual
Chromium	Copper
Cyanide	Iron
Lead	Magnesium
Mercury	Nickel
Selenium	Silver
Zinc	

The watersheds included in the study sites were selected to provide a range of urban conditions. Sampling locations were selected so as to be spatially distributed throughout each land use setting and to be unbiased with respect to known or suspected local problem areas.

Land use in the residential (R_1) watershed is typical medium density single family dwellings. This site has a soil type that allows good infiltration. The R_2 subbasin is a low density, residential area with large houses on small lots. Landscape and lawn care companies are common throughout the year and new house construction, as well as additions on existing houses, is also ongoing.

The Strip Commercial (SC_1) subbasin is a long, narrow catchment on a main highway into the city. It is heavily congested with shopping centers, car lots, and traffic. A second Strip Commercial (SC_2) has the same geographic layout and the same traffic patterns as the SC_1 but is in the east end of the city. An area with heavy commuter traffic, it has just undergone extensive road expansion.

The Central Business District (CBD) catchment is in a typical high-density downtown (metropolitan) area. It is in the middle of the city's medical complex and is also a heavily congested traffic area. Impervious coverage is estimated at 98%.

The Light Industrial (LI) subbasin drains a watershed that includes a truck manufacturing plant and a large distribution center. Population density is sparse but the manufacturing plant causes episodic traffic congestion and the distribution center receives mainly large-truck traffic. A railroad mainline and several spurs run through the watershed.

During the study period, 72 samples were obtained at drain outfalls during the first 20 minutes of each storm's runoff (first flush) and over the first 3 hours of selected storms (flow weighted composite). The method for collecting the first-flush storm runoff was constant time-constant volume, recommended by the U.S. EPA (17), in which samples of equal volume were taken at equal increments of time and combined to make an average sample. To prepare the composite samples, water was collected for the duration of the storm event or the first 3 hours, whichever was shorter, and sample aliquots were combined according to each sample's percentage contribution to the total storm event. Sampling at each of the outfalls followed a dry period of at least 96 hours and were of storms 0.1 inches or greater, as required by the U.S. EPA (17).

Sampling was conducted during a variety of storm events of differing duration, intensity and antecedent conditions, and during all seasons of the year. Climatic conditions were recorded during each rain and between rains.

Water quality may be characterized by literally thousands of properties, elements, and compounds. For some water-quality issues, the choice of target variables is a simple task, as in the substances relevant to the issues of nutrient enrichment and sedimentation and the chemicals present in acidification and salinity, all of which are of limited number and relatively inexpensive to analyze. On the other hand, the selection of target variables for the issue of organic contamination is much more difficult because of the large number of substances to consider and their high cost of measurement. The selection of organic target compounds is further complicated by the fact that there are an estimated 60,000 synthesized organic compounds currently being manufactured, with an unknown number of byproducts and degradation products (19). Because health and environmental concerns are primarily associated with synthetic rather than naturally occurring organic compounds, analyses of the former were emphasized.

The timing and duration of collections were established as a compromise between achieving a "snapshot" of conditions and observing a wide range of conditions over each season. Because the study was an assessment (as opposed to monitoring), collections were periodic rather than continuous.

Analyses

A prescribed set of study approaches and protocols for sample collection and handling, laboratory analyses, and quality assurance were followed so that the data collected could be interpreted on a nationally consistent set of water quality constituents (17, 18). Training sessions and discussions about protocols were held to ensure that standard procedures were followed.

Characterization of base neutral and acid compounds, organochlorine pesticides and PCBs, and volatile organic compounds (VOCs) were according to the EPA's Methods 625, 608, and 624, respectively (17). Methods used for determining organic and inorganic substances were those recommended by U.S. Geological Survey (USGS) Techniques of Water Resources Investigations (20).

Because many chemical, biological, and physical reactions or processes can occur in samples between sampling and analysis, resulting in losses of organic contaminants or formation of artifacts, recommended preservation techniques were conducted (21). Samples were immediately chilled and stored in the dark to prevent or decrease biological activity and to slow chemical reactions and loss of volatile compounds. A portion of each sample was preserved with HCl, decreasing the pH to less than 2, to prevent biodegradation of aromatic VOCs.

Digestions for total recoverable metals were performed by adding 5% 6 M HCl to the water sample and heating to just below boiling to reduce the volume by 20%. The sample was then brought back to its initial volume using a solution of 5% 6 M HCl in nanopure water.

Sampling at each of the outfalls followed a dry period of at least 96 hours and was of storms 0.1 inches or greater, as required by the U.S. EPA (17). Data that were generated from the water analyses were used to compare the toxicity of the runoff with that of the cities which participated in the preliminary Nationwide Urban Runoff Program (Table 2).

RESULTS AND DISCUSSION

The NURP study consisted entirely of chemical analyses and did not include bioassays. For this reason, it was not possible to compare Louisville's effluent toxicity results with those of other cities. However, it was possible to compare results of the chemical analyses.

The results of the NURP study (13, 14) showed that the heavy metals (copper, lead, and zinc in particular) were the most prevalent

TABLE 2. Cities participating in the National Urban Runoff Program (NURP) and their U.S. EPA regions.

Location	U.S. EPA Region
Boston, MA (2)	I
Durham, NH	II
Long Island, NY	II
Lake George, NY	II
Rochester, NY	II
Washington, DC	III
Baltimore, MD	III
Winston-Salem, NC	IV
Myrtle Beach, SC	IV
Knoxville, TN	IV
Tampa, FL	IV
Champaign-Urbana, IL	V
Lansing, MI	V
Detroit, MI	V
Ann Arbor, MI	V
Milwaukee, WI	V
Little Rock, AR	VI
Austin, TX	VI
Kansas City, KS/MO	VII
Denver, CO	VIII
Rapid City, SD	VIII
Salt Lake City, UT	VIII
San Francisco, CA	IX
Fresno, CA	IX
Eugene, OR	X
Bellevue, WA	X

TABLE 3. Percent of collections which either contained measurable amounts (P) or exceeded Federal criteria limits (E) of twenty constituents. Both first flush (F) and composite (C) samples were analyzed from fifteen storm events.

Constituent	% P	% E
(F) Total Phos	100	100
(C) Total Phos	100	100
(F) SO4	100	100
(F) Chloride	100	86
(F) Copper	67	0
(C) Copper	53	0
(F) Iron	100	40
(C) Iron	100	20
(F) Lead	16	0
(C) Lead	8	0
(F) Zinc	93	0
(C) Zinc	93	0
(F) Beryllium	18	0
(F) Mercury	31	0
(C) Mercury	15	0
(F) Chromium	92	0
(C) Chromium	58	0
(C) Cadmium	08	0
(F) Arsenic	18	0
(F) Antimony	29	0
(F) Silver	08	0
(F) Selenium	07	0
(F) Lindane	53	47
(F) Endrin	18	18
(F) Methoxy	63	63
(F) 24D	100	08
(F) 245TP	18	0
(F) DDT	08	08
(F) Phenol	45	0
(F) Xylene	27	0
(F) Fecal Coliform	100	17
(F) Fecal Strep	100	08

priority pollutants. All 13 metals on U.S. EPA's priority pollutants list were detected in the urban runoff samples, and copper, lead, and zinc were found in 91% of the samples. Freshwater acute criteria were exceeded by copper concentrations in 47% of the samples, and by lead in 23%. Regarding human toxicity, the most significant pollutants were lead and nickel, and for human carcinogenesis, arsenic and beryllium.

The exceedances noted above do not necessarily imply that an actual violation of standards existed. Rather, the enumeration of exceedances serves as a screening function to identify those heavy metals whose presence in urban runoff warrants high priority for further evaluation.

Unusually high concentrations of copper and zinc can indicate acid rain effects on material used for gutters, culverts, and roofing. The southern, southeastern, and northwestern regions of the country seemed to be the most susceptible to negative aquatic life effects due to heavy metals. It is quite plausible that acid rain could increase the level of pollutants in urban runoff and may transform them to more toxic and more easily assimilated forms. Although Louisville runoff contained high levels of these metals, no samples exceeded Federal criteria (Table 3).

The organic priority pollutants were detected in the Louisville runoff less frequently and at lower concentrations than the heavy metals in the cities participating in the NURP study. Sixty three of a possible 106 organics were detected in NURP samples. The most commonly found organic was the plasticizer bis (2-ethylhexl) phthalate (22%), followed by the pesticides ∂-BHC (20%). Neither of these products were found in the analyses of Louisville's runoff. In the category of human carcinogens, the NURP study found that lindane, chlordane, penanthrene, pyrene, and chrysene

TABLE 4. Federal criteria for 8 constituents which exceeded the limits, and the maximum, minimum, and mean of each constituent at each collection site.

Constituent	Federal criteria	R_1	R_2	SC_1	SC_2	LI
Total phos (mg/l)	0.01 mg/l	*	0.21	0.37	0.78	*
		*	0.21	0.24	0.72	*
		*	0.21	0.31	0.75	*
Copper (mg/l)	10 μg/l	*	0.025	0.026	0.059	*
		*	0.017	0.019	0.015	*
		*	0.021	0.023	0.037	*
Iron (mg/l)	3 μg/l	*	5.97	6.17	4.42	1.21
		*	2.32	1.71	4.24	1.21
		*	4.15	3.94	4.33	1.21
Lead (mg/l)	50 μg/l	*	0.055	0.06	0.08	*
		*	0.055	0.06	0.06	*
		*	0.055	0.06	0.07	*
Chloride (mg/l)	10 mg/l	11.0	340.0	130.0	1100.0	51.0
		1.6	88.0	60.0	70.0	37.0
		6.3	214.0	95.0	585.0	44.0
Sulfate (mg/l)	1–3 mg/l	19.0	91.0	68.0	37.0	38.0
		7.2	23.0	6.5	12.0	11.0
		13.1	57.0	37.25	19.5	24.5
2,4-D (μg/l)	100 μg/l	4.4	0.26	0.62	276.0	*
		4.4	0.26	0.14	0.59	*
		4.4	0.26	0.38	138.0	*
Lindane (μg/l)	0.01 μg/l	0.02	0.02	0.06	0.37	*
		0.02	0.02	0.04	0.14	*
		0.02	0.02	0.05	0.26	*
Endrin (μg/l)	0.003 μg/l	0.04	0.03	0.04	0.05	*
		0.04	0.03	0.02	0.03	*
		0.04	0.03	0.03	0.04	*
Methoxychlor (μg/l)	0.03 μg/l	0.08	0.08	0.08	1.21	*
		0.08	0.08	0.05	0.19	*
		0.08	0.08	0.07	0.7	*

* Samples lost.

exceeded criteria. Of those chemicals, Louisville's runoff contained excess amounts of lindane; however, it also carried concentrations of endrine, methoxychlor, and 2,4-D, which exceeded criteria (Table 4). In addition, one sample from the R_1 collection site not only contained DDT, but the concentration exceeded criteria. NURP concluded that occurrences of organic pollutants tend to be site specific and this was borne out by the DDT, the extremely high levels of lindane, endrin, methoxychlor, and 2,4-D at the R_2 and SC_2 sites, the presence of phenol at the LI, R_1, and R_2 sites, and xylene at the SC_2 and R_1 sites.

Coliform bacteria were present at high levels in the NURP urban runoff and Louisville's as well (Table 3). Coliform bacteria exceeded U.S. EPA water-quality criteria during and immediately after storm events in many of the surface waters, with counts typically in the tens to hundreds of thousand per 100 ml during warm weather conditions. However, the NURP analyses, as well as current literature (4, 22, 23), suggest that fecal coliform may not be the most appropriate indicator organism for identifying potential health risks when the source is stormwater runoff.

Nutrients were generally present in the NURP sites, but with a few individual exceptions, concentrations did not appear to be high. This was not the case in Louisville, where total phosphorous concentrations exceeded criteria in 100% of the samples.

Total suspended solids (TSS) concentrations in the NURP urban runoff were fairly high. Although there is no formal water quality criterion for TSS relating to either human health or aquatic life, the nature of suspended solids in urban runoff is different from other types of runoff, being higher in minerals and man-made products (tire and street surface-wear particles) and somewhat lower in organic particulates. Also, the solids in urban runoff are more likely to have other contaminants adsorbed onto them.

Significant causes of habitat disruption determined by the NURP study were the physical aspects of urban runoff, erosion, and scour. Specific changes in fish diversity were studied incidently in some of the subwatersheds and were considered to be due to urbanization. Several of the projects identified possible problems in the sediment because of the buildup of priority pollutants contributed wholly or in part by urban runoff. It was recommended that both of these areas be the subjects of more study after each city has completed its initial water quality assessment.

LITERATURE CITED

1. U.S. EPA. 1984. Report to Congress: NPSP in the United States. Office of Water Programs, Water Planning Division, Washington, DC.

2. Marsalek, J. and H. Y. F. Ng. 1989. Evaluation of pollutant loadings from urban NPS: methodology and applications. J. Great Lakes Res. 15:444–451.

3. Seager, J. and L. Maltby. 1989. Assessing the impact of episodic pollution. Hydrobiologia 188:633–640.

4. Thompson, P. 1989. Poison runoff. Natural Resources Defense Council, Inc., USDA Soil Conservation Service, New York.

5. Badics, R. 1990. Huron River pollution abatement project education program. Urban Nonpoint Source Pollution and Stormwater Management Symposium, University of Kentucky, Lexington.

6. Field, R. and R. Pitt. 1990. Urban storm-induced discharge impact. Water Env. and Tech. 3:47–49.

7. Latimer, J. S., E. J. Hoffman, G. Hoffman, J. L. Fasching, and J. G. Quinn. 1990. Sources of PHCs in urban runoff. Water, Air, and Soil Pollution 52:1–21.

8. Ochmba, P. B. O. 1990. Massive fish kills within the Nyanza Gulf of Lake Victoria, Kenya. Hydrobiologia 208:93–99.

9. Ohio River Valley Sanitation Commission. 1990. Assessment of nonpoint source pollution of the Ohio River. ORSANCO. Cincinnati, Ohio.

10. Austin, Texas. 1988. Modeling studies for the city of Austin stormwater monitoring programs. Austin, Texas.

11. Irwin, R. 1988. Impacts of toxic chemicals on Trinity River fish and wildlife. U.S. Fish and Wildlife Service, Fort Worth, Texas.

12. Texas Water Commission. 1986. NPS water pollution control for the State of Texas, recommendations for the future. Nonpoint Source Advisory Committee, Austin, Texas.

13. U.S. EPA. 1983a. Results of the Nationwide Urban Runoff Program, Vol. 1, 2, and 3. Water Planning Division, Washington, DC.

14. U.S. EPA. 1983b. Results of the Nationwide Urban Runoff Program, Vol. 1, Final report. Water Planning Division, Washington, DC.

15. Code of Federal Regulations. 1990. Title 40, Parts 100-149. U.S. Government Printing Office, Washington, DC.

16. Hamilton, M.A., R. C. Russo, and E.V. Thurston. 1977. Trimmed Spearman-Karber method for estimating median lethal concentrations in toxicity bioassays. Env. Sci. Tech. 11:714–719.

17. U.S. EPA. 1986. Development of standard methods for the collection and analysis of precipitation. Environmental Monitoring and Support Laboratory, Cincinnati, Ohio. EPA 600/S4-86/024.

18. U.S. EPA. 1987. Comprehensive experimental design plan to relate pollutant sources to acidic deposition. Atmospheric Sciences Research Laboratory, Research Triangle Park, North Carolina. EPA/600/S3-86/070.

19. Shackleford, W. M. and D. M. Cline. 1986. Organic compounds in water. Environ. Sci. and Techn. 20: 652–657.

20. Wershaw, R. L., M. J. Fishman, R. R. Grabbe, and L. E. Lowe (eds.) 1987. Methods for the determination of organic substances in water and fluvial sediments. USGS Techniques of Water Resources Investigations, Book 5, Chapter A3, U.S.G.S. Redmond, Washington.

21. Ward, J. R. and C. A. Harr (eds.) 1991. Methods for collection and processing of surface water and bed material samples for physical and chemical analyses. USGS Techniques of Water Resources Investigations, Book 1, Chapter D3, U.S.G.S. Denver, Colorado.

22. Pitt, R. and P. Bissonnette. 1984. Bellvue urban runoff program summary report. Special publication for the EPA, nationwide Urban Runoff Program, Bellvue, Washington.

23. Novotny, V. and G. Chester. 1989. Delivery of sediment and pollutants from NPS: a water quality perspective. J. Soil and Water Conserv. 44:568–576.

Trans. Ky. Acad. Sci., 54(3–4), 1993, 82–86

Rules for Reaction Mechanisms

P. L. Corio

Department of Chemistry, University of Kentucky, Lexington, Kentucky 40506-0055

Abstract

Several rules governing the structure of reaction mechanisms are developed and illustrated by a number of examples. Their simplicity notwithstanding, these rules may be used as an aid in the construction of reaction mechanisms, or as tests for the consistency of a given mechanism. The application of these rules to the solution of practical problems presented by certain mechanisms is also discussed.

Introduction

Reaction mechanisms are subject to some simple rules (1, 2) that are useful in the construction of reaction mechanisms, and in determining whether a given mechanism is consistent. These rules provide relations among the following parameters: ρ, the number of reactants; π, the number of products; ν, the number of independent conservation conditions; κ, the number of chemical components; ι, the number of intermediates; and n, the number of independent reactions. Except for n and ν, these definitions may be quickly recalled by alliteration: ρ for *r*eactants, π for *p*roducts, κ for *c*omponents, ι for *i*ntermediates.

A consistent mechanism satisfies the equations (1, 2).

$$\kappa = \rho + \pi + \iota = \mathrm{n} + \nu. \qquad (1)$$

The first equality follows from the fact that the sum $\rho + \pi$, that is, the sum of reactants and products, is obtained by subtracting the number of intermediates from the total number of components in the mechanism. Similarly, on subtracting the number of independent conservation conditions from the number of components, we obtain the number of independent reactions, which may also be characterized as the number of degrees of freedom, or as the number of independent, first-order differential equations required to define the kinetics.

It is assumed that the reaction under consideration occurs in a closed system without mass-energy conversion, and admits an interpretation in terms of a mechanism with a finite number of independent steps. Beyond this, however, the system may be arbitrary: the reaction may be homogeneous or heterogeneous, its kinetics simple or complex. Equations (1) are independent of all details of the reaction.

When the mechanism is given ρ, π, κ, and ι, can be determined by inspection, but n and ν must be determined algebraically. As an illustration, consider the mechanism for the gas phase reaction of nitric oxide and chlorine:

$$NO + Cl_2 \rightleftarrows NOCl_2, \qquad (2)$$

$$NOCl_2 + NO \rightarrow 2NOCl. \qquad (3)$$

Evidently $\kappa = 4$, $\rho = 2$, $\pi = 1$, and $\iota = 1$, so that the first of equations (1) is satisfied. To verify the second we must determine n and ν. We first number the components 1 through 4 in the order NO, Cl_2, $NOCl_2$, NOCl, and write out the conservation conditions for nitrogen, oxygen, and chlorine:

$$\begin{aligned} [NO] \quad\quad\quad &+ [NOCl_2] + [NOCl] = c_1, \\ [NO] \quad\quad\quad &+ [NOCl_2] + [NOCl] = c_2, \\ 2[Cl_2] &+ 2[NOCl_2] + [NOCl] = c_3, \end{aligned}$$

where c_1, c_2, c_3 are constants equal to the initial values of the left-hand members. Clearly $c_1 = c_2$, so that there can be at most two independent conservation conditions; but to see the general rule, we write out the 3×4 matrix of coefficients determined by the left-handed members:

$$\begin{pmatrix} 1 & 0 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 0 & 2 & 2 & 1 \end{pmatrix},$$

The value of ν is the rank of this matrix, that is, ν is the number of rows (or columns) in the nonvanishing determinant(s) of greatest order contained in the matrix. Now the first 2 rows are equal, so that every 3×3 determinant in the matrix is zero, which means $\nu < 3$. The determinant of the 2×2 matrix in the lower left-hand corner is not zero, so that $\nu = 2$. Note that although there are three distinct atoms, ν

< 3. In general, if N denotes the number of the distinct atoms, then the number of independent conservation conditions is less than or equal to N + 1 or N, according as there is or is not a charge conservation condition.

With $\kappa = 4$ and $\nu = 2$, it follows that n = 2, but we can compute the value of n independently as follows. Rewrite the reaction equations in the following algebraic form, ordering the components as before, but transposing products to the left-hand members:

$$NO + Cl_2 - NOCl_2 \qquad = 0,$$

$$NO \qquad + NOCl_2 - 2NOCl = 0.$$

The rank of the matrix of coefficients, namely,

$$\begin{pmatrix} 1 & 1 & -1 & 0 \\ 1 & 0 & 1 & -2 \end{pmatrix},$$

is the number of independent reactions. In this case, n = 2 so that equations (1) are satisfied. Note that forward and reverse steps of a reversible reaction must be written as a single mechanistic step, since such steps are dependent.

For mechanisms with a sizable number of distinct atoms, or numerous mechanistic steps, the determination of ν or n can be considerably simplified by row or column operations, as discussed in texts on algebra (3). In the following examples we cite the values of ν and n without writing out the appropriate matrices, leaving these computations as exercises for the reader.

EXAMPLES

1. A proposed mechanism (4) for the gas phase decomposition of ozone is

$$O_3 \rightleftarrows O_2 + O, \tag{4}$$

$$O_3 + O \rightarrow 2O_2, \tag{5}$$

in which atomic oxygen is an intermediate. Equations (1) are satisfied since $\kappa = 3$, $\rho + \pi = 2$, $\iota = 1$, n = 2, and $\nu = 1$.

2. Hexachlorocyclopentadiene couples (5) to bis-(pentachlorocyclopentadienyl) in a suitable solvent, and a suggested mechanism is

$$C_5Cl_6 + CuCl \rightleftarrows C_5Cl_6 \cdot CuCl, \tag{6}$$

$$C_5Cl_6 \cdot CuCl \rightarrow C_5Cl_5 + CuCl_2, \tag{7}$$

$$2C_5Cl_5 \rightarrow C_{10}Cl_{10}, \tag{8}$$

in which $C_5Cl_6 \cdot CuCl$ and C_5Cl_5 are intermediates. Since $\kappa = 6$, n = $\nu = 3$, $\rho = \pi = \iota = 2$, equations (1) are satisfied.

3. The following mechanism for the gas phase decomposition of nitric acid (6) is also consistent.

$$HNO_3 \rightleftarrows HO + NO_2, \tag{9}$$

$$HO + HNO_3 \rightarrow H_2O + NO_3, \tag{10}$$

$$NO_2 + NO_3 \rightarrow NO_2 + NO + O_2, \tag{11}$$

$$NO + NO_3 \rightarrow 2NO_2. \tag{12}$$

There are 7 components, 4 independent reactions, 3 intermediates (HO, NO, NO_3), 1 reactant, 3 products, and 3 independent conservation conditions.

4. The classical chain mechanism for the gas phase reaction of hydrogen and bromine (7) also conforms to equations (1):

$$Br_2 + M \rightleftarrows 2Br + M, \tag{13}$$

$$Br + H_2 \rightleftarrows HBr + H, \tag{14}$$

$$H + Br_2 \rightarrow HBr + Br. \tag{15}$$

Here, $\kappa = 5$, $\pi = 1$, $\rho = \iota = \nu = 2$, n = 3. Note that the first step leaves M chemically intact, so that M is not counted among the components. Bromine molecules could serve the function of M, but bromine would be counted as a component by virtue of its dissociation in the first step, not by assuming the collisional function of M.

5. Equations (1) also apply to photochemical reactions, but a photon of energy is not counted as a component of the mechanism anymore than thermal energy would in thermal reactions. For example, a frequently cited mechanism for the depletion of ozone in the atmosphere is

$$O_3 + h\nu \rightarrow O_2 + O, \tag{16}$$

$$O_2 + h\nu \rightarrow O + O, \tag{17}$$

$$O + O_3 \rightarrow 2O_2. \tag{18}$$

The third step is equal to the first step minus the second, so that n $\neq$ 3. In fact, n = 2, and with $\kappa = 3$, $\nu = \iota = \rho = \pi = 1$, equations (1) are satisfied.

A mechanism may have any number of dependent steps, but the number of independent mechanistic steps must satisfy equations (1).

Dependent steps contribute to the kinetics, and are sometimes essential to the mechanism, as, for instance in the unimolecular, cyclical conversion of isomers:

$$A \rightleftarrows B, \qquad B \rightleftarrows C, \qquad C \rightleftarrows A. \qquad (19)$$

There are only 2 independent reactions, but omission of any one reaction would fail to disclose the cyclic nature of the mechanism.

STOICHIOMETRIES AND MECHANISMS

The values of ρ and π can also be obtained from the observed stoichiometry (8). The stoichiometry for the decomposition of nitric acid, for instance, is

$$4HNO_3 \rightarrow 4NO_2 + 2H_2O + O_2, \qquad (20)$$

which yields $\rho = 1$, $\pi = 3$.

There is one point (1, 2), however, that needs to be carefully noted in the case of catalyzed reactions, namely, that although catalysts do not appear in the net stoichiometric equation, each catalyst must be counted once in the sum $\rho + \pi$. As an illustration, consider the oxidation of V^{3+} and by Fe^{3+}, which is catalyzed by cupric ion (9). The stoichiometry is

$$V^{3+} + Fe^{3+} \xrightarrow{Cu^{2+}} V^{4+} + Fe^{2+}. \qquad (21)$$

Since there is one catalyst, the value or $\rho + \pi$ is $4 + 1 = 5$. Hence a consistent mechanism must satisfy $\kappa = 5 + \iota = n + \nu$. The proposed mechanism (10)

$$V^{3+} + Cu^{2+} \rightarrow V^{4+} + Cu^{+},$$
$$Cu^{+} + Fe^{3+} \rightarrow Fe^{2+} + Cu^{2+}, \qquad (22)$$

with Cu^{+} as an intermediate, $\nu = 4$ (mass and charge), $n = 2$, and $\kappa = 6$, is therefore consistent.

The observed stoichiometric relation also implies a certain number, ν_s, say, of conservation conditions, but the value of ν_s is, in general, less than or equal to the value of ν. For example, the stoichiometry of an isomerization $A \rightarrow B$ has $\nu_s = 1$, since the conservation conditions are multiples of each other. But a mechanism for the isomerization may take place in several steps involving the rupture and formation of bonds, and in such steps additional conservation conditions may come into play. In general, therefore,

$$\nu_s \leq \nu \leq N, \text{ or } N + 1, \qquad (23)$$

where, as before, N denotes the number of distinct atoms in the system. It can be shown (2) that in the case of a catalyzed reaction, each catalyst is to be counted once in the computation of ν_s. Thus, for the stoichiometry (21), mass and charge conservation yield 3 conservation conditions, so that, with one catalyst, $\nu_s = 3 + 1 = 4$. In this case, $\nu_s = \nu$.

REPRESENTATIVE PROBLEMS

Equations (1) can be used to construct interesting problems of an investigative nature. The following examples illustrate the sort of problems that can be generated.

Problem 1.—The following mechanism (10) has been proposed for the thermal decomposition of ethylene oxide:

$$CH_2CH_2O \rightarrow CH_2CHO + H,$$
$$CH_2CHO \rightarrow CH_3 + CO,$$
$$CH_2CH_2O + CH_3 \rightarrow CH_2CHO + CH_4,$$
$$CH_2CHO + CH_3 \rightarrow \text{stable products.}$$

(a) How many new products are generated in the final step of the mechanism? (b) How many products are there in the right member of the stoichiometric relation? (c) What might the stable products be?

Solution.—(a) There are three intermediates (H, CH_3, CH_2CHO), three conservation conditions, and four independent reactions. It follows that $\kappa = n + \nu = 7$. The mechanism exhibits six components explicitly, so that the final step can only generate one new product.

(b) Since $\kappa = 7$, and $\iota = 3$, the value of $\rho + \pi = \kappa - \iota = 4$. Since $\rho = 1$, we must have $\pi = 3$, namely CO, CH_4, and the new product formed in the last step.

(c) Since at most one new product is formed in the last step, it would be impossible to form formaldehyde and ethylene, or allene and water, or methanol and acetylene; but carbon monoxide and ethane, or methane and ketene could be formed in that step. If we suppose only one product formed in the final step, seven possibilities are acetone, propanal, propylene oxide, cyclopropanol, trimethylene oxide, 1-propene-1-ol, and 1-propene-2-ol. In arriving at these results, we have used the fact that the coefficients of the components in a *mechanistic step* are necessarily integers.

It should be noted that the mechanism makes no provision for the depletion of hydrogen atoms. One possibility is $CH_3 + H \rightarrow CH_4$. This reaction is a *dependent* reaction, being the third reaction minus the first. Since it is a dependent reaction, it can be added to the mechanism without altering the values of n, κ, ρ, π, ι, ν; it will, however, contribute to the kinetics.

Problem 2.—How would the results of Problem 1 be altered if hydrogen atoms are eliminated by the reaction $2H \rightarrow H_2$?

Solution.—(a) We now have five independent reactions, three conservation conditions, three intermediates, and seven explicit components; hence $\kappa = 8$, so only one new product is generated in step 4.

(b) With $\kappa = 8$, $\iota = 3$, and $\rho = 1$, the number of products in the stoichiometric relation is $\pi = \kappa - \rho - \iota = 4$, namely, H_2, CO, CH_4, and the new product formed in step 4.

(c) In addition to the possibilities already mentioned in Problem 1, the stable products in step four could be molecular hydrogen, carbon monoxide, and ethylene, or molecular hydrogen and methyl ketene.

Problem 3.—The uncatalyzed photochemical decomposition of iodomethane conforms to the stoichiometry

$$11CH_3I \rightarrow 5CH_4 + C_2H_6 + C_2H_4 + CH_2I_2 + CHI_3 + 3I_2.$$

How many components are there in a mechanism with ten independent steps? How many intermediates?

Solution.—According to the observed stoichiometry, $\rho + \pi = 7$, and $\nu_s = 3$, so that $\kappa = 7 + \iota = n + \nu$. Now, according to equation (23), ν equals 3 or 4. If $\nu = 3$, a ten-step mechanism must have 13 components and 6 intermediates. If $\nu = 4$, a ten-step mechanism must have 14 components and 7 intermediates.

Problem 4.—A certain reaction is initiated by three reactants, but analytical difficulties make the determination of the number of products uncertain. Other experimental evidence suggests there are eight components. How many possible products are there?

Solution.—From the given data, $\kappa = 8$, $\rho = 3$, and the first of equations (1) gives $8 = 3 + \pi + \iota$, or, $\pi + \iota = 5$. Now the number of intermediates can be zero, but there must be at least one product, so that the possible values of π and ι summing to 5 are $(\pi, \iota) = (5, 0)$, (4, 1), (3, 2), (2, 3), (1, 4). Thus, $\pi = 5, 4, 3, 2$, or 1.

Problem 5.—Show that the following mechanism is inconsistent.

$$C_2H_6 \rightarrow 2CH_3,$$

$$CH_3 + C_2H_6 \rightarrow CH_4 + C_2H_5,$$

$$C_2H_5 \rightarrow C_2H_4 + H,$$

$$C_2H_6 + H \rightarrow C_2H_5 + H_2.$$

Solution.—The mechanism has 7 components, three intermediates, four independent steps, and two mass conservation conditions. The mechanism is inconsistent, since $\kappa = 7$, but $n + \nu = 4 + 2 = 6$. If the independent reaction

$$C_2H_5 + H \rightarrow C_2H_6,$$

is appended to the mechanism, equations (1) will be satisfied.

CONCLUDING REMARKS

The preceding examples and problems illustrate the usefulness of equations (1) in the study of reaction mechanisms. It should be emphasized, that a mechanism conforming to these equations need not be the correct mechanism for the reaction under investigation. On the other hand, a mechanism that does not conform to equations (1) must be accordingly modified.

The rules embodied in equation (1) may be regarded as a concise way of using the concepts of stoichiometry, intermediate, conservation conditions, etc. in a consistent manner. With mechanisms containing few steps these rules have usually been implicitly observed, but they must be taken into account explicitly when dealing with mechanisms containing many steps and many components. Examples of the application of these rules to complex mechanisms, and some theoretical relations of a more technical nature are given elsewhere (2, 11).

LITERATURE CITED

1. Corio, P. L. 1984. Stoichiometric relations, mechanisms, and steady states. J. Phys. Chem. 84:1825–1833.

2. Corio, P. L. 1989. Topics in current chemistry. Springer-Verlag, Berlin. 150:249–283.

3. Birkhoff, G. D. and S. MacLane. 1977. A survey of modern algebra, 4th ed. MacMillan, New York.

4. Benson, S. W. and A. E. Axworthy. 1957. Mecha-

nism of the gas phase, thermal decomposition of ozone. J. Chem. Phys. 26:1718–1726.

5. Roberts, C. W., D. H. Haigh, and W. G. Lloyd. 1960. A kinetic study of the coupling of hexachlorocyclopentadiene to form bis-(pentachlorocyclopentadienyl). J. Phys. Chem. 64:1887–1891.

6. Johnston, H. S. 1966. Gase phase reaction rate theory. Ronald, New York.

7. Frost, A. A. and R. G. Pearson. 1961. Kinetics and mechanism, 2nd ed. Wiley, New York.

8. Corio, P. L. 1970. Mass conservation and multiple stoichiometries. Trans. Ky. Acad. Sci. 32:51–56.

9. Ashmore, P. G. 1963. Catalysis and inhibition of chemical reactions. Butterworths, London.

10. Crocco, L., I. Glassman, and I. E. Smith. 1959. Kinetics and mechanism of ethylene oxide decomposition at high temperatures. J. Chem. Phys. 31:506–510.

11. Corio, P. L. and B. G. Johnson. 1991. Conditions for reaction mechanisms. J. Phys. Chem. 95:4166–4171.

Trans. Ky. Acad. Sci., 54(3–4), 1993, 87–92

A Survey of Small Mammals in the Morehead Ranger District, Daniel Boone National Forest, Kentucky

James Kiser and Les Meade

Department of Biological and Environmental Sciences, Morehead State University, Morehead, Kentucky 40351

Abstract

In 1991, a survey of rare, threatened and endangered plants and animals in the Morehead Ranger District, Daniel Boone National Forest (DBNF) was undertaken as a cooperative effort between the U.S. Forest Service and The Nature Conservancy (TNC), with further cooperation from the Kentucky Department of Fish and Wildlife Resources, Kentucky State Nature Preserves Commission, and Morehead State University.

Small mammals were surveyed by using pitfall traps and snap traps placed in selected habitats throughout national forest lands and private lands adjacent to the DBNF. Bats were collected with mist nets during the summer and fall, and in December, they were surveyed at hibernacula. Twenty-two species of mammals were captured and observed. These included 4 species of shrews, 7 species of rodents and 11 species of bats. Dominant species captured in the Morehead Ranger District of the DBNF were *Blarina brevicauda, Sorex fumeus, Peromyscus leucopus, Myotis lucifugus, Myotis septentrionalis, Pipistrellus subflavus* and *Eptesicus fuscus*.

Introduction

A survey of rare, threatened and endangered plants and animals in the Morehead Ranger District, Daniel Boone National Forest (DBNF) was undertaken in 1991, as a cooperative effort between the U.S. Forest Service and The Nature Conservancy (TNC), with additional support from the Kentucky Department of Fish and Wildlife Resources, Kentucky State Nature Preserves Commission and Morehead State University (1). Similar studies in the DBNF were also completed by cooperative effort in the Somerset (2), Stanton (3), Stearns (4) and Berea (5) Ranger Districts. Earlier mammal surveys in eastern Kentucky by Welter and Sollberger (6), and Fassler (7), also included records from the Daniel Boone National Forest. Other surveys by Hamilton (8), Barbour (9), and Barbour and Hardjasasmita (10) reported mammals from adjacent regions.

Fieldwork in the the Morehead Ranger District occurred between May and December of 1991. Small mammals and bats were surveyed in selected habitats throughout national forest lands, and private lands adjacent to the DBNF. Twenty-two species of small mammals were collected; these included 4 species of shrews (*Sorex fumeus, S. hoyi, S. longirostris* and *Blarina brevicauda*), 7 species of rodents (*Peromyscus leucopus, Reithrodontomys humulis, Synaptomys cooperi, Microtus pennsylvanicus, M. ochrogaster, M. pinetorum* and *Napaeozapus insignis*) and 11 species of bats (*Eptesicus fuscus, Myotis lucifugus, M. leibii, M. sodalis, M. septentrionalis, Lasionycteris noctivagans, Pipistrellus subflavus, Lasiurus borealis, L. cinereus, Plecotus rafinesquii* and *P. townsendii virginianus*).

Small mammals previously documented in the Morehead Ranger District, but not collected during this research project, included *Cryptotis parva, Parascalops breweri, Ochrotomys nuttalli, Peromyscus maniculatus, Mus musculus* and *Tamias striatus*.

Materials and Methods

Small mammals were surveyed by using pitfall traps (960 ml plastic cups) and snap traps (mouse and museum special traps). Pitfall trapping was conducted at 17 sites in a variety of habitats, including mesophytic forest (usually with abundant boulder talus), open mesophytic forest, prairie sites, upland fields, lowland fields, swamp forest (MSU Sphagnum Swamp) and floodplain forest. Snap traps were placed at 9 sites, including mesophytic forest (adjacent to boulder talus and logs), prairie sites, upland fields, lowland fields and swamp forest. These efforts results in 97,417 trap nights of sampling time, although leaf litter reduced the effective trapping time during late fall.

Pitfall traps were partially filled with 10% formalin (9:1 ratio of water to formaldehyde) so that complete specimens could be obtained.

When formalin was not used, specimens were quickly devoured by carrion beetles. Pitfall traps were set by using a posthole digger and were placed in areas where signs of mammal activity were noticed, or in suitable habitats, and were checked at 1–2 week intervals. Snap traps were placed in similar areas and baited with peanut butter. They were checked on a daily basis and set out for 4–5 day intervals. Additional records of small mammals were observed while walking, or were found as road kills. All specimens collected with traps, and usable road kills, were deposited in the Morehead State University Vertebrate Collection. Collection sites surveyed for small terrestrial mammals were as follows:

(1) Kendrick Ridge, 5.3 km E of KY 36. Menifee Co., Ky. Scranton Quadrangle.
(2) Lowland fields along Beaver Creek, ca. 5.8 km E of KY 36. Menifee Co., Ky. Scranton Quadrangle.
(3) Botts Fork, 1.0 km E of Brushy Fork. Menifee Co., Ky. Scranton Quadrangle.
(4) Murder Branch, 0.32 km W of Murder Branch Cave. Menifee Co., Ky. Ezel Quadrangle.
(5) Craney Creek, FS 947 nr. Craney, ca. 0.48 km N of Cave Run Lake. Morgan Co., Ky. Wrigley Quadrangle.
(6) Black Cave Hollow, Craney Creek. Rowan Co., Ky. Wrigley Quadrangle.
(7) Murder Branch, boulder talus site, 5.8 km from KY 1274 on FS 1074. Menifee Co., Ky. Bangor Quadrangle.
(8) Prairie site, KY 1274, ca. 3.2 km S of KY 519. Rowan Co., Ky. Bangor Quadrangle.
(9) Prairie site, KY 1274, ca. 6.4 km S of KY 519. Rowan Co., Ky. Bangor Quadrangle.
(10) Zilpo Campground, Cave Run Lake. Bath Co., Ky. Bangor Quadrangle.
(11) Hog Hollow, 0.48 km S of dam at Cave Run Lake. Bath Co., Ky. Salt Lick Quadrangle.
(12) Hog Hollow, 0.81 km SW of dam at Cave Run Lake, nr. end of FS 1062. Bath Co., Ky. Salt Lick Quadrangle.
(13) Floodplain forest at oxbow lake, Minor Clark Fish Hatchery. Rowan Co., Ky. Salt Lick Quadrangle.
(14) Glady Hollow, FS 906. Bath Co., Ky. Salt Lick Quadrangle.
(15) Tater Knob, FS 918B. Bath Co., Ky. Salt Lick Quadrangle.
(16) Mud Lick Youth Camp, 1.3 km NE of Olympia Springs. Bath Co., Ky. Olympia Quadrangle.
(17) MSU Sphagnum Swamp, KY 1722 ca. 4.8 km W of Farmers. Rowan Co., Ky. Farmers Quadrangle.
(18) FS 977, ca. 2.1 km S of KY 799. Rowan Co., Ky. Cranston Quadrangle.
(19) FS 977, ca 3.2 km S of KY 799. Rowan Co., Ky. Cranston Quadrangle.
(20) Floodplain forest on island, North Fork of Triplett Creek, 0.81 km S of Cranston. Rowan Co., Ky. Cranston Quadrangle.
(21) Amburgy Rock Rd. (FS 964), 0.32 km N of FS 16. Rowan Co., Ky. Morehead Quadrangle.
(22) Triangle Tower Rd. (FS 12), ca. 0.48 km NE of radio tower. Rowan Co., Ky. Morehead Quadrangle.

Preliminary fieldwork indicated that most of the rare and endangered species of bats in the Morehead area were associated with caves and shelters of cliffines. Thus, a special effort was made to census the bats and other animals of these habitats. During the summer months, we surveyed cliffines, recorded species localities, and recorded locations of shelters and caves that were found. We returned to many of these sites and mist-netted for bats during the summer and early fall. Mist nets were placed in potential foraging regions in front of sandstone shelters and limestone caves, along cliffines, and across streams, pipeline corridors, and logging roads. Two or three nets were set up at selected sites before dark and left in place until bat activity stopped. All collected bats were examined with regard to species, age, sex and reproductive maturity; specimens were then marked on their wings with correction fluid and released. Recaptures were easy to identify because of the white spot. Mist-netting sites with captured bats were as follows:

(1) Murder Branch Gap, 5.6 km from KY 1274 on FS 1074. Menifee Co., Ky. Bangor Quadrangle.
(2) Leatherwood Cove Area, along pipeline corridor nr. Scale Ladder Hollow. Menifee Co., Ky. Bangor Quadrangle.
(3) Beaver Creek, ca. 3.5 km E of KY 36. Menifee Co., Ky. Scranton Quadrangle.
(4) Craney Creek, nr. Craney, ca. 0.16 km N of Cave Run Lake. Rowan-Morgan Co. line. Wrigley Quadrangle.
(5) Head of Mine Branch, off FS 933. Morgan Co., Ky. Bangor Quadrangle.
(6) North Fork of Triplett Creek, ca. 0.32 km S of Cranston. Rowan Co., Ky. Cranston Quadrangle.
(7) Skidmore Sandstone Shelter, FS 1227A, ca. 1.6 km W of mouth of Skidmore Creek. Menifee Co., Ky. Salt Lick Quadrangle.
(8) Triplett Creek, 0.81 km E of Becky Branch. Rowan Co., Ky. Morehead Quadrangle.
(9) Mud Lick Area, along pipeline corridor, ca. 0.81 km

N of Mud Lick Youth Camp. Bath Co., Ky. Olympia Quadrangle.
(10) Licking River at KY 801, 0.81 km S of US 60. Rowan-Bath Co. line. Farmers Quadrangle.
(11) Oxbow Lake, 0.48 km SW jct. of US 60 and KY 801. Rowan Co., Ky. Farmers Quadrangle.
(12) Leatherwood Creek Area, SE corner of Chestnut Cliffs. Menifee Co., Ky. Salt Lick Quadrangle.
(13) Triangle Tower No. 11, Shelter on FS 12A. Rowan Co., Ky. Morehead Quadrangle.
(14) Murder Branch Cave. Menifee Co., Ky. Ezel Quadrangle.
(15) Spaws Creek, ca. 2.4 km SW of Open Fork. Menifee Co., Ky. Ezel Quadrangle.
(16) Menifee County Park. Menifee Co., Ky. Scranton Quadrangle.
(17) Mine Branch Cave. Morgan Co., Ky. Bangor Quadrangle.

In December, we examined shelters and all known caves of the Morehead District for hibernating bats. Many of the sandstone shelters examined were picked from biological evaluations of timber sales. Only one cave, Ellington Pit Cave, was not completely explored because the 50-foot pit required special expertise to enter. Shelters and caves with hibernating bats included the following:

(1) Risk Cave, Triangle Tower. Rowan Co., Ky. Morehead Quadrangle.
(2) Clack Mountain Railroad Tunnel. Rowan Co., Ky. Morehead Quadrangle.
(3) Old House Creek Cave. Rowan Co., Ky. Haldeman Quadrangle.
(4) Hardin Cave No. 1. Rowan Co., Ky. Bangor Quadrangle.
(5) Hardin Cave No. 2. Rowan Co., Ky. Bangor Quadrangle.
(6) Ellington Pit Cave. Rowan Co., Ky. Bangor Quadrangle.
(7) Pickett Branch Pit Cave. Rowan Co., Ky. Bangor Quadrangle.
(8) Silver-haired Cave. Rowan Co., Ky. Bangor Quadrangle.
(9) Dock Hollow Cave. Menifee Co., Ky. Scranton Quadrangle.
(10) Skidmore Sandstone Shelter. Menifee Co., Ky. Salt Lick Quadrangle.
(11) Clifton Creek Iron Mines. Menifee Co., Ky. Scranton Quadrangle.
(12) Murder Branch Cave. Menifee Co., Ky. Ezel Quadrangle.
(13) Cold Cave Pit Cave. Menifee Co., Ky. Ezel Quadrangle.
(14) Spaws Creek Cave. Morgan Co., Ky. Ezel Quadrangle.
(15) Mine Branch Cave. Morgan Co., Ky. Bangor Quadrangle.
(16) Mine Branch Sandstone Shelter. Morgan Co., Ky. Bangor Quadrangle.
(17) Donahue Sandstone Cave. Morgan Co., Ky. Bangor Quadrangle.
(18) Shooting Range Cave. Bath Co., Ky. Salt Lick Quadrangle.

TABLE 1. Species of small mammals collected in the Morehead Ranger District with pitfall traps in 1991. Trapping success rate was calculated as a percentage of traps that captured specimens.

Species	Number	Sites	Success rate
Sorex fumeus	137	14	18.00
Blarina brevicauda	106	14	13.93
Peromyscus leucopus	32	12	4.20
Sorex hoyi winnemana	16	9	2.10
Sorex longirostris	8	3	1.05
Napaeozapus insignis	6	5	0.79
Microtus pinetorum	1	1	0.13
Microtus ochrogaster	1	1	0.13
Totals	307	17	40.33

RESULTS AND DISCUSSION

A total of 374 small mammals and 224 bats were captured during the summer and fall of 1991. Trapping with pitfall and snap traps reached its peak in early summer between May 15 and July 1. Heat and dryness probably slowed mammal activity in late summer. Additional trapping in September and October produced only small numbers of mammals.

Species of small mammals collected in the Morehead Ranger District with pitfall and snap traps in 1991 are presented in Tables 1 and 2.

TABLE 2. Species of small mammals collected in the Morehead Ranger District with snaptraps in 1991. Trapping success rate was calculated as a percentage of traps that captured specimens.

Species	Number	Sites	Success rate
Peromyscus leucopus	27	7	3.21
Blarina brevicauda	22	5	2.62
Microtus pennsylvanicus	8	4	0.95
Reithrodontomys humulis	3	2	0.36
Synaptomys cooperi	2	2	0.24
Microtus ochrogaster	2	1	0.24
Microtus pinetorum	2	1	0.24
Sorex longirostris	1	1	0.12
Totals	67	9	7.98

TABLE 3. Major habitats surveyed and associated species of small mammals in the Morehead Ranger District.

Species	Habitats						
	A	B	C	D	E	F	G
Sorex fumeus	X	X	X	X	X		
Blarina brevicauda	X	X	X	X	X	X	X
Peromyscus leucopus	X	X	X	X	X	X	X
Sorex longirostris				X		X	X
Sorex hoyi winnemana		X					
Napaeozapus insignis		X					
Microtus pinetorum		X				X	
Microtus ochrogaster							X
Microtus pennsylvanicus							X
Reithrodontomys humulis							X
Synaptomys cooperi						X	

A = Open, mixed mesophytic forest.
B = Mixed mesophytic forest with boulder talus.
C = Floodplain forest.
D = Swamp forest.
E = Prairie sites.
F = Upland fields.
G = Lowland fields.

Trapping success rate for small mammals was calculated as a percentage of the traps that produced specimens. Eleven species of small mammals were captured, but only 3 species (*Sorex fumeus, Blarina brevicauda* and *Peromyscus leucopus*) were abundant. Seven species (*Sorex hoyi winnemana, S. longirostris, Reithrodontomys humulis, Microtus pinetorum, M. ochrogaster, Synaptomys cooperi* and *Napaeozapus insignis*) were somewhat rare in the Morehead area. Only 1 of these species (*Sorex hoyi winnemana*) was listed by Warren et al. (11) as endangered, threatened or rare. However, *S. h. winnemana* was captured in all 4 counties of this region, and is probably more common in the DBNF than currently known.

TABLE 4. Species of bats mist-netted in the Morehead Ranger District in 1991. RS = number of reproductive sites.

Species	Number	Sites	RS
Lasiurus borealis	27	11	5
Eptesicus fuscus	31	11	1
Pipistrellus subflavus	37	10	5
Myotis septentrionalis	42	9	6
Myotis lucifugus	71	8	5
Plecotus rafinesquii	9	4	1
Myotis sodalis	2	2	0
Lasionycteris noctivagans	2	1	0
Plecotus townsendii virginianus	1	1	1
Myotis leibii	1	1	0
Lasiurus cinereus	1	1	0
Totals	224	17	12

Major habitats surveyed and associated species of small mammals in the Morehead Ranger District are presented in Table 3. Mixed mesophytic forest with boulder talus, lowland fields and upland fields included the greatest species diversity; open mesophytic forest, floodplain forest and prairie regions contained the fewest species. *Blarina brevicauda* and *Peromyscus leucopus* occurred in all habitat types. *Sorex hoyi winnemana* and *N. insignis* were restricted to mesophytic forest with boulder talus. *Sorex fumeus* was only found in forested areas. *Microtus pennsylvanicus, M. ochrogaster, R. humulis* and *Synaptomys cooperi* were occupants of fields. *Sorex longirostris* was found in swamp forest and moist fields. *Microtus pinetorum* inhabited mesophytic forest and fields.

Species of bats mist-netted in the Morehead Ranger District are given in Table 4. Eleven species were captured during this study, but only 5 species (*Lasiurus borealis, Eptesicus fuscus, Pipistrellus subflavus, Myotis lucifugus* and *M. septentrionalis*) were common. *Plecotus rafinesquii* was occasionally captured in the Morehead Ranger District. Five additional species (*Myotis sodalis, M. leibii, Plecotus townsendii virginianus, Lasionycteris noctivagans* and *Lasiurus cinereus*) were rarely found; however, all of these bats, except *P.*

TABLE 5. Major habitats surveyed and associated species of bats mist-netted in the Morehead Ranger District.

Species	Habitats A	B	C	D	E	F	G	H	I
Lasiurus borealis		X		X		X	X	X	X
Eptesicus fuscus	X	X		X		X	X	X	
Pipistrellus subflavus	X			X			X	X	
Myotis septentrionalis	X	X		X		X	X		
Myotis lucifugus		X			X	X	X	X	
Plecotus rafinesquii		X				X			
Myotis sodalis		X			X				
Lasionycteris noctivagans						X			
Plecotus townsendii virginianus	X								
Myotis leibii					X				
Lasiurus cinereus							X		

A = Sandstone cliffline.
B = Sandstone cliffline with sandstone cave/rock shelter.
C = Sandstone cliffline and logging road.
D = Ridgetop pond and adjacent gravel road.
E = Deep woodland ravine.
F = Mouth of limestone cave.
G = Stream/river corridor.
H = Oxbow in riparian forest.
I = Bottomland forest with pipeline corridor.

t. virginianus, migrate northward during the warmer parts of the year. *Myotis sodalis, M. leibii* and *Plecotus townsendii virginianus* were listed by Warren et al. (11) as endangered; *Plecotus rafinesquii* was listed as threatened (T) and *Myotis septentrionalis* was listed as special concern (S). Reproductive sites were also recorded for 7 of the 11 species captured; these sites were based on the capture of lactating females and immature specimens.

Major habitats surveyed and associated species of bats mist-netted in the Morehead Ranger District are given in Table 5. Five species (*Lasiurus borealis, Eptesicus fuscus, Pipistrellus subflavus, Myotis septentrionalis* and *M. lucifugus*) were found in a variety of habitats. Along sandstone clifflines, usually in areas with sandstone caves or rock shelters, all 5 of these species were very common. Six other species were only captured in 1–2 habitats; these included *Plecotus rafinesquii, P. townsendii virginianus, Myotis sodalis, M. leibii, Lasionycteris noctivagans* and *Lasiurus cinereus*. *Plecotus rafinesquii, P. t. virginianus* and *M. sodalis* were also captured along sandstone clifflines; *L. noctivagans* was captured at the mouth of a limestone cave; *M. leibii* was mist-netted in a deep woodland ravine; and *L. cinereus* was collected along a stream corridor.

Species of bats found during a winter cave survey in the Morehead Ranger District are given in Table 6. Only 6 species were found during this winter survey, and 4 of these (*Pipistrellus subflavus, Eptesicus fuscus, Myotis lucifugus* and *Plecotus rafinesquii*) accounted for 98.3% of the bats found. Two other species (*Myotis septentrionalis* and *Lasionycteris noctivagans*) were rarely observed, and hibernating individuals of *Myotis sodalis, M. leibii, Lasiurus borealis* and *Plecotus townsendii virginianus* were not found. However, *P. t. virginianus* has been previously found at three sites in the Morehead Ranger District during winter surveys (12).

ACKNOWLEDGMENTS

Thanks and appreciation to John MacGregor, Tom Biebighauser, Dave Manner, Peggy Measel and Kathryn Huie (U.S. Forest Service); Steve Bonney, Dave Yancy and Bren-

TABLE 6. Species of bats found during a winter cave survey in the Morehead Ranger District in December 1991.

Species	Number	Sites
Pipistrellus subflavus	290	14
Eptesicus fuscus	41	13
Plecotus rafinesquii	64	5
Myotis lucifugus	114	4
Myotis septentrionalis	4	2
Lasionycteris noctivagans	5	1
Totals	518	18

da Hamm (Kentucky Department of Fish and Wildlife Resources); Robert Kiser (Kona, Letcher Co., Ky.); Julian Campbell (The Nature Conservancy) and Richard Hannan (Kentucky State Nature Preserves Commission). The cooperative effort of these individuals and organizations made this project possible.

LITERATURE CITED

1. Campbell, J. J. N., S. A. Bonney, J. D. Kiser, L. E. Kornman, J. R. MacGregor, L. E. Meade, and A. C. Risk. 1992. Cooperative inventory of endangered, threatened, sensitive and rare species, Daniel Boone National Forest, Morehead Ranger District. Kentucky State Nature Preserves Commission, Frankfort.

2. Palmer-Ball, B., Jr., J. J. N. Campbell, M. E. Medley, D. T. Towles, J. R. MacGregor, and R. R. Cicerello. 1988. Cooperative inventory of endangered, threatened, sensitive and rare species, Daniel Boone National Forest, Somerset Ranger District. Kentucky State Nature Preserves Commission, Frankfort.

3. Campbell, J. J. N., D. T. Towles, M. R. MacGregor, R. R. Cicerello, B. Palmer-Ball, Jr., M. E. Medley, and S. Olson. 1989. Cooperative inventory of endangered, threatened, sensitive and rare species, Daniel Boone National Forest, Stanton Ranger District. Kentucky State Nature Preserves Commission, Frankfort.

4. Campbell, J. J. N., A. C. Risk, V. L. Andrews, B. Palmer-Ball, Jr., and J. R. MacGregor. 1990. Cooperative inventory of endangered, threatened, sensitive and rare species, Daniel Boone National Forest, Stearns Ranger District. Kentucky State Nature Preserves Commission, Frankfort.

5. Campbell, J. J. N., J. E. Flotemersch, J. R. MacGregor, D. Noe, A. C. Risk, M. D. Studer, and D. T. Towles. 1991. Cooperative inventory of endangered, threatened, sensitive and rare species, Daniel Boone National Forest, Berea Ranger District. Kentucky State Nature Preserves Commission, Frankfort.

6. Welter, W. A. and D. E. Sollberger. 1939. Notes on the mammals of Rowan and adjacent counties in eastern Kentucky. Jour. Mamm. 20(1):77–81.

7. Fassler, D. J. 1974. Mammals of Pulaski County, Kentucky. Trans. Ky. Acad. Sci. 35(1–2):37–43.

8. Hamilton, W. J., Jr. 1930. Notes on the mammals of Breathitt County, Kentucky. Jour. Mamm. 11:306–311.

9. Barbour, R. W. 1951. The mammals of Big Black Mountain, Harlan County, Kentucky. Jour. Mamm. 32: 100–110.

10. Barbour, R. W. and S. Hardjasasmita. 1966. A preliminary list of the mammals of Robinson Forest, Breathitt County, Kentucky. Trans. Ky. Acad. Sci. 27(3–4):85–89.

11. Warren, M. L., Jr., W. H. Davis, R. R. Hannan, M. Evans, D. L. Batch, B. D. Anderson, B. Palmer-Ball, Jr., J. R. MacGregor, R. R. Cicerello, R. Athey, B. A. Branson, G. J. Fallo, B. M. Burr, M. E. Medley, and J. M. Baskin. 1986. Endangered, threatened, and rare plants and animals of Kentucky. Trans. Ky. Acad. Sci. 47(3–4):83–98.

12. Meade, L. E. 1992. New distributional records for selected species of Kentucky mammals. Trans. Ky. Acad. Sci. 53(3–4):127–132.

Trans. Ky. Acad. Sci., 54(3–4), 1993, 93–97

Observations on Long-term Effects of Sedimentation on Freshwater Mussels (Mollusca: Unionidae) in the North Fork of Red River, Kentucky

Ronald E. Houp

Division of Water, Water Quality Branch, Ecological Support Section,
14 Reilly Road, Frankfort, Kentucky 40601

Abstract

Mussel surveys and observations in the Wild River segment of the north fork of Red River, Kentucky, in 1986 and 1991, are compared to a 1980 survey. Mussel community dynamics have changed through time according to the tolerances of individual species to chronic sedimentation. Observed recruitment and continued increases in numbers of *Elliptio dilatata, Ptychobranchus fasciolaris, Lasmigona costata* and *Pleurobema coccineum* indicates the highest tolerances to sedimentation. *Actinonaias ligamentina* has remained relatively stable in numbers since 1980. *Alasmidonta marginata, Strophitus undulatus, Fusconaia flava, Lampsilis siliquoidea* and *Lampsilis cardium* have experienced the greatest declines and appear to be among the most intolerant to sedimentation. *Tritogonia verrucosa, Lampsilis fasciola, Obovaria subrotunda, Alasmidonta viridis* and *Potamilus alatus*, though never abundant, are now very low in numbers and could disappear. *Amblema plicata* and *Ligumia recta* have not been observed alive since 1980. The community composition is changing to mussel species that have less-specific habitat requirements and a broader selection of host fishes.

Introduction

The aquatic biota and water-quality conditions in the north fork of Red River in eastern Kentucky was initiated in 1976 by the Division of Water Quality (1). The purpose was to gather background physical, chemical and biological data in the headwaters of the North Fork before the first permitting of surface coal mining in the watershed (Fig. 1). A permanent biological monitoring site was established at the U.S. Geological Survey (USGS) gaging dam downstream from Hazel Green in 1978. That site remains a part of the Basic Water Monitoring Program (BWMP) network for the Division of Water (DOW). Additionally, a survey of freshwater mussels twelve miles downstream in the Wild River segment was published as part of a long-term monitoring strategy for the drainage (2). The accumulated data presented here are the continuation of the monitoring program.

Mussel surveys from the same stream or stream sites in Kentucky over extended time periods are mostly confined to larger rivers (3, 4). The reasons are evident, since larger streams often contain unique mussel assemblages, including commercially valuable and rare and endangered species. The need to protect those resources through water-quality standards is the impetus for those endeavors. That need also extends to smaller streams over the state which serve as refugia for many large river species and/or headwater endemics which form the basis for continued monitoring.

Published literature for the drainage following the 1980 mussel survey includes Branson and Batch (5), who surveyed gastropods and sphaerican clams of the drainage, and Birge et al. (6), who conducted a study in the south and middle forks Red River to establish numerical values on iron and chloride concentrations for the protection of aquatic life. A biological survey of the south and middle forks was also conducted in 1985 by DOW (7) to assess the effects of oil-brine wastes on aquatic life.

Study Site

The north fork of Red River originates in mountainous and heavily forested Wolfe County, Kentucky. Selective logging and farming in the headwater tributaries were the only influences affecting water quality prior to 1980. The entire area is underlain by Middle Pennsylvanian aged coal, along with shale and sandstone of the Lee and Breathitt formations (8). In the mid-reaches of the north fork, the stream was eroded through sandstones into older Mississippian aged siltstone, clay and shale formations, creating impressive sandstone arches, cliffs and boulders. A 14.6 kilometer

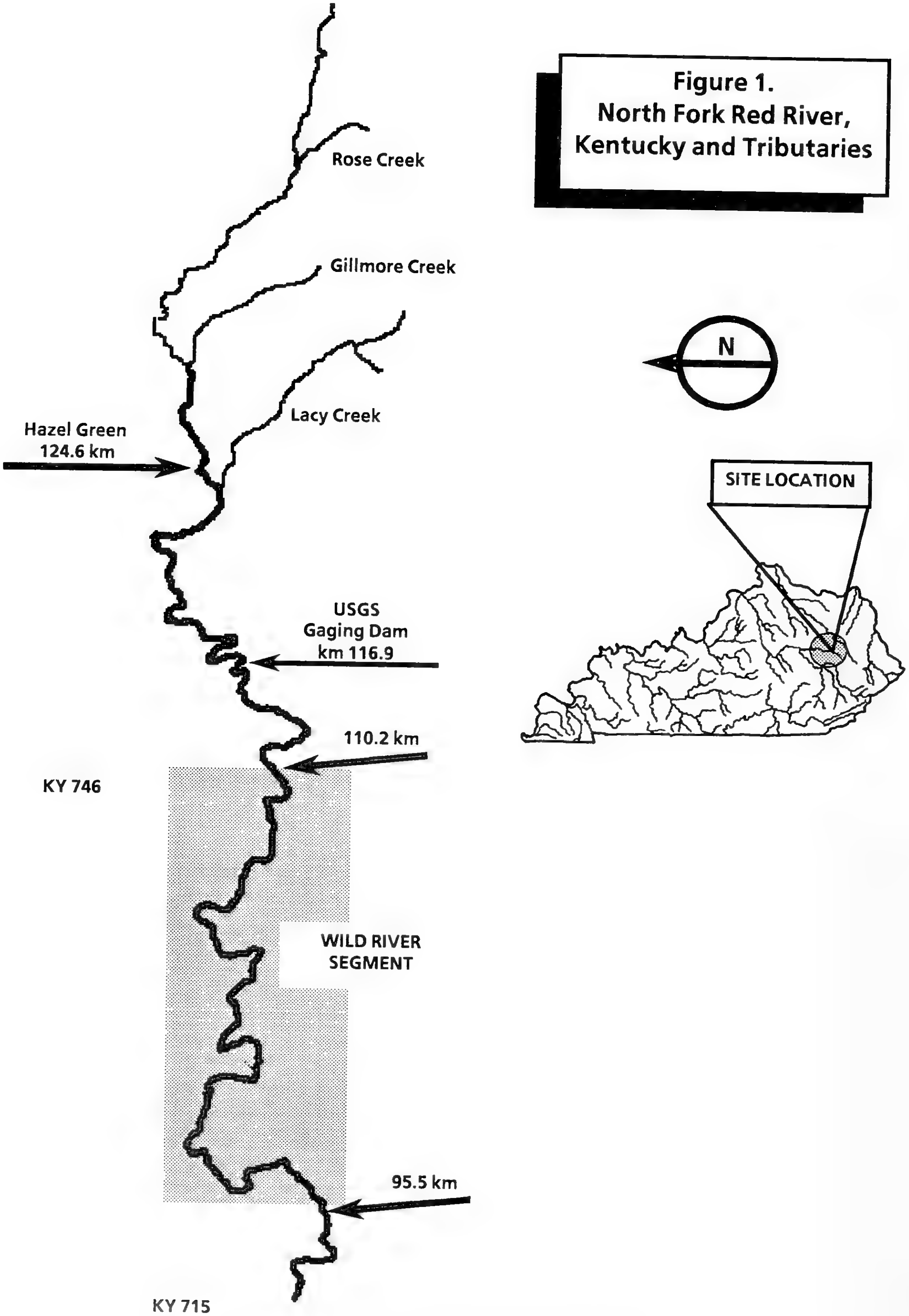


FIG. 1. North fork Red River, Kentucky and tributaries.

segment of the north fork between Kentucky highway 746 bridge and highway 715 bridge was designated a Kentucky Wild River in 1972 and is located upstream from Red River Gorge, an area of exceptional natural beauty. Mussel habitats in the wild river segment are not well defined but are typical of the mussel habitats found in the north fork. The best habitats were most often located in small shoals and upstream and downstream from riffles where various combinations of substrates (i.e., boulders, rubble, cobble, gravel, pebbles and sands) have accumulated to form suitable mussel habitats. Mussels were found scattered throughout the substrate so that mussel densities seldom exceeded 4 individuals per square meter.

MATERIALS AND METHODS

The entire length of the wild river segment of the north fork was waded and hand sampled for mussels in all surveys with the exception of some deep bedrock pools. Mussel surveys began in early May at the downstream boundary (715 bridge) and moved upstream as time and stream conditions permitted. Visits to the study area were designed to include all seasons. In general, mussel habitats throughout the wild river segment are separated by bedrock runs, pools or large boulders weathered from adjacent cliffs. Those geological features helped to delineate sampling areas. Mussels were found in the substrate by visual sighting or looking for small light colored patches of substrate settled around individuals from expelled materials (mostly clays) siphoned from the water column. Vertical movements of mussels up and down into the substrate incorporate some of the materials in the substrate around them. Quantitative monitoring of mussels at fixed sites in order to observe vertical movements over time was conducted using a method described by Houp (9). Further, a technique introduced by the author after the first mussel survey was used in larger sampling areas. That method involved inserting wire stake flags into the substrate beside located mussels to prevent recounting and to expedite sampling efforts. Located mussels were removed, identified, counted, and returned to the substrate. Mussels used for confirmations were transported live in plastic jugs and later returned to the same locations. Photographs taken of the sample areas before the wire stakes were removed proved useful in relocating mussel concentrations or distributions within selected areas. A few sites contained shells collected from muskrat middens which were searched for new species and voucher material. Mussel voucher collections are catalogued and stored in the DOW Mollusk Collection, located at 14 Reilly Road, Frankfort, Kentucky. Nomenclature used for the identification of freshwater mussels follows Turgeon et al. (10).

RESULTS AND DISCUSSION

Sediment Sources.—In 1982, lighter suspended materials were observed accumulating in despositional areas within the wild river segment. Retention ponds at mining sites in the headwaters tributaries were designed to keep heavy sediments from entering the drainage. In spite of that, excessive sands had arrived in the upper wild river segment by 1984. The sources of the heavier sediments were eventually associated with mining activities by observing waste coal mixed with sands that were deposited along stream banks during higher flows. Another sediment source, and a large contributor, was located by accident during 1984, when the author happened upon a stream relocation project on lower Lacy Creek. In that instance, the land owner had used earth moving equipment to create a new stream channel then filled and leveled the old meandering channel thereby consolidating a pasture previously divided by the stream. The small stream size (3–5 meters wide) enabled a quick completion and was not detected soon enough to be considered by the proper regulatory program. Surface mining has decreased, but still continues in the headwaters. Also, land disturbances from accelerated logging, along with some farming, and bed-load sands continue to flush downstream during high flows.

In the sandstone streams of eastern Kentucky, some shell erosion is observed in most older mussels as a natural consequence of age and time. However, excessive sands carried by high flows are very erosive to all mussels exposed to flow. Vannote and Minshall (11) noted that an influx of sediments appeared to be responsible for a shift in predominant species in the Salmon River Canyon, Idaho, a western stream with several habitat features comparable to the Red River.

Faunal Increases.—*Actinonaias ligamentina* has remained stable with slight increases in numbers (Table 1). According to the vertical

TABLE 1. The total numbers of living freshwater mussels found in the (wild river segment) North Fork Red River, Kentucky.

Species	1980	1986	1991
1. *Alasmidonta marginata*	91	26	24
2. *Strophitus undulatus*	73	56	37
3. *Elliptio dilatata*	67	81	114
4. *Lasmigona costata*	55	46	69
5. *Fusconaia flava*	47	21	10
6. *Lampsilis siliquoidea*	37	16	11
7. *Ptychobranchus fasciolaris*	34	38	51
8. *Lampsilis cardium*	27	23	12
9. *Alasmidonta viridis*	18	23	6
10. *Tritogonia verrucosa*	17	11	3
11. *Lampsilis fasciola*	16	18	4
12. *Actinonaias ligamentina*	13	11	15
13. *Obovaria subrotunda*	9	0	1
14. *Amblema plicata*	9	0	0
15. *Ligumia recta*	4	0	0
16. *Pleurobema coccineum*	0	3	17
17. *Potamilus alatus*	0	4	1
Totals	517	377	375

movement patterns observed during this study, this particular mussel, long considered bradytictic (12) is probably tachytictic. While others, such as *Elliptio dilatata* and to a lesser extent *Ptychobranchus fasciolaris, Lasmigona costata* and *Pleurobema coccineum,* appear to be the least affected by sedimentation and have gained in numbers over the years.The increases in some mussels are closely related to the behavioral and morphological features of each species. For example, morphologically, all of the species that increased in numbers are narrow and enlongated and tend to migrate deeper into the substrate for longer periods of time. Also, they are all tachytictic (summer breeders), which aligns their reproductive periods with low flows of summer and minimal sedimentation. When those species are in a siphoning position they orient parallel with the flow (i.e., posterior ridges facing downstream), exposing the least amount of shell surface to the water column. Wilson and Clark (13) suggested that flatter shell forms were better adapted for burrowing in coarse substrates and swifter currents of headwater streams. Also, Huehner (14) found that *Elliptio dilatata* had no substrate preferences in the field of laboratory.

Faunal Declines.—Since the 1980 survey, *Alasmidonta marginata* (the predominant species at that time) along with *Strophitus undulatus, Lampsilis siliquoidea* and *Fusconaia flava* have shown the greatest declines in numbers observed (Table 1). Others, such as *Alasmidonta viridis, Tritogonia verrucosa, Lampsilis fasciola, Obovaria subrotunda,* and *Potamilus alatus,* were never numerous and now are so scarce that extripation from the north fork could occur. *Amblema plicata* and *Ligumia recta* have not been observed since 1980. The reasons for the declines in those species appears to be a behavioral tendency of not completely burrowing under the substrate and tilting upward while in a siphoning position, exposing more shell surface to the water column. Morphologically, most of those species have broader posterior slopes and ridges. More importantly, a bradytictic reproductive period for those mussels contributed to their declines by coinciding with higher flows of later winter and spring when reproduction occurs. A clear separation between the species that have declined (brachytictic) as opposed to those that have increased in numbers (tachytictic) is an indication of how chronic sedimentation can gradually alter community composition by being synchronous with higher spring flow conditions and the reproductive life cycles of certain mussel species.

Shell erosion, reproductive failure, and habitat losses are examples of the direct effects that accelerated sedimentation have on native mussels. However, from the increases in numbers observed for some species (Table 1), it is doubtful that chronic sedimentation would eliminate the entire mussel community. It does indicate that the community composition is changing to mussel species that have less specific habitat requirements and a broader selection of host fishes. Further, the host fishes are also changing in response to sedimentation due to loss or reductions in their habitats. The indirect effects on mussels through the losses of their host fishes is far more long term and difficult to document. If fish habitats (i.e., spawning areas) are eliminated the potential exists to extirpate several mussel species. Fish collections at the BWMP site and in the study site now reflect significant reductions and/or losses in some fish species and age group losses in others. Both are attributed to past spawning failures and/or habitat losses from the effects of sedimentation (15, 16, 17, 18).

The Kentucky Nature Preserves Commission (KNPC) (19) has reported the presence of 3 individuals of *Simpsonaias ambigua* at a single site in 1988. However, extensive searches for that secretive mussel were not successful during the last survey.

ACKNOWLEDGMENTS

I wish to show my appreciation to the following people for help in the field over the past years: Stephan Porter, Sherri Evans, Charlie Roth, Cliff Schneider, Parrish Roush, Don Walker and my son, George Wesley Houp. I am grateful to Karen Smathers for providing invaluable assistance with fieldwork and identifications in the 1990 survey. Her knowledge and enthusiasm is much appreciated. My son Ronald E. Houp, along with Lee Colten, Julie Duncan and Ken Cooke were most generous with their time and knowledge of computers. I also want to thank Steve Ahlstedt, Tennessee Vally Authority for providing positive encouragement and constructive comments on the manuscript. Also, Bob Logan, Commissioner, Department for Environmental Protection, Bob Ware, Assist. Dir. DOW, and Jack Wilson, Dir. DOW for their positive support. I thank them all.

LITERATURE CITED

1. Kentucky Division of Water Quality. 1980. Biological survey of the Red River in Eastern Kentucky. Technical Report No. 1:1–33.

2. Houp, R. E. 1980. A survey of the mussels of the Red River (Wild River segment) in eastern Kentucky. Trans. Ky. Acad. Sci. 41:55–56.

3. Williams, J. C. 1969. Mussel fishery investigations, Tennessee, Ohio, and Green rivers. Final report. Murray State University Press, Murray, Kentucky.

4. Williams, J. C. and G. A. Schuster. 1982. Mussel fishery investigations of the Ohio River mile 317.0 to mile 981.0 U.S. Army Corp of Engineers, Louisville District. Kentucky Dept. of Fish and Wildl. Res., Div. Fish. U.S. Fish and Wildlife Service, Regions III and IV.

5. Branson, B. A. and D. Batch. 1982. The Gastropoda and Sphaerican clams of the Red River, Kentucky. Veliger 24:200–204.

6. Birge, W. J., J. A. Black, A. G. Westerman, T. M. Short, D. M. Bruser, and E. D. Wallingford. 1985. Recommendations on numerical values for regulating iron and chloride concentrations for the purpose of protecting warmwater aquatic life in the Commonwealth of Kentucky. Memorandum of Agreement No. 5429. Ky. Nat. Res. and Environmental Protection Cabinet.

7. Kentucky Division of Water. 1990. South Fork Red River drainage biological and water quality investigation for stream use designation. Tech. Rept. 26:1–55.

8. McDowell, R. C., G. T. Grabowski, Jr., and S. L. Moore. 1981. Geologic map of Kentucky. Ky. Geol. Surv., Lexington.

9. Houp, R. E. 1987. A method used to monitor endangered freshwater mussels and their habitat conditions at water quality trend sites in a Kentucky stream system. Bull. North American Benth. Soc. 4:127.

10. Turgeon, D. D., A. E. Bogan, E. V. Coan, W. K. Emerson, W. G. Lyons, W. L. Pratt, C. F. Roper, A. Scheltema, F. G. Thompson, and J. D. Williams. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. Amer. Fish. Soc. Spec. Publ. 16:1–277.

11. Vannote, R. L. and G. W. Minshall. 1982. Fluvial processes and local lithology controlling abundance, structure, and composition of mussel beds. Proc. Nat. Acad. Sci. 79:4103–4107.

12. Utterback, W. I. 1915. The Naiades of Missouri. Amer. Mid. Nat. 4:1–200.

13. Wilson, D. B. and H. W. Clark. 1914. The mussels of the Cumberland River and its tributaries. U.S. Bur. Fish. Doc. 781:1–63.

14. Huehner, M. K. 1987. Field and laboratory determination of substrate preferences of unionid mussels. Ohio J. Sci. 87:29–32.

15. Kentucky Division of Water. 1981. Basic water monitoring program collections, Station No. 04PRI027.

16. Kentucky Division of Water. 1982. Basic water monitoring program collections, Station 04PRI027.

17. Kentucky Division of Water. 1986. Basic water monitoring program collections, Station 04PRI027.

18. Kentucky Division of Water. 1991. Basic water monitoring program collections, Station 04PRI027.

19. Kentucky Nature Preserves Commission. 1988. Red River Sorting Sheet No. 32.

Trans. Ky. Acad. Sci., 54(3–4), 1993, 98–102

A Comparison of Math Attitudes among Various Groups of Students

AMY C. KING AND PATRICIA S. COSTELLO

Department of Mathematics, Statistics, and Computer Science, Eastern Kentucky University, Richmond, Kentucky 40475-3133

ABSTRACT

Many comparisons have been done among students in the United States and other countries concerning their aptitudes and attitudes toward mathematics. This study was performed to compare the attitudes among several diverse groups in the Commonwealth of Kentucky. A group of 639 subjects was selected, ranging from grade school to college. From the sample it was found, as would be expected, that those students in advanced college math courses and those in the more advanced groups in the high schools had a better attitude than those in remedial classes. However, it was noted that the students in grades 5 through 8 had a better attitude toward math than students in the remedial college math classes. In addition, males had a better attitude toward math than females. Since the sample was somewhat restricted, a follow-up of more randomly selected students throughout the Commonwealth of Kentucky is planned in order to more carefully determine the level at which this negative attitude towards mathematics starts; if there is a difference between the attitudes of males and females; and if there is a distinction in the different geographic regions of the state.

INTRODUCTION

There have been many studies concerning aptitudes and attitudes of students in different countries toward mathematics. Recently a former student at Eastern Kentucky University, Judy Mayes Mings (1), compared attitudes between Japanese and American students. As in the Mings paper, the authors used the Aiken Revised Mathematics Attitude Scale (2). A similar test was conducted to compare the attitudes of several groups of students within the Commonwealth of Kentucky. The results of the survey showed a good attitude from students in both more advanced college and high school mathematics classes. This was expected. However, grades 5 through 8 exhibited a better attitude when compared to the remedial level at college. These findings are unclear. This was a preliminary survey to highlight any outstanding differences, and the authors are currently preparing a follow-up of randomly selected students throughout the entire Commonwealth of Kentucky to determine when this negative attitude towards mathematics begins to form. Are there significant differences in males and females? Does it make a difference in what section of Kentucky one lives? Why do certain students take such a minimum number of mathematics courses in high school that it is necessary for them to enroll in the remedial mathematics classes at the college level?

Inasmuch as the Commonwealth of Kentucky is on the cutting edge of the reform movement in education, additional information concerning areas which need restructuring would be beneficial.

METHODS

Questionnaires were obtained as follows: (a) College classes taught at Eastern Kentucky University by the first author; (b) high school mathematics classes in Jackson, Jessamine, and Laurel counties in Kentucky, taught by former students of the first author; (c) grade school students (5 through 8) from Jackson County; (d) several introductory level college courses taught by colleagues at Eastern Kentucky University.

The 639 subjects included 88 students in grades 5–8 from Jackson County, 95 Geometry students from Jessamine County, 45 high school students from Jackson County, 114 high school students from Laurel County, 6 Remedial Math students from Jessamine County, and 291 college students from Eastern Kentucky University. Since some of the questionnaires were incomplete, not all of the students were used in the analysis. The Geometry students came from a Basic Geometry class, an Average Geometry class, a Regular Geometry class, and an Accelerated Geometry class (all freshman). The college classes consisted of MAT 090 (Basic Mathematics), MAT 093 (Basic Descriptive

TABLE 1. Means and standard deviations for Aikens Math Attitude Scale for each class.

Class	Sample size	Mean	Standard deviation
Basic geometry	13	7.462	18.738
Average geometry	26	−3.962	20.895
Regular geometry	24	8.417	18.337
Accelerated geometry	31	12.871	17.231
Remedial math	6	0.167	9.867
Jackson County High School	38	7.000	14.245
Laurel County High School	106	7.736	16.825
Grades 5–8, Jackson County	82	8.756	16.247
MAT 090	45	−2.822	20.761
MAT 093	52	−4.404	18.553
MAT 095	83	−13.229	19.419
MAT 108	10	13.100	11.628
MAT 223	20	15.550	12.800
MAT 353	13	25.462	6.476
MAT 414	6	28.167	7.305
CSC 104	44	−5.023	23.108

Geometry), MAT 095 (Basic Algebra), MAT 108 (Trigonometry), MAT 223 (Calculus and Analytic Geometry III), MAT 353 (Differential Equations), MAT 414 (Introduction to Analysis), and CSC 104 (Computer Literacy with Software Applications). MAT 090, 093, and 095 are all remedial Math classes. The data were collected during 1989–1990.

For the measure of attitude, the Aikens' Revised Math Attitude Scale (2) was utilized. Each questionnaire consisted of 20 statements, 10 of which were positive and 10 negative. The respondent was to indicate, on a 5-point scale, the extent of agreement or disagreement. Included were positive statements such as, "Mathematics is very interesting to me, and I enjoy math courses." Negative statements included items such as "I am always under a terrible strain in math class." The 5 choices to each statement were: strongly agree (SA), agree (A), undecided (U), disagree (D), and strongly disagree (SD). These were scored as follows: SA = 5, A = 4, U = 3, D = 2, and SD = 1. The positive statements received positive scores and the negative statements received negative numbers. The total scores ranged from a possible 40, indicating a high positive attitude, to −40, a negative attitude. In an experiment by Adwere-Boamah, Miller, and Kahn (3), using the Aiken attitude scale (2), this instrument was found to be of high reliability for students from a white suburban area. The students polled for the Kentucky experiment should form a comparable set, as they were from a mixture of rural and suburban communities.

In addition, each student indicated their grade level and sex, and a like/dislike scale of mathematics. Here, the subject noted the degree of like or dislike of mathematics on a scale of 1 to 7. One meant like and seven a dislike. This scale was used to check against a possible misinterpretation of the responses to the Aiken questionnaire (2).

RESULTS

As previously mentioned, the attitude scale was scored with the highest and lowest possible scoring being 40 (good attitude toward math) and −40 (bad attitude toward math), respectively. The data were analyzed using the statistical computer package SAS on a VAX 2340 computer. A three-way analysis of variance with no interactions was performed using PROC GLM (4) with the Aiken score as the dependent variable, and the classes, grade level, and sex as the main effects. The only significant main effect was the classes, ($F = 4.39$; df = 13,474; $P = 0.0001$). Since this was the case, the model was reduced to the one-way analysis of variance with the Aiken score as the dependent variable and classes as the main effect, ($F = 11.38$; df = 15,583; $P = 0.0001$). Tukey-Kramer multiple comparisons were also performed with an experiment-wise error rate of 0.05. This analysis concluded that the average Aiken scores for MAT 414, 353, 223, and Accelerated Geometry were all significantly larger than the average Aiken scores for MAT 090, MAT 093, MAT 095, CSC 104, and Average Geometry. In addition, the average Ai-

TABLE 2. Means and standard deviations for Aikens Math Attitude Scale for each grade.

Grade	Sample size	Mean	Standard deviation
Grade 5	17	13.529	17.256
Grade 6	20	14.350	14.046
Grade 7	33	5.545	16.386
Grade 8	9	0.333	15.427
High school freshmen	73	9.329	15.727
High school sophomores	49	3.082	20.467
High school juniors	83	6.771	18.026
High school seniors	20	8.550	17.449
College freshmen	128	−7.992	21.025
College sophomores	30	−1.900	23.517
College juniors	32	3.125	20.017
College seniors	22	13.773	21.450

ken score for grades 5–8 were significantly larger than the average Aiken scores for MAT 090, MAT 093, MAT 095, and CSC 104, and the average Aiken score for the high school students from Laurel County was significantly larger than the average Aiken scores for MAT 093, MAT 095, and CSC 104. Finally, the average Aiken score for MAT 095 was significantly lower than the average Aiken score for MAT 108, Regular Geometry, Basic Geometry, high school students from Jackson County, as well as MAT 414, 353, 223, Accelerated Geometry, grades 5–8, and high school students from Laurel County (as was previously mentioned). The sample sizes, means and standard deviations for each group are contained in Table 1.

Although the variables sex and grade level were not significant in the three-way analysis of variance model, they were each significant when a one-way analysis of variance was performed. When the variable sex was the main effect ($F(1,510) = 9.02$, $P = 0.0028$) males had a significantly higher average Aiken score than females. (For males, N = 229, $\bar{x} = 6.100 \pm 18.438$. For females, N = 283, $\bar{x} = 0.742 \pm 21.312$). This was probably due to the fact that the classes CSC 104, MAT 090, MAT 093, and MAT 095 each contained approximately twice as many females as males and also had low average Aiken scores. Grades 5–8, MAT 223, and MAT 353, which had higher average Aiken scores, also had more males than females.

When the variable grade level was the main effect, ($F = 7.04$; df = 11,504; $P = 0.0001$), college freshmen had a significantly lower average Aiken score than students from grades 5, 6, and 7; high school freshmen, sophomores, juniors, and seniors; and college seniors. This is probably due to the fact that all but 3 college freshmen were enrolled in CSC 104, MAT 090, MAT 093, and MAT 095 (all these courses had low Aiden scores). The sample sizes, means and standard deviations for each grade are contained in Table 2.

The results of the like/dislike scale are given in Tables 3, 4, and 5, for each class, sex, and grade, respectively. These results support the conclusions reached by the use of the Aiken attitude test. The chi-square test for equal proportions, performed using PROC FREQ (5), indicated that there was a significant difference in the proportion of male and female students who chose each possible score, (χ^2 =

TABLE 3. Percentages from the like/dislike scale for each class.

Class	Like	1	2	3	4	5	6	7	Dislike
Basic geometry		21.4	14.3	7.1	35.7	14.3	0.0	7.1	
Average geometry		11.5	3.8	7.7	23.1	7.7	26.9	19.2	
Regular geometry		13.6	27.3	9.1	27.3	9.1	4.5	9.1	
Accelerated geometry		16.1	29.0	16.1	19.4	12.9	6.5	0.0	
Remedial math		0.0	20.0	20.0	20.0	20.0	0.0	20.0	
Jackson County HS		5.3	26.3	21.1	23.7	15.8	5.3	2.6	
Laurel County HS		17.7	22.1	20.4	16.8	14.2	1.8	7.1	
Grades 5–8, Jackson Cty		17.1	26.8	19.5	12.2	9.8	7.3	7.3	
MAT 090		10.6	14.9	12.8	27.7	8.5	8.5	17.0	
MAT 093		9.4	9.4	9.4	22.6	15.1	17.0	17.0	
MAT 095		7.1	4.8	6.0	14.3	19.0	16.7	32.1	
MAT 108		10.0	20.0	50.0	10.0	10.0	0.0	0.0	
MAT 223		10.5	42.1	36.8	10.5	0.0	0.0	0.0	
MAT 353		33.3	53.3	6.7	6.7	0.0	0.0	0.0	
MAT 414		50.0	16.7	33.3	0.0	0.0	0.0	0.0	
CSC 104		10.9	10.9	10.9	15.2	17.4	8.7	26.1	

TABLE 4. Percentages from the like/dislike scale for each sex.

Sex	Like	1	2	3	4	5	6	7	Dislike
Male		12.1	21.6	21.1	16.4	13.8	7.8	7.3	
Female		15.3	16.7	11.8	17.1	13.2	8.0	17.8	

20.221; df = 6; $P = 0.003$). The most noticeable difference was that 17.8% of the females indicated a dislike score of 7 as compared to 7.3% of the males.

Chi-square tests were not valid for class or grade level, since too many of the expected cell counts were smaller than 5. To rectify this for the variable class, Basic Geometry, Remedial Math, and MAT 108 were eliminated since these classes were so small, and the classes MAT 223, 353, and 414 were combined, since they contained students with similar scores on the Aiken attitude test. For the variable grade level, grades 5 through 8 were combined as well as high school juniors and seniors. In addition, for both class and grade level, the like/dislike categories of 1 and 2 were combined as well as the categories of 6 and 7. Once these modifications were made, the chi-square test for equal proportions indicated that there was a significant difference in the proportion of students in the different classes who chose each possible score, ($\chi^2 = 145.344$; df = 40; $P < 0.0005$), as well as a significant difference in the proportion of students in the different grades who chose each possible score, ($\chi^2 = 64.252$; df = 28; $P < 0.0005$). The most noticeable differences for the variable class is the high percentage of Regular Geometry (40.9%), Accelerated Geometry (45.2%), Laurel County High School (39.8%), grades 5–8 (43.9%), and MAT 223, 353, 414 (67.5%) students who chose a Like score of 1 or 2, as well as the high percentage of Average Geometry (46.2%), MAT 093 (34.0%), MAT 095 (48.8%), and CSC 104 (34.8%) who chose a Dislike score of 6 or 7. The most noticeable differences for the variable grade, is the high percentage of grades 5–8 (44.3%), high school freshmen (36.1%), high school juniors and seniors (36.7%), college sophomores (38.7%), and college seniors (54.6%) who chose a Like score of 1 or 2, as well as the high percentage of college freshman (34.9%) and college sophomores (35.5%) who chose a Dislike score of 6 or 7. It is particularly interesting that the college sophomores seemed to either really like or really dislike Math.

DISCUSSION AND SUMMARY

As noted in the introduction, this study was of a preliminary nature, in order to highlight differences in attitudes between males and females, and at different levels and ages. Many questions have been raised. From our restricted sample, there is a significant difference in attitude towards mathematics between students in advanced college and high school math classes versus remedial college mathematics classes. In addition, students in grades 5 through 8 had a better attitude towards mathematics than the students in remedial college mathematics classes. Further, this study indicated

TABLE 5. Percentages from the like/dislike scale for each grade.

Grade	Like	1	2	3	4	5	6	7	Dislike
Grade 5		23.5	23.5	11.8	5.9	5.9	5.9	23.5	
Grade 6		28.6	38.1	14.3	19.0	0.0	0.0	0.0	
Grade 7		12.9	19.4	25.8	6.5	19.4	12.9	3.2	
Grade 8		0.0	30.0	10.0	30.0	10.0	10.0	10.0	
High school freshmen		9.7	26.4	20.8	19.4	15.3	5.6	2.8	
High school sophomores		14.3	18.4	12.2	16.3	12.2	14.3	12.2	
High school juniors		14.8	19.3	17.0	23.9	13.6	3.4	8.0	
High school seniors		28.6	19.0	14.3	19.0	9.5	0.0	9.5	
College freshmen		8.5	10.1	10.1	17.1	19.4	10.9	24.0	
College sophomores		22.6	16.1	9.7	6.5	9.7	12.9	22.6	
College juniors		9.4	21.9	18.8	18.8	6.3	9.4	15.6	
College seniors		27.3	27.3	22.7	4.5	4.5	0.0	13.6	

females disliking mathematics more than did males; however, there were more females than males in the remedial classes.

The study points up the need to obtain a more complete random sample throughout the Commonwealth of Kentucky to further explore differences which have here been noted.

ACKNOWLEDGMENTS

The authors wish to thank Academic Computing Services of Eastern Kentucky University for their assistance in typing the data and for the use of their VAX 2340 computer. Further, we thank Judy Mayes Mings for furnishing us with a copy of her paper comparing Math attitudes between Japanese and American students.

LITERATURE CITED

1. Mings, J. M. 1989. Math attitudes: a comparison between Japanese and American students. Unpublished paper. Eastern Kentucky University, Richmond, Kentucky.

2. Aiken, L. R., Jr. 1963. Personality correlates of attitude toward mathematics. J. Ed. Res. 6:476–489.

3. Adwere-Boamah, J., D. Muller, and G. Kahn. 1986. Factorial validity of the Aiken–Dreger mathematics attitude scale for urban school students. Ed. Psyc. Measur. 46: 233–236.

4. SAS Institute Inc. 1989b. SAS/STAT user's guide, Version 6, 4th Ed. Vol. 2. SAS Institute Inc., Cary, North Carolina.

5. SAS Institute Inc. 1989a. SAS/STAT user's guide, version 6, 4th Ed., Vol. 1. SAS Institute Inc., Cary, North Carolina.

Trans. Ky. Acad. Sci., 54(3–4), 1993, 103–107

Deadlock Detection in Computer Database Systems: An Algorithm of Complexity O(N)

John H. Crenshaw

Department of Computer Science, Western Kentucky University
Bowling Green, Kentucky 42101

Abstract

Deadlock detection is an important process in many computer software systems which involve multitasking. Deadlock detection in a database systems environment is described, along with some traditional methods of implementation. A new algorithm is defined which can perform this task in O(N) time.

Introduction

A deadlock condition is the cessation of activity caused by 2 or more objects operating or applying forces against other objects in a system. In computer science, the term is generally used to describe a condition in which two or more tasks become inactive because each task requires one or more resources for which another task has exclusive rights. If each such task is in a wait-state until a desired resource becomes available, then a deadlock results.

For example, in an operating system where several jobs share the physical resources, job A may have gained possession of a printer and 2 of the 4 tape units, and is now requesting one more tape unit. If job B has possession of the other 2 tape units and is requesting the printer, the result is a deadlock between these 2 jobs. A deadlock is often diagramed (Fig. 1) as a directed graph where each node represents a job and each directed edge (X, Y) represents the state in which job X is waiting for a resource possessed by job Y.

A computer deadlock as defined above could involve many more jobs than simply the 2 shown in Figure 1. Whenever a deadlock occurs, the control system must detect that it exists and then take measures to break the impasse and permit normal processing to continue.

In recent years, databases have been utilized by governments, private and public corporations, and scientific laboratories to permit rapid accessing and modification of large amounts of information which are critical to those institutions. When these databases are accessed by several different individuals at one time, a deadlock situation is a distinct possibility. Date (1) said that as many as 10% of all such accesses result in a deadlock. Even if his figures are off by a factor of 10, the potential for costly tie-ups of computer systems is very real and must be addressed.

This paper discusses the issues involved with deadlock detection in a database environment, the detection methods used in the past, and the standards used to measure the efficiency of detection methods. Finally, a new algorithm for deadlock detection is described and shown to be O(N) where N is the number of concurrently running jobs.

Discussion

In computer databases, the primary unit of information is called a *Record*. A record, such as a Physical-Sighting, may be composed of several *Fields* such as date, place, time, Object-Sighted, etc., but the discussion here will be limited to handling information at the record level only. A particular job or task is referred to as a *Transaction*. Thus, in a given database, there may be several different transactions accessing the same or different records during a given time period.

In order to maintain the integrity of the database, a transaction will not be permitted to change a record without first gaining exclusive control of that record. This process is referred to as *Locking*. If Transaction A has locked Record R then Transaction B is not permitted access to Record R. If Transaction B requests Record R, then B must wait until A finishes and releases the lock it possesses on R.

Figures 2 and 3 illustrate 2 states of a database system. In Figure 2, there is no deadlock even though several transactions are waiting; transaction B is still operating normally. In Figure 3, however, a deadlock has occurred

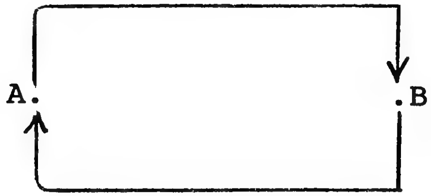


FIG. 1. Two transactions in deadlock.

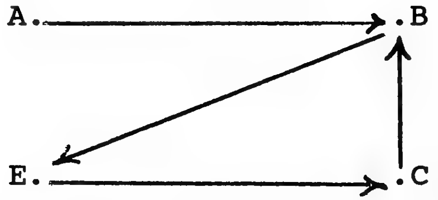


FIG. 3. Four transactions with a deadlock (B, E, C).

because transactions B, C, and E are all waiting for records locked by others in the group.

Figures 1–3 are examples of directed graphs referred to in the literature as *Wait-For Graphs.* A given computer system is in a deadlock situation if and only if its current Wait-For graph contains a *Cycle.* A Cycle is a closed path from any node X passing through one or more nodes before returning to node X. Each edge in the path must follow the directional orientation of the existing edges in the graph. For example, the deadlock of Figure 3 corresponds to the Cycle {B, C, E, B}. There is no cycle in the other direction {B, E, C, B}.

The classical techniques for detecting deadlock require the construction of the Wait-For graph and then searching that graph for cycles.

An early algorithm (2) for detecting cycles in a directed graph required the construction of the Adjacency Matrix, A, for the Wait-For graph. A(I, J) = 1 if there is an edge from node I to node J. Otherwise, A(I, J) = 0. If Y is computed to be the Kth power of A, then it can be shown that Y(I, J) = the number of different paths of length K from I to J. It then follows that a Wait-For graph will not have any cycles if there exists a value K between 1 and N such that Y(I, J) = 0 for all I and J.

Algorithm 1

Input.—A directed graph G = (V, E) represented by its adjacency matrix, A, which is N × N where N is the number of vertices or nodes.

Output.—A message saying whether or not G contains a cycle.

Method.—

1. Set Y = A.
2. Set K = 1.
3. While Y <> 0 and K < N do
4. Set Y = Y*A
5. If Y = 0 then display "There is no cycle in G"
   else display "There is a cycle in G"

This algorithm is very elegant but extremely slow. Using the standard Big-O measure for representing the speed of an algorithm, the cost of computing the product of 2 N × N matrices is $O(N^3)$. Thus, the cost of computing the Nth power of a matrix, A, is $((N^4)$. The total cost of utilizing this algorithm for deadlock detection is even higher since the Adjacency Matrix itself must be constructed from the Wait-For graph before the algorithm may be applied.

Aho (3) formalized a much faster algorithm which is still referenced by many texts (4) and researchers (5) as a standard method for detecting deadlocks. In Aho's presentation, the emphasis was on finding the strongly connected components of a directed graph. A strongly connected component is any set of nodes such that there exists a path from any node to any other node in that set. Thus, if there is a strongly connected component in the Wait-For graph, there must be a cycle involving the nodes in that component.

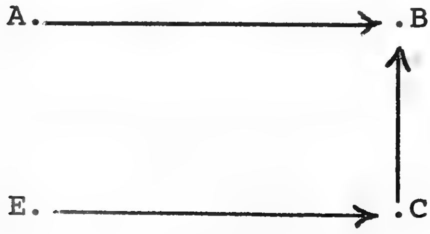


FIG. 2. Four transactions with no deadlock.

Algorithm 2

Input.—A directed graph G = (V, E) represented by a set of adjacency lists L(v) where each L(I) is a linked list of all nodes connected to vertex I.

Output.—A list of the strongly connected components of G. If any component is not nil, then a cycle is present in G.

Method.—
Main algorithm:
1. Set COUNT = 1
2. For all v in V mark v as "new."
3. Clear STACK.
4. While there exists a vertex v marked as "new" perform SEARCHC(v)
5. End.

SEARCHC(v) procedure:
1. Mark v as "old."
2. Set DFNUMBER[v] = COUNT.
3. Add one to COUNT.
4. Set LOWLINK[v] = DFNUMBER[v].
5. Push v onto STACK.
6. For each vertex w on L[v] do step 7.
7. If w is marked "new"
   then do
8. Perform SEARCHC(w);
9. Set LOWLINK[v] = MIN-(LOWLINK[v],LOWLINK[w]).
   else do
10. If DFNUMBER[w] < DFNUMBER[v] and w is on STACK then LOWLINK[v] = MIN-(DFNUMBER[w], LOWLINK[v])
11. If LOWLINK[v] = DFNUMBER[v] then one strongly connected component has been found. Stack contains the nodes. Print STACK contents and clear STACK for search for next component.

Aho's fundamental algorithm requires O(max(N, E)), where N is the number of nodes and E is the number of edges in the Wait-For graph. Since, in our application, each node could be waiting on at most one other node, there would be a maximum of N edges so the efficiency reduces to O(N). The algorithm requires the use of 2 additional vectors and a Stack, all of size N. A procedure internal to the algorithm is recursive of order N also. Finally, there is again the overhead problem of constructing the necessary graph data structures before beginning to execute this algorithm.

The method to be defined and described in this paper seeks to utilize data structures already in existence and knowledge of the state of the system in order to achieve a simpler and less costly algorithm. While it is probably not possible to create an algorithm whose Big(O) measure is better than O(N), the algorithm to be described will be shown to be O(N) with less processing needed prior to and during the algorithm execution.

TABLE 1. Locking matrix data structure.

Transaction #	Locked record(s)	Record waiting for	Trans. # which has locked it
T1	A, D	J	T7
T2	C, E		
T3	B	C	T2
T4		D	T1
T5	G	C	T2
T6	F	A	T1
T7	J, L		

First of all, it is necessary to have a clear idea of the data structures required in maintaining the locks on the records. Table 1 illustrates a typical structure for this purpose. Each row represents an active transaction. The first column shows the transaction number: T1–TN. The second column shows the records currently locked, if any, by that transaction. The third column shows which record, if any, that transaction is waiting for. In Table 1, the records in columns 2 and 3 are denoted by capital letters A–Z. Finally, column 4 contains the number, Ti, of the transaction which has locked the record listed in column 3. If column 3 is blank, then so is column 4. For example, the third row of Table 1 shows that Transaction T3 has locked record B and is waiting for record C which has already been locked by Transaction T2.

This data structure is very easy to maintain. New locks may be added and removed quickly. Information about which transactions are active and which are waiting can be obtained directly from the structure.

Some database systems perform detection only after a fixed time has elapsed; a deadlock, if it exists, may have been created soon after the last detection was performed, with the result being that nothing productive has occurred during the intervening period of time. In the algorithm to be described here, detection is to be initiated every time a lock request is denied. By performing the detection procedure whenever a lock request is denied, the system guarantees that a deadlock will never go undetected. The algorithm is designed to take advantage of the fact that no deadlock can be in existence prior to the current request, and if a deadlock is created, it must include the current request as one of the participating nodes.

The logic of the algorithm can be simply stated as follows: Starting with the transaction whose locking request has been denied, push onto a stack the number of each transaction which has locked a record for which the previously stacked transaction is waiting. If this chain of waiting transactions ever includes the starting transaction again, then a cycle has been detected. If not, then no cycle exists and normal database processing may continue. The algorithm is described more formally below:

Algorithm 3

Input.—A directed graph G = (V, E) represented by its locking matrix as illustrated in Table 1. In general, the locking matrix is a 2-dimensional array, LM, with N rows and 4 columns. Column 1 is the transaction number, Column 2 is the list of records locked by that transaction, Column 3 is the record the transaction is waiting for, and Column 4 is the transaction which has locked the record being waited for. The transaction, T, which has just been denied a requested lock.

Output.—A message as to whether or not a deadlock occurs.

Method.—

1. Set TARGET = T.
2. Push T onto STACK.
3. Set T to be the transaction which has a lock on R.
4. Repeat steps 5–7 while (T is waiting on a record) and (T <> TARGET)
5. Set R to be the record T is waiting on.
6. Push T onto STACK.
7. Set T to be the transaction which has a lock on R
8. If T = TARGET then Deadlock exists. STACK contains all transactions on the deadlock cycle.

Using Table 1 as an example, suppose Transaction T7 has locked records J and L as shown, and then makes a request for record F. Since F is locked by T6, the request is denied and the detection algorithm is performed. Transactions T7, T6, and T1 are then pushed onto the stack. The loop at step 4 terminates when Transaction T7 is processed again and pushed onto the stack. Thus, step 8 indicates a cycle is present.

Similarly, suppose Transaction T7 has locked J and L as shown, and then requests record E. Since E is locked by T2, the request is denied and the detection algorithm is performed. Transaction T7 is pushed onto the stack. Since Transaction T2 is not waiting on any record, the loop at step 4 terminates and step 8 shows that there is no deadlock.

To evaluate the Big(O) complexity of this algorithm, each step must be evaluated separately. Step 1 is O(1). Steps 2 and 6 are both O(1) because a Push operation on a stack inserts an element into the first position with no search or traversal of a list being necessary. Steps 3 and 7 are also O(1) because the locking Table can be accessed directly in column 4 to obtain the number of the transaction which has locked record R. Step 5 is O(1) because, once again, the locking matrix permits a direct access in column 3 to discover the record number which transaction T is waiting on. Finally, step 4 defines a loop which is O(N) since there are at most N transactions to be looked at and no transaction other than the Target will be examined more than once.

Therefore, the algorithm itself is O(N), requiring only the locking matrix which is maintained by the locking subsystem of the database management system and an integer stack as additional data structures.

SUMMARY

Deadlock detection is an essential component of database systems. Without reliable deadlock detection a computer system could become idle and remain that way for an indefinite period of time. The method of detecting deadlock described in this paper runs in O(N) time and does not require the construction of additional data structures as Aho's (3) does.

LITERATURE CITED

1. Date, C. J. 1983. Database—a primer. Addison-Wesley, Reading, Massachusetts.

2. Berztiss, A. T. 1975. Data structures—theory and practice. Academic Press, New York, New York.

3. Aho, A. V. 1975. The design and analysis of computer algorithms. Addison-Wesley, Reading, Massachusetts.

4. Kroenke, D. M. 1988. Database processing: fundamentals, design, implementation. Science Research Associates, Chicago, Illinois.

5. Stonebraker, M. 1988. Readings in database systems. Morgan Kaufmann, Palo Alto, California.

Trans. Ky. Acad. Sci., 54(3–4), 1993, 108–111

Somatic Embryogenic Response of Soybean (*Glycine max* (L.) Merr.) Genotypes to Culture Media

M. M. Rahman

Plant and Soil Science, Community Research Service, Kentucky State University, Frankfort, Kentucky 40601

Abstract

Tissue-culture protocols for soybean (*Glycine max* (L.) Merr.) regeneration vary widely. In this study, immature embryos of 7 soybean genotypes of different maturity groups were evaluated for their ability to regenerate plantlets in 3 different culture media. Regenerable calli and organogenesis were obtained from all genotypes in all media, but the frequency of regeneration was greatly influenced by the genotypes, culture media, and their interactions. Though genotype was found to be a determinant factor, the culture media also influenced regeneration. It appeared that optimal media for in vitro soybean regeneration varied with genotypes.

Introduction

In vitro propagation protocols have been developed for many soybean (*Glycine*) species, including *Glycine max* (L.) Merr., using various explants (1, 2, 3, 4). Since culture media is a source of variation (6, 7), the principal barrier to soybean regeneration via tissue culture is the lack of nutrient medium which would maximize routine regeneration of various genotypes. The formulation of nutrient media such as MS (8), B5 (9), and L2 (10) was a major advance regarding the nutritional requirements of in vitro cultures. Notwithstanding the nutritional advancements, there is no consensus about the optimal culture medium/media for in vitro soybean regeneration.

Many studies provide evidence that genotype exerts direct influence upon organogenesis (11, 12, 2). Since soybean regeneration in vitro is difficult, several nutrient media such as MS (8), B5 (9), and L2 (10), etc. and various explants, such as leaves (15), cotyledonary nodes (1, 11), protoplasts (4), immature embryos (12), etc. are used to induce regeneration. Consequently, it is difficult to determine which culture medium/media and explant(s) combination is most suitable to induce routine organogenesis to particular soybean genotypes.

Since the basic constituents of media differ from one another, this study is an attempt to determine the organogenic responses of divergent groups of soybean genotypes to widely used culture media supplemented with different plant growth regulators. This information is considered important to initiate a protocol for developing a medium/media which would consistently regenerate soybean plants from a wide range of genotypes.

Materials and Methods

Media.—Treatments consisted of MS, B5, and L2 basal media supplemented with one of the following plant growth regulators/combinations: BAP (2.0 mg^{-1}liter) + IBA (1.0 mg^{-1}liter)); 2,4-D (2.0 mg^{-1}liter); NAA (11.0 mg^{-1}liter) and IAA (2.0 mg^{-1}liter) + Kn (2.0 mg^{-1}liter)) were used. The pH was adjusted to 5.8 before autoclaving for 15 minutes at 120°C 1 kg cm^{-2}. Twenty-five milliliters of media were poured into 20 × 100 mm sterilized plastic petri dishes.

Plant Materials.—Soybean seeds were obtained from the U.S. Department of Agriculture Soybean Germplasm Collection Centre at Urbana, Illinois. The genotypes, Adams, Century, Columbia, Lincoln, Sloan, Wayne, and Williams-82 were chosen because of their ability to produce multiple shoots, and represent different maturity groups (1, 11).

Immature embryos, 4 to 5 mm in length, were extracted from the seeds of surface sterilized pods of field grown plants. The immature embryos were removed from their em-

---

Abbreviations: BAP: 6-benzylaminopurine; IBA: Indolebutyric acid; 2,4-D: 2,4-dichlorophexyacetic acid; NAA: Naphthaleneacetic acid; IAA: Indoleacetic acid; Kn: Kinetin.

TABLE 1. Plantlet means of seven soybean genotypes cultured in three different culture media.

Genotype	Media		
	MS	B5	L2
Adams	8.06A; a	6.67B; a	6.72B; a
Century	6.06A; b	5.89A; ab	6.19A; ab
Columbia	6.42A; a	5.28A; ab	4.25C; ab
Lincoln	7.42A; a	5.69B; b	6.97A; a
Sloan	5.11A; b	4.47B; cd	5.31A; b
Wayne	4.64B; c	4.23B; c	5.33A; b
Williams-82	5.14B; ab	3.72C; c	6.22A; ab
$\bar{x}$ for medium	6.12	5.13	5.85

Within rows, means followed by a different uppercase letter differ according to Duncan's new multiple range test ($P < 0.05$). Within columns, means followed by a different lowercase letter differ according to Duncan's new multiple range test ($P < 0.05$).

bryo sacs and placed onto the various culture media. Each petri dish contained three immature embryos of one genotype. Each treatment consisted of 10 petri dishes. The cultures were incubated at 25 ± 1°C with 16 hr of light (68 μMol $s^{-1}M^{-2}$ PAR) supplied by Vitalite (Dura Test Corporation, N.J.). Results are the combined means of three repeated experiments.

Beginning with the eighth week, callus tissues were examined under 10× magnification to observe for the signs of differentiation (embryoid formation). Callus tissue that was suspected to be embryogenic was selected. To initiate regeneration callus sections which showed embryogenic morphology were severed and transferred to freshly prepared identical medium. Since the main objective was to determine the effect of genotype and media on regeneration, and since there is ample evidence about embryogenic callus initiation from immature embryos, no score of such calli induction was recorded. Individual cultures were scored for regeneration of plantlets. Each regeneration was traced to an individual immature embryo of a genotype.

The experimental design was a 7 genotypes × 3 media × 4 growth regulators factorial replicated three times. The experimental data were analyzed as split-split plot. The main plot was the media, hormone × media and media × genotypes were the sub-plots.

RESULTS AND DISCUSSION

Immature embryos of all seven soybean genotypes were induced to plantlet regeneration via somatic embryogenesis by the three cultural media (Table 1). Induction of somatic embryogenesis was affected by genotypes, cultural media and their interaction ($P < 0.001$; ANOVA is not presented here). Significant differences in plantlet regeneration were detected among the genotypes grown in MS, B5, and L2 media. Genotype was the most important determining factor regarding plantlet regeneration.

Table 1 represents the overall responses of seven soybean genotypes to 3 culture media whose basic constituents differed from one another. Comparison of the genotypes across the media reveals that a specific genotype, except Century, responded differently to a specific medium. Genotypic variation in organogenesis has been reported in soybean (1, 11), Alyceclover (7), and Cereals (6). Though B5 medium was considered to be better for in vitro soybean regeneration (6a), plantlets regenerability in the present study was found to be best in MS

TABLE 2. Plantlet means of seven soybean genotypes in three culture media supplemented with various plant growth regulators.

Genotype	Plant growth regulator (mg^{-1})			
	BAP (2.0) + IBA (2.0)	IAA (2.0) + Kn (2.0)	2,4-D (2.0)	NAA (11.0)
Adams	7.56B; a	5.37C; a	9.04A; a	6.30B; a
Century	7.70A; a	4.59B; abc	7.30A; b	2.59C; cd
Columbia	5.52B; b	4.63B; abc	7.63A; b	4.81B; b
Lincoln	8.07A; a	5.18B; a	9.07A; b	2.44C; cd
Sloan	6.18A; b	4.26B; bc	5.67A; c	3.74B; c
Wayne	5.37A; b	2.29C; d	3.85B; d	2.19C; cd
Williams-82	5.85A; b	2.13C; d	4.37B; d	3.89B; bc
$\bar{x}$ of hormones	6.61	4.08	6.13	3.71

Within rows, means followed by a different uppercase letter differ according to Duncan's new multiple range test ($P < 0.05$). Within columns, means followed by a different lowercase letter differ according to Duncan's new multiple range test ($P < 0.05$).

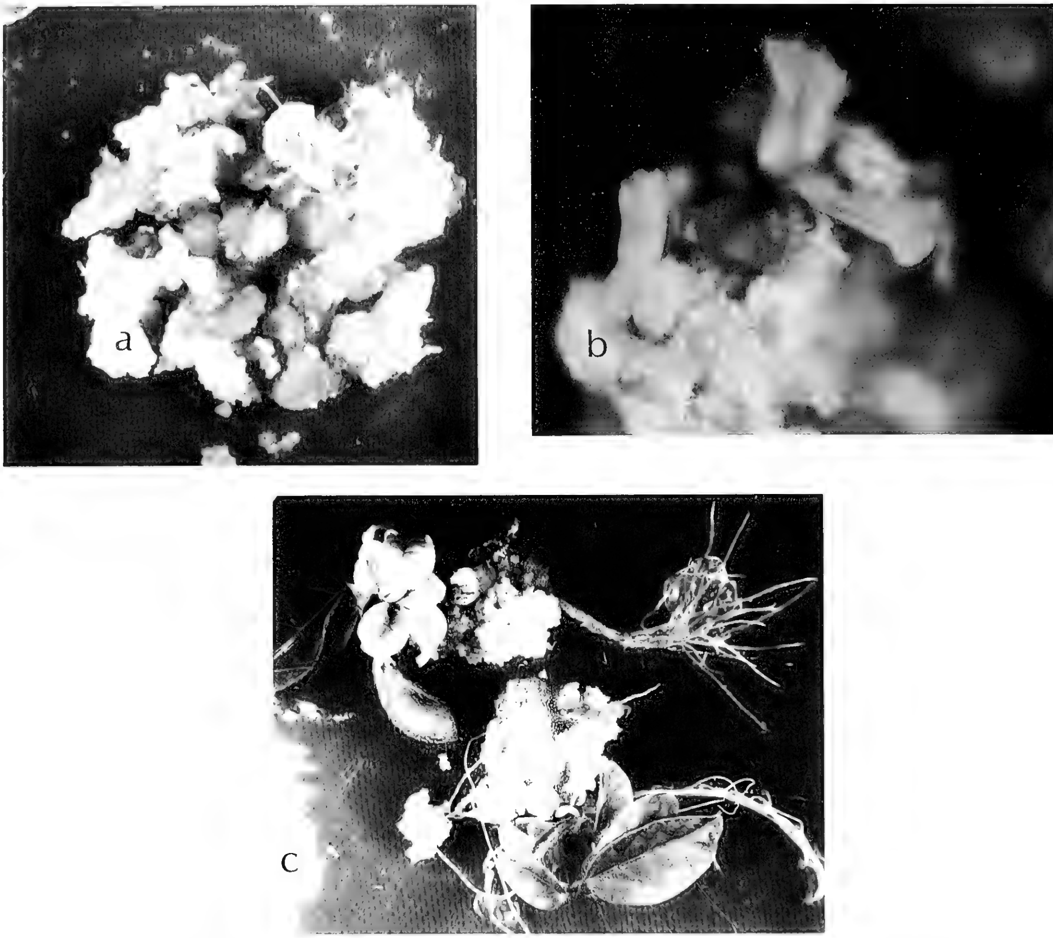


FIG. 1. In vitro soybean plant regeneration. (a) Embryogenic callus derived from immature embryos. 2× actual size. (b) Somatic embryoid which developed into plantlets 10× actual size. (c) Regenerated plantlets 2× actual size.

medium (Table 1). In comparing the organogenic capability of a medium across the genotypes L2 was found to be superior. This further confirmed that genotypes exert influence in regeneration, and optimal medium for regeneration varies with genotypes.

The callus culture from which the somatic embryoids originated were off-white to cream coloured and friable (Fig. 1a). Calli that were compact, greenish or yellowish in colour produced neither embryoids nor showed any sign of differentiation.

In almost all cases, the somatic embryoids grew in clusters (Fig. 1b) as did the plantlets (Fig. 1c). Though the regenerates phenotypically seemed to be normal, 45–65% died before they reached 4–5 cm in height. Careful separation of clustered regenerates at early stages of growth (2–3 cm) did not promote their survival. Such demise of regenerates was neither associated with any particular genotypes nor confined to any particular medium. High proportional death of regenerates could be an indication of somaclonal variants.

Besides genotypes, plant growth hormones in the culture media also affected plantlet regeneration. Table 2 presents the genotypic responses to plant growth hormones added to culture media. Statistically genotypes, hormones and their interactions were significant ($P < 0.01$; ANOVA not presented here). Comparison of the genotypes across the growth hormones shows that the cultivars responded differently to any one growth regulator. However, comparison within the column across the genotypes revealed that hormone combination BAP + IBA and 2,4-D were equally effective in inducing organogenesis. Though 2,4-D is reported to produce morphologically abnormal and non regenerable somatic embryos (12), in the present study the use of low concentration of 2,4-D (2.0 mg^{-1}) enhanced regeneration. Plantlet regeneration of some genotypes were better in BAP + IBA combination than 2,4-D and vice versa (Table 2). The overall advantage of BAP + IBA over 2,4-D, however, was not that great.

In this study there was a strong indication that not only genotype affected regeneration, but also the culture medium/media. Therefore, it seemed that the optimal medium/media for soybean regeneration in vitro culture was dependent upon genotypes as well as the nutrient media.

ACKNOWLEDGMENT

This research is supported by the USDA Cooperation State Research Service grant to Kentucky State University under agreement KYX10-90-12P. Mention of a trade name does not constitute a guarantee or warranty of the product by Kentucky State University and USDA/CSRS and does not imply approval to the exclusion of other products that may also be suitable.

LITERATURE CITED

1. Barwale, U. B., H. R. Kerns, and J. M. Widholm. 1986. Plant regeneration from callus cultures of several soybean genotypes via embryogenesis and organogenesis. Planta 167:473–481.

2. Lippman, B. and G. Lippmann. 1962. Induction of somatic embryos in cotyledonary tissue of *Glycine max* L. Merr. Plant Cell Rep. 3:215–218.

3. Parrott, W. A., E. G. Williams, D. F. Hildebrand, and G. B. Collins. 1989. Effect of genotype on somatic embryogenesis from immature cotyledons of soybean. Plant Cell Tissue Organ Cult. 16:15–21.

4. Dhir, S. K., S. Dhir, and J. M. Widholm. 1991. Plantlet regeneration from immature cotyledon protoplasts of soybean (*Glycine max* L.). Plant Cell Rep. 10: 39–43.

5. Hymowitz, T., N. L. Chalmers, S. H. Costanza, and M. M. Saam. 1986. Plant regeneration from leaf explants of *Glycine clandestine* Wendl. Plant Cell. Rep. 3:192–194.

6. Bregitzer, P. 1992. Plant regeneration and callus type in barley: effects of genotype and culture media. Crop Sci. 32P 1108–1112.

7. Hildebrand, D. F., G. C. Phillips, and G. B. Collins. 1986. In Y. P. S. Bajaj, (ed.) Biotechnology in agriculture and forestry, Vol. 2, Crop 1. Springer-Verlag, Berlin.

8. Wofford, D. S., D. D. Baltensperger, and K. H. Quesenbery. 1992. In vitro culture responses of alyceclover genotypes on four media systems. Crop Sci. 32:261–265.

9. Murashige, T. and F. Skoog. 1962. A revised medium for rapid growth and bioassay with tobacco tissue cultures. Physiol. Plant. 15:473–497.

10. Gamborg, O. L., R. A. Miller, and K. Ojima. 1968. Nutrient requirements of suspension culutes of soybean root cells. Exp. Cell. Res. 50:151–158.

11. Phillips, G. C. and G. B. Collins. 1979. In vitro tissue culture of selected legumes and plant regeneration from callus culture of red clover. Crop Sci. 19:59–64.

12. Barwale, U. B., M. M. Meyer, Jr., and J. M. Widholm. 1986. Screening of *Glycine max* and *Glycine soja* genotypes for multiple shoot formation at the cotyledonary nodes. The. Appl. Genet. 72:423–428.

13. Ranch, J. P., L. Oglesby, and A. C. Zielensky. 1985. Plant regeneration from embryo derived tissue cultures of soybean. In Vitro Cell. Dev. Biol. 21:653–658.

Trans. Ky. Acad. Sci., 54(3–4), 1993, 112–135

FORUM

History of the Kentucky Academy of Science, 1914–1992

TED M. GEORGE*

Department of Physics and Astronomy, Eastern Kentucky University, Richmond, Kentucky 40475

INTRODUCTION

At this writing (1992), the Kentucky Academy of Science (KAS) is in its 78th year of continuous operation. It is the largest scientific organization in the Commonwealth and embraces some 22 different disciplines of science. Membership is open to anyone who has an interest in science and includes citizens of Kentucky as well as many individuals outside the state. The Academy is an affiliate of the American Association for the Advancement of Science (AAAS). KAS has cooperated with the national academy since the early days.

The Kentucky Academy has changed drastically since those early days as, indeed, has science, our country, and the world. As far as is known, those early pioneers of the Academy have all deceased. Therefore, much of the history must be read from their writings. Also, much help can be obtained from present members who have been active in the Academy for many years.

The objectives of the Academy are to encourage scientific research, to promote the diffusion of scientific knowledge, and to unify the scientific interests of the Commonwealth.

The Academy holds an annual meeting in which concurrent sectional meetings are held; there is also an annual business meeting, a banquet, and general sessions intended to stimulate the interests of all scientists. The Academy sponsors the Kentucky Junior Academy of Science (KJAS) that is conducted by and for students at the pre-college levels. KJAS sponsors a statewide spring symposium each year. KAS awards research funds generated by endowments, institutional or corporate affiliations and the Kentucky Academy of Science Foundation (KAS Foundation).

The *Transactions of the Kentucky Academy of Science* is the official publication of the Academy. The journal is published semiannually and is sent to all members in good standing. It publishes results of original research and serves as the official record of the Academy. All papers undergo a review process and conform to the high standards of nationally respected journals. Information in the *Transactions* is distributed widely through interlibrary-exchange programs, international abstracting services, and the distribution of reprints. A newsletter that contains items of general interest and official announcements is distributed to the members at least twice a year.

* Present address: 5212 Smartt Dr., Nashville, Tennessee 37220.

What are the origins of this Academy which began so long ago? In the archives of the University of Kentucky there is a letter, dated 13 Nov. 1912, addressed to R. H. Spahr, Assistant Professor of Physics at State University (present day University of Kentucky) from E. W. Gudger of North Carolina Normal School which gives data about the North Carolina Academy of Science. There is a similar letter from Wilbur Nelson of the Tennessee Academy in the same month. Also, there are letters from the Indiana, Illinois and Michigan academies dated Nov. 1914 (1).

The call for organization that was issued to all scientists in Kentucky is as valid today as when it was first penned (probably in the spring of 1914). For this reason, it is reproduced here in toto.

Call for Organization of the
Kentucky Academy of Science

The advantages and necessities of a State Academy of Science for the state of Kentucky, such as exist in at least seventeen other states, viz.: Wisconsin, Kansas, Iowa, Indiana, Minnesota, Nebraska, California, Ohio, Illinois, Michigan, Colorado, Utah, Oklahoma, Maryland, Tennessee, North Carolina and New York, are too numerous to mention in this brief space. Science is essentially mutualistic—successes in one branch are hailed with delight by those interested in other branches. A discovery made in one may be the stepping stone to future achievements along another branch of science. At present it is difficult for one person to keep abreast with the discoveries and achievements in one branch of science alone. Thus, you obtain from the diversified program the grain from the chaff—that of which the author of the paper has made a special study requiring months or even years.

Then the value of submitting results for discussion, of discussing others' results, of broadening the scientific mind, of mutual stimulus and encouragement, of personal education by coming in contact with fellow workers. Then, also, the value to the community at large, giving them that which is best and most useful from the various branches, in the form of publications and otherwise, must not be overlooked.

In many cases they have served as scientific advisors, governmental or otherwise, to the states in which they exist. As expert non-partisan investigators, they have linked science to the problems of everyday life, suggesting legislation for the betterment of human welfare in industry, public health, sanitation and social conditions. The results are that the past quarter of a century has witnessed a more rapid progress than any equal period in the world's history.

Another reason for such an organization is the opportunity for acquaintance and the establishment of good fellowship among the laborers in this line of work. This in itself would be sufficient.

The State's interests are promoted in a number of ways by the co-operation of these people who are interested in the welfare of its citizens. This service may be political, literary, scientific or social, but after all they have in common the encouragement of the individual to nobler efforts and benefit to the community.

The membership shall in the main consist of Active Members, Nonresident and Corresponding Members and Honorary Members. Everyone in the State of Kentucky interested in any of the following subjects is urged to join the proposed Association whether teacher or businessman: Mathematics, Astronomy, Physics, Geography, Geology, Botany, Zoology, Physiology, Medicine, Engineering, Social and Economic Science, Agriculture and Anthropology.

The meeting for the Organization of the Kentucky Academy of Science will be held at the State University of Kentucky, Lexington, April 10th and 11th, 1914. More details and the announcement of a program will be made later.

The Committee on Organization appointed by the Kentucky Association of Colleges and Universities, urgently invites any criticism or suggestions from anyone interested.

R. H. Spahr, State University, Chairman
F. L. Rainey, Central University
Garnett Ryland, Georgetown College

The above call for organization was supported by 44 names (2).

The First Meeting and Papers Presented

Dr. P. P. Boyd, of State University, at the request of the Committee on Organization called the meeting to order. A motion was offered that a Kentucky Academy of Science be organized and duly incorporated under the laws of the state. Dr. Boyd was elected permanent chairman for the organizational meeting and Dr. Charles Robinson of the University of Louisville was elected secretary. A committee was appointed to confer on a constitution and by-laws for the proposed organization. This committee was composed of Messrs. Spahr, Ryland, Rainey, W. M. Anderson, and Lloyd (3).

The following papers and addresses were then presented:

Dr. J. W. Pryor of State University, "Some Interesting Features of the Ossification of Bones," with many illustrations by lantern slides.

Dr. N. F. Smith, Professor of Physics, Central University, Danville, "Theories of Thermal and Electrical Conductivity."

Dr. Joseph H. Kastle, Director of the Kentucky Agricultural Experiment Station. "The Significance of the Scientific Work of the Experiment Station to the Agricultural Prosperity of the State."

Dr. Stanley Coulter, Purdue University, La Fayette, Indiana. Address: "Science and the State."

At the conclusion of the program, the Committee on Constitution reported a constitution and bylaws which were read and adopted unanimously, after some slight modification—see Appendix I (4).

The Nominating Committee reported the following nominations for officers:

For President, Joseph H. Kastle, Experiment Station
For Vice-President, N. F. Smith, Central University
For Secretary, Garnett Ryland, Georgetown College
For Treasurer, W. M. Anderson, University of Louisville

It was moved, seconded, and unanimously carried that these nominees be elected as officers of the Academy for the ensuing year.

Prof. Coulter was nominated and unanimously elected as an honorary member of the Academy.

The motion was offered and carried that a vote of thanks be extended by the Academy to the Organization Committee, and especially to Mr. Spahr, for its efforts in bringing about the organization.

It was also moved and carried that the Academy extend a vote of thanks to the speakers on the program, and especially to Prof. Coulter for his somewhat lengthy trip in order to address the meeting.

(Signed): Chas. J. Robinson, Secretary (4).

The Second Annual Meeting and Papers Presented

The second annual meeting was called to order by President J. H. Kastle in the Chemistry Lecture Hall of the State University on Saturday 15 May 1915, at 9:30 A.M. The report of the treasurer W. M. Anderson showed a balance on hand of two dollars. The secretary showed that the roll of members contained the names of 60 persons who had indicated a desire to be charter members of the Academy, but that seven of these had left the state (5).

The Membership Committee nominated 65 persons for active memberships, 11 for corresponding memberships and Professor Dayton C. Miller for Honorary Membership, all of whom were duly elected. The papers presented were:

"Relation between Matter and Radiant Energy." N. F. Smith, Centre College, Danville, Ky.

"Faulting in North Central Kentucky." A. M. Miller, University of Kentucky.

"The Removal of Mineral Plant Food by Drainage Waters." J. S. McHargue, Experiment Station, Lexington.

"The Translocation of the Mineral Constituents of the Seeds of Certain Plants during Growth." G. D. Buckner, Experiment Station, Lexington.

The Academy then adjourned to the Phoenix Hotel for lunch and reassembled at 2:30 in the Physics Lecture Room. Dr. Dayton Miller, Professor of Physics, Case School of Applied Science, Cleveland, Ohio, by special invitation of the Academy, delivered an illustrated address on "The Science of Musical Sounds" (6).

The Third Annual Meeting

By the third meeting 6 May 1916 in the Department of Physics, University of Kentucky, fiscal affairs had improved over that of the previous years:

From Garnett Ryland, Treasurer	$ 8.80
Amounts collected as dues and initiation fees	76.00
Total	84.80
Total disbursements	26.50
Balance on hand	$58.30

(Itemized statement and vouchers filed) (7).

The first resolutions of record were made this third meeting by Professor A. M. Miller of the University of Kentucky (8).

RESOLVED. That the Kentucky Academy of Science heartily approves the move to substitute the Centigrade thermometer scale for the Fahrenheit scale in all government publications, and endorses the bill to that effect now pending in Congress, H.R. 528.

RESOLVED. That the Secretary transmit a copy of this resolution to the Thermometer Committee, A.A.A.S., Bureau of Standards, Washington.

Membership in the Academy

It is interesting to observe the evolution of the concept of membership in the Academy. In the original constitution (Appendix I) (9), there were 3 classes of members, Active, Corresponding, and Honorary. Active members were residents of Kentucky who were interested in scientific work. Dues were one dollar per year. Corresponding members were persons who were actively engaged in scientific work but were not Kentucky residents. They had duties and privileges of active members but could not hold office. Honorary members were those who had acquired special prominence in science and were not residents of Kentucky. They were not to exceed 20 in number at any time.

For election to any class of membership the candidates must have been nominated in writing by 2 members, 1 of whom must know the applicant personally; receive a majority vote of the Committee on Membership and a three-fourths vote of the members of the Academy that are present at any session or, in the interim between meetings of the Academy, the unanimous vote of the members of the council, present or voting by letter (9).

The early Academy seemed to be quite vigilant to prevent unworthy persons from entering the Academy! Indeed, in the minutes of the 1933 meeting we find that 33 people were elected but that 16 did not qualify (10)! In the 1934 minutes the names of 4 persons who did not qualify that year were actually listed (11)! Understandably, the record does not show why these people did not qualify. Could it be that when they say "elected" we would mean nominated? When they say "did not qualify" could that mean simply that they had not paid their dues?

In the 1987 revision of the constitution (Appendix II), it was formalized what had actually been in practice for many years (12). Presently, the requirements for membership are simply an interest in science and payment of annual dues. In the 1987 revision of the constitution, the classes of membership are: Regular, Life, Student, Honorary, Emeritous, Corporate Affiliate, and Institutional Affiliate. Regular Membership is the same as active but is not restricted to citizens of Kentucky. Life members pay one single fee. Student members must be college students and Honorary members are the same as before except that they may be residents of Kentucky. Emeritous members are members who are retired from active service. Corporate and Institutional Affiliates are business, industrial or academic institutions who support the aims and purposes of the Academy.

Affiliation with AAAS

At the eighth annual meeting in May 1921, KAS formally accepted affiliation with The American Association for the Advancement of Science (AAAS) (13). There had been prior collaboration, since abstracts of papers presented at the 1916 meeting were published in the 14 July 1916 issue of *Science* (the official journal of AAAS). This practice continued until in 1923 when the editor of *Science* informed the secretary, A. M. Peter, that he could no longer continue this arrangement because of the limitation of space in the journal (14). The affiliation has continued to this day. Over the years, KAS has maintained a representative to AAAS and the collaboration continues.

The *Transactions of the Kentucky Academy of Science*

Loss of an outlet for the publication of their papers forced the issue of publication. Willard Rouse Jillson, State Geologist, was president for the 1923–1924 term. He saw that the Academy did not have the funds to underwrite a new journal; therefore he agreed to put up the money out of his own pocket. Five hundred copies of the first volume were printed at a cost of over $600, which would average to about $1.25 per copy. Each member was entitled to one free copy. Inasmuch as the treasury at that time had only about $100, each member was encouraged to buy as many extra copies at $1.25 as they could to help defray the cost of printing (14). Ultimately, W. R. Jillson paid $242 and the Academy paid the rest (15).

Williard Rouse Jillson graduated from Syracuse University in 1912, took a Master's Degree from the University of Washington and did additional graduate work at Chicago and Yale. He was a very prolific writer. In his memoirs (16), he stated that he wrote 91 books, published 31 state maps, delivered 42 public addresses in this country and abroad, published 391 paper bound pamphlets, 121 historical articles, and 29 newspaper articles! In the early days of the Academy, he contributed much—not only did he father the *Transactions* but he also contributed many presentations at the annual meetings. Not only was he interested in geology but he was very active in Kentucky history as well. He wrote articles for the Filson Club and the Kentucky Historical Society. He was president of the latter organization in 1958–1959.

Alfred M. Peter was a founding member of the Academy who also performed yeoman's service in the early days. In 1915, he was elected secretary of the Academy and served in that capacity for 18 years. He edited the *Transactions* from 1918 to 1949 and continued to help in an unofficial capacity for many more years.

We know something about Mr. Peter from a eulogy given at his death by Alfred Brauer of the University of Kentucky. "He was born in Lexington in 1857. He graduated from State College with the degree of Bachelor of Science in 1880. He was then appointed Assistant Professor of Chemistry at State College and was also appointed Assistant Chemist for the Kentucky Geological Survey. He obtained his Master's degree in 1885 [not stated, but probably from State College]. He was awarded an honorary Doctor of Science from his Alma Mater in 1913" (17).

In the early editions of the *Transactions* (volumes one through six), deceased members of the Academy were recognized in the journal just before the membership list. It was stated:

IN MEMORIUM

They have crossed the river and are resting in the shade of the trees.

Following this statement was a list of deceased members. This statement is attributed to Stonewall Jackson as his last words on his deathbed after the battle of Chancellorsville by *Bartlett's Quotations* (18). No meaning has ever been attributed to Jackson's words as he was delirious at the time he spoke them. What was the appeal to editor Willard Rouse Jillson (editor of Volume 1) and subsequent editors (A. M. Peter and Ethel Caswell)? (Caswell was secretary to Peter and apparently not a member of the Academy [19].) An evidence of southern sentiment? (Jillson was from New York.) A reference to the river Styx in greek mythology? This statement of Jackson's was discontinued in 1938, Volume 7.

A. M. Peter was instrumental in the founding of the Kentucky Junior Academy of Science (KJAS) in 1933, an early attempt to interest high school students in science. Peter showed his interest in this organization by giving an annual award for the best effort by a student (17).

Volume 1 was printed in 1924 and covered the ten years from 1914 to 1923. After that, the *Transactions* were printed at intervals of 2 or 3 years until Volume 9, printed in 1941, where an attempt was made to publish quarterly each year in order to get papers into print in a timely manner. This proved to be rather difficult because of the scarcity of money and/or papers. At various times after that, quarterly issues were sometimes combined into semiannual issues. Beginning with Volume 24 in 1963, semiannual publication was adopted and continued with 1 or 2 exceptions to the present. (Numbers 1 and 2 were combined, as were 3 and 4.)

Editors of the *Transactions* had a difficult and demanding job. Many long hours were spent of their own free time in order to produce the *Transactions*. All honor must go to them for their labors for the Academy, and they are listed with appreciation in Appendix III. The modern professional format was initiated by Louis Krumholz of the University of Louisville, who served as editor from 1974 to 1980. Krumholz got the Academy firmly established with the Allen Press, a printer that specializes in scientific journals. His successor, Branley Branson of Eastern Kentucky University, the editor from 1980 to the present, has continued the development of the *Transactions*. He served through a very difficult period when funds were very short. Today's journal has a very professional appearance and is attractive to authors because worthwhile articles can be published in a timely manner, as contrasted with the rate of publication in larger journals. Branley Branson has labored long and hard and deserves much credit for the success of the *Transactions* today.

TABLE 1. Composition of membership, 1917.

Agriculture and agronomy	5
Animal husbandry	2
Astronomy	2
Bacteriology	4
Biology	6
Botany, entomology and zoology	8
Chemistry	24
Electrical engineering	1
Forestry	2
Geology	10
Horticulture	1
Mathematics	6
Meteorology	2
Microscopy	1
Mining engineering	3
Psychology	2
Physics	9
Physiology	1
Philosophy	1
Unclassified	1
	91

Many officers, in addition to the editors, have contributed so much to make the Academy what it is today. As a tribute to them and to preserve a record of their service, their names are listed in appendices. The presidents are listed in Appendix IV, the secretaries in Appendix V, treasurers in Appendix VI, and the meeting locations are listed in Appendix VII.

Composition of Membership

In 1917, the membership list classified by subject can be found in Table 1 (20). With respect to this list, A. M. Peter made this comment:

> The Secretary desires to call attention to the predominance of chemists among our membership, as shown in the list of members arranged by subjects, and to make an appeal to the workers in other branches of science to come to the support of the Academy. There must be more workers in Kentucky in the mathematical sciences and biological sciences than there are in chemistry. Are these satisfied to allow the chemists to outdo them in activity? Should not all scientists of

TABLE 2. Membership classified by discipline, 1990.

Zoology and entomology	148
Botany and microbiology	133
Chemistry	117
Physiology, biophysics, biochemistry and pharmacology	95
Geology	37
Physics	35
Engineering	33
Science education	32
Psychology	31
Geography	25
Mathematics	22
Health sciences	21
Scientific information	20
Computer science	16
Agricultural sciences	11
Anthropology	7
Industrial sciences	7
Sociology	6
Unspecified	108
	904

the State vie with each other in supporting an organization like ours?

However, we may note, if we group Bacteriology with 4, Biology 6, Botany, Entomology and Zoology 8, and Physiology 1, we get a total of 19. However, the preponderance of chemists in the Academy has changed over the years and now the Life Sciences predominate in numbers. For comparison, we may check the membership classified by discipline in 1990 in Table 2 (21).

At the meeting in 1920, the secretary, A. M. Peter, listed the membership classified geographically. That list is reproduced here in Table 3 (22). As a comparison, we may check Table 4 for the geographical distribution in 1990 (23). There we find not only has the Academy grown by a factor of 9 but there is a much wider distribution of members across the state.

TABLE 3. Geographical distribution of membership, 1920.

University of Kentucky, Lexington	47
University of Louisville, Louisville	5
Centre College, Danville	4
Georgetown College, Georgetown	3
Berea College, Berea	2
Transylvania College, Lexington	1
Cardome, Georgetown	1
College of Pharmacy, Louisville	1
Williamsburg Institute, Williamsburg	1
Not connected with educational institutions in the state are:	
Lexington	5
Louisville	5
Frankfort	5
Bowling Green	1
Newport	1
Jenkins	1
Winchester	1

Besides these are 26 from outside the state, including honorary and corresponding members.

TABLE 4. Geographical distribution of members, 1990.

University of Kentucky	130
Western Kentucky University	62
Eastern Kentucky University	57
University of Louisville	48
UK Community Colleges	29
Northern Kentucky University	29
Murray State University	24
Morehead State University	23
Kentucky State University	16
Centre College	11
Berea College	8
Transylvania University	7
Georgetown College	6
Cumberland College	5
Kentucky Wesleyan	5
Other schools in Kentucky	27
Out-of-state schools	80
Members not identified by educational institution:	
Lexington	66
Louisville	64
Ashland	27
Frankfort	22
Bowling Green	18
Owensboro	12
Berea	9
Morehead	6
Others	113
	904

Also, in 1920, A. M. Peter noted the growth in membership and number of speakers in the early years of the Academy. His figures are reproduced in Table 5. As we can see, the membership grew rather slowly during the first years but participation, as measured by the number of speakers, grew at a faster rate (24).

Interest in the Teaching of Science

The famous Scopes trial concerning the teaching of evolution in the public schools brought an immediate reaction from AAAS in January 1923 in the form of a resolution published in *Science*, 26 Jan. 1923. This resolution supported without reservation the teaching of evolution and

TABLE 5. Growth in membership and speakers, 1914–1920.

Year	Membership	Speakers
1914	46	5
1915	88	6
1916	87	10
1917	91	9
1918	98	12
1919	93	14
1920	110	26

argued vehemently against any state passing laws against the teaching of evolution (25). In the May meeting of 1923, KAS passed a resolution strongly supporting the position of AAAS, even though such a position was extremely unpopular in Kentucky at that time. This is the first indication of the long-term concern of the Academy for education in the public schools. In 1926, AAAS led in raising a scholarship fund for Mr. Scopes in view of his loyalty to the cause of science. A total of $47 was raised in KAS for this cause and forwarded to AAAS (26).

The teaching of evolution continued to be a sore spot with fundamentalist religious groups whose article of faith accepted a literal interpretation of the Bible. In the late 1970s, a group of people joined together to espouse what they called "Scientific Creationism." "Creationism" is the view that a Supreme Being created the world and all its creatures, including human beings, essentially as they are today, perhaps only thousands of years ago. Evolution is the widely taught theory that all animals and plants are descendents of simple organisms that evolved over billions of years into increasingly numerous and more complex forms (27).

The Creationists asserted that evolution was only a theory and should not be taught as fact. If evolution was a theory, then other theories should be taught. They, of course, advocated Scientific Creationism. Furthermore, they argued that textbooks must present all sides of the argument and they should contain Scientific Creationism as an alternative theory. This proposal was seriously considered by several states (among them: Texas, California, and Louisiana [27]).

The Kentucky Academy of Science appointed an ad hoc committee chaired by Wallace Dixon of Eastern Kentucky University (28). In the 1981 meeting, the Academy adopted a policy statement that, in essence, objected to "attempts to require any religious teaching as science" (29). This resolution was to be held in readiness in case a proposal for Creationism should be introduced in the Kentucky General Assembly. In 1981, the Louisiana legislature passed a law that Creationism must be taught along with evolution in public schools (30). In 1987, the U.S. Supreme Court struck down the Louisiana law. "Writing in a 7 to 2 opinion, Justice William J. Brennan, Jr. said that the First Amendment forbids alike the preference of a religious doctrine or the prohibition of a theory which is deemed antagonistic to a particular dogma. Therefore, Brennan noted, because the primary purpose of Louisiana's Creationism Act is to advance a particular religious belief, the act endorses religion in violation of the First Amendment" (27).

Over the years, the Academy realized that the health of science in Kentucky rested upon the efforts of science teachers in the public schools. In 1925, Cloyd N. McAllister of Berea College (31), in his President's Address, devoted his entire time to a critique of science teaching in the public schools. This concern for science teaching appears repeatedly over the years: Robert T. Hinton, in his President's Address (32), devoted his entire speech to this concern; in 1940, a resolution was presented against the reduction of science training for prospective teachers (33); in 1955, a resolution was presented which exhorted members of the Academy to promote better science teaching in the public schools in any way possible (34); in 1958, a resolution was presented which supported requiring 12 credit hours in science for all prospective teachers (35).

In 1934, Elmer Sulzer, a geologist from the University of Kentucky, suggested that the Academy make some radiocasts (36). He proposed to arrange 3 Academy radiocasts from the University studio of WHAS, which was accepted. There is no description but we can surmise that they were broadcasts put on by various members about subjects in their fields of endeavor. Undoubtedly, busy members had great difficulty finding time for such productions in their already busy days. Such public education in science is today carried out by Kentucky Educational Television. They broadcast all school subjects (including science) to the public schools during the day. In addition, during the evening hours, they broadcast many excellent programs in science such as Nova, Nature, Planet Earth and many others. These programs are beautifully produced with resources that are far beyond what the Academy could muster.

In 1963, a 10-member committee began to draw up a proposal to the National Science Foundation (NSF) for a Visiting Scientist Program. They envisioned making a list of scientists and their expertise available to public high schools. At the invitation of the teacher, the selected speaker would travel to the school and give a lecture on the desired subject. The proposal would be for money from NSF to pay the expenses of the program (37). This proposal was funded by NSF for $8,005 in March 1963 (38). In the fall of 1964, it was reported that E. Fergus of the University of Kentucky was acting director of the program and that a visitor roster list had been sent to 462 high schools. This roster contained a list of 105 scientists. Twenty-one requests had been received but about 75 visits were available with the money on hand (38). In 1965, Dr. Fergus announced that there was a considerable improvement in the second year since there were 69 requests for speakers compared to 21 at the same time the previous year. Dr. Fergus announced his resignation (39) and he was succeeded by Roger Barbour of the University of Kentucky. In 1966, Dr. Barbour reported that 16 visits had been completed but there was money for 60 more visits (40). From the available records, it does not seem that this program met expectations. The reason seemed to be lack of interest or time in the high schools.

This idea was revived in 1983 in the form of a Speakers Bureau. Again Academy members were called upon to volunteer their services. However, this time, there was no funding for the program (41).

The Kentucky Junior Academy of Science

It was in 1932 that the Kentucky Junior Academy of Science (KJAS) was formed under the leadership of A. M. Peter of the University of Kentucky and Anna Schneib of Eastern Kentucky State College. The membership of KJAS would be composed of high school students who were interested in science. Professor Louis A. Astill, then director of the Illinois Junior Academy of Science, gave much helpful information and encouragement. The KJAS held its first meeting on 19 May 1934 in Berea. Five hundred students and teachers were in attendance, and KJAS began life with 310 student members in 9 science clubs. The dues were set at 15 cents per year (42).

The first issue of the official *The Junior Science Bulletin* was published in Nov. 1934 with Anna Schneib serving as editor. The listed advantages of membership were:

(1) volunteer speakers from KAS for the local science clubs,
(2) each club received a copy of the *Transactions of the Kentucky Academy of Science,*
(3) *The Junior Science Bulletin* published 3 times a year was distributed to each member,
(4) competitions would be held each year for awards for the best science paper or project,
(5) each member was entitled to wear a pin in the form of an official insignia of KJAS.

The KJAS was governed by an executive committee appointed by the President of KAS. Dr. Schneib was the chair of that committee and was also editor of *The Junior Science Bulletin*. Much of the early success of KJAS must be attributed to Anna Schneib's hard work and leadership. Enrollment steadily increased to over 1,000 in 45 clubs in 1942. Anna Schneib served as Chair, Director and Editor until 1952, when she retired from active teaching.

The Junior Academy has had its ups and downs in the later years. Herb Leopold of Western Kentucky University struggled valiantly to keep KJAS alive and oversaw many innovations. He started a Spring Symposium in which KJAS members presented papers on their own research. The winners often compete in the national meetings of the American Junior Academy of Science. A Science Bowl competition has been introduced (patterned after popular game shows on television) in which opposing teams compete to answer various questions in science. A lab skills competition has also been added (43).

In 1992, membership in the Junior Academy was approximately 1,000 students. At the Spring Symposium in that year, 162 research papers were submitted for presentation. At this meeting, a resolution was passed that the AAAS award that supports the attendance of 2 KJAS members and a sponsor to the annual AAAS meeting would henceforth be known as the KAS–William P. Hettinger, Jr. AAAS Award. This action is motivated by the active interest William Hettinger had had over the years in the Junior Academy (44).

KJAS has been highly successful with the students it does reach. One would wish that it would reach far more of the hundreds of thousands of students in Kentucky schools. Doubtless, it would require far more resources to expand its operations.

The Collegiate Academy

In addition to the Junior Academy, efforts are going forward at this writing to establish a Kentucky Collegiate Academy of Science for college undergraduates and graduate students. The intention is to have a paper session and awards for their presentation. It is hoped that this will increase the participation of these students in scientific work (45).

The Science Education Committee

In 1972, the Academy started on the road to become a more active participant in science education in the public schools—kindergarten through the twelfth grade. In that year, the Academy passed a resolution asking President Marvin Russell of Western Kentucky University to appoint an ad hoc committee on Science Teacher Certification. This committee should review requirements to certify science teachers in the public schools and make recommendations for any changes and any action thereof. The rationale for this action was that the good of the country and of science depended on public understanding of science as well as assuring a future supply of scientists (46).

Ted M. George of Eastern Kentucky University was appointed chairman of this committee and gave an interim report at the next annual meeting in 1973 (47). This report proposed 3 levels of certification: K–5, 6–8, and 9–12 grades. This was a radical departure from the guidelines that existed, i.e., 2 levels: K–8 and 7–12 grades. This proposal was rejected by the Kentucky Council on Teacher Certification at that time. Several years later, the same council agreed to reconsider the proposal. In 1977, the Academy committee reported that the Teacher Council had accepted this idea, keeping the same requirements then in force for elementary teachers for grades K–5 and for secondary teachers for grades 9–12. They then proposed a new set of guidelines for middle school teachers for grades 6–8. Unfortunately, the new middle school guidelines appeared too weak to the Academy committee (48).

The KAS Committee on Teacher Certification then enlisted the aid of many other science groups throughout the Commonwealth and argued against this proposal. Later, this plan was withdrawn by the Kentucky Teacher Council on Certification (49). In 1984, this plan was resurrected by the Kentucky Teacher Council and approved by the Kentucky Board of Education in the following July to take effect for entering freshmen effective 1 Sept. 1989. Thus the Academy, through its Committee on Teacher Certification, played a part in effecting this change. But there were still reservations that the requirements for middle school teachers were too weak. At the time of this writing (1992), it is too early to make an evaluation of this program.

Another proposal of the Department of Education was to pay schools different sums of money for certain classes (Vocational Education was emphasized). Payment for science classes would have been no more than for English, History, etc. Since science is so much more expensive to teach because of lab and demonstration equipment and special rooms, it was thought that the teaching of science would be seriously hurt. The Education Committee of the Academy then enlisted the aid of other science societies across the state and opposed the program vigorously. This proposal was subsequently dropped (50).

The Academy committee met with failures as well as successes. A proposal for a Science Advisory Council to the Superintendent of Public Instruction was never approved (51). A regulation was approved by the Department of Education that teachers of Vocational Education could teach academic science courses. This ruling was allowed to stand over the vigorous protests of the Academy and its Education Committee (52).

Effects of Wars and Depression

One would expect that the two world wars would have a significant effect on the operations of the Academy. Strangely, little reference can be found in the minutes with respect to World War I. In 1918, we find "on motion of Dr. Buckner, it was unanimously resolved that the Academy go on record as offering its services to the Government in any capacity, during the time of war" (53). There is no further reference to the resolution, to whom it was sent, or if it was ever sent.

World War II had a more definite effect. No meeting was held in 1945 (primarily because of rationing of gasoline). Prospective speakers, however, submitted their articles to be published in Volume 12 of the *Transactions*. In the meeting of 1942, a resolution points with pride to the number of members in the service of the country (54).

The meetings of 1944 and 1946 were held but were published only in abstract form in 1947 (55). In July 1947, the President, Alfred Brauer of the University of Kentucky, wrote an editorial which called for more active participation in the Academy (56). While agreeing that the Academy had operated under great difficulties during World War II, he urged that much more work must be done if the Academy were to meet its obligations. He listed things to be done or improved:

(1) obtain sustaining memberships,
(2) enroll more workers from industrial research labs,
(3) affiliate with more scientific associations,
(4) be more active in conservation of resources,
(5) greater participation by members, i.e., give more papers, present ideas, present resolutions, etc.

At the time of the Great Depression, in the early 1930s, "a worldwide financial panic and depression began with the 1929 stock market crash. Twelve million wage earners were jobless in the United States in 1932 and many bankruptcies" (57). In 1932, there were very few two-wage earner families and an out-of-work wage earner was in serious trouble. There were no government services to aid those with no income as there is today. As a consequence, in Kentucky as in the rest of the nation, tax revenues fell precipitously and many salaries were late, reduced or paid in part. It was proposed to the Council of KAS that dues should be reduced because of the financial situation. The Council, however, rejected this idea (58).

Incorporation of KAS

In 1936, Dr. L. Oatley Pindar, a physician and a member of the Medical Science section, left a bequest to the Academy. In the discussion of how to handle this transaction, Judge Samuel Wilson of Lexington, Ky., was asked for advice. Judge Wilson advised the Academy to incorporate and offered to do the legal work without charge. Consequently, in 1937, the Academy incorporated with headquarters of Kentucky Academy of Science, Inc. located in Lexington, Ky. (59, 60). Dr. Pindar's legacy was $281.30, which brought the endowment to $356.30. In 1932, at the 19th annual meeting the financial report makes reference to $75 in Life Memberships invested in Building and Loan Association stock (61). Dr. Pindar's bequest must have been added to this amount to total $356.30. The interest from this was used to help pay costs of publication of the *Transactions* (62).

Surprisingly, no further mention of the endowment can be found in the *Transactions* for many years. In fact, no financial report can be found from 1939 to 1955. In 1955, the financial report refers to the "balance on hand of $1200.35" (63). There is no mention of the endowment. Presumably, it had been added to the operating funds at some time.

When the Academy incorporated in 1937, a Board of Directors was added to the officers of the Academy by an amendment to the constitution. Normally a Board of Directors of a corporation would set the policy for that corporation. When one reads the constitutional amendment, however, it is not really clear what the function of this board is. "In said Board shall be vested and by said Board shall be exercised all the ordinary and appropriate corporate powers and functions of the Kentucky Academy of Science" (60). Such a Board was duly elected and continued to be elected but never seemed to function in any viable way.

At the meeting in 1969, at Murray State University, it was stated that the Board was not now meeting but should become active in stimulating industry to support the activities of the Academy (64). In 1974, the Board became more active and attempted to find a role for itself (65). In 1975, the Board proposed, and the Academy accepted, an amendment to the constitution, in which the Board would explicitly assume the overall direction of the Academy and the Executive Committee would carry on the day-to-day activities of the Academy (66).

Although the Board did serve some useful functions, such as selecting and awarding honors for Outstanding Scientist, Outstanding Teacher, etc., it still did not set policy for the Academy. The Board of Directors was dissolved in the new constitution installed in 1987 (67).

Support of Research

Of course, the reason for being for the Academy is the advancement and enjoyment of science. A prime occupation of the organization members is engaging in scientific research. The Academy has, over the years, aided in the publication of the research of its members and, in the later years, has sponsored some research, particularly college students and its own members. In the early days, when the Academy did not have a journal, members were allowed to publish in *Nature*, the official AAAS journal. When this was no longer possible, Willard Rouse Jillson published, partially at his own expense, Volume 1 of *The*

TABLE 6. Papers read at annual meetings, 1920 and 1990.

	1920	1990
The Future of KAS	1	
Agricultural science	7	3
Anthropology		21
Astronomy	1	
Botany and microbiology	3	25
Chemistry	2	23
Coal and petroleum	1	9
Genetics	1	
Geography		14
Geology	2	12
Industrial sciences		9
Nutrition	1	
Physiology, biophysics, biochemistry and pharmacology		14
Physics	2	20
Science education		17
Psychology	1	31
Sociology		9
Zoology and entomology	4	34
Computer science		9
Mathematics		12
Engineering		10
Health sciences		2
Kentucky Junior Academy of Science	11	
Poster presentations	42	
Abstracts	46	

Transactions of the Kentucky Academy of Science. Volume 1 recorded the activities of the first ten years of the Academy's activities. The quality and quantity of the published articles was not a steady progression of excellence. The Great Depression of the 1930s was a very difficult and troubling time. Very little money was available. Paydays were missed and salaries were reduced; therefore, there was virtually no money for research (68). The Second World War was also a severe setback. The homefront was denuded of many able-bodied young men and women because of this mighty upheaval. Since the Second World War, the *Transactions* have improved steadily in both quantity and quality. It is instructive to compare activity in 1920 when 26 papers were presented at the meeting and were published in Volume 1 (69) with those presented in 1990 (70). Then 285 papers were read at the meeting, 46 abstracts of those papers were in the *Transactions*, one workshop was given at the meeting, 42 poster presentations were made and 19 separate articles were printed in the *Transactions* that were not read at the meeting. Papers read at each meeting are shown in Table 6 and are distributed by discipline, which gives a graphic picture of the increase in scientific activity of the Academy from its early beginnings.

The Academy, never too flush with funds, has made a rather slow start in making grants for the encouragement of scientific research. In 1925, at the Twelfth Annual Meeting, W. R. Jillson proposed that a gold medal be frequently given for "first excellence in scientific investigation" to a member of the Academy (71). He had found a donor who wished to remain anonymous who would pay for the medals. The project apparently fell through since there is no record of a medal ever being given to anyone.

The first mention of money to encourage research occurred in April 1939 at the Twenty-Sixth Annual Meeting at Murray State Teachers College. Mr. Fain W. King and Mrs. Blanch B. King of Wickliffe, Ky., announced that they were offering to the Academy an annual prize award of 50 dollars for 5 consecutive years. The prize was to be awarded by the Academy to the individual presenting the most meritorious paper of original research. The first award was given at that meeting to W. R. Allen of the University of Kentucky. His paper was entitled "Science and Human Mores" (72). Other awards were made over the next 40 years.

At the meeting in 1974 at Centre College, Joe Winstead of Western Kentucky University announced that "through the generosity of an anonymous donor, the Kentucky Academy of Science is authorized to periodically award a cash grant of $500 to any student who is a member of the Kentucky Academy of Science and who is enrolled in a course of study with an emphasis in botanical science at any college or university in the Commonwealth" (73). Basically, the grants were to support county floristic studies. In 1976, this same anonymous donor established an endowment fund of $10,000 to support students doing botanical research in Kentucky. That endowment was in addition to the donor's continuing support of county floristic work (74).

Eventually, it became known that the anonymous donor was Mr. Raymond L. Athey of Paducah, Kentucky. In 1982, Mr. Athey and the family of his late wife, Marcia Athey, made a donation of $50,000 to set up an endowment. The earnings were to be used only for scientific research in Kentucky and it was named The Marcia Athey Fund in honor of Mrs. Athey (75).

In 1986, the Academy recognized Mr. Athey by according him a Citizen Scientist Award in recognition of his many achievements in the documentation of rare and unusual plants of Kentucky and for his support of botanical and scientific research in the mid-south (76).

Quoting from the Citation: "Among plant taxonomists of the southeastern United States, the name of Raymond Athey is well known for his collection, documentation and dissemination of information concerning the herbaceous flora, particularly grasses, of Kentucky and the surrounding states. Perhaps less well known is his personal support of numerous students in sharing his knowledge about Kentucky plants as well as his support in developing permanent endowment funds to provide financial support of botanical and scientific research. Since 1979, no fewer than 18 students and faculty of colleges and universities in Kentucky, Indiana, North Carolina and New York have had individual research projects supported financially via the Kentucky Academy of Science from endowment funds developed through the interest and efforts of Raymond Athey" (76).

Mr. Athey died in July 1991. In his will, Mr. Athey set up a trust fund which contained all of his assets (estimated to be over a million dollars). One-half of the earnings from this trust fund are to go to the Academy and the other half to his children. Eventually, all of the earnings of the trust fund will come to the Academy.

It is no exaggeration to say that Mr. Athey literally transformed the Kentucky Academy of Science—not only with his gifts of money—but also by his example of enthusiasm for scientific research and his desire to improve the scientific literacy of the Commonwealth. It was reported that the day before his death, Mr. Athey was asked by his lawyer and trust officer why he was giving so much of his estate to the Kentucky Academy of Science. His reply was "By God, I want the future generations of Kentuckians to have the opportunity to know something about science."

Much of the credit for the relationship between the Academy and Mr. Athey must go to Joe Winstead. Joe met Mr. Athey in 1972 and they realized that they had common interests and they eventually became close friends. All of Mr. Athey's donations to the Academy were made through Joe, since he had complete confidence in his honesty and scientific acumen.

Kentucky Academy of Science Foundation

At the suggestion of Mr. Athey, a separate organization was established to keep the money that he and the Athey family had donated separate from the day-to-day operation of Academy affairs. Therefore, in 1980, the Kentucky Academy of Science Foundation (KAS Foundation) was established. A Board of Trustees was to address the affairs of the Foundation and the President of the Academy was the President of the Foundation. The officers of the Academy and the Board of Directors were automatically members of the Board of Trustees of the KAS Foundation. The Board of Trustees may, at their discretion, elect additional members up to a total of twenty (77).

With the new constitution of 1987, control of the KAS Foundation was taken over by the Governing Board of the Academy. The Board of Trustees of the Foundation as well as the Board of Directors of the Academy were eliminated (67).

At the meeting in Owensboro in 1991, the treasurer announced that the KAS Foundation had over $99,000 in funds and had disbursed $8,607 in research grants (78). While funds held in the Foundation account include funds from Life Memberships and donations from Academy members, by far most of the funds were from Raymond Athey and his family.

Improving Kentucky's Research Status

In the early 1970s, a study funded by the Kentucky Department of Commerce was conducted under the joint auspices of the Kentucky Academy of Science and the Task Force on Public Science and Technology. A series of reports based on that study were published in 1973 and 1974 and covered various aspects of science and technology in the Commonwealth. One of these reports, written by William G. Lloyd (1974), showed that Kentucky fared poorly in comparison with the rest of the United States in terms of federal support for research and developement activities (79). The Academy was involved to the extent that many members of the study panel were members of the Academy.

The results of this report were far more disturbing than anyone realized. Quoting from the Lloyd report: "in fiscal 1971 the United States government committed a total of $15,180,000 to support research and developement activities throughout the nation. That amounted to $74.71 for every man, woman and child in the nation. In Kentucky, the federal research and developement investment for that year amounted to $7.14 per capita, less than one-tenth of the national average. This was the lowest per capita share of federal research and developement money received by any state in the union" (79).

The Lloyd report also showed that if funds for research and development were adjusted for personal income, the Commonwealth received one-tenth of its equitable share, which gave Kentucky a rank of 50th in the 50 states and Washington D.C. Kentucky ranked 21st among the states in federal taxes paid but, again, received one-tenth of its equitable share, which again placed it in 50th position (79).

"In December, 1977, letters were written by the President of the Kentucky Academy of Science to the Governor, the Executive Director of the Council on Higher Education, the Director of the Legislative Research Commission, the President of the Senate and the Speaker of the House. In these letters, findings of the Lloyd report were highlighted and appeal was made to join the Academy in a comprehensive study of the health of the federally-funded research and developement enterprise in the Commonwealth. The letter suggested that the task would be to update the Lloyd report, and then go beyond to explore reasons why Kentucky ranked so low and possible ways of correcting any continuing disparity. It was also pointed out that while the health of science and technology in the Commonwealth was of direct concern to the Academy, the research and developement enterprise was directly related to the economy and many other facets of life in the Commonwealth to state government" (80).

"As a result of this appeal by the Academy, Senate Resolution 33 was passed in 1978 which directed the Council on Higher Education in cooperation with the Legislative Research Commission and KAS to conduct a new study. The tasks especially outlined were:

(1) document Kentucky's share of federal research and development funds for the most recent fiscal year,
(2) determine "why" Kentucky ranks and has ranked relatively low, and
(3) make recommendations relative to this problem.

During the summer of 1978, a fifteen member advisory committee was established. Seven members of the committee were appointed by the president of the Academy and the presidents of the 8 state-supported universities in Kentucky were each asked to appoint an institutional representative. In addition, there were 3 members from the Council on Higher Education" (80).

To summarize a masterful presentation of the research of this committee, Charles Kupchella of Western Kentucky University stated: "In summary, in fiscal 1977, Kentucky ranked 36th among the states in total federal research and developement obligations. While it ranked 23rd in population, it ranked only 47th in federal research and developement obligations per capita. It ranked 25th in federal taxes paid in 1976, but ranked 40th in federal research and developement obligations adjusted for tax dollars. The Commonwealth ranked 24th in personal income, but could only achieve 38th place in federal research and developement obligations per dollar of personal income in 1976." On the basis of funding per capita going to colleges and universities, Kentucky ranked 51st—behind all other states and the District of Columbia (81).

A list of suggestions to help the situation was sent to the then Governor John Y. Brown (82):

(1) Appoint a science advisor with a science background,
(2) Appoint a commission or charge an existing commission with making recommendations for improving the health of science in Kentucky,
(3) Encourage the Council on Higher Education to set up a research and development council to look into solutions to the problem and to be charged with looking after university research and development on an ongoing basis,
(4) Encourage the Council on Higher Education to establish a fund to be used to establish centers of research and development of excellence in one or more scientific areas at each of the state's institutions of higher education,
(5) Work toward the establishment of a federal laboratory in Kentucky, on the order of Oak Ridge in Tennessee,
(6) Encourage state university presidents to develope latent research potential that exists in their respective institutions.

In a concluding article, Kupchella et al. (83) considered the economic effect on Kentucky if the state received its fair share of federal research and development funds. In any kind of injection of funds from an outside source, there is a "multiplier effect." As people receive additional money in salaries from an outside source, they purchase more goods, which in turn increases trade and the manufacturing of more goods, which increases the standard of living. Thus, the net regional product may grow by a factor greater than the original injection. The multiplier effect varies, depending on the particular characteristics of the region, from 1 to 2.5. A rough estimate for Kentucky would be from 1.2 to 1.5. Using these figures, Kupchella et al. estimated that if Kentucky achieved parity with similar states, the effect would be the equivalent of adding 9,800 to 12,000 jobs.

In 1978, the National Science Foundation (NSF) began its EPSCoR program (Experimental Program to Stimulate Competitive Research). This program recognized that many states had fared poorly in the distribution of R&D funds from the federal government, and EPSCoR was an attempt to give these states "seed money" to help them come into a more competitive position with respect to R&D funding. Incredibly, Kentucky was omitted from an initial competition limited to seven states. Subsequently, Kentucky was again not going to be included in a second round. This oversight was noticed by Charles Kupchella who, with others, went to NSF to argue the case for Kentucky. He found that the states were chosen by NSF on the basis of the *gross* amount of federal R&D funds granted to the states. Kentucky had indeed ranked higher than those states selected in terms of gross funds. When presented with the results of the research by Kupchella et al., NSF agreed to review its position and did ultimately include Kentucky in its second list (81).

Lieutenant Governor Steve Brashear was concerned about the future of Kentucky, and particularly its role in science and technology. He had set up a program entitled "Kentucky Tomorrow" to plan for a technological future. The then KAS president, Gary Boggess of Murray State University, along with C. Kupchella and others from the Academy, joined with Kentucky Tomorrow to form an ad hoc Kentucky Science and Technology Council to write a proposal for the EPSCoR program (81).

For this purpose, NSF granted $75,000 and the state, through the governor's office, granted $25,000 to support the planning. Of the 146 proposals submitted by researchers across the state, 15 projects were selected by the ad hoc committee and the proposals were sent to NSF. The project was funded in August 1986 for a total of $16,426,262 to be expended over the next 5 years. Of this total, $3 million was furnished by NSF, $3 million by the state, $0.6 million by various industries and the remainder, $9,826,262, to be furnished by the universities involved. The share of the universities was primarily released time of faculty involved and waiver of their usual indirect cost allotment (84).

At the annual meeting of the Academy in 1990 at Northern Kentucky University, C. Kupchella gave a report indicating that "Kentucky's EPSCoR Program was, generally by then, regarded as one of the most successful programs nationally. Annual external funding (outside of EPSCoR) received by EPSCoR target faculty increased by more than 100% from 1985 to 1989. The number of EPSCoR faculty receiving external support increased from 20 in 1985 to 36 in 1989" (85).

During 1992, the Kentucky EPSCoR Committee has received awards from the Department of Energy (DOE), Environmental Protection Agency (EPA) and National Aeronautics and Space Administration (NASA). DOE awarded a $100,000 planning grant to inventory existing energy related research and to propose a final plan for linking energy-related research activities. DOE also awarded $250,000 in doctoral traineeship grants to increase training in energy-related disciplines. EPA has awarded a $50,000 planning grant to develop a proposal to improve quality of environmental training in colleges and universities. NASA has awarded a $25,000 planning grant to inventory present programs in aerospace and to propose a program to improve training of professionals for the aerospace industry. Kentucky EPSCoR has proposed a 3-year program to improve quality of aerospace education and research (86).

While KAS has not been officially involved in these later programs, many of its member have been. The Academy can take pride, in that, KAS and some of its members were very instrumental in getting this whole process started.

Concern for the Environment

From the early years, the Academy has been deeply concerned with the environment and with taking action for its protection. In May 1921, C. A. Shull (87) who was chairman of the Legislative Committee at that time, proposed a 10-point program to be sent to the Kentucky Legislature. Among them were 5 programs relating to the environment:

(1) an increased appropriation for the hastening of the completion of topographic mapping of the state,
(3) a request that a soil survey be begun, to follow as rapidly as possible the topographic and geological mapping of the state,
(8) a law compelling each person or corporation drilling a well for oil or gas or other purpose to a depth greater than 100 feet, to file with the State Geological Survey a complete log of that well showing the formations gone through, and a careful description of the location of the well so that it can be carefully mapped,
(9) endorsement of the law now before congress to make of Mammoth Cave and its environs, a national park,
(10) a law enabling the State of Kentucky to acquire and set aside for the benefit of future generations, such areas as are deemed worthy of preservation in natural condition, for the purpose of study and enjoyment of nature.

Such resolutions followed almost yearly; only a few will be indicated here.

In April 1924 a letter was sent supporting the position of the Ecological Society of America that Glacier Bay in Alaska should be set aside as a National Monument (88).

At the Twelfth Annual Meeting in 1923, the Academy passed a resolution that the Congress adopt an adequate program covering the acquisition of forest lands by the federal government. This resolution was sent to Congress in cooperation with the American Forestry Association (89).

A resolution in 1954 against encroachments on public lands (90).

A resolution in 1967 against the construction of a dam in Red River Gorge (91).

All of the above resolutions were sent either to members of Congress or members of the legislature. Many were successful—some were not. But successful or not, certainly the Academy took a leading role in conservation during its entire lifetime.

Rare and Endangered Species

As early as 1972, in its fifty-eighth annual meeting at Morehead State University, the Academy passed a resolution about its concern that there was no list of Rare and Endangered Species of plant and animal life compiled for the Commonwealth (46).

In its continuing concern for the environment, in 1972, Glenn Murray presented a paper concerning the problems of rare and endangered species in Kentucky. He promised the cooperation of the Soil Conservation Service in accumulating a list of rare and endangered species. As a consequence, a resolution was introduced to the Academy that a committee be established to:

(1) prepare a list of the state's rare or endangered plant and animal species,
(2) describe the measures needed to preserve the habitat of these species,
(3) develop a monitoring program that would provide an advanced warning of actions or disturbances that might further endanger these species so necessary protective actions can be taken (92).

The Committee on Rare and Endangered Species was formed and 15 specialists from differing fields in a monumental work compiled a list of endangered, threatened and rare animals and plants in Kentucky, by Branson et al. (93). The Kentucky Nature Preserves Commission, a state agency mandated to identify and protect natural areas, worked jointly with the Academy's committee. This list was later updated by Warren et al. in 1986 (94).

Awards

At the meeting in 1976 at the University of Kentucky, the Academy made its first honorary award. John Philley (95) of Morehead State University, speaking for the Board of Directors, gave the Distinguished Scientist Award to Louis A. Krumholz of the University of Louisville for outstanding service in science to the University of Louisville, the Commonwealth of Kentucky and the Kentucky Academy of Science. A suitable plaque commemorating the event was given.

Since that time, annual awards have been given in addition to the Distinguished Scientist Award. At this writing they are: Outstanding Secondary School Teacher Award, Outstanding College Science Teacher and Industrial Scientist Award. These awards recognize outstanding service from different populations within the Academy. They focus public attention on the accomplishments of the individuals so recognized and also bring the Academy to the attention of the general public.

In 1985, the Academy instituted the practice of honoring the winners of the Symposium of the Junior Academy at the annual banquet at Morehead State University. Each winner and their sponsoring teacher were publicly awarded plaques, complimentary banquet tickets and a year's membership in the Academy. This further enhances the work of the Junior Academy, encourages the young people in their interest in science and helps focus the attention of Academy members on the work of the Junior Academy.

The Executive Secretary

At the meeting of 1965 at the University of Kentucky, Mary Wharton (96) of Georgetown College made a report as the AAAS representative. She commented that "several nearby states had academies that were considerably larger and stronger than was our academy. Perhaps one of our greater needs is that of a permanent officer, such as an executive secretary or archives. This need was voiced very frequently thereafter. In 1969, M. Wharton reported that AAAS recommended that each academy have an executive secretary. AAAS would supply without charge a consultant to any state academy which wishes to set up and operate under the Executive Secretary system (97).

It was realized by everyone that a permanent secretary was needed very much to make the Academy affairs run more smoothly and to provide more continuity from one year to the next. The financial situation of the Academy would not support such an expense. Indeed, in the late 1970s and early 1980s expenses exceeded income. Through the activity of several presidents and other members of the Academy, recruiting of new members and particularly Educational Affiliates and Industrial Affiliates, the finances of the Academy improved significantly. In the new constitution of 1987, provision was made for an Executive Secretary should one be available. Provision was also made if one were not available (98).

In 1987, the Academy became very fortunate. J. D. Rodriguez of the University of Kentucky volunteered his services as assistant to the president and would, in effect, become the Executive Secretary. Upon acceptance of the new constitution in 1987, the Governing Board accepted his generous offer to serve as the Executive Secretary without compensation from the Academy. He retired from his position at the University in 1989 and has since maintained an office, a telephone and a mailbox for the Academy which gives a quasi-permanent address for the Academy. In 1990, the Governing Board authorized a part-time secretary to work under the direction of the Executive Secretary, and a committee was established to work toward finding a permanent headquarters for the Academy (98).

Programs that have been sponsored by the Academy under the direction of the Executive Secretary, J. G. Rodriguez (99), have been: a national symposium on the "Utilization of Wetlands," a series of workshops across Kentucky on the "use of animals in the classroom" and organizing, establishing and publishing a directory of the "Kentucky Mentor Program—Women in Science, Math and Engineering."

SUMMARY

In its 78 years of life, the Academy has certainly come far. Much of the progress has come in the last 15 years or so. One of the big turning points for the Academy is due to the support of Raymond Athey and his family. Their generous support has made it possible to actively support research and thus encourage the members of the Academy to be more active scientists.

Another improvement has been the addition of an Executive Secretary. With a new president each year, continuity suffers. Many projects have been started by one president but not continued by his successor, who may have had other emphases in mind. We are indeed fortunate to have the services of J. G. Rodriguez in that position for now and it is hoped that this position will become permanent. The Academy urgently needs a permanent office and a fixed address which it did not have before.

The membership is almost to the 1,000 mark in 1992, and the number of sections is now 18. The Academy seems to be approaching a critical mass and has a large number of capable leaders as was shown in the background work leading up to the first EPSCoR grant which documented how poorly Kentucky fared with respect to other states for R&D funds from the federal government.

The finances of the Academy are the best they have ever been in its history. The size of the membership and the number of affiliates has resulted in more more money for support of administration and other enterprises. However, it has not been a steady improvement. In the late 1970s and early 1980s, the Academy was spending more than its income. Many people worked to change that situation—certainly the presidents of the 1980s and early 1990s contributed immensely. Growth in membership along with financial help from the affiliates changed the financial situation. The Academy has had financial help before from various outside sources, but credit must go to Louis Krumholz for initiating the idea of Educational Affiliates during his presidency. Credit must also go to William Hettinger who, during his presidency, made tremendous progress in enlarging the number of Industrial Affiliates.

The improvement in the *Transactions* is very noticeable. The use of the Allen Press has improved the professional appearance. The *Transactions* also reflect the growth in scientific activity of Academy members. In 1990, the journal had 202 pages in two issues, which is quite respectable for an organization of this size. This also shows the increase in workload of the editor, who contributes large amounts of his free time for no compensation. The *Transactions* is the public face of the Academy and it looks good!

The Academy must continue its concern for science teaching in the public schools. Its effect on science teaching has never been what it should be. This seems to be tied in with another problem—the Academy has very little visibility to the general public. Scientists are not prone to toot their own horns, so to speak. But this must be done. A large percentage of Kentuckians do not know that the Kentucky Academy of Science exists. This must be changed if the Academy is ever to reach its full potential in Kentucky. Recently, the Executive Secretary has been given the task of taking charge of the Committee on Public Relations. In the opinion of the author, this committee has its work cut out for it. It will be a very difficult task to change the low profile of the Kentucky Academy of Science in the consciousness of Kentuckians. Out of a membership of about 1,000, surely we can find enough talent to do this job!

ACKNOWLEDGMENTS

The author is deeply indebted to many who have given help in the writing of this history. George H. Paine of Ludlow, Ky., graciously furnished a rare copy of Volume 1 of the *Transactions*. Charles Hay, Archivist of Eastern Kentucky University, was extremely helpful in giving access to the material in the Academy archives. Varley Wiedeman furnished data and additional copies of the *Transactions* from the library at the University of Louisville. Douglas Dahlman, of the University of Kentucky, also helped with data unavailable in print. I appreciate the comments and valuable suggestions given to me by the following members of the Academy: Branley Branson of Eastern Kentucky University, Charles Kupchella of Western Kentucky University, J. G. Rodriguez of the University of Kentucky and Joe Winstead of Western Kentucky University.

LITERATURE CITED

1. Archives. University of Kentucky. Kentucky Academy of Science.
2. Spahr, R. H. 1924. Call for organization of the Kentucky Academy of Science. Trans. Ky. Acad. Sci. 1:21.
3. Robinson, C. J. 1924. Minutes of the Secretary. Trans. Ky. Acad. Sci. 1:23, 24.
4. Robinson, C. J. 1924. Report of Committee on Constitution. Trans. Ky. Acad. Sci. 1:27.
5. Anderson, W. M. 1924. Report of Secretary and Treasurer. Trans. Ky. Acad. Sci. 1:28.
6. Miller, D. C. 1924. The science of musical sounds. Trans. Ky. Acad. Sci. 1:30.
7. Miller, D. C. 1924. Acting Treasurer's report. Trans. Ky. Acad. Sci. 1:35.
8. Miller, A. M. 1916. Resolution—Ky. Acad. Sci. Trans. Ky. Acad. Sci. 1:34.
9. Constitution. Ky. Acad. Sci. 1924. Trans. Ky. Acad. Sci. 1:10.
10. Peter, A. M. 1935. Secretary's report. Trans. Ky. Acad. Sci. 6:21.
11. Peter, A. M. 1935. Secretary's report. Trans. Ky. Acad. Sci. 6:91.
12. Constitution. Ky. Acad. Sci. 1988. Trans. Ky. Acad. Sci. 49(1–2):61–65.
13. Terrell, G. 1924. Resolutions Comm. report. Trans. Ky. Acad. Sci. 1:99.
14. Peter, A. M. 1927. Secretary's report. Trans. Ky. Acad. Sci. 2:17.
15. Peter, A. M. 1927. Secretary's report. Trans. Ky. Acad. Sci. 2:20, 91.
16. Jillson, W. R. 1971. The memoirs of Willard Rouse Jillson. Roberts Printing Co., Frankfort, Kentucky.
17. Brauer, A. 1954. Alfred Meredith Peter, 1857–1953. 14:89.
18. Bartlett's Quotations. 1980. 15 Edition:594.
19. Jillson, W. R. 1924. Trans. Ky. Acad. Sci. 1:Preface.
20. Peter, A. M. 1924. Secretary's report. Trans. Ky. Acad. Sci. 1:43.
21. Wiedeman, V. E. 1991. Secretary, Ky. Acad. Sci., private communication.
22. Peter, A. M. 1924. Secretary's report. Trans. Ky. Acad. Sci. 1:73.
23. Wiedeman, V. E. 1991. Secretary, Ky. Acad. Sci., private communication.
24. Peter, A. M. 1924. Secretary's report. Trans. Ky. Acad. Sci. 1:74.
25. Peter, A. M. 1924. Secretary's report. Trans. Ky. Acad. Sci. 1:149.
26. Peter, A. M. 1927. Secretary's report. Trans. Ky. Acad. Sci. 2:171.
27. The World Book, Year Book. 1988:492.
28. Committee on Legislatively Mandated Education Programs. 1981. Trans. Ky. Acad. Sci. 42(3–4):160.
29. Dixon, W. 1982. Report on legislatively mandated educational programs. Trans. Ky. Acad. Sci. 43(1–2):84.
30. The World Book, Year Book. 1984:300.
31. McAllister, C. N. 1927. President's address. Trans. Ky. Acad. Sci. 2:155.
32. Hinton, R. T. 1938. President's address. Trans. Ky. Acad. Sci. 7:78.
33. Pennebaker, G. B. 1941. Resolution from the floor. Trans. Ky. Acad. Sci. 9(3):53.
34. Report of Resolutions Committee. 1956. Trans. Ky. Acad. Sci. 17(3–4):148.
35. Report of Resolutions Committee. 1959. Trans. Ky. Acad. Sci. 20(3–4):83.
36. McHargue, J. S. 1935. Report. Trans. Ky. Acad. Sci. 6:85.
37. Chapman, R. 1963. Report. Trans. Ky. Acad. Sci. 24(3–4):126.
38. Chapman, R. 1964. Report of Visiting Scientist Committee. Trans. Ky. Acad. Sci. 25(3–4):139.
39. Fergus, E. N. 1965. Report of Visiting Scientist Program. Trans. Ky. Acad. Sci. 26(3–4):92.
40. Barbour, R. 1968. Report of Visiting Scientist Program. Trans. Ky. Acad. Sci. 29(1–4):38.
41. Creek, R. 1984. Secretary's report. Trans. Ky. Acad. Sci. 45(1–2):88.
42. Hutto, T. A. 1963. Status of the Junior Academy of Science in Kentucky. Trans. Ky. Acad. Sci. 24(3–4):110–112.
43. Report of the Junior Academy of Science. 1991. Trans. Ky. Acad. Sci. 52(1–2):54.
44. Dahlman, D. L. 1992. President, Ky. Acad. Sci., private communication.
45. Early, B. 1992. President's report. Trans. Ky. Acad. Sci. 53(1–2):62.
46. LaFuze, H. H. 1972. Resolution's Comm. report. Trans. Ky. Acad. Sci. 33(3–4):84.
47. George, T. M. 1973. Science Education Comm. report. Trans. Ky. Acad. Sci. 34(3–4):61.

48. George, T. M. 1978. Science Education Comm. report. Trans. Ky. Acad. Sci. 39(1–2):89.

49. George, T. M. 1979. Report of the Science Education Comm. Trans. Ky. Acad. Sci. 40(1–2):71, 72.

50. Batch, D. 1976. Report—Resolutions Comm. Trans. Ky. Acad. Sci. 37(1–2):46.

51. Prins, R. 1987. Report of Resolutions Comm. Trans. Ky. Acad. Sci. 48(1–2):30.

52. George, T. M. 1986. Report of the Science Education Comm. Trans. Ky. Acad. Sci. 47(1–2):62, 64.

53. Buckner, G. D. 1924. Motion from the floor. Trans. Ky. Acad. Sci. 1:60.

54. Leggett, J. L. 1942. Report—Resolutions Comm. Trans. Ky. Acad. Sci. 10(1–2):2.

55. Abstracted Minutes of 1944 and 1946 Meetings of Kentucky Academy of Science. 1947. 12(3):22.

56. Brauer, A. 1947. Editorial by the President. Trans. Ky. Acad. Sci. 12(3):2.

57. World Almanac. 1990:511.

58. Peter, A. M. 1935. Report of the Secretary. Trans. Ky. Acad. Sci. 6:22.

59. McHargue, J. S. 1938. Report to the Academy. Trans. Ky. Acad. Sci. 7:33.

60. McHargue, J. S. 1938. Amendments to the constitution. Trans. Ky. Acad. Sci. 7:75.

61. Anderson, W. S. 1933. Report of the Treasurer. Trans. Ky. Acad. Sci. 5:41.

62. Brauer, A. 1940. Report of the Secretary. Trans. Ky. Acad. Sci. 8:5.

63. Chapman, R. A. 1955. Report of the Treasurer. Trans. Ky Acad. Sci. 16(4):112.

64. Wilson, G. Jr. 1969. Comment from the floor. Trans. Ky. Acad. Sci. 30(3–4):79.

65. Kupchella, C. 1974. Report of Board of Directors. Trans. Ky. Acad. Sci. 35(3–4):86.

66. Philly, J. C. 1976. Report of Board of Directors. Trans. Ky. Acad. Sci. 37(1–2):46.

67. Revised Constitution of The Ky. Aca. of Sci. 1988. Trans. Ky. Acad. Sci. 49(1–2):61, 62.

68. Cooper, T. P. 1935. Letter to the President. Trans. Ky. Acad. Sci. 6:21, 22.

69. Papers Presented, Seventh Annual Meeting. 1924. Trans. Ky. Acad. Sci. 1:76–99.

70. Papers Presented, Seventy-Sixth Annual Meeting. 1991. Trans. Ky. Acad. Sci. 52(1–2):57–86.

71. Jillson, W. R. 1927. Report of the Council. Trans. Ky. Acad. Sci. 2:79.

72. Allen, W. R. 1940. President's address. Trans. Ky. Acad. Sci. 8:23.

73. Winstead, J. 1974. Announcement: floristic survey grant. Trans. Ky. Acad. Sci. 35(3–4):84.

74. Payne, C. 1977. President's address. Trans. Ky. Acad. Sci. 38(1–2):110.

75. Winstead, J. 1984. Report of Board of Directors. Trans. Ky. Acad. Sci. 45(1–2):83.

76. Kentucky Academy of Science Citizen Scientist Award to Raymond Athey. 1986. Trans. Ky. Acad. Sci. 47(3–4):140.

77. Articles of Incorporation of the Kentucky Academy of Science Foundation. 1981. Trans. Ky. Acad. Sci. 42(1–2):66.

78. Hartman, D. 1992. Treasurer's report. Trans. Ky. Acad. Sci. 53(1–2):63.

79. Lloyd, W. G. 1974. Federal research and development funding in Kentucky, a technical report of the Ogden College of Science and Technology, Western Kentucky University.

80. Kupchella, C. E., R. Sims, M. L. Collins, and K. Walker. 1979. Federal funding for research and development in Kentucky. Trans. Ky. Acad. Sci. 40(3–4):151.

81. Kupchella, C. E. 1992. Private communication.

82. Kupchella, C. E., R. Sims, M. L. Collins, and K. Walker. 1980. Federal funding for research and development in Kentucky, III. Trans. Ky. Acad. Sci. 41(3–4):155.

83. Kupchella, C. E.; W. F. Edwards, R. Sims, M. L. Collins, and K. Walker. 1981. Federal funding for research and development in Kentucky: IV. Trans. Ky. Acad. Sci. 42(1–2):29.

84. Newsletter, Kentucky Academy of Science. Fall, 1986. EPSCoR Summary:1–4.

85. Kupchella, C. 1991. Report of the Committee on Science and Government. Trans. Ky. Acad. Sci. 52(1–2):53.

86. Brochure, Kentucky EPSCoR Program. 1992. P.O. Box 22302, Lexington, Kentucky 40522-2302.

87. Schull, C. A. 1924. Report of the Legislative Comm. Trans. Ky. Acad. Sci. 1:107.

88. Peter, A. M. 1927. Report of the Secretary. Trans. Ky. Acad. Sci. 2:18.

89. Report of Resolutions Comm. 1927. Report. Trans. Ky. Acad. Sci. 2:84.

90. Report of Resolutions Comm. 1954. Report. Trans. Ky. Acad. Sci. 15(4):129.

91. Kuehne, R. 1968. Report of the Resolutions Comm. Trans. Ky. Acad. Sci. 29(1–4):43.

92. Murray, G. 1972. Need to identify rare and endangered plant and animal species in Kentucky. Trans. Ky. Acad. Sci. 33(3–4):83.

93. Branson, B., D. Harker, Jr., J. Baskin, M. Medley, D. Batch, M. Warren, Jr., W. Davis, W. Houtcooper, B. Monroe, Jr., L. Phillippe, and P. Cupp. 1981. Endangered, threatened, and rare animals and plants of Kentucky. Trans. Ky. Acad. Sci. 42(3–4):77.

94. Warren, M., Jr., W. Davis, R. Hannan, M. Evans, D. Batch, B. Anderson, B. Palmer-Bell, Jr., J. MacGregor, R. Cicerello, R. Athey, B. Branson, G. Fallo, B. Burr, M. Medley, and J. Baskin. 1986. Endangered, threatened, and rare plants and animals of Kentucky. Trans. Ky. Acad. Sci. 47(3–4):83.

95. Philley, J. C. 1977. Distinguished scientist award. Trans. Ky. Acad. Sci. 38(1–2):99, 100.

96. Wharton, M. 1965. Report of the annual meeting of the Amer. Assoc. for the Adv. of Sci. Trans. Ky. Acad. Sci. 26(3–4):93.

97. Wharton, M. 1969. Report of the annual meeting

of the Amer. Assoc. for the Adv. of Sci. Trans. Ky. Acad. Sci. 30(3–4):80, 82.

98. Constitution of the Kentucky Academy of Science. Revised 1987. 1988. Trans. Ky. Acad. Sci. 49(1–2):62.

99. Rodriguez, J. G. 1991. Report of the Executive Secretary. Trans. Ky. Acad. Sci. 52(1–2):51.

APPENDIX I

CONSTITUTION OF THE KENTUCKY ACADEMY OF SCIENCE

(As adopted 8 May 1914 and subsequently amended.)

ARTICLE I—NAME. This organization shall be known as The Kentucky Academy of Science.

ARTICLE II—OBJECT. The object of this Academy shall be to encourage scientific research, to promote the diffusion of useful scientific knowledge and to unify the scientific interests of the State.

ARTICLE III—MEMBERSHIP. The membership of this Academy shall consist of Active Members, Corresponding Members, and Honorary Members.

Active members shall be residents of the State of Kentucky who are interested in scientific work. They shall be of two classes, to wit: National members who are members of the American Association for the Advancement of Science as well as of the Kentucky Academy of Science, and Local Members, who are members of the Kentucky Academy but not of the Association. Each active member shall pay to the Secretary of the Academy an initiation fee of one dollar, at the time of election. National members shall pay to the Secretary of the Academy an annual assessment of five dollars,* payable October 1st, of each year, four dollars of which shall be transmitted by the Secretary of the Academy to the Permanent Secretary of the American Association for the Advancement of Science, and one dollar shall be turned over to the treasurer of the Academy. Local members shall pay an annual assessment of one dollar, payable October first of each year.

Corresponding members shall be persons who are actively engaged in scientific work not resident in the State of Kentucky. They shall have same privileges and duties as Active Members but shall be free from all dues and shall not hold office.

Honorary members shall be persons who have acquired special prominence in science not residents of the State of Kentucky and shall not exceed twenty in number at any time. They shall be free from dues.

For election to any class of membership the candidate must have been nominated in writing by two members, one of whom must know the applicant personally; receive a majority vote of the committee on membership and a three fourths vote of the members of the Academy, present at any session or, in the interim between meetings of the Academy, the unanimous vote of the members of the council, present or voting by letter.

ARTICLE IV—OFFICERS. The officers of the Academy shall be chosen annually by ballot at the recommendation of a nominating committee of three, appointed by the President, and shall consist of a president, vice-president, secretary, treasurer, and councilor of the American Association for the Advancement of Science, who shall perform their duties usually pertaining to their respective offices. Only the secretary, treasurer, and councilor shall be eligible to re-election for consecutive terms.

It shall be one of the duties of the Retiring President to deliver an address before the Academy at the annual meeting.

The Secretary shall have charge of all books, collections, and records that may belong to the Academy.

ARTICLE V—COUNCIL. The Council shall consist of the President, Vice-President, Secretary, Treasurer, and President of the preceding year. The Council shall direct the affairs of the Academy during the intervals between the regular meetings and shall fill all vacancies occurring during such intervals.

ARTICLE VI—STANDING COMMITTEES. The Standing Committees shall be as follows:

A Committee on Membership appointed annually by the President, consisting of three members.

A Committee on Publications consisting of the President, Secretary, and a third member chosen annually by the Academy.

A Committee on Legislation consisting of three members appointed annually by the President.

ARTICLE VII—MEETINGS. The regular meetings of the Academy shall be held at such time and place as the Council may select. The Council may call a special session, and a special session may be called at the written request of twenty members.

ARTICLE VIII—PUBLICATIONS. The Academy shall publish its transactions and papers which the Committee on Publications may deem suitable. All members of the Academy shall receive the publications of the Academy gratis.

ARTICLE IX—AMENDMENTS. This Constitution may be amended at any regular annual meeting by a three-fourths vote of all active members present, provided a notice of said amendment has been sent to each member ten days in advance of the meeting.

BYLAWS

I—The following shall be the order of business:

1. Call to order.
2. Reports of Officers.
3. Report of Council.
4. Report of Standing Committees.
5. Election of Members.
6. Report of Special Committees.
7. Appointment of Special Committees.

* A recent action of the A.A.A.S. requires the payment to be made to the permanent Secretary in Washington, who returns the one dollar of each five to the Kentucky Academy.

8. Unfinished Business.
9. New Business.
10. Election of Officers.
11. Program.
12. Adjournment.

II—No meeting of this Academy shall be held without thirty days' notice having been given by the Secretary to all members.

III—Twelve members shall constitute a quorum of the Academy for the transaction of business. Three of the Council shall constitute a quorum of the Council.

IV—No bill against the Academy shall be paid without an order signed by the President and Secretary.

V—Members who shall allow their dues to be unpaid for two years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

VI—The President shall annually appoint an auditing committee of three who shall examine and report in writing upon the account of the Treasurer.

VII—The Secretary shall be free from all dues during his term of office.

VIII—All papers intended to be presented on the program or abstract of the same must be submitted to the Secretary previous to the meeting.

IX—These bylaws may be amended or suspended by a two-thirds vote of the members present at any meeting.

APPENDIX II

(Adopted 8 May 1914. Revised November 1951, 1970, 1979, 1987)

ARTICLE I

NAME AND OBJECTIVES

Section I. Name. This organization shall be known as the Kentucky Academy of Science.

Section 2. Objectives. The objectives of the Academy shall be to encourage scientific research, promote the diffusion of scientific knowledge, and to unify the scientific interests of the Commonwealth of Kentucky.

ARTICLE II

MEMBERSHIP

Section I. Classes of Membership. The membership of the Academy shall consist of Regular Members, Life Members, Student Members, Honorary Members, Emeritus Members, Corporate Affiliates, and Institutional Members.

Section 2. Regular Members. Regular Members shall be individuals who are interested in science and the objectives of the Academy. Each regular member shall pay to the Academy annual dues as prescribed by the Bylaws.

Section 3. Life Members. Life Members shall be members who have paid at one time a suitable sum, or have paid at least that sum as an endowment as prescribed in the Bylaws, and are therefore relieved from further payment of dues.

Section 4. Student Members. Student Members shall be full-time undergraduate, or part-time or full-time graduate students at a recognized institution of higher learning. Each Student Member shall pay to the Academy annual dues as prescribed in the Bylaws. Student Members shall have all the rights and privileges of Regular Members but may not hold office. No individual shall be allowed to be a Student Member for more than five years.

Section 5. Honorary Members. Honorary Members shall be persons who have acquired national or international renown in science. They shall enjoy all the privileges of active membership except holding office and shall be free from all dues. The number of Honorary Members shall not exceed twenty at any time.

Section 6. Emeritus Members. Emeritous Members shall be members who have retired from active service and who petition the Executive Committee for a change in classification. They shall enjoy the privileges of active membership except that they shall not hold office and shall be released from the payment of all dues. They shall receive all mailings except the *Transactions*.

Section 7. Corporate and Institutional Affiliates. Corporate and Institutional Affiliates shall be businesses, industrial or academic institutions, departments of such corporations or institutions, or individuals who through support have indicated their endorsement and espousal of the aims and purposes of the Academy. Annual dues shall be paid as prescribed in the Bylaws.

Section 8. Election to Membership. For election to any class of membership, the individual should apply for membership and must have paid the first year's dues.

ARTICLE III

OFFICERS

Section 1. Elected Officers. The elected officers of the Academy shall consist of President, President Elect, Vice President, Past President, Secretary, and Treasurer.

Section 2. Appointed Officers. The appointed officers shall be the Representative to the American Association for the Advancement of Science (AAAS) and the National Association of Academies of Science (NAAS), the Editor of the *Transactions* of the Academy, and the chair of the Kentucky Junior Academy of Science. An Executive Secretary may also be appointed. These officers shall be appointed by the President, approved by the Governing Board, and all shall serve at the discretion of the President and the Governing Board.

Section 3. Election of Officers. The Vice President shall be elected annually by mail ballot and, after having served one year, shall succeed to the office of President Elect. The Secretary and Treasurer shall be elected for three-year terms, the election to take place by mail ballot in the fall of the year prior to taking office.

Section 4. Term of Office. The elected officers shall take office on January 1 following the fall meeting and shall hold office until their successors have been elected. Any vacancy of an office may be filled by appointment by the President.

Section 5. Presidential Succession. The President Elect shall succeed the retiring President and the Vice President shall become President Elect. If the President Elect is unable to assume office, the Vice President shall succeed to the presidency and both a President Elect and a Vice President shall be elected at the fall meeting.

ARTICLE IV

GOVERNING BOARD

Section 1. Governing Board. The Governing Board shall have the responsibility for the overall direction of the affairs of the Academy. It shall conduct the business of the Academy, subject to decision on policy by membership by mail ballot or at a meeting of the Academy. The Board shall consist of the following: President, President Elect, Vice President, Past President, Secretary, Treasurer, Executive Secretary, Editor, Representative to AAAS and NAAS, Chair of the Kentucky Junior Academy, six representatives elected by the three divisions of the Academy (two from each Division), and two representatives elected from the Academy at-large.

Section 2. Meetings. The first meeting of the new Governing Board shall be held within three months after the adjournment of the fall meeting of the Academy, and quarterly thereafter.

Section 3. Executive Committee. The Executive Committee shall consist of the President, President Elect, Vice President, Past President, Secretary, and Treasurer. The Executive Secretary and Editor shall serve on the Executive Committee in an *ex officio* capacity. The Executive Committee shall execute and administer the affairs of the Academy during intervals between scheduled meetings of the Governing Board.

ARTICLE V

DUTIES OF OFFICERS

Section 1. President. The President shall discharge the usual duties of a presiding officer at all general meetings of the Academy, the Governing Board, and the Executive Committee. The President shall stay constantly informed on the affairs of the Academy and on its acts and those of its officers, and shall cause the provisions of the Constitution and Bylaws to be faithfully carried into effect, including making appointments described herein.

Section 2. President Elect. The President Elect shall assume the duties of the President in the event of the President's disability or absence from the general meetings of the Academy, the Governing Board, or the Executive Committee. The President Elect shall serve as Chair of the Program Committee.

Section 3. Vice President. The Vice President may assist the President Elect in the discharge of their duties. In the event that both the President and the President Elect are unable to preside over a meeting of the Academy, the Governing Board, or the Executive Committee, the Vice President shall preside in their stead. The Vice President shall also serve as chair of the Awards Committee.

Section 4. Past President. The Past President shall serve as an advisor and consultant to the President in order to provide continuity in the development and implementation of long-term policies of the Academy. The Past President shall serve as Chair of the Planning Committee.

Section 5. Secretary. The Secretary shall keep the records of the proceedings of the Academy, the Governing Board, and the Executive Committee. The Secretary shall maintain a complete list of members of the Academy with the dates of their election to the different classes of membership and their separation from the Academy; shall cooperate with the President in attending to the ordinary affairs of the Academy; shall have charge of the registration of the fall meeting; and shall have responsibility for preparation, printing and mailing of circulars, forms, and meeting announcements.

Section 6. Treasurer. The Treasurer shall have custody of all funds of the Academy and may deposit these funds in banks that are insured by the Federal Government, but shall not invest them without authority from the Finance Committee, of which the Treasurer is a member, and from the Governing Board. The Treasurer shall keep a detailed account of receipts and disbursements, and the account shall be audited as provided in the Bylaws. The Treasurer shall furnish a suitable corporate security bond, the premium thereof to be paid by the Academy.

Section 7. Executive Secretary. The Executive Secretary shall serve at the discretion of the President and Governing Board, and shall have duties as directed by the President and the Executive Committee. The Executive Secretary shall serve as Chair of the Public Relations Committee and shall work in concert with any officer in any manner that benefits the Academy. In the event that the Executive Secretary is not appointed or is not able to serve, these duties fall back to the other officers of the Academy. If empowered to handle financial duties, the Executive Secretary shall furnish a suitable corporate security bond, the premium thereof to be paid by the Academy, and shall be subject to the same audit as the Treasurer.

Section 8. Editor. The Editor of the *Transactions of the Kentucky Academy of Science* shall be appointed by the President, serve at the discretion of the President and the Governing Board, and be assisted by an Associate Editor, also appointed by the President. The Editor shall serve as Chair of the Publications Committee and is responsible for editing the *Transactions* and other publications of the Academy.

Section 9. AAAS/NAAS Representative. The Representative to the American Association for the Advancement of Science and National Association of Academies of Science represents the Academy in AAAS matters, and shall keep the Academy informed on AAAS and NAAS transactions that may relate to the Academy activities. An alternate shall also be named to serve in the event that the Representative is not able to serve.

Section 10. Chair of the Kentucky Junior Academy of Science. The Chair of the Junior Academy of Science is responsible for science competitions, projects, and all activities of the Junior Academy (a full description is found in Article XI).

ARTICLE VI

DIVISIONS

Section 1. Designations of Divisions. For representation on various bodies of the Academy and otherwise facilitate the functions of the Academy, the membership shall be grouped into three broad divisions:

A. Biological Sciences
B. Physical, Mathematical, and Computer Sciences
C. Social Sciences and Science Education

Section 2. Membership in Divisions. A member may join any Division of individual choice but shall not belong to more than one Division at one time. Membership in one Division shall not preclude participation in the program activities of other Divisions.

Section 3. Representatives to the Governing Board. Each Division shall elect two members as Division Representatives to the Governing Board. Each Representative shall serve for four years, but the terms shall be staggered so that a Representative from a given Division is elected every two years. The Senior Representative shall serve as Chair of the Division in all matters that concern the Division. In addition, two Representatives shall be elected from the Membership-at-large.

ARTICLE VII

SECTIONS

Section 1. Organization. Sections of the Academy shall be organized to represent the various fields, or disciplines, of science in each Division.

Section 2. Approval. The establishment of Sections shall be approved by the Governing Board upon recommendation by the Program Committee.

Section 3. Section Officers. Each Section shall elect annually a Chair and a Secretary to take office concurrently with the Officers of the Academy.

Section 4. Program Committee. The Chairs of all the Sections shall serve collectively as the Program Committee under the direction of the President Elect.

ARTICLE VIII

COMMITTEES

Section 1. Standing Committees. Except where otherwise specified below, members of the Standing Committees shall be appointed by the President with the approval of the Governing Board and shall serve for a term of three years on a rotational basis. The President shall designate the Chair of each committee at the time the committee appointments are announced. There shall be twelve Standing Committees, namely:

1. A Committee on Membership that consists of at least three members. The Committee shall periodically review and update, if necessary, criteria and procedures for membership and provide leadership in devising and implementing recruitment activities.
2. A Committee on Publications that consists of the President, the Editor and the Associate Editor of the *Transactions,* and three members from the Membership-at-large as well as any other member(s) of the Executive Committee appointed by the President. The Editor shall serve as the Chair of the Committee.
3. A Committee on Legislation that consists of three members. The Committee shall be responsible for the legislation that affects the scientific interests of the Commonwealth of Kentucky and the Academy and shall recommend to the Executive Committee appropriate action to be taken.
4. A Committee on the Distribution of Research Funds that consists of six members. The Committee shall be responsible for evaluating research proposals, distributing funds, and shall have accountability in use of research funds.
5. A Committee on Science Education that consists of six members. The Committee shall be responsible for promoting science education in the Commonwealth, especially in the primary and secondary schools.
6. A Program Committee. The President Elect shall serve as Chair of the Program Committee, the other members of which shall be the Chairs of the Sections. The Committee shall be responsible for the program of the annual meeting and any other meetings of the Academy.
7. A Committee on Awards. This Committee, consisting of the Vice President and three other members of the Governing Board, shall solicit and evaluate nominations for the awards of the Academy. The Vice President is responsible for presenting the awards.
8. A Committee on Nominations and Elections. The Committee shall consist of three members and shall present nominations for all officers to be elected for the following year. Two candidates for each office shall be nominated and presented to the membership in appropriate form for mail balloting. Nominations of other candidates may be written in. Ballots for Division Representatives to the Governing Board shall be mailed only to members having identified with that Division. Ballots for the Representatives of the Membership-at-large to the Governing Board shall be mailed to all members of the Academy. It shall be the further responsibility of the Committee to canvass the membership to provide the Governing Board a list of members interested in serving as officers or on committees.
9. An Audit Committee consisting of three members. The Committee shall conduct a yearly audit of all financial transactions of the Academy.
10. A Finance Committee consisting of the President, as Chair, the President Elect, Vice President, Executive Secretary, and the Treasurer shall periodically review

financial policies of the Academy and make recommendations to the Governing Board.

11. A Planning Committee that consists of the Past President and three other members. The Committee shall research meeting sites, programs and activities for the Academy and any other goals or objectives deemed appropriate by the Executive Committee. The Committee shall make recommendations to the Governing Board.
12. A Public Relations Committee that consists of the Executive Secretary as Chair, two members from the Governing Board, and two members from the Membership-at-large. In case there is no Executive Secretary, the President shall appoint a Chair. The Committee shall be responsible for promoting the Academy in any appropriate manner as determined by the Executive Committee.

Section 2. Ad Hoc Committees. Ad hoc committees shall be named as required, by the President and Executive Committee. These may include Resolutions, Local Arrangements, Rare and Endangered Species, and other committees as deemed appropriate by the President and Executive Committee. The President shall designate the Chair of each committee at the time the committee appointments are announced.

ARTICLE IX

MEETINGS

Section 1. Annual Meetings. The Kentucky Academy shall hold annually a fall meeting. In addition, spring or other special sessions may be called by the Governing Board upon the written request of twenty active members.

ARTICLE X

PUBLICATIONS

Section 1. *Transactions.* The Academy shall publish the *Transactions* of the Kentucky Academy of Science, and other publications, with the approval of the Governing Board.

Section 2. Recipients. Every dues-paying member of the Academy and each club in the Junior Academy shall receive a copy of the *Transactions.*

Section 3. Editor and Associate Editor. The President shall appoint the Editor and Associate Editor of the *Transactions* subject to the approval of the Governing Board. The Editor and Associate Editor shall be members of the Academy.

ARTICLE XI

KENTUCKY JUNIOR ACADEMY OF SCIENCE

Section 1. Relationship to Kentucky Academy of Science. The Kentucky Junior Academy of Science shall be a component of the Kentucky Academy of Science.

Section 2. Steering Committee. The President of the Kentucky Academy of Science shall appoint a Steering Committee for the Junior Academy of Science consisting of three members of the Kentucky Academy of Science and shall designate one of the three as Chair.

Section 3. Chair. The Chair of the Steering Committee shall direct the affairs of the Junior Academy.

Section 4. Treasurer. The Steering Committee shall designate one of its members as Treasurer of the Junior Academy. The Treasurer shall be responsible for banking all dues paid and contributions made to the Junior Academy.

Section 5. Disbursements. Bills against the Junior Academy shall be paid only when authorized by the Chair of the Steering Committee.

Section 6. Audit. The accounts of the Treasurer of the Junior Academy shall be audited annually by a committee of two members, one to be appointed by the President of the Kentucky Academy of Science and one to be appointed by the Chair of the Steering Committee.

Section 7. Annual Report. The Chair of the Steering Committee shall make an annual report to the Kentucky Academy of Science. The report shall include a statement on major activities of the Junior Academy and a report on the finances of the Junior Academy as prepared by its Treasurer.

Section 8. Constitution. The Junior Academy shall operate under a Constitution approved by the Kentucky Academy of Science. All revisions of the Constitution of the Junior Academy shall be referred to the fall meeting of the Kentucky Academy of Science for approval.

ARTICLE XII

AMENDMENT OF CONSTITUTION

Section 1. Constitution. The Constitution of the Kentucky Academy of Science may be amended by mail ballot if approved by two-thirds of the members responding, and if at least ten per cent of the members have voted. The Constitution may also be amended at any regular meeting by two-thirds of the members present, provided a notice of said amendment has been sent to all members at least thirty days in advance of the meeting.

BYLAWS

I. Items of Business. The following items may be included in the order of business for general or Governing Board meetings:

1. Call to order.
2. Reports of officers.
3. Report of the Executive Committee.
4. Reports of the Standing Committees.
5. Reports of the ad hoc Committees.
6. Appointment of ad hoc Committees.
7. Unfinished business.
8. New business.
9. Election of officers and representatives.
10. Program.
11. Adjournment.

II. Quorums. Forty members shall constitute a quorum of the Academy for transaction of business. Nine members shall constitute a quorum of the Governing Board. Four members shall constitute a quorum of the Executive Committee.

III. Membership dues. Annual membership dues for Regular Members shall be fixed by recommendation of the Governing Board and approval of the membership by simple majority. Other categories of membership dues shall be fixed by the Executive Committee and the Governing Board and shall be published from time to time in Academy publications.

IV. Endowments and Life Membership. Life Membership monies shall be credited to an endowment account. Any member may become a Life Member by designating a one-time donation, the sum of which is at least equal to the life membership fee.

V. Elections. Balloting shall be by mail, allowing at least six weeks between mailing of the ballots by the Secretary and their return by October 15. The candidate who receives a simple majority of the ballots cast shall be declared elected. The Committee on Nominations shall be responsible for the election process.

VI. Members in arrearage. Members who have allowed their dues to lapse for two consecutive years, having been notified of their arrearage by the Treasurer, shall have their names stricken from the membership list. Members in arrears shall not receive the *Transactions*.

VII. Submitting Titles and Abstracts. All titles and/or abstracts of same, intended for presentation on any program of the Academy, must be submitted to the Section Secretary or Section Chair prior to the meeting at the designated times.

VIII. Establishing Rotation. To establish a proper rotational basis for terms on Standing Committees, the first year one member shall be appointed for a three-year term, one for a two-year term, and one for a one-year term.

IX. Representative to AAAS/NAAS. The President shall appoint a representative to the American Association for the Advancement of Science and the National Association of Academies of Science. The term of appointment shall be three years.

X. Scientific Organizations. Any scientific organization in the Commonwealth of Kentucky in a field of science recognized by the American Association for the Advancement of Science may affiliate with the Academy.

XI. Division and at-large representatives to the Governing Board will be phased in over the four years following ratification of this Constitution and Bylaws. The mechanism for this phase-in will be established by the Governing Board.

XII. Amendment of Bylaws. These Bylaws may be amended or suspended by a two-thirds vote of the members present at any general meeting or Governing Board meeting, or by a two-thirds majority of members responding to a mail ballot, provided at least ten per cent of the members have voted.

KENTUCKY ACADEMY OF SCIENCE ORGANIZATION

GOVERNING BOARD

President	Executive Committee
President Elect	Executive Committee
Vice President	Executive Committee
Past President	Executive Committee
Secretary	Executive Committee
Treasurer	Executive Committee
Executive Secretary (*ex officio*)	Executive Committee
Editor (*ex officio*)	Executive Committee
Division Representatives—6	Other Members
At-large Representatives—2	Other Members
AAAS/NAAS Representative	Other Members
Chair, Kentucky Junior Academy of Science	Other Members

STANDING COMMITTEES

1. Membership
2. Publications
3. Legislation
4. Research Funds
5. Science Education
6. Program
7. Awards
8. Nominations and Elections
9. Audit
10. Finance
11. Planning
12. Public Relations

AD HOC COMMITTEES

1. Resolutions
2. Local Arrangements
3. Rare and Endangered Species
4. Others

APPENDIX III

EDITORS OF THE
KENTUCKY ACADEMY OF SCIENCE

1924	Willard Rouse Jillson—State Geologist, Frankfort
1924–1940	Alfred M. Peter & Ethel V. T. Caswell—University of Kentucky
1940–1941	Charles Hire—Murray State Teachers College
1941–1945	John Kuiper—University of Kentucky
1945–1946	Harlow Bishop—University of Kentucky
1946–1950	M. C. Brockman—Joseph Seagram & Sons, David R. Lincicone—University of Kentucky
1950–1956	William M. Clay—University of Louisville
1956–1958	Gerald A. Cole—University of Louisville
1958–1963	Roger W. Barbour—University of Kentucky

1963–1967	Raymond E. Hampton—University of Kentucky
1967–1974	William F. Wagner—University of Kentucky
1974–1980	Louis A. Krumholz—University of Louisville
1980–	Branley A. Branson—Eastern Kentucky University

APPENDIX IV

PRESIDENTS OF THE KENTUCKY ACADEMY OF SCIENCE

1914	Paul P. Boyd, Organizational Meeting—University of Kentucky
1914–1915	Joseph H. Kastle—Experiment Station–Lexington
1915–1916	N. F. Smith—Central University–Danville
1916–1917	A. M. Miller—University of Kentucky
1917–1918	R. C. Ballard Thruston—Louisville
1918–1919	J. E. Barton-State Forester—Frankfort
1919–1920	Paul P. Boyd—University of Kentucky
1920–1921	W. H. Coolidge—Centre College
1921–1922	George D. Smith—State Normal School–Richmond
1922–1923	Lucien Beckner—Winchester
1923–1924	Willard Rouse Jillson—State Geologist–Frankfort
1924–1925	Cloyd N. McAllister—Berea College
1925–1926	Austen R. Middleton—University of Louisville
1926–1927	W. G. Burroughs—Berea College
1927–1928	W. D. Valleau—Experiment Station–Lexington
1928–1929	G. Davis Buckner—Experiment Station–Lexington
1929–1930	Frank L. Rainey—Centre College
1930–1931	V. F. Payne—Transylvania University
1931–1932	Anna A. Schneib—Eastern Kentucky State Teachers College
1932–1933	George Roberts—Experiment Station–Lexington
1933–1934	John S. Bangson—Berea College
1934–1935	Alfred M. Peter—University of Kentucky
1935–1936	J. S. McHargue—Experiment Station–Lexington
1936–1937	R. T. Hinton—Georgetown College
1937–1938	L. Y. Lancaster—Western Kentucky State Teachers College
1938–1939	W. R. Allen—University of Kentucky
1939–1940	A. W. Homberger—Louisville
1940–1941	Charles Hire—Murray State Teachers College
1941–1942	G. B. Pennebaker—Morehead State Teachers College
1942–1943	J. T. Skinner—Western Kentucky State Teachers College
1943–1944	L. A. Brown—Transylvania University
1944–1945	L. A. Brown—Transylvania University
1945–1946	Paul Kolachov—Joseph Seagram & Sons
1946–1947	Ward Sumpter—Western Kentucky State Teachers College
1947–1948	Alfred Brauer—University of Kentucky
1948–1949	Morris Scherago—University of Kentucky
1949–1950	Walter E. Blackburn—Murray State Teachers College
1950–1951	E. B. Penrod—University of Kentucky
1951–1952	H. B. Lovell—University of Louisville
1952–1953	Thomas Herndon—Eastern Kentucky State College
1953–1954	C. B. Haman—Asbury College
1954–1955	R. H. Weaver—University of Kentucky
1955–1956	J. G. Black—Eastern Kentucky State College
1956–1957	A. M. Wolfson—Murray State College
1957–1958	William A. Clay—University of Louisville
1958–1959	William B. Ousley—Morehead State College
1959–1960	Pete Panzera—Murray State College
1960–1961	H. H. LaFuze—Eastern Kentucky State College
1961–1962	Charles Whittle—Western Kentucky State College
1962–1963	Lyle Dawson—University of Kentucky
1963–1964	R. A. Chapman—University of Kentucky
1964–1965	C. B. Haman—Asbury College
1965–1966	John M. Carpenter—University of Kentucky
1966–1967	Robert M. Boyer—University of Kentucky
1967–1968	Paul G. Sears—University of Kentucky
1968–1969	Orville Richardson—Kentucky Wesleyan College
1969–1970	Lloyd Alexander—Kentucky State College
1970–1971	Karl Hussung—Murray State University
1971–1972	Louis Krumholz—University of Louisville
1972–1973	Marvin Russell—Western Kentucky University
1973–1974	Donald Batch—Eastern Kentucky University
1974–1975	Ellis Brown—University of Kentucky
1975–1976	Frederick M. Brown—Kentucky State Hospital
1976–1977	Charles Payne—Morehead State University
1977–1978	Charles E. Kupchella—University of Louisville
1978–1979	Sanford L. Jones—Eastern Kentucky University
1979–1980	Rudolph Prins—Western Kentucky University
1980–1981	John C. Philley—Morehead State University
1981–1982	Ted M. George—Eastern Kentucky University
1982–1983	J. G. Rodriguez—University of Kentucky
1983–1984	Gary Boggess—Murray State University
1984–1985	Joe Winstead—Western Kentucky University
1985–1986	Charles Covell—University of Louisville

1986–1987	Larry Giesmann—Northern Kentucky University
1988	William P. Hettinger—Ashland Petroleum Company
1989	Richard Hannan—Kentucky Nature Preserves Commission
1990	Debra K. Pearce—Northern Kentucky University
1991	W. Blaine Early, III—Cumberland College
1992	Douglas L. Dahlman—University of Kentucky
1993	Charles N. Boehms—Georgetown College

APPENDIX V

SECRETARIES OF THE
KENTUCKY ACADEMY OF SCIENCE

1914	Charles J. Robinson—Louisville–Organizational Meeting
1914–1915	Garnett Ryland—Georgetown College
1915–1934	Alfred M. Peter—University of Kentucky
1934–1937	A. R. Middleton—Georgetown College
1937–1947	Alfred Brauer—University of Kentucky
1947–1948	J. R. Stuetz—Joseph Seagram & Sons–Louisville
1948–1952	C. B. Haman—Asbury College
1952–1956	Mary E. Wharton—Georgetown College
1956–1964	Gerrit Levey—Berea College
1964–1966	Dwight Lindsey—Georgetown College
1966–1971	Robert S. Larance—Eastern Kentucky University
1971–1976	Rudolph Prins—Western Kentucky University
1976–1978	Thomas N. Seay—Georgetown College
1978–1987	Robert Creek—Eastern Kentucky University
1988	Virginia Eaton—Western Kentucky University
1989–1991	Varley E. Wiedeman—University of Louisville
1992	Peter X. Armendarez—Brescia College

APPENDIX VI

TREASURERS OF THE
KENTUCKY ACADEMY OF SCIENCE

1914–1915	W. M. Anderson—University of Louisville
1915–1916	Garnett Ryland—Georgetown College
1916–1918	Paul P. Boyd—University of Kentucky
1918–1921	J. S. McHargue—Experiment Station–Lexington
1921–1922	Charles A. Shull—University of Kentucky
1922–1935	W. S. Anderson—Experiment Station–Lexington
1935–1937	Alfred Brauer—University of Kentucky
1937–1938	Julian H. Capps—Berea College
1938–1947	William J. Moore—Eastern Kentucky State College
1947–1953	Ralph H. Weaver—University of Kentucky
1953–1961	Richard A. Chapman—University of Kentucky
1961–1962	Paul Ray—Asbury College
1962–1965	J. H. B. Garner—University of Kentucky
1965–1971	C. B. Haman—Asbury College
1971–1976	Wayne Hoffman—Western Kentucky University
1976–1978	Bartlett G. Dickinson—Georgetown College
1978–1987	Morris Taylor—Eastern Kentucky University
1988–1990	Paul H. Freytag—University of Kentucky
1991	David R. Hartman—Western Kentucky University

APPENDIX VII

MEETING LOCATIONS OF THE
KENTUCKY ACADEMY OF SCIENCE

1914, 1915	State College (presently University of Kentucky)
1916–1928	University of Kentucky
1929	Berea College
1930	Centre College
1931	Transylvania University
1932	Eastern Kentucky State Teachers College
1933	University of Kentucky
1934	Berea College
1936	University of Kentucky
1936	Western Kentucky State College
1937	University of Louisville
1938	Morehead State Teachers College
1939	Murray State Teachers College
1940	University of Kentucky
1941	Eastern Kentucky State Teachers College
1942	University of Kentucky
1943	University of Louisville
1944	University of Kentucky
1945	No Annual Meeting
1946	University of Louisville
1947	Western Kentucky State College
1948	University of Kentucky
S1949	Cumberland Falls State Park
F1949	Eastern Kentucky State College
1950	University of Louisville
1951	University of Kentucky
1952	Georgetown College
S1953	Ashland
F1953	University of Kentucky
S1954	Berea College
F1954	University of Louisville
S1955	Cumberland Falls State Park
F1955	Kentucky State College
S1956	Kentucky Dam Village
F1956	Eastern Kentucky State College
S1957	Western Kentucky State College and Mammoth Cave National Park
F1957	Berea College
S1958	Natural Bridge State Park

F1958	University of Kentucky
S1959	Lake Cumberland State Park
F1959	Western Kentucky State College
S1960	Murray State College
F1960	University of Louisville
S1961	Morehead State College
F1961	University of Louisville
1962	Eastern Kentucky State College
1963	University of Kentucky
1964	Morehead State College
1965	University of Kentucky
1966	Kentucky Wesleyan College
1967	University of Louisville
1968	Western Kentucky University
1969	Murray State University
1970	Georgetown College
1971	Eastern Kentucky University
1972	Morehead State University
1973	Transylvania University
1974	Centre College
1975	University of Louisville
1976	University of Kentucky
1977	Western Kentucky University
1978	Eastern Kentucky University
1979	Northern Kentucky University
1980	Transylvania University
1981	Murray State University
1982	Ashland Oil Inc., Ashland
1983	University of Louisville
1984	Kentucky State University
1985	Morehead State University
1986	Lexington, Kentucky (with SSMA)
1987	Western Kentucky University
1988	Eastern Kentucky University
1989	University of Kentucky
1990	Northern Kentucky University
1991	Owensboro, Kentucky
1992	Ashland Community College

Trans. Ky. Acad. Sci., 54(3–4), 1993, 136–140

FORUM

Unattended High-resolution Earthquake Data Collector

Robert J. Dugan

College of Engineering, University of Kentucky, Lexington, Kentucky 40506–0046

Introduction

Movements caused by earthquakes are typically sensed by velocimeters buried in boreholes drilled to some depth determined by seismologists. The low-level, low-frequency voltages generated are amplified by signal conditioners at the surface and transmitted in some manner to a recorder/readout device. The most common device is the rotating drum chart recorder commonly seen on commercial television when a major quake occurs. The drum is large and it moves slowly and continuously. Since no one knows when a quake may occur, continuous recording is an absolute requirement to be sure that the event is not missed. (Previously, a system was designed to examine every signal received that exceeded a baseline threshold, and record it only if it were an earthquake signal. However, signals from blasting in quarries, mines, and construction sites were too difficult to reject in a low-cost system. The seismologists desiring this data collector preferred the better-safe-than-sorry approach of continuous recording.)

Modern seismic researchers endeavor to analyze the seismic motion signal in detail, both in the time domain and using the Fourier transform to find the frequency distribution and amplitudes. To do so means finding a solution to the problem of the recording method. The rotating drum chart recorder moves slowly in order to capture about 24 hours of signal on a strip of paper approximately 30 inches in length. Obviously, with one hour of signal crammed onto a 1¼ inch section of paper, not much detail can be extracted. In addition, ink on paper is not a very useful medium for other than visual inspection. The signal detail problem could always be remedied by running the chart paper at fairly fast speeds past the pen. However, this would require vast quantities of paper. So vast, in fact, that it cannot be a solution. Using a computer-based data acquisition system to record seismic activity holds promise as a workable solution. One computer-based system, with associated software, is described.

Materials

System Requirements.—1. Signal frequency range: DC to 10 Hz (Note: Anti-alias must be dealt with using suitable low-pass filters); 2. channels: two signal and one time sync; 3. sample rate: 50 samples/second/channel minimum; 4. continuous data collection; 5. unattended operation; 6. storage: most recent 64 hours of data; 7. data format: ASCII characters.

Operational Requirements.—Several practical matters demand attention in setting up the system: 1. after an earthquake event occurs, the control program must be stoppable in an orderly manner; 2. the event signal must be easily found within the many megabytes of data on the disk; 3. as a minimum, the file size and disk size must accommodate at least 64 hours of unattended operation; enough to cover, for example, a 5:00 P.M. Friday to 8:00 A.M. Monday period of time; 4. each data file must be tagged with the date and time at which data began to be collected in the file.

Continuous Data Collection and Unattended Operation

A large selection of plug-in data acquisition boards for DOS-based microcomputers are commercially available. Sample rates for almost all of them go up to 20 kHz or higher, so there is no limitation here. Data acquisition boards are potentially very capable, but they do not run themselves. Software must be provided, and the odds are very high that the software needed is not provided by the manufacturer of the board. That usually means the software must either be purchased from a third party, or written by the owner of the board. Third-party software (e.g., Labtech Notebook) can be applied only for semicontinuous data collection; very large files can be created, but after a file is full a keyboard entry is required to initiate another data file. This does not allow unattended operation. Custom-written third-party software is usually quite expensive, and can easily exceed the total cost of the hardware. However, this is certainly not the case for the software described in this article.

Writing your own software ranges in difficulty from moderate (if you have experience) to extreme (if you don't). The usual sampling procedure consists of a command to do an A/D conversion on the data acquisition board and then transfer the number to a memory location in RAM. This number then must be transferred to a disk file (only hard disks are practical) and tagged in some way to determine which channel was sampled. In addition, the file structure must be organized to make the data retrieval easy for subsequent data analysis software. Sampled data could be stored in a variable array in RAM until the array fills up; but then the array must have its contents dumped onto the disk. The problem with this scenario is that data collecting must stop while the data are being transferred to the disk. Although this gap in the data may only be a few seconds, it is likely to represent an unacceptable percentage of the data collection cycle, and it would be most awkward to have it by chance occur at the start of, or even during, the earth motion signal.

The most continuous type of data collection is "streaming" data directly from the data acquisition board to the disk, bypassing RAM storage altogether. Data files can be made arbitrarily large, limited only by the disk size. But streaming software, unfortunately, is not a common option from the data acquisition board makers. And streaming must also be initiated file by file from keyboard entries. There is, however, one exception. Keithley Metra-Byte makes a line of data acquisition boards, many of which have a software option called Streamer. This streaming software is unique in that it may be initiated from a statement line in BASIC (the SHELL command). Unattended operation with virtually continuous data collection is made possible by writing a control program in BASIC that establishes an endless loop of Streamer calls. A big advantage of Streamer is that it packs the data in binary form in the data file, thereby conserving valuable disk space. A utility program bundled with Streamer later unpacks the data to ASCII numbers in columns by channel number. The unpacked file is readily imported into popular spreadsheets or scientific analysis packages.

MAKING STREAMER WORK

As is true with virtually all software, Streamer has a number of peculiarities. The price to be paid for getting continuous data collection is learning to deal with these peculiarities. For example, the Streamer software works only if the data files are located in the drive root directory. Rather than clutter up the root of the boot-up drive, a small 3 Mb C: drive and a large 77 Mb D: drive should be created. The boot-up, DOS, and utility files reside on the C: drive, and the program, data, and Streamer files reside on the D: drive. The data files lie happily in the root directory of the D: drive, while program files are placed in one subdirectory and tag files (explained below) are placed in another subdirectory. Streamer data files must be created before being used, and a Streamer utility called MKFILE does this.

When a DOS file is created, it carries with it the date and time of its creation, and if it is overwritten with the same name, a new date and time is assigned to it. All DOS users know this. But the Streamer data files, even though they are given new data every 64 hours, never change the date and time of the original creation. The Streamer software sends data to the file using Direct Memory Access (DMA), which does not update the date and time listed in the directory. If the data are not tagged in some way with date and time information, after a few days, and surely after a few weeks, some difficulty or confusion would result when trying to figure out just when an earth motion event occurred. This situation is addressed in the control program by writing date and time to an ASCII file with a .TAG extension just prior to calling Streamer to fill the next data file. The .TAG file is given the same base name as the data file being filled and contains only the current date, time, and the data filename associated with it. For example, a data file named Q47.DAT would have a corresponding Q47.TAG file with the date and time at which Q47.DAT started storing data.

Data collecting using the Streamer software may be initiated in 2 ways. Like many other streaming programs, it may be started from a menu in which pertinent information regarding file name, sampling rate, channels, etc. are entered. Unlike the others, it may also be initiated by a batch file containing that same pertinent information. Each data file (e.g., Q47.DAT) has a corresponding batch file (Q47.BAT) which Streamer uses to start data collecting into that data file. The command activating the batch file is a DOS command line instruction issued from the DOS prompt in like manner that an .EXE or .COM file would be activated. The control program then uses the BASIC command SHELL "..." to issue the command which streams data to one of the data files.

DATA FILES

A number of tradeoffs are involved in selecting the size and number of data files. No matter how many files are used, the oldest file is always being written over. So if N files are chosen, then 64 hours of data must be contained in N-1 files. Assuming 100 Mb of storage and 5 files, each file must be 20 Mb, and 80 Mb out of 100 Mb would hold 64 hours of data. But if 50 files are used, each would be 2 Mb, and 98 Mb out of 100 Mb would hold 64 hours of data. From this perspective, disk space is most efficiently used by assigning data in small files.

When a data file is filled, the control program must tag it with date and time and then check for a stop signal before starting the next data file. This interfile time takes slightly less than two seconds and is not affected by the size of the data file. During the interfile time, however, no data can be collected, and this amount of time represents the departure of the system from true continuous operation. Since this time is fixed, a few large files give the most continuous operation. The actual file size will obviously trade off between the competing requirements. The tradeoff is examined by looking at the time it takes to fill a file.

Data are stored by Streamer using 2 bytes per sample. The sample rate (S) in bytes per hour depends on how many channels of data (C) are collected, and the sample rate per channel (R). $S = R \times C \times 2$ bytes/sample $\times$ 3600 sec/hour; $S = 7{,}200$ RC (bytes/hour). To collect 64 hours of data, the disk storage (D) required would be: $D = 64 \times 7{,}200\,RC = 460{,}800$ RC bytes = 0.4608 RC Megabytes, which for this $R = 50$ sample/sec/channel, $C = 3$ channel design calls for storage of $D = 0.4608 \times 50 \times 3 = 69.12$ Megabytes. A common hard disk size is 80 Mb which was chosen for this system. A previous design called for 11 channels of data which required $D = 0.4608 \times 50 \times 11 = 253.44$ Megabytes and a disk size of 300 Mb had to be used. One can see the tradeoffs between economics and specifications. The large hard drives cost hundreds of dollars more. Economies can be had by relaxing the sample rate (to 40 samples per second, or even 25 perhaps), or by dropping he number of channels down to only the most essential. In this design, 96 files of 768 kb each were chosen. Since this size file fills with data in a little over 42 minutes, 96 of them meets the 64-hour requirement. There are 3 sets of 96 files (exclusive of the control and Streamer programs). The data files are Q1.DAT through Q96.DAT located in the ROOT directory. The batch files which Streamer uses to initiate the data files are Q1.BAT through Q96.BAT located in the PROGRAM subdirectory. The tag files used to keep track of the date and time at which a data file starts collecting data are Q1.TAG through Q96.TAG located in the TAG subdirectory.

THE CONTROL PROGRAM

Figure 1 shows a flow chart of the procedure used to cycle through the 96 data collection files. A printout option is incorporated for the operator who wants to glance at a printed list of data files and see when each was started. Although this option requires a dedicated printer, no fancy features are needed, and the cheapest no-frills dot matrix printer can be used.

Since Streamer displays its own screen showing the data file name and parameters during the collection process, no time countdown can be shown during the data collection. Unless the print option is used, the operator has no good way to determine when a data file will end. Between the end of one data file and the start of the next data file is a period of about 2 seconds while the .TAG file information is written and the keyboard buffer checked. This is too short a time to expect an operator to issue a stop command, but a longer time would compromise the integrity of continuous operation. Therefore, during the interfile period, the program checks the keyboard buffer to see if an

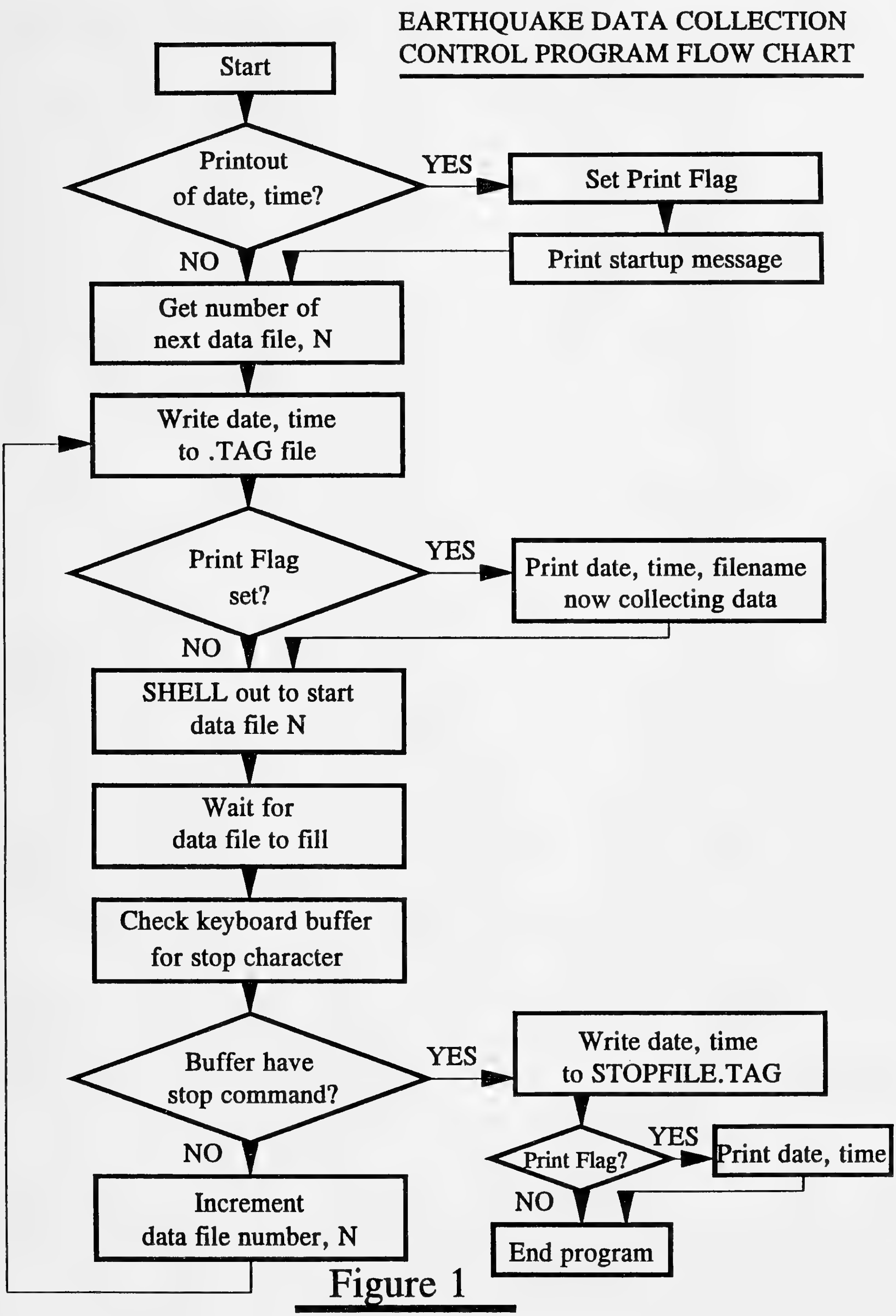


FIG. 1. Earthquake data collection control program flow chart.

entry has been made since the last interfile period. The letter S (for Stop) is used as the entry to be recognized and may be entered at the keyboard at any time. If a letter S is found, the current date and time is written to a file named STOPFILE.TAG in the TAG subdirectory, and the program ends.

To ensure that no one gets bored while putting these systems together, Keithley-MetraByte has issued an updated version of Streamer (V2.35) which unfortunately flushes the keyboard buffer during its operation. This version neatly renders the program stop procedure inoperable, and the only easy way to stop is to do a warm boot (CTRL-ALT-DEL) to stop the program. The older version (V2.01) is obviously recommended.

REMOTE OPERATION

Sensor sites that are remote from the laboratory will typically have the analog signal modulate a carrier frequency within the telephone system bandwidth and be transmitted over dedicated telephone lines back to the laboratory. There the signal is demodulated and displayed on a strip chart recorder. Since the computer-based system described here runs continuously, it also can run unattended at a remote site. To do so requires modems at each end and suitable communications software. Once the comm link is established, the control program can be started from the laboratory end. The control program must be modified to send its printout to the comm port rather than the printer port, and the stop signal must be found in the comm port buffer instead of the keyboard buffer.

The computer comm port buffer will store ASCII characters sent from the laboratory site while the data collection is in progress. At the end of data collecting in a .DAT file, the program checks to see if the comm port buffer is empty. If so, it continues to the next .DAT file. If the buffer contains characters, it must examine each one to see if the legitimate stop character (S) is present; if not, it empties the buffer and continues to the next .DAT file. If a stop character is found, a message is sent back to the laboratory site that the computer is ready for DOS prompt commands. The operator in the laboratory, now controlling the remote site computer, checks the .TAG files to locate the file containing earthquake data. Once identified, the file must be transmitted over the RS-232 comm port to the laboratory computer. Since these are very large files, and since the baud rate is typically 1,200 or less (due to phone lines of uncertain quality), considerable time could be required for the transmission. In order to minimize this time, a file compression program is used to operate on the file. This system uses the commercial program PKZIP with typical compression down to about 45–65%. Once the compressed file is received, the remote site computer is commanded to restart the data collection program. Then the received file is decompressed and unpacked to obtain usable data.

MISCELLANY

The system must deal with power outages either by having a battery backup at the remote site or by having the computer reestablish operation from a cold boot condition. Either way, reliability is essential; otherwise lab personnel are forced to make inspection trips to a site that may be 200 or so miles away.

The sample rate of 50 samples/sec/channel for 3 channels means that the A/D sample rate is 150 samples/sec, or 6.667 milliseconds between each sample. When making time comparisons between the signals on different channels, this time difference may need to be accounted for in the analysis.

Computer clocks do drift to some degree over a few weeks or months. It is advisable to reset the clock from time to time. One channel of the system is recording a time signal from WWV, but nonetheless the computer clock should be kept fairly accurate.

Trans. Ky. Acad. Sci., 54(3–4), 1993, 141

NEWS AND COMMENTS

Computerized Database Inclusion of the Transactions

The U.S. Fish and Wildlife Service has added the abstracts of papers appearing in the *Transactions* that deal with wetland biology.

Thanks to John T. Riley

The editor herewith extends his thanks to John T. Riley for his services as Associate editor for the last several years. His efforts were greatly appreciated.

Interesting New Book

John C. Kricker and Gordon Morrison. 1933. *A Field Guide to the Ecology of Western Forests*. Houghton Mifflin Co., Boston, 554 pages ($24.95).—This beautiful little book, a companion to the authors' guide to our eastern forests, takes a synecological approach in a field-guide format. The book explains many forest mechanisms and the animals associated with different forest types. It includes extensive color illustrations.

Annual Meeting

The 79th meeting of the Kentucky Academy of Science will be held at Georgetown College, 21–23 October 1993, and will be sponsored jointly by the college and the Toyota Motor Corporation.

INDEX TO VOLUME 54

Instructions for Contributors

Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

Manuscripts may be submitted at any time to the Editor. Each manuscript will be reviewed by one or more persons prior to its acceptance for publication, and once accepted, an attempt will be made to publish papers in the order of acceptance. Manuscripts should be typed double spaced throughout on good quality white paper 8½ × 11 inches. NOTE: For format of feature articles and notes see Volume 43(3–4) 1982. The original and one copy should be sent to the Editor and the author should retain a copy for use in correcting proof. Metric and Celsius units shall be used for all measurements. The basic pattern of presentation will be consistent for all manuscripts. The Style Manual of the Council of Biological Editors (CBE Style Manual), the Handbook for Authors of the American Institute of Physics, Webster's Third New International Dictionary, and a Manual of Style (Chicago University Press) are most useful guides in matters of style, form, and spelling. Only those words intended to be italicized in the final publication should be underlined. All authors must be members of the Academy.

The sequence of material in feature-length manuscripts should be: title page, abstract, body of the manuscript, acknowledgments, literature cited, tables with table headings, and figure legends and figures.

1. The title page should include the title of the paper, the authors' names and addresses, and any footnote material concerning credits, changes of address, and so forth.

2. The abstract should be concise and descriptive of the information contained in the paper. It should be complete in itself without reference to the paper.

3. The body of the manuscript should include the following sections: Introduction, Materials and Methods, Results, Discussion, Summary, Acknowledgments, and Literature Cited. All tables and figures, as well as all literature cited, must be referred to in the text.

4. All references in the Literature Cited must be typewritten, double spaced, and should provide complete information on the material referred to. See Volume 43(3–4) 1982 for style.

5. For style of abstract preparation for papers presented at annual meetings, see Volume 43(3–4) 1982.

6. Each table, together with its heading, must be double spaced, numbered in Arabic numerals, and set on a separate page. The heading of the table should be informative of its contents.

Each figure should be reproduced as a glossy print either 5 × 7 or 8 × 10 inches. Line drawings in India ink on white paper are acceptable, but should be no larger than 8½ × 11 inches. Photographs should have good contrast so they can be reproduced satisfactorily. All figures should be numbered in Arabic numerals and should be accompanied by an appropriate legend. It is strongly suggested that all contributors follow the guidelines of Allen's (1977) "Steps Toward Better Scientific Illustrations" published by the Allen Press, Inc., Lawrence, Kansas 66044.

The author is responsible for correcting galley proofs. He is also responsible for checking all literature cited to make certain that each article or book is cited correctly. Extensive alterations on the galley proofs are expensive and costs will be borne by the author. Reprints are to be ordered when the galley proofs are returned by the Editor.

CONTENTS

TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

Volume 55
Numbers 1–2
March 1994

Official Publication of the Academy

The Kentucky Academy of Science

Founded 8 May 1914

All manuscripts and correspondence concerning manuscripts should be addressed to the Editor. Authors must be members of the Academy.

The TRANSACTIONS are indexed in the Science Citation Index. Coden TKASAT. ISSN No. 0023-0081.

Membership in the Academy is open to interested persons upon nomination, payment of dues, and election. Application forms for membership may be obtained from the Secretary. The TRANSACTIONS are sent free to all members in good standing.

Annual dues are $25.00 for Active Members; $15.00 for Student Members; $35.00 for Family; $350.00 for Life Members. Subscription rates for nonmembers are: domestic, $45.00; foreign $50.00; back issues are $30.00 per volume.

The TRANSACTIONS are issued semiannually in March and September. Four numbers comprise a volume.

Correspondence concerning memberships or subscriptions should be addressed to the Secretary. Exchanges and correspondence relating to exchanges should be addressed to the Librarian, University of Louisville, Louisville, Kentucky 40292, the exchange agent for the Academy.

∞ This paper meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).

INDUSTRIAL AFFILIATES

Associate Patron

Ashland Oil, Inc.

Fellow

Brown & Williamson Tobacco Corporation

Sustaining Member

Air Products & Chemicals, Inc.
ISP Chemicals, Inc.

Member

Corhart Refractories Corporation
MPB, Inc.
United Catalysts, Inc.

Associate Member

3M Tape Mfg. Division-Cynthiana Plant
All-Rite Pest Control
Westvaco
Wood Hudson Cancer Research Laboratory, Inc.

INSTITUTIONAL AFFILIATES

Fellow

UNIVERSITY OF KENTUCKY

Sustaining Member

Morehead State University
Murray State University
Northern Kentucky University
University of Louisville
Western Kentucky University

Member

Campbellsville College
Cumberland College
Eastern Kentucky University

Associate Member

Berea College
Brescia College
Centre College
Georgetown College
Kentucky State University
Kentucky Wesleyan College
Lees College
Midway College
Spalding University
Transylvania University

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

March 1994
Volume 55
Numbers 1–2

Trans. Ky. Acad. Sci., 55(1–2), 1994, 1–5

Abnormal Coproducts in the Oxidation of Styrene by Palladium(II) in Ethanol

Darwin B. Dahl,[a] Alan J. Simmons,[b] and William G. Lloyd[a]

[a]Department of Chemistry, Western Kentucky University, Bowling Green, Kentucky 42101
[b]Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

Abstract

Styrene in ethanol at ambient temperatures and pressures is readily oxidized in the presence of $PdCl_2$. In addition to the expected products, phenylacetaldehyde and acetophenone, 2 unexpected products have been identified: β-ethoxystyrene and benzaldehyde. These appear to arise from abnormal decompositions of the intermediate organopalladium σ-complexes.

Introduction

Terminal alkenes are well known to undergo Pd(II)-catalyzed reactions in aqueous systems, typically at 65–85°C, to yield carbonyl products (1, 2). The reduced Pd(0) is reoxidized, most commonly by $CuCl_2$, and the resulting Cu_2Cl_2 is in turn reoxidized by oxygen to provide a catalytic process:

$$R\text{–}CH{=}CH_2 + PdCl_2 + H_2O \rightarrow R\text{–}CO\text{–}CH_3 + Pd(0) + 2HCl$$

$$Pd(0) + 2CuCl_2 \rightarrow PdCl_2 + Cu_2Cl_2$$

$$Cu_2Cl_2 + 2HCl + \tfrac{1}{2}O_2 \rightarrow 2CuCl_2 + H_2O$$

Overall,

$$R\text{–}CH{=}CH_2 + \tfrac{1}{2}O_2 \rightarrow R\text{–}CO\text{–}CH_3 \qquad (1)$$

When R is an alkyl group the product is typically 90–95% methyl ketone, with the corresponding aldehyde $R\text{-}CH_2\text{-}CHO$ making up the balance. When the aqueous medium is replaced with a primary alcohol these oxidations proceed readily at ambient temperatures (3, 4) to form the same carbonyl compounds and their acetals. There is substantial agreement (5–8) concerning the mechanism of alkene oxidations by Pd(II): a fast reversible formation of the Pd(II)-alkene π-complex followed by a rate-determining π-to-σ rearrangement and the rapid solvolytic decomposition of the σ-complex(es) to products.

When R is an electron-withdrawing group, for example the cyano group in acrylonitrile, the main product is the corresponding aldehyde (4). Since the phenyl group is electron withdrawing, it is not surprising that the main product of styrene oxidation is phenylacetaldehyde (4, 9–11). What is surprising is the number and variety of coproducts formed, including carbon-carbon cleavage products (4, 10). We here examine the products of this oxidation in more detail.

Materials and Methods

Oxidations were conducted in a 500-mL flask immersed in a constant temperature bath

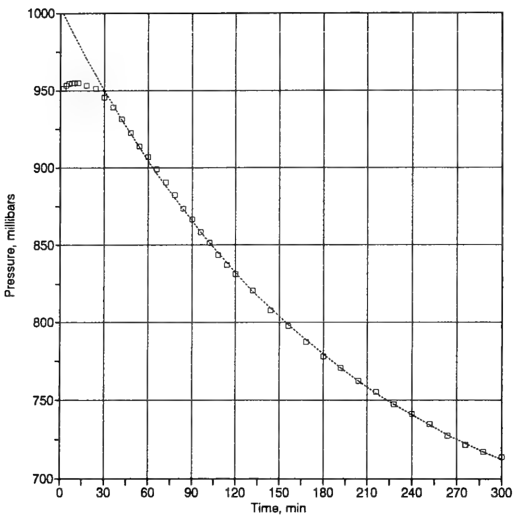


FIG. 1. Oxygen pressure drop during the catalyzed oxidation of styrene in ethanol at 30.4°C. Initial styrene concn. 0.334_5 M; $PdCl_2$ 0.0050 M; $CuCl_2$ 0.0403 M. The fitting curve is a simple exponential decay expression (r^2 = 0.9996 for 30 to 300 min): P (mbars) = 634.0 ± 369.07*exp(−0.0051873*t).

TABLE 1. Oxidation products of styrene at 30°C.[a]

	Run 1[b]	Run 2[c]	Mass fragments[d]
Benzaldehyde	6.3%	1.7%	**106**, 105, 77
β-Ethoxystyrenes	5.6	9.1	**148**, 120, 91
Phenylacetaldehyde	3.3	3.0	**120**, 92, 91
Acetophenone	8.8	6.2	**120**, 105, 77
Ethyl benzoate	0.6	0.0	105, 77
$PhCH(OEt)_2$	3.5	3.7	135, 107, 105
$PhCH_2COOEt$	2.0	1.1	**164**, 148, 120
$PhCH_2CH(OEt)_2$	70.1	75.0	149, 148, 121, 103, 91
$PhCOCH_2Cl$	0.0	0.3	119, 105, 77

[a] From 300-min oxidations in ethanol solution at 30° under 1 atm. oxygen and 0.0080 M $PdCl_2$. Initial styrene concentrations were 0.348 M. Quantitation is estimated from FID integration areas.
[b] With 0.064 M $CuCl_2 \cdot 2H_2O$ and 0.016 M $Cu(BF_4)_2$; styrene conversion was 85%.
[c] With 0.136 M $CuCl_2 \cdot 2H_2O$; styrene conversion was 82%.
[d] Fragments in boldface are molecular ions.

controlled to ±0.12°. The flask was agitated by a 17 × 40 mm teflon-clad magnetic ellipsoid at 500 r.p.m., this system permitting oxygen uptake rates in excess of 50 mbar/min; rates with styrene were 1–3 mbar/min. Each oxidation was commenced by charging the oxygen-filled flask with 25 ml of ethanolic catalyst solution, containing $PdCl_2$ 0.002–0.020 M and $CuCl_2$ 0.008–0.30 M, followed by 25 ml of ethanolic styrene solution containing the internal standards chlorobenzene and 1-chloronaphthalene. Pressure and temperature were recorded continuously during each oxidation. At the conclusion of each run, a 5-ml portion of the oxidate was combined with 2 ml of aqueous ammonia to provide a homogeneous time-stable sample for analysis.

Time series runs were conducted similarly, using a 3-neck flask at constant oxygen pressure, making periodic withdrawals of the reaction mixture by syringe through a septum, and stabilizing each sample as above.

Gas chromatographic analyses were carried out using a 3 mm × 2 m glass column packed with 3% polymethylphenylsiloxane (OV-17) on 80–100 mesh silica, at 110–160°. The flame ionization detector provided integrator sensitivity of approximately 1.6 × 10^7 units μl^{-1}.

Provisional identifications were made by matching retention times with those of authentic samples; these were confirmed by GC/mass spectrometry, using a 0.24 mm × 30 m capillary column. β-Ethoxystyrene, a single GC peak on the packed column, was resolved on the capillary column to two nearly equal peaks yielding identical mass fragment patterns. At 25° *trans*-β-ethoxystyrene is favored over the *cis*-isomer by only 0.6–0.8 kJ/mol (12, 13).

RESULTS

Solutions of styrene in ethanol undergo smooth oxidations at 30° in the presence of $PdCl_2$ and $CuCl_2$. Figure 1 shows a typical oxygen consumption curve, the pressure following a simple exponential decay law. The initial slope in Figure 1 corresponds to a styrene oxidation rate of 53.4 mmol liter^{-1} hr^{-1}, which with 0.0050 M $PdCl_2$ affords a turnover number (TN) of 10.7. In Run 1 of Table 1, part of the $CuCl_2$ was replaced by $Cu(BF_4)_2$, producing a slightly faster initial oxidation (TN = 12.7). In Run 2 of Table 1 the $CuCl_2$ concentration was increased to 0.136 M; the initial rate was slightly slower (TN = 9.0) although the 300-min conversion was nearly the same.

GC analysis showed 9 significant product peaks (Table 1). The expected oxidation products, phenylacetaldehyde (and its acetal) and acetophenone, made up 80–85% of the product mixture. The balance was composed mainly of β-ethoxystyrenes (5–10%), along with a group of carbon-carbon cleavage products (benzaldehyde, its acetal, and ethyl benzoate, together 5–10%). Ethyl phenylacetate, a minor product (1–2% in these runs), arises from secondary oxidation of the easily oxidized phenylacetaldehyde. ω-Chloroacetophenone (phenacyl chloride) is the product of a secondary oxidation of acetophenone by $CuCl_2$; it was found in detectable amounts only when $CuCl_2$ concentration exceeded 0.1 M.

The formation of β-ethoxystyrenes was unexpected. No other terminal alkene yields vinylic ethers under these conditions. In time series runs, the β-ethoxystyrene fraction fell with oxidation time, from 20.5% of products at 6 min to 13% at 30 min to 6% at 300 min. Comparing the compositions of the oxidates of a series of 300 min runs at various temperatures, the β-ethoxystyrene fraction was highest in low temperature runs (14% at 12.9°) and lowest in high temperature runs (4% at 50.1°). In oxidates from a series of runs at 30° with varying concentrations of $CuCl_2$ the ethoxystyrene fraction increased smoothly at 30° with increasing $CuCl_2$ concentration, from 0.8% at 0.008 M $CuCl_2$ to 9.1% at 0.288 M $CuCl_2$.

The other abnormal product of this oxidation is benzaldehyde. At ambient temperatures and in the absence of high-energy reactants the vinylic C-C bond is not ordinarily cleaved. A detailed study of coproducts from the oxidation of 1-hexene found no such cleavage products (14). Yet in all styrene oxidates we have found the 3 related cleavage products: benzaldehyde, its acetal, and ethyl benzoate (from the secondary oxidation of benzaldehyde).

DISCUSSION

Vinylic ethers such as β-ethoxystyrene were once thought to be the initial products of all Pd(II)-catalyzed olefin oxidations. There is, however, persuasive evidence that this is not the general case. Pd(II)-catalyzed oxidation of C_2H_4 in CH_3OD has been shown to produce $CH_3CH(OCH_3)_2$ virtually free of deuterium (15, 16), demonstrating that the acetal cannot have been formed via alcohol addition to methyl vinyl ether.

The explanation of the abnormal products lies in the influence of structure upon the reactivities of the 2 oxypalladation σ-complexes which are the immediate precursors to the final products. Complex 1 normally decomposes by an electron shift from the α-carbon to the Pd atom and a concerted β-hydride shift (reaction (2)).

EtO–CH–CH(R)–PdCl
   |
   H
1

$$\rightarrow \overset{(+)}{\text{EtO–CH}}\text{–CH}_2\text{R} + \text{PdCl}^- \qquad (2)$$
2

The cation **2** then hydrolyzes to aldehyde or solvates to form the acetal. The normal decomposition of σ-complex **3** is completely analogous:

EtO–CR–CH_2–PdCl
   |
   H
3

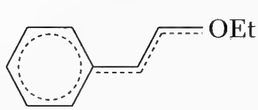
$$\rightarrow \overset{(+)}{\text{EtO–CR}}\text{–CH}_3 + \text{PdCl}^- \qquad (3)$$
4

Here the cation 4 hydrolyzes to the methyl ketone or solvates to form the ketal.

When the substituent group R is a phenyl group, however, other factors come into play. Competing with reaction (2) is an E2 elimination:

EtO–CH – CH(Ph)–PdCl
   |
   H + Cl^-
1a

$$\rightarrow \text{EtO–CH=CHPh} + \text{PdCl}^- + \text{HCl} \qquad (4)$$
5



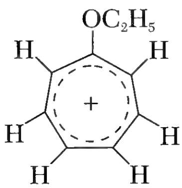
5

Reaction (4) becomes a significant competitor owing to the appreciable incremental resonance stabilization (estimated to be 23 kJ/mol) for the ethoxystyrenes **5**.

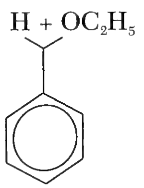
Similarly, reaction (5) becomes a competitor owing to the extraordinary stability of the tropylium ion formed (structures shown below):

EtOH + EtO–CH–CH_2–Pd–Cl
|
Ph
3a

→ EtO–$C_7H_6^+$ + $EtOCH_3$ + $PdCl^-$ (5)
6



6



6a

Tropylium ion **6** has a hybrid structure, represented conventionally as a cycloheptatrienyl cation but undergoing reaction as the benzylic cation **6a**.

Reaction (5) accounts for the emergence of the several carbon-carbon cleavage products (reaction 6). Products **7** and **8** are found in all of the oxidation mixtures.

6a $\xrightarrow{H_2O}$ PhCHO **7**

↓ EtOH ↓ O_2 (6)

$PhCH(OEt)_2$ $\xrightarrow{O_2}$ PhCOOEt
8 **9**

The observed effects of reaction time and temperature upon ethoxystyrene concentration arise from the slow solvolysis of **5** to phenylacetaldehyde diethyl acetal **10**:

EtO–CH=CHPh + EtOH
5

$\xrightarrow{H^+}$ $(EtO)_2CH$–CH_2Ph (7)
10

Other vinyl ethers are known to form acetals readily in ethanolic $PdCl_2$ (17). So, while there is good evidence against vinyl ether intermediation in the Pd(II)-catalyzed oxidation of ethylene (15, 16), there is, we feel, compelling evidence for reactions (4)–(7) in the oxidation of styrene. The impact of $CuCl_2$ concentration upon β-ethoxystyrene production appears to be that of providing an abundant supply of Lewis base to facilitate the elimination (reaction 4).

SUMMARY

Styrene, like other terminal olefins, is readily oxidized in ethanol at ambient temperatures in the presence of catalytic amounts of $PdCl_2$ and cocatalyst $CuCl_2$. The panel of products has been identified. 99+% of the products are accounted for in terms of the expected carbonyl compounds (85%) and 2 additional products arising from competing abnormal decompositions of the 2 oxypalladation σ-complexes.

LITERATURE CITED

1. Smidt, J., W. Hafner, R. Jira, J. Sedlmeier, R. Sieber, R. Rüttinger, and H. Kojer. 1959. Katalytische Umsetzungen von Olefinen an Platinmetall-Verbindungen. Angew. Chem. 71:176–182.

2. Moiseev, I. I., M. N. Vargaftik, and Ya. K. Syrkin. 1960. Oxidation reactions of olefins. Doklady Akad. Nauk SSSR 130:820–823.

3. Moiseev, I. I., M. N. Vargaftik, and Ya. K. Syrkin. 1960. On the mechanism of the reaction between palladium salts and olefins in hydroxyl-containing solvents. Doklady Akad. Nauk SSSR 133:377–380.

4. Lloyd, W. G. and B. J. Luberoff. 1969. Oxidations of olefins with alcoholic palladium(II) salts. J. Org. Chem. 34:3949–3952.

5. Henry, P. M. 1964. Kinetics of the oxidation of ethylene by aqueous palladium(II) chloride. J. Amer. Chem. Soc. 86:3246–3250.

6. Moiseev, I. I. 1970. Kinetics and mechanism of the oxidation of olefins by palladium salts. Kinetics and Catalysis 11:286–297.

7. Maitlis, P. M. 1971. The organic chemistry of palladium, Vol. 2. Academic Press, New York. 78 pp.

8. Henry, P. M. 1980. Palladium catalyzed oxidation of hydrocarbons. D. Reidel, Dordrecht. 133 pp.

9. Okada, H., T. Noma, Y. Katsuyama, and H. Hashimoto. 1968. Reactions of transition metal-olefin complexes. III. Kinetics of the oxidation of substituted styrenes catalyzed by palladium salts in aqueous tetrahydrofuran. Bull. Chem. Soc. Japan 41:1395–1400.

10. Hosokawa, T., T. Takahashi, T. Ohta, and S. Murahashi. 1987. A palladium(II) catalyst for oxygenation of terminal olefins with molecular oxygen. J. Organomet. Chem. 1987:334.

11. Vojtko, J., A. Kaszonyi, M. Čihová, and M. Hrušovský. 1981. Mechanism of the oxidation of styrene by palladium salts. Coll. Czechoslovak Chem. Commun. 46: 573–583.

12. Okuyama, T., T. Fueno, and J. Furukawa. 1969. Structure and reactivity of α,β-unsaturated ethers. X. Acid-catalyzed hydrolysis of ring-substituted styryl ethyl ethers. Tetrahedron 25:5409–5414.

13. Huet, J. 1978. Influence des Interactions Attractives non Liées sur les Stabilités Relatives d'Éthers et d'Acetates d'Énol Renfermant un Groupe Styryle. Tetrahedron 34:2473–2479.

14. Kirova, M. L. 1992. The palladium(II)-catalyzed homogeneous oxidation of 1-hexene. M.S. Thesis. Western Kentucky University, Bowling Green.

15. Moiseev, I. I. and M. N. Vargaftik. 1965. Carbonium ions in the oxidation reaction of olefins with palladium chloride. Izvest. Akad. Nauk SSSR, Ser. Khim. 1965: 759–760.

16. Maitlis, P. M., in reference 7, p. 106.

17. Ketley, A. D. and L. P. Fisher. 1968. Reactions of alkenepalladium chloride complexes with alcohols. J. Organomet. Chem. 13:243–248.

Trans. Ky. Acad. Sci., 55(1–2), 1994, 6–19

Late Pleistocene and Holocene Vegetation History of Land Between The Lakes, Kentucky and Tennessee

Scott B. Franklin

Department of Plant Biology, Southern Illinois University, Carbondale, Illinois 62901, and
The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee 37044

Abstract

The vegetation history of Land Between The Lakes (LBL), Kentucky and Tennessee, is summarized beginning with the Pleistocene Series. A zonation of boreal, northern deciduous/*Pinus* and southern deciduous/*Pinus* spp. similar to that in North America today was compacted below the Laurentide Ice Sheet. Boreal or northern hardwood species dominated LBL during glacial extensions and alternated with southern and prairie constituents during warmer and drier periods.

The Holocene, a warming and drying period, followed the Pleistocene and was accompanied by the onset of human occupation. During the height of this middle period, Hypsithermal, mesophytic species retreated to bottomlands and protected coves while *Quercus*, *Carya*, and herbaceous species dominated uplands. Following the Hypsithermal, the climate became cooler and more moist. Souther *Pinus* and *Quercus* spp. migrated north and invaded prairie and open forest. However, succession was delayed by aboriginal disturbance, which included annual burning and swidden agriculture.

When Europeans began exploring the LBL area, they found bottomland hardwoods of enormous size and upland park-like forests with an herbaceous understory. Europeans began settling the area in the late 1700s. Their influence on the vegetation included farming, grazing, whiskey distilling, timber cutting for charcoal production, railroad ties, and other wood products, and damming the Cumberland and Tennessee rivers. Agrodeforestation and the control of wildland fire led to the reversal of forest dominance across the landscape. Bottomland forests were converted to agricultural land and were later inundated by Kentucky Lake and Lake Barkley. Previously open uplands succeeded to closed forest, currently dominated by *Quercus* species.

Introduction

Land Between The Lakes (LBL) is a 69,000 ha inland peninsula bordered on the west by Kentucky Lake and on the east by Lake Barkley (Fig. 1). The area, located in western Kentucky and Tennessee, ranges from 6 to 13 km wide and is approximately 66 km long. Land Between The Lakes is part of the Western Highland Rim subsection of the Interior Low Plateau Province (1), and most of the area consists of highly dissected uplands (2). The former gently sloping bottomlands of the Tennessee and Cumberland rivers are now inundated by Kentucky Lake and Lake Barkley, respectively. Currently, over 80% of LBL is forested (3).

Braun (4) classified the region as Mixed Mesophytic, a transition zone between the Mesophytic Region to the east and the Oak-Hickory Region to the west. Küchler (5) mapped the potential vegetation as Oak-Hickory. Recent studies have documented the forest vegetation of LBL (3), including the Bear Creek Natural Area old-growth mesophytic hardwoods (6) and the Devil's Backbone, a natural stand of *Pinus echinata* (7). Forest dynamics and successional trends of upland communities have been analyzed by Fralish and Crooks (8, 9), Franklin (10), and Kettler (11). The impact of the iron industry on LBL forests was outlined by Gildrie (12). However, the vegetation history of LBL has not been summarized.

This article integrates information from geology, archeology, anthropology, pollen analyses, and vegetation studies with written and oral testimony. In some instances, it was necessary to extrapolate information from adjacent areas because few analyses or oral testimonies were found from within LBL. This was especially true for the reconstruction of Wisconsinan vegetation, where vegetation descriptions were composed from pollen studies surrounding LBL (13). Because of the uncertainty of species identification (Appendix A), this article was written on a general basis.

The objectives were to summarize past vegetation and to analyze the effects of past disturbance, beginning with the Wisconsinan Glacial Stage. An overview of early cultures is

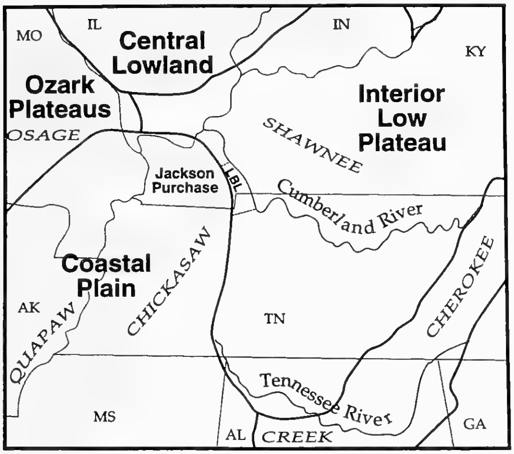


FIG. 1. Locality of Land Between The Lakes, Kentucky and Tennessee, including Physiographic Regions (1) and dominant Native American Indian tribes prior to European settlement (31).

incorporated to present their impact on vegetation. The influence of European settlement is subsequently analyzed and related to the present vegetation of LBL.

Wisconsinan Stage (Pleistocene Series) Vegetation

Although the Laurentide Ice Sheet did not extend as far south as LBL (13), the changes in climate created by the Wisconsinan glacial advance had an impact on LBL's vegetation. A vegetation zonation similar to that across eastern North America today was compressed below the advancing glaciers. Tundra bordered the southern edge of the Laurentide Ice Sheet. Boreal species were present in the adjacent zone while a Mixed Coniferous-Northern Hardwoods assemblage was associated with the Polar Frontal Zone. South of the Polar Frontal Zone, a Mixed Mesophytic association, a *Quercus-Carya* association, and southern *Pinus* spp. dominated (14). Delcourt and Delcourt (13, 14) have mapped the migration of these vegetation zones from 40,000 years before present (y.B.P.) to the present in accordance with fluctuating glacial and climate patterns. Pollen and macrofossils predating the Wisconsinan State indicate a similar migration took place at each glacial advance (15, 16, 17) (Table 1). The impact on the vegetation of LBL was dependent on the southern extension (i.e., influence) of these advances.

The Wisconsinan Stage began approximately 75,000 y.B.P. and ended approximately 12,500 y.B.P. (Table 1). A warm-temperate environment pervaded the Altonian and Farmdalian Substages. Approximately 40,000 y.B.P. (i.e., Altonian Substage), LBL was likely dominated by *Quercus*, *Carya*, and southern *Pinus* spp. (e.g., *P. echinata* and *P. virginiana*) (13). The Mixed Hardwood forest of *Quercus*, *Acer*, *Fagus*, *Tilia*, *Ulmus*, *Juglans*, *Tsuga*, and *Nyssa* persisted along the Tennessee and Cumberland River corridors (13).

The Farmdalian Substage was a mild warming period that generated a minor glacial retreat. At 25,000 y.B.P., LBL was likely dominated by a *Quercus-Carya* assemblage. Southern *Pinus* spp. were a minor part of this assemblage (13). The development of grasslands was favored during this interval and was

TABLE 1. Summation of the Pleistocene and Holocene Series (14, 17, 79).

			y.B.P.
Holocene Series	Late Holocene		5,000
	Middle Holocene 'Hypsithermal'		8,700
	Early Holocene		12,500
Pleistocene Series	Wisconsinan Stage (glacial)	Woodfordian Substage	23,000
		Farmdalian Substage	28,000
		Altonian Substage	75,000
	Sangamonian Stage		125,000
	Illinoian Stage (glacial)	Jubileean Substage	
		Monican Substage	
		Liman Substage	175,000
	Yarmouthian Stage		225,000
	Kansan Stage (glacial)		500,000
	Aftonian Stage		600,000
	Nebraskan Stage (glacial)		915,000

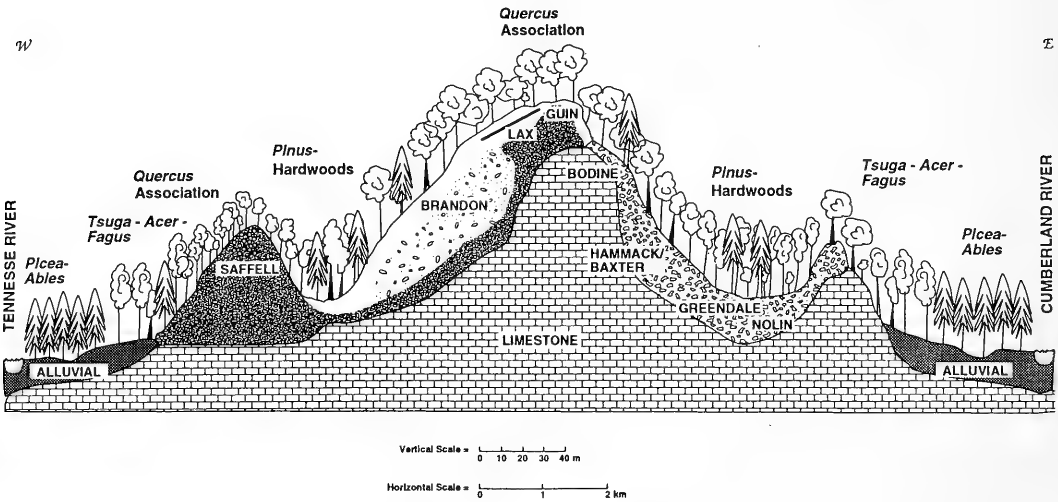


FIG. 2. Reconstruction of vegetation pattern of Land Between The Lakes, Kentucky and Tennessee, during the Wisconsinan Stage glacial advance. Schematic is drawn to show migration of Mixed Conifer-Northern Hardwoods Association through LBL, 11,200–13,500 y.B.P.

most likely a component of the LBL uplands. Pollen samples taken along the Mississippi Valley indicate that Cyperaceae, Poaceae, and Asteraceae species dominated exposed upland areas (18). Prairie was a major component in the Missouri Ozarks (18) and in central and southern Illinois (19).

At the beginning of the Woodfordian Substage (23,000 y.B.P.), a major transition took place. The *Quercus-Carya* mixture changed to a *Picea-Quercus* mixture because of the influence of the Pacific Airmass (18). Forests became closed and prairie elements disappeared. During the height of the Wisconsinan glaciation (18,000 y.B.P.), LBL was dominated by northern *Pinus* spp. (e.g., *P. banksiana* and *P. resinosa*), with *Picea* and *Abies* spp. subdominant (13).

The last major interval of climatic warming and deglaciation began approximately 16,500 y.B.P. At 14,000 y.B.P. (i.e., Woodfordian Substage), LBL was dominated by a *Picea-Pinus* assemblage. Between 11,500 and 13,500 y.B.P., a Mixed Conifer-Northern Hardwood assemblage migrated through LBL (20). This assemblage included *Tsuga, Pinus, Picea, Abies, Quercus, Betula, Ulmus, Fraxinus, Ostrya, Acer,* and *Fagus* (Fig. 2). The Mixed Conifer-Northern Hardwood assemblage was followed by Mixed Hardwoods, which were succeeded by significant increases in *Quercus* spp. and a warm-temperate flora (13).

Holocene Series and Aboriginal History

The Holocene Series began approximately 12,500 y.B.P. (14) and was followed shortly by human inhabitation of Land Between The Lakes (LBL) (21). Four historic cultures inhabited LBL: Paleoindian, Archaic, Woodland, and Mississippian (21) (Table 2, Fig. 3).

The first inhabitants, the Paleoindians, led a highly nomadic lifestyle, following and hunting large Pleistocene fauna (21, 22). Their tools and weapons were constructed from the large amount of chert in the area (23). Chert was so accessible from the Cumberland River (rivers were the main form of transportation) that later settlements in Illinois and Missouri quarried chert in Stewart County, Tennessee (24).

Early inhabitants likely impacted vegetation through their use of fire. Cultures migrating into North America during the Pleistocene were already using fire for management purposes (23). Early cultures commonly fired forests and grasslands to drive game, improve visibility, facilitate travel, decrease reptiles and arthropods, increase grass, seeds, and berries, and for offense and defense during war (25,

TABLE 2. Aborigines of Land Between The Lakes, Kentucky and Tennessee (21).

Approximate dates	Culture	Summary	Climate
10,000–8,000 y.B.P.	Paleoindians	First extant cultures of man in southeast U.S. Big game hunters, nomadic.	Cool-temperate, abundant moisture.
8,000– 2,500 y.B.P.	Archaic	Relied on less mobile and more concentrated resource pattern.	Warm and dry, expansion of prairie.
2,500–1,000 y.B.P.	Woodland	Hunting and gathering pattern continued, gathering increased in importance.	Progression to cooler and more moist conditions.
1,000–500 y.B.P.	Mississippian	Permanent sites established with agriculture.	
500–300 y.B.P.	Native American Indians: Chickasaw, Shawnee, Cherokee, Creek, Iroqois	Decentralization of large villages into small agricultural villages; greater reliance on hunting.	
300–200 y.B.P.	Unoccupied	Hunting by various tribes and exploration by Europeans.	
200 y.B.P.–present	European settlement	Logging, iron mining, grazing, and agriculture.	

26, 27, 28). Fire is still used by most aboriginal cultures in the world to manage vegetation (25).

By 10,000 y.B.P., LBL was likely dominated by Mixed Hardwoods because of the effects of the Maritime Tropical airmass (13). Toward the end of glacial advance, *Quercus* spp. dominated forests in the area (14, 15). The last pulse of glacial meltwater was approximately 9,200 y.B.P. During the extremely dry Hypsithermal (8,700–5,000 y.B.P.), prairie expanded eastward while southern and swamp vegetation (e.g., *Taxodium distichum*) expanded northward (14, 15, 29). At 5,000 y.B.P., xeric *Quercus* and *Carya* spp. probably dominated LBL (14). Mixed Hardwoods were restricted to favorable ravines and slopes along the Tennessee and Cumberland rivers (13). Exposed upland areas were composed of open forest or dominated by herbaceous flora.

Along with changes in vegetation, a transition from the Paleoindian culture to the Archaic culture took place during the mid-Holocene. The Archaic culture, 8,000–2,500 y.B.P., a hunting and gathering culture, was less mobile and more concentrated than the Paleoindians (21, 26). Archaic settlements were large (up to 4.1 ha in Stewart County) and were often occupied for long periods of time. The greatest impact of the Archaic Indians occurred on and around their settlements.

From the end of the Hypsithermal (5,000 y.B.P.) to present, increased precipitation raised watertables (29). Southern *Pinus* spp. (e.g., *P. echinata* and *P. virginiana*) invaded prairie areas and southern *Quercus* spp. soon followed northward. Alluvial terraces and lower slopes dominated by *Quercus* spp. were succeeded by more mesophytic species from floodplains and protected cove refugia (14, 30). However, this succession was slowed because of the extensive use of fire on the uplands and clearing of forest on the bottomlands by the Woodland, Mississippian, and Native American Indians.

The hunting subsistence of the Archaic culture continued into the beginning of the Woodland culture (2,500-1,000 y.B.P.), but the Woodland culture depended more on gathering wild plant foods, e.g., nuts, berries and roots (21). Woodland settlements were later pushed out of the area by Mississippians (21). The Mississippian culture (1,000–500 y.B.P.) had the greatest community structure of all the early cultures (21). Agriculture was introduced to the LBL area and the products, mainly corn, beans, squash, and pumpkin (*Curcurbita pepo*), were supplemented by hunting, fishing (including shellfish), and gathering of fruits and seeds (21, 22, 23, 24). The Mississippian's sedentary way of life allowed time for the construction of large temple mounds, a hallmark of this culture. These structures, along with permanent villages, were associated with agricultural lands that

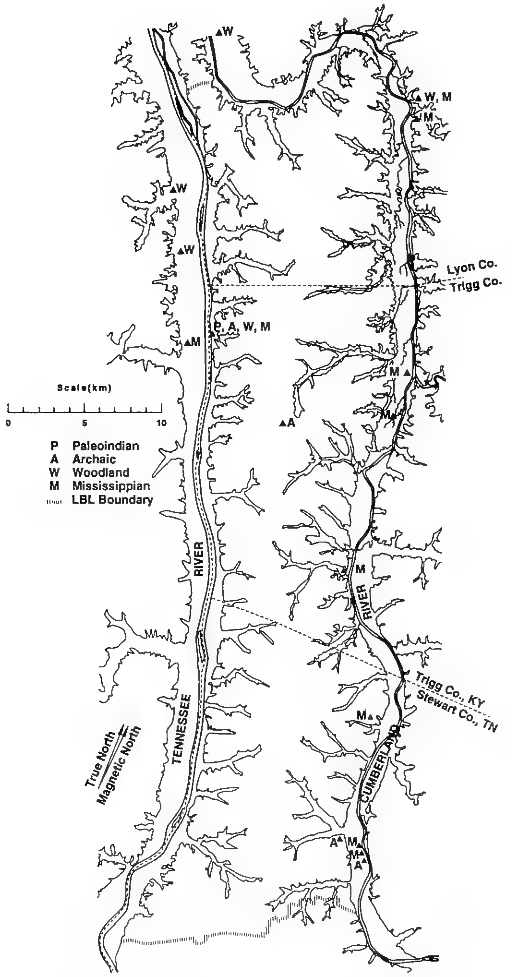


FIG. 3. Aboriginal settlements in Land Between The Lakes, Kentucky and Tennessee (21). Alluvial bottomland and valleys are outlined.

supported more dense populations than Woodland cultures.

Aboriginal disturbance was focused along the major rivers and their tributaries. Alluvial corridors several kilometers wide were cleared for settlements and agriculture (14). Satz (31) believed that early Americans used the alluvial soil because it was easier to till and soil nutrients were replenished by frequent flooding. Swidden agriculture (slash and burn) and sedentary farming were common practices among later cultures who (B. M. Butler, Center Archaeological Invest., Southern Illinois Univ., pers. comm.) felled trees with stone axes and fire (14, 27). The Mississippian culture made greater use of fire for cooking and clearing of land than the Woodland culture (14).

Approximately 500 y.B.P., a decentralizing trend began and large Mississippian communities disintegrated into Native American Indian tribes (21, 32). These tribes led a more migratory lifestyle, in which hunting and gathering increased and agriculture declined (21, 33). The Chickasaw Indians had settlements in the Jackson Purchase area and probably inhabited fragmented communities along the Tennessee and Cumberland rivers and their tributaries (21, 32). A considerable area of forest was cleared for home sites, agricultural land, and other forest products (14, 27) and the longer a site was occupied, the further the forest receded because of the demand for fuelwood. Old open Indian sites were often used by early Europeans to establish their own settlements (27, 34).

Land Between The Lakes was likely dominated by the *Quercus-Carya* association throughout the late-Holocene. Upland areas remained open because of a combination of large ungulate grazing and annual anthropogenic burning. Although the occupation of Tennessee and Cumberland River valleys near LBL ended just before the eighteenth century (300 y.B.P.), most early writers claim LBL and lands east of LBL were used by Native Americans for hunting purposes (31, 35, 36). Choctaw, Chickasaw, Shawnee, and Cherokee Indians annually burned these areas and parties from all tribes continued to hunt on the land (32, 37, 38, 39). Jeromiah Nickell in 1782, one of the first settlers between the rivers, found open uplands approximately 0.8 km from the Tennessee River because Native Americans had burned the lands so frequently (34). Sauer (40) stated "[t]here is nothing in the distribution of forests in this part of the country to suggest that climate or the history of forest migration could explain the lack of forests in the Pennyroyal uplands."

Ungulates, especially large herds of bison (*Bison bison*), had an impact on the vegetation through grazing and soil compaction. Several trails, ranging from 18–61 m wide crisscrossed the area connecting the rivers and streams (32). The Trace, the main road in LBL running north-south, was in fact an old bison trace (trail) (32). However, intensive harvesting of

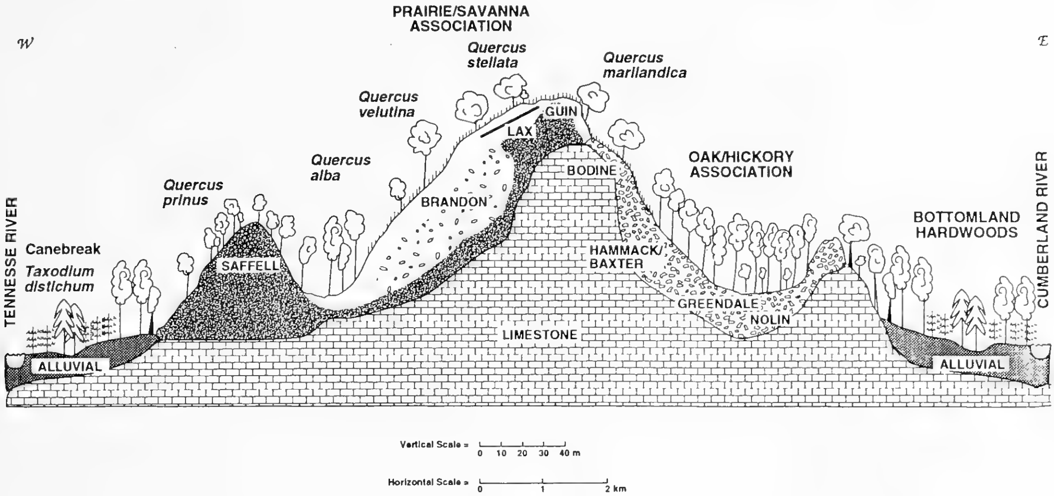


FIG. 4. Reconstruction of vegetation pattern of Land Between The Lakes, Kentucky and Tennessee, prior to European settlement.

deer (*Odocoileus virginianus*), elk (*Cervus elaphus*), bison, and beaver (*Castor canadensis*) began in the mid 1700s (41). Bison were essentially extirpated east of the Mississippi River by 1800 (35, 42).

Settlement by early American cultures, through agricultural activity, use of various wood products and annual burning, influenced the vegetation seen by European explorers in the 1700s (Fig. 4).

Pre-European Settlement Vegetation

Prior to extensive settlement of the LBL area, hunters, fur-traders, and explorers visited and traded with natives. These early writers describe three main types of terrestrial vegetation: (1) swamps and bayous, (2) bottomland/upland hardwoods, and (3) savannas/prairies/barrens (Fig. 5) (39, 43).

Swamp lowland communities included *Taxodium distichum, Planera aquatica, Nyssa aquatica,* and canebrakes (*Arundinaria gigantea*) (32, 35, 39, 43). Towering cypress 36–46 m high with "truly enormous" buttresses were observed along the Big Sandy River which empties into the Tennessee River just upstream from LBL (43). Stands of *T. distichum* and *N. aquatica* were described in the low-lying sloughs of the Jackson Purchase (44), the Cache River bottomlands (45) and the Wabash Valley (46). *Alnus serrulata, Salix humilis, Cephalanthus occidentalis* and *Malus angustifolia* were found along the margins of wet areas (32, 43). Perrin (47) described the Cumberland River floodplain as more "checkered" (i.e., contained more sloughs and swamps) than the Tennessee River floodplain. The mouth of the Cumberland River was interspersed with marshes, ponds, and lagoons (48). Sand bars and islands within the river floodplain were covered with *Populus deltoides* and *Salix* spp. (35).

Cane (*Arundinaria gigantea*) was found along the lower courses of rivers in rich soils above inundations (49) and on alluvial soils along rivers and creeks (39, 43, 44, 45, 46, 49, 50). *Arundinaria* grew in thick groves or canebrakes up to several kilometers in area and stems ranged from 3.0–9.0 m in height (35, 43, 46, 49). In many instances, dense stands of cane comprised the entire understory of bottomland hardwoods (35). Cane was a massive resource for early cultures who used it to make weapons, mats, couches, and walls for buildings (31, 51). However, overgrazing by cattle or rooting by hogs easily killed cane (51). Thus, most of the breaks were eliminated by grazing or farming. Remnant canebrakes with stems up to 6.5 m in height can still be found in the LBL area. Some breaks cover 0.4–0.8 ha (52).

Alluvial and ravine forests consisted of *Quercus nigra, Q. phellos, Q. alba, Q. rubra,*

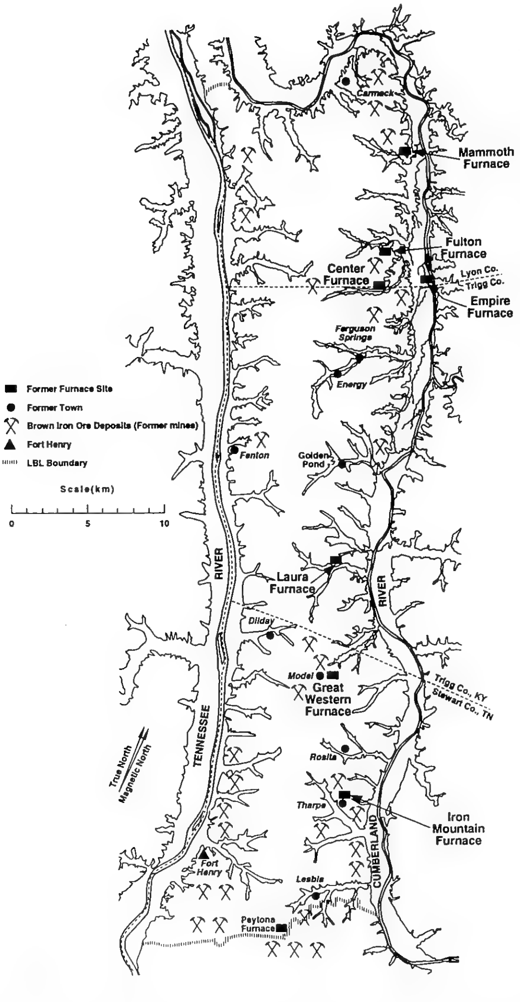


FIG. 5. Location of iron furnaces, iron ore mining sites and towns of Land Between The Lakes, Kentucky and Tennessee, during the later part of the 1800s. Alluvial bottomland and valleys are outlined.

Q. palustris, Q. bicolor, Q. macrocarpa, Q. lyrata, Carya glabra, C. illinoensis, C. ovata, C. laciniosa, Liquidambar styraciflua, Populus deltoides, Nyssa sylvatica, Diospyros virginiana, Betula, Gleditsia triacanthos, Fraxinus, Catalpa, Magnolia acuminata, Liriodendron tulipifera, Acer saccharum, A. negundo, Platanus occidentalis, and *Fagus grandifolia* (6, 35, 39, 40, 44, 49, 53). These bottomland hardwood trees were of enormous size. An account of tree size in the mid 1800s, Pennyroyal Region, found "[t]he white oak, burr oak, and swamp white oak, form immense trunks, reaching to a height of eighty feet [24.4 m], where they still seem to be three feet [.9 m] in diameter. One could hardly determine which to admire most, their number, their size, or their grand uniform straight trunks" (40). Flint (49) described thickly timbered areas of huge trees along the Mississippi Valley with undergrowth consisting of *Asimina triloba* and *Vitis* spp. the width of humans. In some instances, *Cercis canadensis, Ceanothus, Forestiera acuminata,* and *Lindera benzoin* contributed to the understory canopy (35, 39, 44, 46, 49). Extensive woody vines, e.g., *Vitis* spp., *Toxicodendron radicans, Anistostichus capreolata, Campsis radicans,* and *Smilax* spp., sometimes formed impenetrable thorny tangles (32, 35, 39, 43, 46).

Alluvial forests graded into lower slope forests of similar vegetation but with a greater abundance of *Fagus grandifolia* and upland *Quercus* spp. (35, 54). Lower slope and bottomland forests were sometimes described by early writers as "park-like" (i.e., widely spaced trees with an herbaceous understory) because of periodic fires. Andre Michaux, a French botanist who explored the Lower Cumberland Valley in 1802, remarked that a stag could be seen 183–274 m away because trees were so widely spaced. He further wrote that the understory used to be composed of cane (35). *Quercus* spp. dominated areas where fires influenced forests. Abrams (28) considers the dominance of *Quercus* spp. throughout the eastern hardwood region to be the result of fire.

Along the highland rim, open forest (including savanna and barrens) and prairies dominated the dissected topography on middle and upper slopes (Fig. 5). Typical trees of these open communities included *Quercus marilandica, Q. velutina, Q. stellata, Q. prinus, Q. falcata,* red oak (*Q. rubra* or *coccinea*), *Oxydendrum arboreum,* and *Castanea dentata* (32, 39, 43). Shrubs included *Corylus americana, Amelanchier arborea, Hydrangea,* and various *Vaccinium* spp. (32, 39, 44). "Gravelly hills" of a cherty strata were dominated by *Q. prinus, Q. arboreum, Carya tomentosa,* and *C. glabra.* Unlike the present upland forests, these park-like forests had an abundance of graminoids and other herbaceous species in their understory (43, 55). Also, barrens were common on long, uniform, undulating hills in the Mississippi Valley. They were covered with tall coarse grass and sparse, scrubby trees (49).

Michaux described a dense sward (i.e., Poaceae) that blanketed terrain adjacent to the strip of riparian forest between the rivers (32). Flint in 1852 (49) separated prairies into healthy, alluvial, and dry. Alluvial prairies, found along great water courses, were inundated for long periods of time and formed "reserves of stagnant water." This environment was not conducive to tree growth. Dry prairies were the most extensive class of prairies found on the flat plains. They contained "weeds," forbs, and grasses. The healthy prairies were intermediate to the alluvial and dry prairies. These prairies contained springs surrounded by shrubs, including *Corylus* and *Sassafras albidum. Vitis* spp. stems and summer flora were abundant.

Two types of barrens were identified on the Western Highland Rim, Tennessee: (1) loess barrens on the surface of the rim, and (2) shallow clay soils over limestone (limestone barrens) found on flat to sloping sites near the Tennessee River (41). Both barren types were dominated by *Schyzachyrium scoparium.* Codominants of the loess barrens included *Andropogon gyrans, Parthenium integrifolium,* and *Panicum angustifolium.* Codominants of limestone barrens were *Galactia volubilis, Opuntia compressa, Fimbristylis puberula, Andropogon gerardii, Sorghastrum nutans,* and *Smilax* spp. (41). Numerous other forb species also contributed to the composition of these communities (41, 43). DeSelm (41) suggested these communities may be remnants of the Hypsithermal prairie expansion. Early reports on the Jackson Purchase (56) and Montgomery and Stewart counties (54) also noted extensive prairie. In fact, almost all lands lying east of the Cumberland River were classified as barrens (35, 57, 58, 59) up to approximately 1.6 km from the river (35).

Post-European Settlement Vegetation

European settlement had an enormous impact on the vegetation of LBL. Disturbances related to iron manufacturing, agriculture, timbering, whiskey distilling, changes in fire frequency, and damming of rivers have shaped the present vegetation.

Little effort was expended to settle lands west of the Appalachians until the late 1700s (39). In 1782, Jeromiah Nickell built a cabin on an old Indian site and started a garden in the open uplands (34). By 1795, several farmsteads were established on the alluvial terraces of LBL (32). Plantations were constructed where bottomland forests and impenetrable thickets of cane and briers once persisted (54). But, the steep slopes and rocky uplands were not farmed and swamps were often avoided since settlers believed they were unhealthy (60).

Following the eradication of Native American Indians and the cessation of annual burning, prairies quickly succeeded to forest (39). Small trees began to "spring up" under parklike woods within the Jackson Purchase (36). Prairie was replaced by scrub oak (*Q. marilandica, Q. velutina,* and red oak) forest within 30 years (56), which in turn succeeded to magnificent stands of *Carya, Fraxinus, Nyssa sylvatica, Ulmus, Acer, Quercus, Liriodendron tulipifera, Catalpa, Juglans,* and *Platanus occidentalis* (61). This rapid succession on the "barrens" in Kentucky and Tennessee has led some researchers to reconsider whether these areas were actually part of the Prairie Peninsula (38, 62). The landscape impact by Europeans was similar to that of Native American cultures, in that while the effects of fire shaped the vegetation on the uplands, a variety of disturbance shaped the bottomland vegetation.

Iron production had a severe impact on the bottomland forests of LBL. A total of 8 furnaces were constructed within LBL between 1843 and 1912 (12), as well as a rolling mill and iron works located near Empire Furnace (63). Furnaces were built out of limestone mined from the surrounding area. Because of hauling expense, both iron ore and limestone were mined within a few miles of the furnace site. Hardwood forests supplied wood for charcoal (63, 64, 65). Most of the "coalings" (i.e., forest land used in iron manufacture) were found along the bottomlands and adjacent slopes (12, 63). Wood was transformed into charcoal in hearths, remains of which are still visible in the LBL forests. The circular sites of past charcoal hearths are distinguished by depauperate vegetation and black soil that was sterilized because of intense heat. *Sassafras albidum* and *Cornus florida* are generally the major tree species found on old charcoal hearths (66).

More than 10,000 cords of wood, 81–200 ha of "coalings," were necessary to keep a typical furnace "in blast" around the clock, 6 days a week, for 8 to 10 months (12, 64). However, iron-furnace productivity was highly variable. In estimating the impact of each furnace, Gildrie (12) concluded that the maximum area of timber cut by the industry prior to 1865 was 8,500–12,750 ha (12–19% of the total area between the rivers). After 1865, only 4,450 ha (6% of the total area) of timber was utilized. Three to 4 times as much forest was cut in Kentucky than in Tennessee. In addition, "coalings" were only utilized in Tennessee until 1862, while Kentucky "coalings" were exploited as late as 1912. Upland "coalings," being much more open, i.e., trees more widely spaced (39), required a greater area to produce the necessary amount of charcoal. The Center Furnace recorded higher acreage estimates from 1905–1912, when the policy was to use "scrub oak, blackjack, and other small trees that wouldn't be suitable for crossties" (12). Dense stands of *Q. stellata, Q. velutina,* or *Q. alba* regenerated on old "coalings" in upland areas (26, 40). These species presently dominate several old "coalings" in LBL.

In 1874, J. B. Killebrew, the Tennessee State Commissioner of Agriculture, mourned, "[i]n the neighborhood of old furnaces, it [timber] has been cut down for a distance of 3 to 4 miles, and used for making charcoal. Sprouts put up every year, but the annual fires which sweep over the old 'coalings' with devastating fury, destroy them. No new timber is taking place of the old. Barren, sightless old fields, covered in broomsedge [*Andropogon virginicus*], meet the eye on every hand" (12, 64, 67). Timber depletion was one reason for the demise of the iron industry (12, 63, 65). Killebrew advocated laws that prevented harvesting immature timber (<30 years) (65). Although 30 years may seem young for being designated a mature forest, roots of bottomland forest trees reaching the water table grow at an enormous rate (H. Newland, Former State Forester, Kentucky, pers. comm.). For example, in 20–25 years red oaks grew to produce 2.4–3.1 m railroad ties, approximately 40 cm diameter at breast height (H. Newland, Former State Forester, Kentucky, pers. comm.).

Bottomland forest was converted from "coalings" into cropland or simply cultivated after "deadening" trees. "Deadening" was a practice of girdling trees, subsequently burning over the land and then cultivating between trunks. Slash and burn agriculture was adopted from Native Americans by European settlers (25). In the early 1800s, farms remained frontier-like (23), but crop plantations soon appeared (47). In the early twentieth century, LBL homesteads ranged from impoverished and isolated, like those of mountain regions (40), to large plantations created by iron industries to supplement workers (47, 64). By the early 1900s, farmlands comprised most of the bottomlands and alluvial terraces (40).

Cattle grazed and hogs rooted in open woodlands of the dissected upland slopes. Hogs sustained themselves almost entirely on mast (40). Sauer (40) promoted the cessation of open grazing, a practice that slowed natural succession. Canebrakes, while at first excellent forage, were soon destroyed (51). In an effort to rejuvenate the forest, laws were passed ordering domestic livestock confinement.

"Firing" the land was widely employed to manage private property in LBL (32, 38, 39, 44). Early settlers routinely followed Native American Indian practices into the twentieth century, including using fire for swidden agriculture and hunting (25, 39). Miller (68), an Illinois State Forester, and Killebrew denounced "firing" the land after harvest because of its harmful effects on forest regeneration (65). In 1936, fire towers were erected within LBL, but laws were not passed and funds were not available to fight fire until the late 1950s and early 1960s (H. Newland, Former State Forester, Kentucky, pers. comm.). Finally, in 1953, the United States Department of Agriculture called for a cooperative fire-control program to protect forests of private, corporate, state, and Tennessee Valley Authority ownership. Fire scars from tree cross sections taken at LBL indicate fires decreased in size, intensity and/or frequency 60–80 years ago (69). Similar results have been found through analysis of fire scars of upland *Quercus* and *Carya* spp. in southern Illinois (70). Three patterns of anthropogenic fire frequency have occurred: (1) Native Americans annually burned large areas, (2) early settlers imitated this practice but not always annually or during the fall, and its use was generally not as widespread because homesites dissected the landscape and created fire breaks, and (3) twentieth century land owners suppressed fire because of its harmful effect on forests. During the 1800s, LBL uplands succeeded to a more closed forest, because of the difficulty in cultivating the dissected terrain and a decrease in fire frequency.

In the 1870s, J. B. Killebrew observed "wood-choppers, stave-makers, sawyers, and shingle-makers are especially numerous between the rivers" (12, 53). Eddyville, located on the north side of the Cumberland River, was a ship building site in the early 1800s. Schooners and gunboats were built from the surrounding forest (48). Production of railroad ties was heavy from the 1880s to 1920s during the push to expand the rail system westward (55). "Tie making" was a particularly important occupation during the winter season (40). Whatever was missed by the iron industry, or had regenerated since its domination, was harvested during this period. Cutting practices were poor, often leaving only remnant seed trees on broad areas otherwise cleared. Clearcutting (removing all stems) and highgrading (removing the best stock) were the main harvesting methods and reduced the area to scrub stock (H. Newland, Former State Forester, Kentucky, pers. comm.). Within LBL, few stands of trees date older than 130 years and most date between 80–100 years (8, 10).

Patches of forests were also cleared for whiskey distillation, although areas adjacent were left uncut to hide the still. With hundreds of stills in operation in the early 1900s, LBL was known as the "whiskey capital of the world" (71). Although small areas were impacted by a single still, as many as 7 stills could be found along a single creek. Often, moonshiners set fires to screen stills from prohibitioners (H. Newland, Former State Forester, Kentucky, pers. comm.).

In the early 1900s, Lyon and Trigg counties were approximately 61% and 62% forested, respectively (72). *Quercus alba* and *Quercus velutina* comprised at least 64% of these counties' total estimated lumber (72). *Quercus* spp., noted for their sprouting ability following both fire and cutting (73), now dominate LBL because of periodic fire and past logging practices (28). Mesophytic species are far less adapted to sprouting following disturbance.

Much of the remaining bottomland hardwoods, canebrakes, and swamp vegetation were inundated by Kentucky Lake and Lake Barkley. The Kentucky Lake dam, completed in 1944, and the Lake Barkley dam, completed in 1965, impounded nearly all alluvial areas between the rivers (Fig. 5). The suppression of fire, large-scale use of natural resources, and inundation of alluvial valleys have shaped the present vegetation composition and structure of LBL.

Present Vegetation

The present vegetation of LBL is mostly second and third-growth timber, comprised mainly of *Quercus* species. Canebrakes and bottomland hardwoods remain in the alluvial areas that have escaped cultivation and inundation by the lakes.

Upland prairie and savanna communities have succeeded to closed forest with a depleted herbaceous layer. The closed forest microclimate is cooler and moister than open forests, thereby allowing the invasion of and succession to more mesophytic species (74). Alluvial and mid-slope areas currently dominated by *Quercus* spp. are succeeding to more mesophytic species, especially *Acer saccharum* and *Fagus grandifolia* (11, 75). Invasion of *A. saccharum* into upland *Quercus* stands has been observed throughout the Central Hardwoods Region (28, 76, 77, 78). Natural stands of *Pinus echinata* are still found on the Devil's Backbone, Tennessee, but are rapidly succeeding to several species of *Quercus* (7, 11, 75). A similar succession is occurring within natural stands of *P. virginiana* along the bluffs of the Tennessee River across from Blood River's mouth.

CONCLUSION

The vegetation of LBL has not been static. Glacial advances during the Pleistocene caused migrations of boreal and northern deciduous taxa to pass through LBL. Following their retreat, southern *Quercus* and *Pinus* spp. dominated. Drier climates and burning regimes of early Americans created open communities on the uplands until the onset of Europeans.

Agrodeforestation and wildfire control by the Europeans have led to the reversal of forest dominance across the landscape. The once open uplands, dominated by prairie grasses and scattered *Quercus* spp., have been replaced by closed forest. Crop fields and recreation lakes have replaced the heavily timbered bottomland forests. The current vegetation patterns and successional trends in vegetation throughout LBL are expressions of its past history and predictions of its future.

ACKNOWLEDGMENTS

I wish to thank Marty Vogt, Steve Kettler, and Jim Peters for their help with data collection and analysis. Thanks also to Larry Doyle, Dr. Edward W. Chester, Dr. Betty Jo Wallace, Dr. Brian Butler, Matt Peterson, and Harrod Newland for their generous assistance with research and for sharing personal information. A special thanks to Dr. Philip A. Robertson, Dr. David J. Gibson, Deanna B. Franklin, Dr. Ralph Thompson, and an anonymous reviewer for their guidance and critical review of the manuscript. Portions of this research were supported by Land Between The Lakes, Tennessee Valley Authority.

LITERATURE CITED

1. Fenneman, N. M. 1938. Physiography of eastern United States. McGraw-Hill Book Co., New York.

2. Harris, S. E., Jr. 1988. Summary review of the geology of Land Between The Lakes, Kentucky and Tennessee. Pp. 84–144. In D. H. Snyder (ed.) Proc. First Annual Symposium on the Natural History of the Lower Cumberland and Tennessee River Valleys. The Center for Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

3. Schibig, J., R. J. Jensen, and E. W. Chester. 1990. The Fagaceae and Juglandaceae of Land Between The Lakes: a review. Pp. 129–146. In S. W. Hamilton and M. T. Finley (eds.) Proc. Third Annual Symposium on the Natural History of the Lower Tennessee and Cumberland River Valleys. Center for Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

4. Braun, E. L. 1950. Deciduous forests of eastern North America. Blakiston Co., Philadelphia, Pennsylvania.

5. Küchler, A. W. 1964. Potential natural vegetation of the conterminous United States. American Geographical Society, Special Publication 36, New York.

6. Carpenter, J. S. and E. W. Chester. 1988. A floristic and vegetation characterization of the Bear Creek Natural Area, Stewart County, Tennessee. Pp. 220–239. In D. H. Snyder (ed.) Proc. First Annual Symposium on the Natural History of the Lower Tennessee and Cumberland River Valleys. Center for Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

7. Schibig, J. and E. W. Chester. 1988. Vegetation and floristic characterization of a mixed hardwoods-shortleaf pine stand in Stewart County, Tennessee. J. Tenn. Acad. Sci. 63:83–88.

8. Fralish, J. S. and F. B. Crooks. 1988. Forest communities of the Kentucky portion of Land Between The Lakes: a preliminary assessment. Pp. 164–175. In D. H. Snyder (ed.) Proc. First Annual Symposium on the Natural History of the Lower Tennessee and Cumberland River Valleys. Center for Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

9. Fralish, J. S. and F. B. Crooks. 1989. Forest composition, environment and dynamics at Land Between The Lakes in northwest middle Tennessee. J. Tenn. Acad. Sci. 64:107–112.

10. Franklin, S. B. 1990. The effect of soil and topography on forest community composition at Land Between The Lakes, KY and TN. M.S. Thesis. Dept. Forestry, Southern Illinois Univ., Carbondale, Illinois.

11. Kettler, S. M. 1990. The effect of soil and topography on forest successional patterns at Land Between The Lakes, KY and TN. M.S. Thesis. Dept. Forestry, Southern Illinois Univ., Carbondale, Illinois.

12. Gildrie, R. P. 1991. Estimated iron industry wood usage in the LBL region, 1843–1912. Pp. 121–139. In D. H. Snyder (ed.) Proc. Fourth Annual Symposium on the Natural History of the Lower Tennessee and Cumberland River Valleys. Center for Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

13. Delcourt, P. A. and H. R. Delcourt. 1981. Vegetation maps for eastern North America: 40,000 yr B.P. to the present. Pp. 123–165. In R. C. Romans (ed.) Geobotany II. Plenum Press, New York.

14. Delcourt, P. A. and H. R. Delcourt. 1987. Long-term forest dynamics of the temperate zone. Springer-Verlag, New York.

15. Ogden, J. G. 1965. Pleistocene pollen records from eastern North America. Bot. Review 31:481–501.

16. Kapp, R. O. and A. M. Gooding. 1974. Stratigraphy and pollen analysis of Yarmouthian interglacial deposits in southeastern Indiana. Ohio J. Sci. 74:226–238.

17. Jackson, S. T. 1978. A middle Illinoian florule from southeastern Jackson County, Illinois. M.S. Thesis. Dept. Botany, Southern Illinois Univ., Carbondale.

18. Delcourt, P. A., H. R. Delcourt, R. C. Brister, and L. E. Lackey. 1980. Quaternary vegetation of the Mississippi Embayment. Quat. Res. 13:111–132.

19. Grüger, E. 1972. Pollen and seed studies of Wisconsinan vegetation in Illinois, U.S.A. Ecol. Soc. Am. Bull. 83:2715–2734.

20. Delcourt, P. A. and H. R. Delcourt. 1983. Late-Quaternary vegetation dynamics and community stability reconsidered. Quat. Research 19:265–271.

21. Nance, J. D. 1973. Ancient man in Land Between The Lakes. Tennessee Valley Authority, Golden Pond, Kentucky.

22. Schwartz, D. W. 1967. Conceptions of Kentucky prehistory a case study in the history of archeology. Univ. of Kentucky Press.

23. Smith, F. E. 1971. Land Between The Lakes. University Press of Kentucky, Lexington.

24. Cole, F-C. 1951. Kincaid a prehistoric Illinois metropolis. University of Chicago Press, Chicago.

25. Pyne, S. J. 1982. Fire in America: a cultural history of wildland and rural fire. Princeton Univ. Press, Princeton, New Jersey.

26. Lewis, T. M. N. and M. Kneberg. 1958. Tribes that slumber: Indian times in the Tennessee region. The University of Tennessee Press, Knoxville.

27. Day, G. M. 1953. The Indian as an ecological factor in the northeastern forest. Ecology 34:329–346.

28. Abrams, M. D. 1992. Fire and the development of oak forests. Bioscience 42:346–353.

29. Delcourt, P. A. 1985. The influence of late-Quaternary climatic and vegetational change on paleohydrology in unglaciated eastern North America. Ecologia Mediterranea, Tome XI (Fascicule 1):17–26.

30. Gleason, H. A. 1923. The vegetation history of the middle west. Annals Assoc. Am. Geog. 12:39–85.

31. Satz, R. N. 1974. Tennessee's Indian peoples from white contact to removal, 1540–1840. University Tennessee Press, Knoxville.

32. Wallace, B. J. 1992. Between the rivers: history of the Land Between The Lakes. Center For Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

33. Henry, J. M. 1975. The land between the rivers. Taylor Publishing Co., Knoxville, Tennessee.

34. Nickell, W. S. 1952. My old Kentucky home. In J. Milton Henry Collection (1650–1968), Land Between The Lakes Project (1965–1968). Tennessee State Library and Archives, Nashville.

35. Michaux, F. A. 1805. Travels to the west of the Allegheny Mountains in the states of Ohio, Kentucky, and Tennessee undertaken in the year 1802. Pp. 105–306. In Thwaites, R. C. 1904–1907. Early western travels, Vol. 3. The Arthur H. Clark Co., Cleveland, Ohio.

36. Graves, R. 1958. History and memories of Carlisle County. Advance-Yeoman Publishers, Wickliffe, Kentucky.

37. Featherstonhaugh, G. W. 1968. Excursion through the slave states. Negro Universities Press, New York.

38. Chester, E. W. 1988. The Kentucky barrens of northwestern middle Tennessee: an historical floristic perspective. Pp. 145–163. In D. H. Snyder (ed.) Proc. First Annual Symposium on the Natural History of the Lower Tennessee and Cumberland River Valleys. Center for Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

39. McCrain, G. R. and A. L. Grubb. 1987. An analysis of past and present vegetation patterns and historic parameters at Fort Donelson National Battlefield with recommendation for restoration and future management. Resource Management Co., Raleigh, North Carolina.

40. Sauer, C. O. 1927. Geography of the Pennyroyal. Kentucky Geological Survey, Frankfort.

41. DeSelm, H. R. 1988. The barrens of the Western Highland Rim of Tennessee. Pp. 199–219. In D. H. Snyder (ed.) Proc. First Annual Symposium on the Natural History of the Lower Tennessee and Cumberland River Valleys. Center for Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

42. Cope, M. E. 1988. The history of American bison and bison at Land Between The Lakes. P. 313. In D. H. Snyder (ed.) Proc. First Annual Symposium on the Natural History of the Lower Tennessee and Cumberland River Valleys. Center for Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

43. Gattinger, A. 1901. Flora of Tennessee and a philosophy of botany. Gospel Advocate Publishing Co., Nashville, TN.

44. Davis, D. H. 1923. The geography of the Jackson Purchase. Kentucky Geological Survey, Frankfort.

45. Hutchinson, M. 1992. Remembering the Cache. Ill. Steward 1:13–20.

46. Joy, J. 1976. The legendary forest of the Wabash. Outdoor Illinois June/July:9–14.

47. Perrin, W. H. 1959. Counties of Christian and Trigg, Kentucky. F. A. Battey Publishing Co., Louisville, Kentucky.

48. Bedford, J. R. 1919. Notes or memorandum of a tour from Nashville to New Orleans down the Cumberland, Ohio and Mississippi Rivers in the year 1807. Tenn. Historical Magazine 5:48–70.

49. Flint, T. 1832. The history and geography of the Mississippi Valley. Press of L. R. Lincoln, Cincinnati, Ohio.

50. Cox, A. P., C. M. Briggs, B. Peebles, and O. R. Watkins. 1859. Report of the commissioners appointed to mark the boundary line between the states of Kentucky and Tennessee to the Governor of Kentucky. Yeoman Office, Frankfort, Kentucky.

51. Swayne, J. R. 1973. Paleoecology of southern Illinois and Pleistocene glaciation effect as indicated by modern distribution of disjunct species, French's Shooting Star, and cane. M.S. Thesis. Botany Dept., Southern Illinois Univ., Carbondale.

52. Easterla, D. A. 1990. Summer birds using giant cane (*Arundinaria gigantea*) in Land Between The Lakes. Pp. 49–56. In S. W. Hamilton and M. T. Finley (eds.) Proc. Third Annual Symposium on the Natural History of the Lower Tennessee and Cumberland River Valleys. Center for Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

53. U.S.D.A. 1953. Soil survey of Stewart County, Tennessee. Soil Cons. Serv. Superin. Doc., Washington, D.C.

54. Haywood, J. 1959. Natural and aboriginal history of Tennessee. Kingsport Press, Kingsport, Tennessee.

55. Ladd, D. 1991. Reexamination of the role of fire in Missouri oak woodlands. Pp. 67–80. In G. V. Burger, J. E. Ebinger, and G. S. Wilhelm (eds.) Proc. Oak Woods Management Workshop. Eastern Illinois Univ., Charleston.

56. Bryant, W. S. and W. H. Martin. 1988. Vegetation of the Jackson Purchase of Kentucky based on the 1820 General Office Land Survey records. Pp. 264–274. In D. H. Snyder (ed.) Proc. First Annual Symposium on the Natural History of the Lower Tennessee and Cumberland River Valleys. Center for Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

57. Bright, J. and L. Munsell. 1830. In Boundaries, Tennessee, Record Group 20. Tennessee State Library and Archives, Nashville.

58. Steele, W. and A. Looney. 1821. In Boundaries, Tennessee, Record Group 20. Tennessee State Library and Archives, Nashville.

59. District Surveyors of Tennessee. 1836. Survey of Stewart County. Tennessee State Library and Archives, Nashville.

60. Courier Company. 1886. History of Union County, Kentucky. Courier Co., Evansville, Indiana.

61. Starling, E. L. 1887. History of Henderson County. Unigraphic, Inc., Evansville, Indiana.

62. Baskin, J. M. and C. C. Baskin. 1981. The Big Barrens of Kentucky not a part of Transeau's Prairie Peninsula. Pp. 43–48. In R. L. Stuckey, and K. J. Reese (eds.) Proc. Sixth North American Prairie Conference. Ohio State University, Columbus.

63. Henry, J. M. no date. J. Milton Henry Collection (1650–1968), Land Between The Lakes Project (1965–1968). Tennessee State Library and Archives, Nashville.

64. Ash, S. V. no date. Tennessee's iron industry revisited. Stewart and Houston County Historical Societies. Dover, Tennessee.

65. Davis, J. S. 1976. The charcoal iron industry of Montgomery and Stewart Counties, Tennessee. M.S. Thesis. Austin Peay State Univ., Clarksville, Tennessee.

66. Clatterbuck, W. K. 1990. Forest development following disturbances by fire and by timber cutting for charcoal production. U.S.D.A. For. Serv. Gen. Tech. Report SE-69, Asheville, North Carolina.

67. Adams, D. F. no date. J. Milton Henry Collection (1650–1968), Land Between The Lakes Project (1965–1968). Tennessee State Library and Archives, Nashville.

68. Miller, R. B. 1920. Fire prevention in Illinois forests. Dept. Registration and Education, Natural History Survey, Forestry Circular No. 2, Urbana, Illinois.

69. Franklin, S. B. Unpublished data. Effects of fire on *Quercus* communities of Land Between The Lakes, KY and TN. Dept. Plant Biology, Southern Illinois Univ., Carbondale.

70. Heikens, A. and P. A. Robertson. Unpublished data. Fire frequency in dry-land oak communities of southern Illinois. Dept. Plant Biology, Southern Illinois Univ., Carbondale.

71. Wallace, B. J. 1988. History of Land Between The Lakes. Pp. 84–144. In D. H. Snyder (ed.) Proc. First Annual Symposium on the Natural History of the Lower Tennessee and Cumberland River Valleys. Center for Field Biology, Austin Peay State Univ., Clarksville, Tennessee.

72. Barton, J. E. 1919. The amount of standing timber in Kentucky. Kentucky Department of Geography and Forestry, Series 5, Bulletin No. 1–4:251–284.

73. Burns, R. M. and B. H. Honkala. 1990. Silvics of North America. Vol. 2. Hardwoods. U.S.D.A. Ag. Handbook 654.

74. Waring, R. W. and W. H. Schlesinger. 1985. Forest ecosystems concepts and management. Academic Press Inc., Orlando, Florida.

75. Franklin, S. B., P. A. Robertson, J. S. Fralish, and S. M. Kettler. 1993. Overstory vegetation and successional trends of Land Between The Lakes, U.S.A. J. Veg. Sci. 4(4):1–12.

76. Parker, G. R. 1989. Old-growth forest of the Central Hardwoods Region. Nat. Areas J. 9:5–11.

77. Fralish, J. S., F. B. Crooks, J. L. Chambers, and F. M. Harty. 1991. Comparison of presettlement, second growth and old-growth forest on six site types in the Illinois Shawnee Hills. Am. Midl. Nat. 125:294–309.

78. Shotola, S. J., G. T. Weaver, P. A. Robertson, and W. C. Ashby. 1992. Sugar maple invasion of an old-growth oak-hickory forest in southwestern Illinois. Am. Midl. Nat. 127:125–138.

79. Haq, B. U. and F. W. B. van Eysinga. 1987. Geologic time table: fourth revised enlarged and updated edition. Elsevier Science Publishers Inc., New York.

APPENDIX A. Common name, generic name, specific epithet, and taxonomic authority for species used in text.

Scientific name	Common name
Acer negundo L.	Box elder
saccharum Marsh.	Sugar maple
Aesculus glabra Willd.	Ohio buckeye
Alnus serrulata (Ait.) Willd.	Smooth alder
Amelanchier arborea (Michx. f.) Fern.	Serviceberry
Andropogon gerardii Vitman	Big bluestem
gyrans Ashe	Elliott's broom sedge
virginicus L.	Broom sedge
Arundinaria gigantea (Walt.) Chapm.	Giant cane
Asimina triloba (L.) Dunal	Paw-paw
Campsis radicans (L.) Seem.	Trumpet creeper

APPENDIX A. Continued.

Scientific name	Common name
Carya glabra (Mill.) Sweet	Pignut hickory
illinoensis (Wangenh.) K. Koch	Pecan
laciniosa (Michx. f.) Loud.	Shellbark hickory
ovata (Mill.) K. Koch	Shagbark hickory
tomentosa (Poir.) Nutt.	Mockernut hickory
Castanea dentata (Marsh.) Borkh.	American chestnut
Cephalanthus occidentalis L.	Buttonbush
Cercis canadensis L.	Eastern redbud
Cladrastis lutea (Michx. f.) K. Koch	Yellowwood
Cornus florida L.	Flowering dogwood
Corylus americana Walt.	American hazelnut
Cucurbita pepo L.	Pumpkin
Diospyros virginiana L.	Persimmon
Fagus grandifolia Ehrh.	American beech
Fimbristylis puberula (Michx.) Vahl.	Fimbristylis
Forestiera acuminata (Michx.) Poir.	Swamp privet
Galactia volubilis (L.) Britt.	Downy milk pea
Gleditsia triacanthos L.	Honeylocust
Gymnocladus dioicus (L.) K. Koch	Kentucky coffee-tree
Juglans nigra L.	Black walnut
Juniperus virginiana L.	Eastern red cedar
Lindera benzoin (L.) Blume.	Spicebush
Liriodendron tulipifera L.	Tulip poplar
Liquidambar styraciflua L.	Sweetgum
Magnolia acuminata L.	Cucumber magnolia
Malus angustifolia (Ait.) Michx.	Narrow-leaved crab apple
Nyssa aquatica L.	Swamp tupelo
sylvatica Marsh.	Black gum
Opuntia compressa (Salisb.) Macbr.	Prickly-pear cactus
Oxydendrum arboreum (L.) DC.	Sourwood
Panicum angustifolium Ell.	Narrow-leaved panic grass
Parthenium integrifolium L.	American feverfew
Pinus banksiana Lamb.	Jack pine
echinata Mill.	Shortleaf pine
resinosa Ait.	Red pine
virginiana Mill.	Virginia pine
Planera aquatica J. F. Gmel.	Planertree
Platanus occidentalis L.	American sycamore
Populus deltoides Bartr. ex Marsh.	Eastern Cottonwood
Quercus alba L.	White oak
bicolor Willd.	Swamp white oak
coccinea Muenchh.	Scarlet oak
falcata Michx.	Southern red oak
lyrata Walt.	Overcup oak
macrocarpa Michx.	Bur oak
marilandica Muenchh.	Blackjack oak
nigra L.	Water oak
palustris Muenchh.	Pin oak
phellos L.	Willow oak
prinus L.	Chestnut oak
stellata Wangenh.	Post oak
rubra L.	Northern red oak
velutina Lam.	Black oak
Salix humilis Marsh.	Prairie willow
Sassafras albidum (Nutt.) Nees	Sassafras
Schizachyrium scoparium (Michx.) Nash.	Little bluestem
Sorghastrum nutans (L.) Nash.	Indian grass
Taxodium distichum (L.) Rich.	Bald cypress
Toxicodendron radicans (L.) Kuntze.	Poison ivy
Tsuga canadensis (L.) Carr.	Eastern hemlock
Zea mays L.	Corn

Trans. Ky. Acad. Sci., 55(1–2), 1994, 20–27

The Relict Darter, *Etheostoma chienense* (Percidae): Status Review of a Kentucky Endemic[1]

Melvin L. Warren, Jr.
USDA Forest Service, Southern Forest Experiment Station, Forest Hydrology Laboratory, P.O. Box 947, Oxford, Mississippi 38655

and

Brooks M. Burr and Christopher A. Taylor[2]
Department of Zoology, Southern Illinois University at Carbondale, Carbondale, Illinois 62901

Abstract

The distribution, microhabitat affinity and availability, and conservative estimates of numbers of *Etheostoma chienense,* the relict darter, were assessed. All known historical sites and sites in nearby drainages that might harbor the species were surveyed. The relict darter is endemic to the Bayou du Chien drainage, Graves and Hickman counties, Kentucky, where it is most abundant in Jackson Creek and a limited reach of upper Bayou du Chien near the town of Water Valley. The species has a decided affinity for undercut banks and adjacent narrow (<4 m), shallow (<25 cm), moderately flowing (<0.3 m/sec) runs underlain with sandy gravel. At the 5 sites yielding the species, estimates of the extent of suitable habitat ranged from <5 to 110 m of stream. Suitable cover and spawning habitat were deemed primary limiting factors for the species. Given its limited distribution and apparent dependence on one spawning area, the relict darter is extremely vulnerable to anthropogenic activities.

Introduction

The relict darter, *Etheostoma chienense* Page and Ceas, a recently described member of the *Etheostoma squamiceps* complex (subgenus *Catonotus,* family Percidae), is endemic to the Bayou du Chien drainage of western Kentucky (1). Because the species is restricted in distribution and has a limited spawning area, it is being considered for federal listing as an endangered or threatened species (2, 3). We summarize here the findings of a status survey of the relict darter (2) including a near-comprehensive review and summary of the literature related to its taxonomy, biology, and distribution.

Materials and Methods

All known contemporary and historical literature regarding the relict darter was reviewed and relevant findings summarized or referenced herein (see Appendix I for summary of all known historical sites). In 1991, selected localities in Bayou du Chien and Obion Creek drainages, Kentucky, were surveyed for the relict darter using standard minnow seines and dip nets (see Appendix II for complete locality data on sites surveyed or reconnoitered). Institutional acronyms are given in Appendix I and follow Leviton et al. (4) and Leviton and Gibbs (5).

To characterize the habitat of the relict darter, we measured stream width, depth, and velocity at the site of capture as well as the overall channel width. Velocity was determined by repeatedly timing a submerged object over a given distance. Substrate and cover at each capture site also were recorded.

Results

Taxonomy and Synonymy.—The relict darter is one of 10 recognized species in the *Etheostoma squamiceps* complex of the subgenus *Catonotus* and is the sister species to a monophyletic group comprised of *E. pseudovulatum, E. neopterum,* and *E. oophylax* (1). The relict darter was first recognized as a distinct taxon by Page et al. (1), although apparently

[1] As this article went to press the U.S. Fish and Wildlife Service determined the relict darter to be Endangered under the authority of the Endandered Species Act of 1973 (Fed. Reg. 58(246):68480–68486).

[2] Present address (CAT): Center for Biodiversity, Illinois Natural History Survey, Champaign, Illinois 61820.

it was first discovered in Bayou du Chien by Webb and Sisk (6; reported as *E. squamiceps*). In other publications, the relict darter has been included in the synonymy of the spottail darter (*E. squamiceps*) by Burr (7), Page (8), Kuehne and Barbour (9), and Page (10); and the lollypop darter (*E. neopterum*) by Braasch and Mayden (11), Burr and Warren (12), and Page and Burr (13). Distinguishing features of the subgenus *Catonotus* and the *E. squamiceps* complex, as well as a complete description and illustrations of the relict darter, were provided by Page et al. (1). Braasch and Mayden (11) also provided illustrations of the species (as *Etheostoma neopterum,* see 11, Figs. 2b and 13, upper half-tone).

Distribution.—The relict darter is known only from the Bayou du Chien system in western Kentucky (Appendix I). Bayou du Chien is a small primarily sand and mud bottomed Coastal Plain stream in extreme western Kentucky that drains about 554 km^2 (12). To provide perspective on the likelihood of persistence or occurrence of the relict darter in other drainages, we note that previous survey work in surrounding drainages, including Clarks River (14, 15) and Obion River (16 and records at SIUC, UT, INHS) failed to reveal any species possibly representing the relict darter. Moreover, the immediately adjacent drainages of Mayfield and Obion creeks have failed to yield the species. Historical collections from Mayfield and Obion creeks were made by Woolman (17) at Hickory Grove and Cypress, Kentucky, respectively, but no species representing the subgenus *Catonotus* were reported by him. Smith and Sisk (18) provided information specifically documenting the fauna of Obion Creek from 39 collections at 21 stations but did not report any species currently placed in the subgenus *Catonotus*.

Our review of records compiled by Burr and Warren (12) and recently updated at SIUC indicate that at least 42 collections are represented for Mayfield Creek, excluding those made in wetlands. Likewise, records for 56 collections (including those in 18) are available for the Obion Creek mainstem and tributaries. We also examined 5 sites in Brushy Creek (Obion Creek drainage) which has its headwaters immediately adjacent Jackson Creek and upper Bayou du Chien and, given this geographical proximity, is a logical area to search for the species. However, of the 5 sites visited, 3 were completely dry, and relict darters were not collected from the remaining 2 (see Appendix II).

TABLE 1. Summary of present and historical distribution localities and numbers of individuals observed of the relict darter, an endemic species of Bayou du Chien in Fulton, Graves, and Hickman counties, Kentucky. Localities are arranged from upstream to downstream (complete locality information is referenced by site number and/or catalog number in Appendix I and II). ND = not determined; NA = not available.

Locality	Number of Individuals	
	1991	Pre-1991
Bayou du Chien (Site 2, NE Water Valley)	5	NA*
Bayou du Chien (Hwy 45)	ND	NA*
Jackson Cr. (Site 1)	18	100+
Bayou du Chien (Site 3, Hwy 1283)	46	2
Bayou du Chien (Site 4, Hwy 307)	2	3
Sand Creek (Hwy 307)	0	NA*
Bayou du Chien (Site 5, Davis Rd.)	1	2
Little Bayou du Chien (Hwy 239 bridge)	0	NA*
Bayou du Chien (UT 91.2839, N of Moscow)	0	1

* Webb and Sisk (1975), specimens unavailable.

Within the Bayou du Chien drainage, the downstream-most locality known from previous collections of the relict darter is in the vicinity of Moscow, Hickman County (but see following) (Table 1). The upstream-most locality is from Bayou du Chien, NW of Water Valley (Table 1, Site 2). This site in Jackson Creek has been surveyed by us and others (Appendices I and II) in March, April, August, and September, and consistently has yielded numerous relict darters. Our survey revealed only 1 other locality (Site 3) that harbored the species in abundance (Table 1). Site 3 previously has yielded only 1 individual (INHS 68008, Appendix I).

Habitat and Population Density.—We attempted to quantify the habitat affinities of the relict darter at the 5 sites in our survey that yielded the species (Table 2). At most sites, the species was associated with slow flow, undercut banks (and associated root mats), and substrates of fine gravel mixed with sand and overlain with leaf litter. At sites along the mainstem of Bayou du Chien, the species showed a decided affinity for undercut banks

TABLE 2. Microhabitat characteristics of the relict darter. Site numbers are referenced in Appendix II. D = mean depth, nearest cm (range in parentheses); W = mean width, nearest 0.1 m (range in parentheses); CW = maximum stream channel width, nearest 0.1 m; V = velocity, m/sec; No. = number of individuals captured; cover, predominant type; substrate, predominant type.

Site	D	W	CW	V	No.	Cover	Substrate
1	9 (3–18)	2.5 (2.1–2.8)	2.8	0.04	18	Undercut bank	Gravel/sand
2	10 (3–16)	3.0 (2.0–4.0)	4.0	0	5	Undercut bank	Gravel/sand
3	18 (9–26)	2.5 (2.0–3.2)	13.0	0.29	46	Undercut bank	Gravel/sand
4	13 (8–15)	11.0 (10–12)	12.0	0.48	2	None	Sand/mud/gravel
5	22 (9–32)	2.0	12.0	0.55	1	Undercut bank	Gravel

adjacent narrow (2–3 m) side channels underlain by gravel mixed with sand.

For sites at which the relict darter was most abundant, we attempted to estimate the extent (i.e., length in meters) of suitable habitat available. At Site 1, we estimated 7 individuals for every 10 meters of suitable habitat. Of the 150-m reach examined at this site, about 110 m provided suitable habitat for the relict darter. Extrapolating, we estimated (conservatively) that 80 individuals may occupy the site (i.e., about 75 m upstream and downstream of the bridge). At Site 3, 36 individuals were taken within a 15-m reach of stream consisting of a narrow channel adjacent an undercut bank lined with root mats. Of the 100-m reach examined at Site 3, approximately 50 m appeared to comprise excellent habitat for the relict darter; hence, 120 individuals (conservatively) could occupy the site (i.e., about 50 m upstream and 50 m downstream of the bridge). At sites where few individuals were taken, we estimated extent of suitable habitat as follows: Site 2, <15 m; Site 4, <5 m; Site 5, 15 m. These estimates exclude intervening reaches of these streams that were not surveyed because of limited access and may be confounded by concentrations of individuals at specific points at some sites (e.g., Sites 1 and 3) or capture of one or 2 individuals in nonspecific habitats (e.g., Site 4). However, suitable habitat does not appear to be uniformly distributed in tributaries of Bayou du Chien or the mainstem but is patchy and localized in the system.

Ecology.—Presently, little is known of the ecology of the relict darter, other than its affinity for undercut banks of small creeks and its use of the undersides of sticks and logs for attachment of eggs. Other *Catonotus* generally use slab rocks for spawning. However, information is available on the ecology of other members of the *E. squamiceps* complex (10, 19, 20), all of which undoubtedly share similar life history attributes.

Within the Bayou du Chien system, only 1 spawning area has been identified (viz., Site 1) (1). In our survey, the species was associated in upper reaches with creek chub, *Semotilus atromaculatus,* and blackspotted topminnow, *Fundulus olivaceus.* Additional frequent associates in the mainstem Bayou du Chien included the saddleback darter (*Percina ouachitae*), suckermouth minnow (*Phenacobius mirabilis*), and freckled madtom (*Noturus nocturnus*).

DISCUSSION

The endemism of the relict darter in Bayou du Chien is unique. No other fish species shares a similarly restricted distribution anywhere on the northern Gulf Coastal Plain of Arkansas, Kentucky, Missouri, or Tennessee (12, 21, 22, 23). Other species restricted to the northern Gulf Coastal Plain, such as least madtom (*Noturus hildebrandi lautus*) and firebelly darter (*Etheostoma pyrrhogaster*), are unknown in Bayou du Chien and are distributed in 2 or more Mississippi River tributaries. We conclude that it is extremely unlikely that additional populations of the relict darter will be discovered outside the immediately adjacent drainage area of Bayou du Chien given the following: (1) the habitat affinities of the relict darter; (2) the complete allopatry between it and its closest relatives (i.e., *E. oophylax, E. pseudovulatum,* and *E. neopterum* all occur to the east in the Tennessee River drainage); (3) the absence of any other species in the *E. squamiceps* complex in Mississippi River tributaries in Kentucky and Tennessee except the relict darter and *E. cros-*

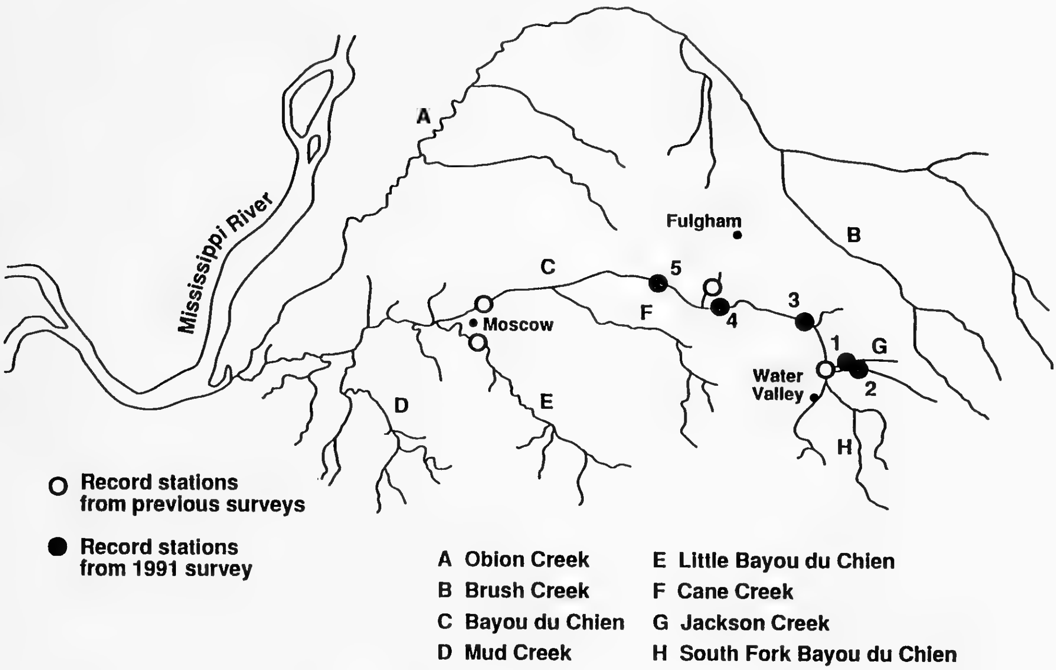


FIG. 1. Localities yielding relict darters (*Etheostoma chienense*) in 1991 (solid circles) and historically (open circles) from Bayou du Chien drainage, Fulton, Graves, and Hickman counties, Kentucky. Complete locality information for positive records as well as all stations surveyed is provided in Appendices I and II. Site numbers are referenced in Tables 1 and 2 and Appendix I.

sopterum; and (5) the availability of summaries of species composition in these drainages that do not record the relict darter (12, 23). As judged from all previous collecting efforts and known distribution of the relict darter, it is clear that the species is restricted to a very limited reach of Bayou du Chien.

As judged from the number of specimens taken in collections from 1972 to 1991 within the Bayou du Chien drainage, the relict darter is most abundant in Jackson Creek (Site 1) and downstream in Bayou du Chien to Site 3 (Table 1, Fig. 1). Although 5 individuals also were taken at Site 2 in isolated pools, the majority of the streambed was essentially dry. Other localities for the relict darter within Bayou du Chien apparently represent either emigrants or waifs from this extremely limited reach of the drainage since numerous visits to sites that yielded 1 or 2 individuals in total generally fail to yield even a single specimen. For example, Site 4 has been sampled at least 10 times by us or colleagues from 1979 to 1991, but only 5 relict darters have been collected from that site (16 July and 11 November 1980 and this survey). We expended over 3 man-hours seining at this site and captured only 3 relict darters. Likewise, between 1978 and 1991 at least 11 collections were made in Bayou du Chien, Little Bayou du Chien, and their respective tributaries in the vicinity of Moscow, Hickman Co. (Fig. 1), but the only positive records of the relict darter from these downstream reaches are those reported by Webb and Sisk (6; including UT 91.2839, 1 individual). The occurrence of the relict darter outside of the Jackson Creek drainage and reaches of Bayou du Chien immediately downstream of Jackson Creek is highly unpredictable.

In prehistoric times, the relict darter may have been more widespread in Bayou du Chien but still restricted to reaches of the watershed lying upstream of the Mississippi River floodplain (i.e., presently from about Moscow and upstream). Bayou du Chien followed a very sinuous course to the Mississippi River floodplain prior to channelization. Channel sinuosities likely afforded a plethora of both undercut banks and associated gravel deposits, which as indicated by this survey support most of the relict darters in the drainage (Table 2). Channelization also removed instream cover and spawning substrates as well as riparian vegetation. Channelization and agricultural practices dewatered the floodplains and curtailed perennial flow in many small tributaries which further limited the habitat of the species. Our survey indicates that many small streams in the watershed are completely dry or consist of isolated pools during the early fall months (Appendix II). Both adults and young-of-the-year trapped in isolated pools are subject to increased pressure from predation, exposure to extremes in water temperature, and ultimately total dessication. These observations suggest dispersal of the species upstream of the Jackson Creek area or into many downstream tributaries may be limited by instream flow. If Jackson Creek is the primary area of recruitment, those individuals which do disperse from the tributary may not spawn (or spawn only infrequently) in flowing reaches of Bayou du Chien because of limited spawning substrates. The observed densities, distribution, and microhabitat availability of the relict darter implies that the species is habitat limited, and recruitment may be constrained by limited spawning substrates. The species is now very restricted in the Bayou du Chien drainage and may be dependent primarily on the integrity of one small tributary, Jackson Creek, for continued recruitment.

In short, probable historic reasons that may have restricted the spawning area, habitat, and distributional extent of the relict darter include: channelization of extensive reaches of the mainstem of Bayou du Chien (6) with concomitant homogenization of instream habitat as well as dewatering of floodplain tributaries; ditching of tributaries and removal of shade-producing riparian vegetation and concomitant decrease in habitat and increase in maximum stream temperatures; increased siltation associated with poor agricultural practices; and deforestation and drainage of riparian wetlands with concomitant decreases in instream low flow, especially in potential spawning areas. All of these factors have continued potential to reduce or eliminate the species.

The relict darter has only recently been recognized as distinct and is being considered for federal conservation status (2, 3). Page et al. (1) recommended that the species be recognized as threatened or endangered nationally because of present or threatened destruction, modification, or curtailment of its habitat or range. The Army Corps of Engineers recently evaluated alternatives to eliminate flooding (e.g., channelization) in the Bayou du Chien watershed and determined that no alternative was cost effective, and the evaluation was terminated (R. R. Cicerello, pers. comm.). Other federal, state, or local government projects that might impact the relict darter or its habitat are unknown at this time. We emphasize, however, that a single accidental chemical or animal waste spill, especially in Jackson Creek, could reduce the population below effective size and render recovery difficult if not impossible. Likewise, any local or individual actions involving modification of the riparian zones or the stream channel could adversely impact the species. Presently, the species receives no state protection, and even if statutory status is invoked, precedents suggest little action will be taken by the state to protect imperiled species or habitats (see Anderson 24). Finally, we implore our ichthyological colleagues to use utmost prudence in collection of the species. The epilogue would be a sorry one indeed if the relict darter became victim to those who would study it.

Notwithstanding potential threats, the presence of apparently healthy populations of the species in Bayou du Chien, even with spawning known from only a limited reach, indicates good potential for recovery of the species. At this point, recovery depends entirely on protection of the Jackson Creek watershed as well as nearby reaches of Bayou du Chien. Addition of spawning habitat (e.g., strategically placed logs or flat rocks) in Bayou du Chien at or near Site 3 (and perhaps other sites) might be a cost-effective means of establishing additional spawning areas and increasing recruitment, population size, and dispersion.

Presently, the only research program concerning the relict darter is the genetic analysis of the species and relatives (P. A. Ceas and L. M. Page, pers. comm.) and our status survey. Research needs on the species include: (1) an autecological study focusing on quantification of seasonal microhabitat preferences and dispersal of different life stages; (2) spring monitoring of Site 3 to determine if spawning actually occurs at or near that reach of Bayou du Chien; (3) identification of additional streams in the Bayou du Chien watershed that could be used to transplant breeding individuals (or guardian males and nests) and ultimately establish additional spawning populations; (4) long-term monitoring of population trends and watershed conditions; and (5) testing the efficacy of addition of spawning substrates to Sites 1 and 3 (or others) in enhancement of recruitment, survival, and dispersion.

ACKNOWLEDGMENTS

We wish to thank P. A. Ceas and L. M. Page (INHS) for graciously providing us with an advance copy of the description of the relict darter as well as sharing collecting information, field observations, and generally enthusiastically supporting this study. We also thank K. M. Cook (SIUC) for field assistance and R. M. Strange (SIUC) for review of a draft. We gratefully acknowledge the following individuals and their respective institutions for providing field and/or logistical assistance, locality information, and numerous other courtesies: R. R. Cicerello and R. R. Hannan, Kentucky State Nature Preserves Commission; R. G. Biggins, U.S. Fish and Wildlife Service; and D. A. Etnier, UT. This study was supported in part by the Office of Endangered Species, U.S. Fish and Wildlife Service, Asheville, North Carolina and the Southern Forest Experiment Station, USDA Forest Service.

LITERATURE CITED

1. Page, L. M., P. A. Ceas, D. L. Swofford, and D. G. Buth. 1992. Evolutionary relationships within the *Etheostoma squamiceps* complex (Percidae; subgenus *Catonotus*) with descriptions of five new species. Copeia 1992: 615–646.

2. Warren, M. L., Jr. and B. M. Burr. 1991. Status survey of the relict darter, *Etheostoma chienense* (family Percidae): a species endemic to Bayou du Chien, western Kentucky. Final Report, U.S. Fish and Wildlife Service, Office of Endangered Species, Asheville, North Carolina. 33 pp.

3. Biggins, R. G. 1992. Endangered and threatened wildlife and plants: proposal to list the relict darter and bluemask (=jewel) darters as endangered species. Federal Register 57(239):58774–58779.

4. Leviton, A. E., R. H. Gibbs, Jr., E. Heal, and C. E. Dawson. 1985. Standards in herpetology and ichthyology: Part I. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. Copeia 1985: 802–832.

5. Leviton, A. E. and R. H. Gibbs, Jr. 1988. Standards in herpetology and ichthyology. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. Supplement No. 1: additions and corrections. Copeia 1988:280–282.

6. Webb, D. H. and M. E. Sisk. 1975. The fishes of west Kentucky III. The fishes of Bayou du Chien. Trans. Ky. Acad. Sci. 36:63–70.

7. Burr, B. M. 1980. A distributional checklist of the fishes of Kentucky. Brimleyana No. 3:53–84.

8. Page, L. M. 1980a. *Etheostoma squamiceps* Jordan, spottail darter. P. 696. In D. S. Lee, et al. (eds.) Atlas of North American freshwater fishes. N.C. State Mus. Nat. Hist., Raleigh, North Carolina.

9. Kuehne, R. A. and R. W. Barbour. 1983. The American darters. University Press of Kentucky, Lexington, Kentucky.

10. Page, L. M. 1983. Handbook of darters. TFH Publications, Neptune City, New Jersey.

11. Braasch, M. E. and R. L. Mayden. 1985. Review of the subgenus *Catonotus* (Percidae) with descriptions of two new darters of the *Etheostoma squamiceps* species group. Occas. Pap. Mus. Natural Hist., Univ. Kan. 119:1–83.

12. Burr, B. M. and M. L. Warren, Jr. 1986. A distributional atlas of Kentucky fishes. Ky. Nature Preserves Commission Sci. Tech. Ser. No. 4.

13. Page, L. M. and B. M. Burr. 1991. A field guide to freshwater fishes, North America north of Mexico. Houghton Mifflin Co., Boston, Massachusetts.

14. Sisk, M. E. 1969. The fishes of west Kentucky. I. Fishes of Clark's River. Trans. Ky. Acad. Sci. 30:54–59.

15. Kuhajda, B. R. and M. L. Warren, Jr. 1985. Clarks River revisited: additions to the ichthyofauna. Trans. Ky. Acad. Sci. 46:144–145.

16. Dickinson, W. C. 1973. The fishes of the Obion River system. M.S. Thesis. University of Tennessee, Knoxville, Tennessee.

17. Woolman, A. J. 1892. Report of an examination of the rivers of Kentucky, with lists of the fishes obtained. Bull. U.S. Fish Comm. 10:249–288.

18. Smith, P. L. and M. E. Sisk. 1969. The fishes of west Kentucky. II. The fishes of Obion Creek. Trans. Ky. Acad. Sci. 30:60–68.

19. Page, L. M. 1974. The life history of the spottail darter, *Etheostoma squamiceps*, in Big Creek, Illinois, and Ferguson Creek, Kentucky. Ill. Natural Hist. Survey Biol. Notes No. 89.

20. Page, L. M. 1980b. The life histories of *Etheostoma olivaceum* and *Etheostoma striatulum*, two species of darters in central Tennessee. Ill. Natural Hist. Survey Biol. Notes No. 113.

21. Pflieger, W. L. 1975. The fishes of Missouri. Missouri Dept. Conservation, Jefferson City, Missouri.

22. Robison, H. W. and T. M. Buchanan. 1988. Fishes

of Arkansas. University of Arkansas Press, Fayetteville, Arkansas.

23. Etnier, D. A. and W. C. Starnes. In press. The fishes of Tennessee. University of Tennessee Press, Knoxville, Tennessee.

24. Anderson, R. M. 1989. The effect of coal surface mining on endangered freshwater mussels (Molluska: Unionidea) in the Cumberland River drainage. M.S. Thesis. Tennessee Technological University, Cookeville, Tennessee.

APPENDIX I

Summary of all known collection localities of the relict darter prior to this survey. Catalog numbers are followed in parentheses by the number of specimens. Institutional acronyms: INHS, Illinois Natural History Survey; KU, University of Kansas; SIUC, Southern Illinois University at Carbondale; UAIC, University of Alabama Ichthyological Collection; UL, University of Louisville; UMMZ, University of Michigan, Museum of Zoology; USNM, National Museum of Natural History; UT, University of Tennessee; Webb and Sisk (1975), disposition of most specimens reported by these authors (as *E. squamiceps*) is unknown. BAYOU DU CHIEN DRAINAGE: INHS 61720 (33) Jackson Cr., 2.6 km NE Water Valley, on Roy Lawrence Dr., Graves Co., 24 Apr 1986. INHS 63526 (45), as above, 18 Aug 1987. INHS 63920 (21), SIUC 18067 (5), UAIC 9998.01 (5), UMMZ 217893 (5), USNM 313758 (5), UT 91.3849 (5), as above, 7 Apr 1988. INHS 58454 (1), as above, 18 Mar 1990. INHS 58221 (33), as above, 18 Mar 1990. INHS 87178 (1), Bayou du Chien, 4.8 km S Fulgham, Hickman Co., 16 July 1980. INHS 68008 (1), Bayou du Chien, 4.5 km N Water Valley, Hickman Co., 23 Aug 1984. SIUC 1175 (2), Bayou du Chien, same as INHS 87178, at Rt 307, 11 Nov 1980. SIUC 1185 (2), Bayou du Chien, 4.8 km SW Fulgham, Hickman Co., 11 Nov 1980. UL 5992 (1), Bayou du Chien system, Hickman Co. (as *E. neopterum in* Braasch and Mayden 1985). UT 91.2839 (1), Bayou du Chien, 0.8 km NW Moscow, Hickman Co., 7 Aug 1973. KU 20900 (1), Bayou du Chien, N of Water Valley, Graves Co., 5 Apr 1981. Webb and Sisk (1975), Station 9, [Little?] Bayou du Chien, 6.4 km N Cayce at Hwy 239, Fulton Co., day/month unknown, 1972–1973 (this station is either Bayou du Chien at Hwy 239, Hickman Co. or Little Bayou du Chien, at Hwy 239, Fulton Co.). Webb and Sisk (1975), Station 10, Bayou du Chien, same as UT 91.2839. Webb and Sisk (1975), Station 14, same as SIUC 1185, day/month unknown, 1972–1973. Webb and Sisk (1975), Station 15, same as SIUC 1175, day/month unknown, 1972–1973. Webb and Sisk (1975), Station 16, Sand Cr., 4 km S Fulgham, at Hwy 307, Hickman Co., day/month unknown, 1972–1973. Webb and Sisk (1975), Station 17, same as INHS 68008, day/month unknown, 1972–1973. Webb and Sisk (1975), Station 18, 1.6 km NW [NE?] Water Valley, at Hwy 45, Graves Co., day/month unknown, 1972–1973. Webb and Sisk (1975), Station 19, 3.2 km NE Water Valley, near Bayou du Chien Church, Graves Co., day/month unknown, 1972–1973.

APPENDIX II

Sites surveyed and reconnoitered for the relict darter in 1991. A. Catalog numbers and complete locality information for sites yielding relict darters (all Bayou du Chien drainage). Site 1: SIUC 18787, Jackson Cr., 2.6 km NE Water Valley on Roy Lawrence Dr., Graves Co., 21 Sept 1991. Site 2: SIUC 18802, Bayou du Chien, 3.2 km NE Water Valley on Bayou du Chien Rd., 0.4 km S jct. with Roy Lawrence Dr., Graves Co., 21 Sept 1991 (same as Webb and Sisk 1975, station 19). Site 3: SIUC 18759, Bayou du Chien, 4.5 km N Water Valley on Hwy 1283, Graves/Hickman county line, 21 Sept 1991. Site 4: SIUC 18779, Bayou du Chien, at Hwy 307 bridge, 4.8 km S Fulgham, Hickman Co., 21 Sept 1991. Site 5: SIUC 18792, Bayou du Chien, at Davis Rd. bridge, 4.8 km SW Fulgham, Hickman Co., 21 Sept 1991. B. Sites sampled or reconnoitered that did not yield relict darters. Field observations are summarized in parentheses following the locality information. BAYOU DU CHIEN DRAINAGE: Bayou du Chien, at Howell Rd., 5.6 km SW Fulgham, Hickman Co., 21 Sept 1991 (diverse fish fauna, but gravel limited, steep banks, slow current). Bayou du Chien, at Hwy 239 bridge, 0.8 km E Moscow, Hickman Co., 22 Sept 1991 (limited, but suitable, habitat for relict darter, but none taken; diverse fish fauna, many lowland species; gravel limited, good flow, undercut banks present; little spawning habitat available). Bayou du Chien, just N Moscow, Fulton Co., 21 Sept 1991 (mud bottom, no flow, steep banks, wide stream). Unnamed trib., Bayou du Chien, Hwy 924 bridge, Fulton Co., 18 April 1991 (sand bottom, small). Unnamed trib., Bayou du Chien, at Rose Rd. bridge, 6.7 km SE Fulgham, Hickman Co., 21 Sept 1991 (extreme headwater fish fauna, very small, no current, little gravel, no undercut banks). Browder Cr., at Hwy 166 bridge, Fulton Co., 18 April 1991 (0.6-m wide, sand bottom, no flow). Cane Cr., Hwy 1698 bridge, Hickman Co., 18 April 1991 (littered with solid waste, sand and some gravel). Cane Cr., at Rushton Rd. bridge, Hickman Co., 18 April 1991 (small, sand bottom). Cane Cr., at Hwy 307 bridge, Hickman Co., October 1991 (dry). Cane Cr., at Hwy 924 bridge, Hickman Co., 18 April 1991 (sand bottom, small, dry). Cane Cr., at Cooley Rd. bridge, Hickman Co., 22 Sept 1991 (dry). Cane Cr., at Howell Rd. bridge, Hickman Co., 22 Sept 1991 (dry). Unnamed trib., Cane Cr., at Byrd Rd. bridge, Hickman Co., 22 Sept 1991 (dry). Cane Cr., at Hwy 1529 bridge, 6.4 km E Moscow, Hickman Co., 22 Sept 1991 (lowland stream, primarily mud bottom, turbid water, littered with solid waste, some gravel in one riffle). Little Bayou du Chien, at Hwy 239 bridge, 1.6 km S Moscow, Hickman/Fulton county line, 22 Sept 1991 (lowland stream, soft, mud bottom, little flow, no riffle habitat). Little Bayou du Chien, at Hwy 94 bridge, 3.2 km W Cayce, Fulton Co., 5 Oct 1991 (small bayou with bald cypress, fairly deep, no flow, mud bottom). Little Bayou du Chien, at Hwy 1125 bridge, 5.2 km SSW Buda, Fulton Co., 18 April 1991 (ditched, no flow, mud and sand bottom), 5 Oct 1991 (turbid, mostly mud bottom, no flow, small stream lowland fish fauna). Little Bayou du Chien, Hwy 1907 bridge, Fulton Co., 18 April 1991 (no flow, sand and mud bottom). Little Bayou du Chien, at Thompson Fields Rd. bridge, Fulton Co., 5 Oct 1991 (dry). Unnamed trib., Little Bayou du Chien, Hwy 166 bridge, Fulton Co., 18 April 1991 (no flow, sand and mud bottom). Unnamed trib., Little Bayou du Chien, Hwy 1125 bridge, Fulton Co., 18 April 1991 (small). Mud Cr., Hwy 1127 bridge, Fulton Co., 18 April 1991 (mud and sand bottom). Mud Cr., Hwy 1128 bridge, Fulton Co., 18 April 1991 (little flow, turbid, mud and sand bottom). Mud Cr., at Hwy 94 bridge, 5.6 km W Cayce, Fulton Co., 5 Oct 1991 (very narrow, no flow, steep muddy banks, mud bottom). Pond Br., at Hwy 307 bridge, Hickman Co., 21 Sept 1991 (dry). Rush Cr., at Hwy 94 bridge, Fulton Co. (dry). Sand Cr., at Hwy 307 bridge, 4.2 km S Fulgham, Hickman Co., 21 Sept 1991 (no flow, only isolated pools, nearly dry, no fish collected). Verhine Cr., at Hwy 94 bridge, Fulton Co. 5 Oct 1991 (dry). South Fk. Bayou du Chien, at Pea Ridge Rd., 0.4 km NE Water Valley, Graves Co., 21 Sept 1991 (no gravel, no flow, no undercut banks). OBION CREEK DRAINAGE (all Graves Co.): Brush Cr., at Cuba Rd., 8 km ENE Water Valley, 5 Oct 1991 (almost dry, one pool contained only creek chubs). Brush Cr., at Ira Bell Rd., 6.8 km NE Water Valley, 5 Oct 1991 (closest to headwaters of Bayou du Chien, but almost dry, water turbid, no undercut banks, gravel soft, negligible flow). Brush Cr., at Hwy 58 bridge, 5 Oct 1991 (dry). Barn Cr., at Wingo Rd. bridge 5 Oct 1991 (dry).

Trans. Ky. Acad. Sci., 55(1–2), 1994, 28–31

Diet of the Spotted Darter, *Etheostoma maculatum* (Pisces: Percidae): A Threatened Species in Kentucky

Richard K. Kessler

Large Rivers Program and Biology Department,
University of Louisville, Louisville, Kentucky 40292

Abstract

A stomach-flushing technique was used to assess the diet of the threatened spotted darter, *Etheostoma maculatum*, in Russell Creek, Kentucky. Forty four *E. maculatum* were collected for food-habit analysis in July and October, 1991, representing the first recorded occurrence of the species in Russell Creek. Interseasonal variation in total number of prey consumed, frequency of prey taxa in the diet, and mean relative abundance of items in the diet were observed. Spotted darters consumed mainly chironomid larvae in both months but also ate water mites, mayflies (mainly Heptageniidae and Oligoneuriidae), stoneflies, and caddisflies (mainly Hydropsychidae). Feeding substantially increased in October (avg. no. items/stomach = 16.5 versus 7.5 for July). A shift in prey taxa was noted as chironomids, water mites, and stoneflies increased and mayflies and caddisflies decreased in October. Further study of the prey relationships of *E. maculatum* is needed to establish food preferences and identify potential interspecific interactions. This information should allow more effective monitoring of its status.

Introduction

Etheostoma maculatum, the spotted darter, is a threatened species in Kentucky (KY) (1). Its distribution throughout the Ohio River basin is extremely localized (2) and it has disappeared from much of its former range (3, 4). Little is known of the life history of the spotted darter. The studies (5, 6) that examined ecological interactions of *E. maculatum* subspecies in the Tennessee and Cumberland River systems no longer apply. Since *E. maculatum vulneratum* and *E. m. sanguifluum* have been elevated to *E. vulneratum,* the wounded darter, and *E. sanguifluum,* the bloodfin darter (7, 8), the only ecological treatments of *E. maculatum* are those of Kessler (9) and Kessler and Thorp (10), who discussed microhabitat segregation between *E. maculatum* and the closely-related orangefin darter, *E. bellum,* in Russell Creek, KY, and Raney and Lachner (11) from their early observations of the species.

The purpose of this study was to examine the food habits of the spotted darter. The objective was not to establish actual prey preferences of *E. maculatum,* but merely to more precisely establish the components of its diet in a Kentucky stream.

Methods and Materials

Fish Collection.—Fish were collected from Russell Creek, a fifth-order tributary of the upper Green River system, Green County, KY (85°29′48″W, 37°11′18″N) on 10–12 July and 18–20 October 1991. Pre-positioned electrofishers were used to collect fish (12). Sampling protocol followed that of Kessler (9) and Kessler and Thorp (10).

Gut Content Removal.—A stomach-flushing technique modified from Culp et al. (13) was used to avoid sacrificing individuals. Fish >38 mm were anesthetized with a 100 mg/liter solution of MS-222 (Finquel) and standard length (SL) recorded before gut contents were removed. A small (1.27 mm OD) polyethylene tube was inserted into the mouth of each hand-held fish and pushed gently into the gut until resistance was felt. Tubing was pre-fitted over a 24-gauge hypodermic needle which was attached to a syringe. Stream water (3 cc) was then forced into the gut with the syringe and the tube was removed slowly to allow gut contents to flow out of the mouth through a funnel and into a glass vial. Gut contents were preserved in 70% ethanol, taken to the laboratory, and taxa were identified (14). Fish were allowed to recover fully in a holding cage and returned to the stream.

Statistics.—Total numbers of prey items consumed and frequency of occurrence of prey in the diet was determined for each sampling period. One-way analysis of variance was used to determine whether numbers of specific prey items or mean relative abundance of

TABLE 1. Total number and percent occurrence of food items in the diet of *E. maculatum* for July (n = 24) and October (n = 20) 1991. Asterisks (*) represent foods making up <1% of total diet. Abbreviations: l = larvae, p = pupae, a = adult.

Food item	July		October	
	Total no.	%	Total no.	%
Acari	5	2.8	16	4.9
Coleoptera				
Elmidae	1	*	—	—
Gyrinidae	1	*	—	—
Terrestrial (l)	1	*	—	—
Diptera				
Chironomidae (l)	75	41.9	211	64.5
Chironomidae (a)	—	—	1	*
Simuliidae (l)	9	5.9	—	—
Simuliidae (p)	1	*	—	—
Tipulidae	1	*	—	—
Ephemeroptera				
Baetidae	5	2.8	6	1.8
Caenidae	1	*	1	*
Heptageniidae	11	6.1	6	1.8
Oligoneuriidae	19	10.6	7	2.1
Other	6	3.4	5	1.5
Plecoptera				
Perlidae	1	*	12	3.7
Other	—	—	39	11.9
Trichoptera				
Glossosomatidae	1	*	—	—
Hydropsychidae	34	19.0	20	6.1
Lepidostomatidae	1	*	—	—
Leptoceridae	1	*	2	*
Other	4	2.2	2	*
Zygoptera	1	*	—	—
Total	179		327	

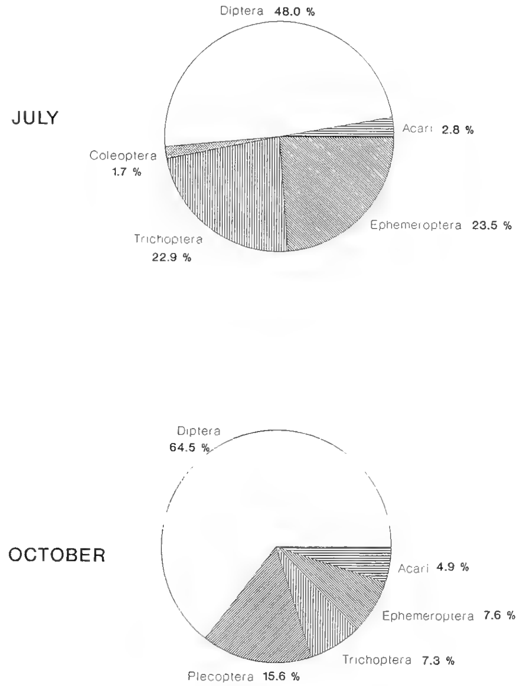


FIG. 1. Comparison of the per cent frequencies of total items, based on major prey taxa only, occurring in the diet of *E. maculatum* in July and October, 1991.

prey varied significantly between sampling periods. Mean relative abundance is based on the proportion of a food item present in the gut of individuals relative to the total number of items in the gut.

RESULTS

Forty four spotted darters (24 in July, 20 in October) were used for diet analysis. Fish size ranged from 38.1 to 71.6 mm (mean SL ± 1 SD = 46.7 mm ± 6.1 SD). No mortalities were observed within an hour of sampling.

Food of *E. maculatum* is similar to that reported for benthic darters by Page (3). Of the individual stomachs containing food (43 out of 44), 93% had consumed chironomids and dipteran larvae (including Chironomidae and Simuliidae), comprising the bulk of the diet in both July (47.8%) and October (64.5%) (Table 1, Fig. 1). Other frequent prey items included water mites (Acari), mayflies (especially Heptageniidae and Oligoneuriidae), stoneflies, and caddisflies (especially Hydropsychidae). Infrequent items included beetles and damselflies.

Variation in both total food consumed and prey taxa existed between sampling periods (Table 1). Individuals consumed less food in July than in October (average no. of items per stomach = 7.5 versus 16.5, respectively). More taxa (Orders) were consumed in July (n = 7) than in October (n = 5). Based on total number of items ingested per individual, more chironomids ($P < 0.001$), stoneflies ($P < 0.0001$), and water mites ($P < 0.05$) were eaten in October. Mean relative abundance of items in the diet of individuals also changed. Relative abundance of dipterans and plecopterans significantly increased while that of mayflies and caddisflies decreased (Table 2).

DISCUSSION

Prey items common to *E. maculatum* are similar to those reported for darters in the

TABLE 2. A comparison of the mean relative abundance of prey items per individual for July and October 1991. Parenthetical numbers are 1 SD. NS = not significant at $P < 0.05$; ind. = individual.

Taxa	Mean Relative abundance/ind.		P
	July	October	
Acari	0.032 (0.074)	0.073 (0.127)	NS
Diptera	0.413 (0.310)	0.584 (0.209)	<0.05
Ephemeroptera	0.282 (0.266)	0.116 (0.150)	<0.05
Plecoptera	0.000 —	0.166 (0.092)	<0.0001
Trichoptera	0.239 (0.214)	0.074 (0.075)	<0.005

subgenus *Nothonotus*, including *E. acuticeps* (15), *E. bellum* (16), *E. camurum* (17), *E. sanguifluum* (op. cit.) and *E. vulneratum* (5). The spotted darter is most likely an opportunistic forager as its terminal mouth and pointed snout enable it to feed from virtually any rock surface. Page and Swofford (18) discussed the relationship of mouth morphology to diet. This may explain its ability to extract hydropsychid caddisflies from their retreats or exploit rock-dwelling mayflies (especially Heptageniidae) and stoneflies. Kessler (9) observed such foraging behavior during snorkeling observations in Russell Creek. Bryant (6) and Butler (17) noted the efficiency of *E. acuticeps* and *E. sanguifluum* in similar foraging activity.

Feeding intensity and seasonality in diet composition most likely is associated with prey availability which may vary depending on availability of foraging habitat, feeding activity of the fish, or life history characteristics of prey (19). Seasonal life cycles among invertebrates of temperate streams often reflect an increase in certain prey numbers in the fall or a decrease in mid- to late summer (20). The increase in the total numbers of prey consumed in fall versus summer was due largely to an increase in chironomids in the diet. Others (17, 21, 22) have documented fall increases in food consumption. In this study the October sampling period was characterized by reduced flows relative to July (Kessler, Weddle, and Casper, unpubl. data) which may have limited availability of foraging areas and habitat for prey. Hlohowskyj and Wissing (23) suggested that during such conditions, increasing predation on numerically abundant chironomids might limit competition and increase feeding efficiency. However, Wynes and Wissing (24) found that rainbow, banded, and greenside darters exhibited a feeding decline in autumn. They concluded that feeding intensity was associated with temperature but that changes in diet composition were a result of shifts in invertebrate taxa abundances. The increase of chironomids and stoneflies ingested in October was associated with a decrease of mayflies and caddisflies. This relationship has been found to exist for both numbers and biomass of mayflies and stoneflies for *E. camurum* and *E. sanguifluum* (19). In his study of *E. flabellare*, Strange (21) found that mayflies were an important food in the summer but were replaced by stoneflies in the fall.

In summary, the spotted darter's diet is most likely linked to its feeding morphology. Shifts in feeding intensity and diet composition are probably related to shifts in prey availability but further research is needed to substantiate such assumptions. Data on actual prey preference (by number, volume, or biomass) and foraging behavior may be especially important to the darter's conservation status.

ACKNOWLEDGMENTS

I wish to thank E. Durham, Fang Wei, T. Henderson, C. Houk, H. Kessler, S. Kessler, G. Weddle, and W. Wilcoxson for help in the field and M. Delong and J. Glover for laboratory assistance. The Biology Department, Campbellsville College, allowed use of a generator and provided an on-site location for material storage. The Water Resources Laboratory, University of Louisville, provided partial support for this project.

LITERATURE CITED

1. Warren, M. L., et al. 1986. Endangered plants and animals in Kentucky. Trans. Ky. Acad. Sci. 47:83–98.

2. Cicerello, R. R. and M. L. Warren. 1984. Range extensions and drainage records for four Kentucky fishes. Trans. Ky. Acad. Sci. 45:157–158.

3. Page, L. M. 1983. Handbook of darters. T. F. H. Publishers, Neptune City, New Jersey.

4. Kuehne, R. A. and R. W. Barbour. 1983. The American darters. Univ. of Kentucky Press, Lexington, Kentucky.

5. Stiles, R. A. 1972. The comparative ecology of three species of *Nothonotus* (Percidae: *Etheostoma*) in Tennessee's Little River. Ph.D. Dissertation. Univ. of Tennessee, Knoxville, Tennessee.

6. Bryant, R. T. 1979. The life history and comparative

ecology of the sharphead darter, *Etheostoma auticeps*. Tenn. Wildl. Res. Agency Tech. Rep. 79-50:1–60.

7. Robins, C. R., et al. 1991. Common and scientific names of fishes from the United States and Canada, 5th American Fisheries Society Spec. Publ. 20, Bethesda, Maryland.

8. Page, L. M. and B. M. Burr. 1991. A field guide to freshwater fishes. Houghton Mifflin Company, Boston, Massachusetts.

9. Kessler, R. K. 1992. Mechanisms promoting coexistence in two closely-related darters (Pisces: Percidae). M.S. Thesis. Univ. of Louisville, Kentucky.

10. Kessler, R. K. and J. H. Thorp. 1993. Microhabitat segregation of the threatened spotted darter (*Etheostoma maculatum*) and closely-related orangefin darter (*E. bellum*). Can. J. Fish. Aquat. Sci. 50:1084–1091.

11. Raney, E. C. and E. A. Lachner. 1939. Observations on the life history of the spotted darter, *Poecilichthyes maculatus* (Kirtland). Copeia 1939:157–165.

12. Weddle, G. K. and R. K. Kessler. 1993. A square-meter electrofishing sampler for benthic riffle fishes. J. N. Am. Benthol. Soc. 12:291–301.

13. Culp, J. M., I. Boyd, and N. E. Glozier. 1988. An improved method for obtaining gut contents from small, live fishes by anal and stomach flushing. Copeia 1988: 1079–1082.

14. Merritt, R. W. and K. W. Cummins. 1984. An introduction to the aquatic insects of North America, 2nd ed. Kendall/Hunt Publ. Company, Dubuque, Iowa.

15. Jenkins, R. E. and N. M. Burkhead. 1975. Recent capture and analysis of the sharphead darter, *Etheostoma acuticeps*, an endangered percid fish of the upper Tennessee River drainage. Copeia 1975:731–740.

16. Fisher, W. L. 1990. Life history and ecology of the orangefin darter *Etheostoma bellum* (Pisces: Percidae). Am. Midl. Nat. 123:268–281.

17. Butler, R. S. 1986. Comparative feeding ecology of darters (Percidae: *Etheostoma*) in Buck Creek, Pulaski County, Kentucky. M.S. Thesis. Eastern Kentucky Univ., Richmond, Kentucky.

18. Page, L. M. and D. L. Swofford. 1984. Morphological correlates of ecological specialization in darters. Env. Biol. Fish. 11:139–159.

19. Wootton, R. J. 1992. Ecology of teleost fishes. Chapman and Hall Publishers, New York, New York.

20. Hynes, H. B. N. 1970. The ecology of running waters. Univ. of Toronto Press, Toronto, Canada.

21. Strange, R. M. 1993. Seasonal feeding ecology of the fantail darter, *Etheostoma flabellare*, from Stinking Fork, Indiana. J. Freshwater Ecol. 8:13–18.

22. Weddle, G. K. 1992. Seasonal, sexual, and size class variation in the diet of the Kentucky darter, *Etheostoma rafinesquei* (Pisces: Percidae), in Middle Pitman Creek, Kentucky. Trans. Ky. Acad. Sci. 53:121–126.

23. Hlohowskyj, I. and A. M. White. 1983. Food resource partitioning and selectivity by the greenside, rainbow, and fantail darters (Pisces: Percidae). Ohio J. Sci. 83: 201–208.

24. Wynes, D. L. and T. E. Wissing. 1982. Resource sharing among darters in an Ohio stream. Am. Midl. Nat. 107:294–304.

Trans. Ky. Acad. Sci., 55(1–2), 1994, 32–35

Seasonal Prevalence of Three Species of Digenetic Trematodes in the Snail *Helisoma trivolvis* at Owsley Fork Reservoir, Kentucky

Ronald B. Rosen, Jose M. Ilagan, Jessica S. Law, Marichelle Asuncion, Melissa E. Denton, and Manuel L. San

Department of Biology, Berea College, Berea, Kentucky 40404

Abstract

Trematode parasites were examined in the snail, *Helisoma trivolvis*, from Owsley Fork Reservoir in central Kentucky. *Echinostoma trivolvis* was the most prevalent trematode during the 12-month survey (15.4%), followed by *Cephalogonimus vesicaudus* (10.8%) and *Spirorchis scripta* (3.4%). Prevalence of *E. trivolvis* peaked in July (27.0%), while *C. vesicaudus* (24.0%) and *S. scripta* (18.2%) peaked in May and June, respectively. Prevalence of *E. trivolvis* and *C. vesicaudus* increased in larger snails, while that of *S. scripta* decreased. Seasonal prevalence is discussed in relation to the life cycles of these parasites and the biology of their various hosts.

Introduction

Esch and his colleagues (1–6) examined the trematode parasites of two snails (*Helisoma anceps* and *Physa gyrina*) from a fresh water pond in North Carolina. They found that the seasonal prevalence of each parasite was affected by snail biology (i.e., natality, mortality, vagility, growth and susceptibility) and by the nature of the parasite's life cycle. For example, infections by the autogenic species (i.e., species that complete their life cycles within the pond, generally in hosts confined to the pond throughout the year (6)) were present much of the year, while an allogenic species (i.e., species that complete their life cycles in hosts ephemeral to the pond (6)) was less prevalent. Appearance of the allogenic species in the snail population was correlated with the arrival of migratory waterfowl (definitive hosts) and subsequent infection of the snails by short-lived miracidia. By contrast, prevalence of the autogenic species was associated with daily foraging behavior of snails and occasional ingestion of an unhatched trematode egg. (A trematode egg is really a shelled embryo (miracidium) which is the hatching stage of the parasite). Esch's work suggested that recruitment of a trematode parasite into a snail population is, indeed, determined primarily by the migratory habits of definitive hosts and the source of infection (egg versus miracidium) for the snail.

To test this prediction in a different aquatic system, we conducted a year-long study of trematode parasites in a single species of snail, *Helisoma trivolvis,* from an impoundment near Berea, Kentucky. The purpose was to identify the autogenic and allogenic species of parasites and determine their seasonal prevalence in the snail host. The patterns of parasite prevalence in the snail population were compared, and the results reported in this paper.

Materials and Methods

Owsley Fork Reservoir was completed in 1975 and currently provides approximately 60% of the water supply for the community of Berea, Kentucky. The reservoir has a surface area of 61.1 hectares, a maximum depth of 12.1 m, and its watershed encompasses 1,823.2 hectares. Water temperature at 0.5 m varied from a high of 27°C in July to a low of 4°C in February during the study. Snails were collected monthly ($\bar{x}$ = 63/month; range 22–100) from 2 small coves immediately across from the Owsley Fork Baptist Church. Snails were allowed to acclimate to room temperature for 24 hr and then placed individually into 50 ml beakers containing 35–40 ml of filtered pond water. The beakers were then placed in an incubator set at 26°C and a 12 hr light:12 hr dark cycle for 24 hr. Beakers were observed with a dissecting microscope at 14:00, 20:30 and 8:30 to determine which snails were releasing cercariae and thus possessed mature cercarial infections. The shell diameters were recorded, and all snails were dissected and examined for larval trematodes. It was assumed that shell size is indicative of host age, although individuals of *H. trivolvis* of similar age may differ in size (7). Our subsequent analysis of seasonal prevalence was confined to snail infections clearly established by ingestion of embryonated trematode eggs or miracidial penetration as indicated by the presence of either sporocysts or rediae.

RESULTS

Morphological observations and measurements of cercariae and intramolluscan stages (i.e., rediae or sporocysts), along with successful experimental infections of second intermediate and definitive hosts with cercariae or metacercariae established the following identifications for digeneans recovered from *H. trivolvis* at Owsley Fork Reservoir; *Echinostoma trivolvis* (Cort, 1914) Kanev, 1985, *Cephalogonimus vesicaudus* Nickerson, 1912, *Spirorchis scripta* Stunkard, 1923 and *Petasiger nitidus* Linton, 1928. Only the initial 3 species were assessed in this study as *P. nitidus* was encountered in just 2 snails.

Echinostoma trivolvis was the most prevalent digenean during the survey (15.4%), followed by *C. vesicaudus* (10.8%) and *S. scripta* (3.4%). Prevalence of *E. trivolvis* peaked in July (27.0%), while *C. vesicaudus* (24.0%) and *S. scripta* (18.2%) peaked in May and June, respectively (Fig. 1). During months of peak prevalence, infected snails usually shed mature cercariae, indicating that most infections were patent. A notable exception was observed in June when only 28% of snails infected with *E. trivolvis* released cercariae of that species (Fig. 1). Prevalence of the 3 trematodes in *H. trivolvis* increased during the late spring or early summer (Fig. 1). Infections with *S. scripta* decreased by mid-summer and disappeared by November, while snails infected with *E. trivolvis* and *C. vesicaudus* were encountered until February (Fig. 1). Prevalence of *E. trivolvis* and *C. vesicaudus* increased in larger snails, while that of *S. scripta* decreased (Fig. 2). Notably, no snails in the 1.9–2.3 cm size class were found to be infected with *S. scripta* (Fig. 2).

DISCUSSION

Echinostoma trivolvis utilizes a few mammals and various migratory waterfowl as definitive hosts. The latter are temporary residents

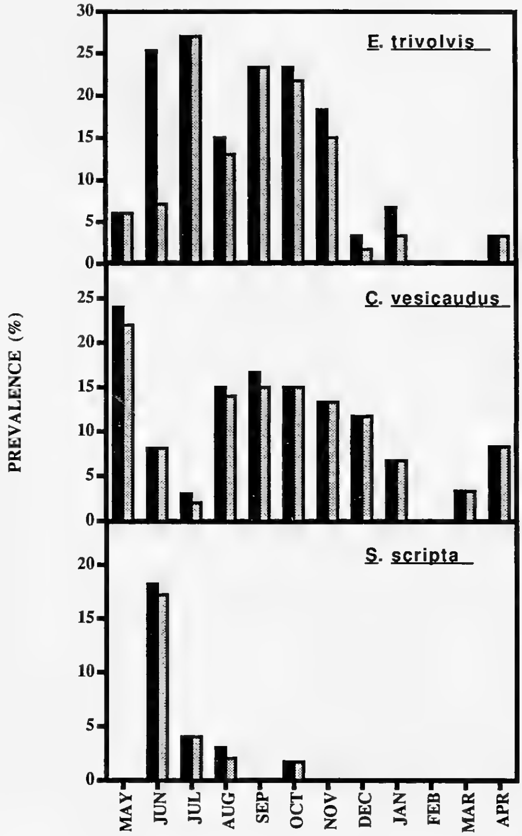


FIG. 1. Monthly prevalence of the snail, *Helisoma trivolvis*, infected with *Echinostoma trivolvis*, *Cephalogonimus vesicaudus* and *Spirorchis scripta* (solid box) and snails releasing cercariae of these three species (stippled box) during May–April 1992–1993.

of aquatic systems, and thus contamination of these habitats with eggs of *E. trivolvis* and infection of snails by its short-lived miracidium should be brief, culminating in a restricted period of snail infection characteristic of an allogenic species. In a previous study, the prevalence of *E. trivolvis* in the snail, *P. gyrina*, was negative in April, peaked in June, and declined until disappearing in November (6). Similar observations were made for this digenean in *H. anceps* (4). In our study, *E. trivolvis* experienced 2 increases in prevalence (i.e., late spring and early fall) separated by a summer decline. In this regard, the seasonal prevalence of *E. trivolvis* was more characteristic of an autogenic rather than an allogenic species. *Cephalogonimus vesicaudus*, which in-

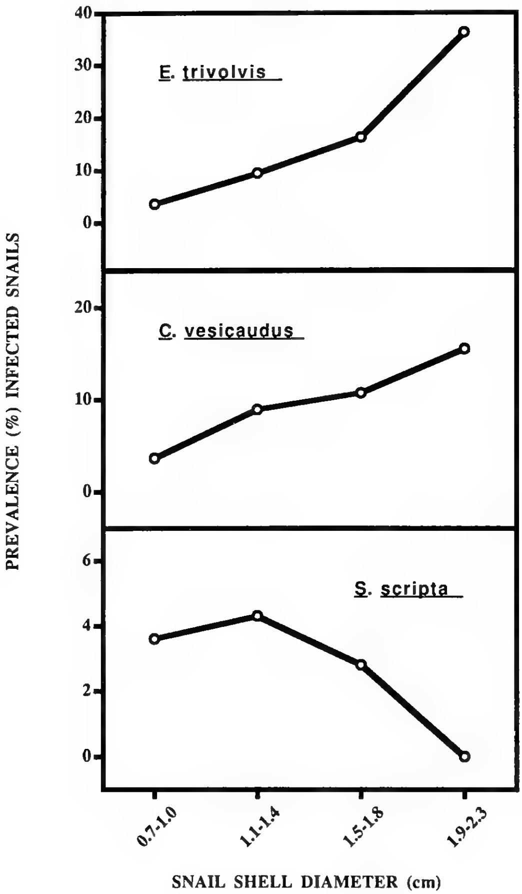


FIG. 2. Prevalence of *Echinostoma trivolvis*, *Cephalogonimus vesicaudus* and *Spirorchis scripta* in four size classes of the snail, *Helisoma trivolvis*, collected from May–April 1992–1993. (Number of snails/size class—0.7–1.0 cm, N = 28; 1.1–1.4 cm, N = 235; 1.5–1.8 cm, N = 432; 1.9–2.3 cm, N = 58).

corporates a turtle definitive host and relies on the ingestion of its embryonated eggs by snails, conformed to the predicted pattern of sustained prevalence for an autogenic species, but *S. scripta* did not. *Spirorchis scripta*, which also incorporates a turtle definitive host in its life cycle but utilizes a miracidium for infection of its snail host, had a markedly restricted prevalence pattern in *H. trivolvis* which was primarily confined to the month of June. The single June increase was identical to that previously documented for a spirorchiid in *H. anceps* (4).

We observed that only 28.0% of snails infected with *E. trivolvis* possessed mature cercariae during the month of June; however, by July, all snails infected with *E. trivolvis* had mature cercariae. As *E. trivolvis* requires a 4–6 week period for development in a snail following exposure to miracidia (8), its first period of snail infection likely began in late May and early June. During May, 1992, a small flock of Canadian geese, *Branta canadensis*, arrived at Owsley Fork and remained within the coves in our study site until September. The geese, documented hosts of *E. trivolvis* (9), likely provided a constant source of miracidia of this parasite for infection of *H. trivolvis*. Peak prevalence of *C. vesicaudus* (May) and *S. scripta* (June) were also associated with a late spring infection and subsequent cercarial development in snails (i.e., 45 days for *C. vesicaudus* in *H. trivolvis* (10) and 27–34 days for *S. scripta* in *H. anceps* (11)). This initial period of infection correlates well with the April/May emergence of aquatic turtles such as *Trionyx spiniferus* and *Trachemys scripta* (hosts for *C. vesicaudus* and *S. scripta*, respectively) from hibernation in the mud (12), and their subsequent release of digenean eggs into the water with their feces. The restricted time (i.e., primarily June) during which snails were found to be infected with *S. scripta* suggested that adults of this species release embryonated eggs for only a limited period each year, and that the longevity of snails subsequently infected by its miracidium is brief. The July and August decrease in prevalence of *C. vesicaudus* and *E. trivolvis*, respectively, may have been correlated with the entry of large numbers of uninfected snails from a new cohort into the population rather than an actual decrease in the number of infected snails as was noted in a previous study of *Halipegus occidualis* in *H. anceps* (3). This is corroborated by our observation during March and April of a large number of snail egg capsules containing developing larvae of *H. trivolvis* attached to the shells of snails, and the subsequent appearance of many small snails in the population during the summer at Owsley Fork. The ensuing increase in prevalence of *C. vesicaudus* (August) and *E. trivolvis* (September) noted in our survey was not observed for the latter species in prior studies (4, 6), and may have been related to infection of snails in the new cohort. The prevalence of snails infected with *E. trivolvis* and *C. vesi-*

caudus began decreasing in late fall, and no snails were found infected with these trematodes by February. Mark-recapture studies have shown that this phenomenon may be associated with either parasite-induced host mortality or loss of infection (2, 4). In addition, turtle hibernation and the observed departure of geese after September at Owsley Fork likely decreased sources for new winter infections of *H. trivolvis* with these digeneans.

Previous studies have indicated that *E. trivolvis* is only infective to younger snails in natural infections of *H. anceps* (3, 4). However, it has been shown in experimental infections that the size of *H. trivolvis* has no effect on its susceptibility to miracidia of *E. trivolvis* (13). Without an age-related resistance, the prevalence of this parasite would be expected to increase in older/larger snails over time (as observed in our study) due to their increased exposure to miracidia and recruitment of younger, infected snails into this larger size class of hosts. The greater prevalence of *S. scripta* in younger/smaller snails indicated decreased susceptibility with age. Supporting this conclusion is the observation that adults of *H. anceps* cannot be infected with *S. scripta* and sporocyst development of this species occurs only in young snails (11). In addition, recruitment of smaller snails infected with *S. scripta* into the largest size class (1.9–2.3 cm) of *H. trivolvis* did not occur, suggesting relatively rapid, parasite-induced host mortality following infection of these younger snails. Rapid snail mortality would, in part, explain the restricted seasonal prevalence observed for *S. scripta* in *H. trivolvis*.

In summary, the 3 digeneans in this study can be classified as autogenic species due to the prolonged presence of their definitive hosts at Owsley Fork Reservoir. The predicted pattern of sustained monthly prevalence associated with autogenic species was observed for *E. trivolvis* and *C. vesicaudus*, but not *S. scripta*. Additional factors, including age-related susceptibility of snails and rapid snail mortality following infection, must be further assessed in order to acquire an understanding of the seasonal prevalence of the latter species.

ACKNOWLEDGMENTS

This study was supported by a grant from Merck & Co., Inc., to R. Rosen and the Department of Biology at Berea College. We would also like to acknowledge Christine Daubenspeck and Audrey d'Souza for technical assistance provided during the course of the project.

LITERATURE CITED

1. Crews, A. E. and G. W. Esch. 1986. Seasonal dynamics of *Halipegus occidualis* (Trematoda: Hemiuridae) in *Helisoma anceps* and its impact on fecundity of the snail host. J. Parasitol. 72:646–651.

2. Goater, T. M., A. W. Shostak, J. A. Williams, and G. W. Esch. 1989. A mark-recapture study of trematode parasitism in overwintered *Helisoma anceps* (Pulmonata), with special reference to *Halipegus occidualis* (Hemiuridae). J. Parasitol. 75:553–560.

3. Williams, J. A. and G. W. Esch. 1991. Infra- and component community dynamics in the pulmonate snail *Helisoma anceps,* with special emphasis on the hemiurid, *Halipegus occidualis.* J. Parasitol. 77:246–253.

4. Fernandez, J. and G. W. Esch. 1991. Guild structure of larval trematodes in the snail *Helisoma anceps*: patterns and processes at the individual host level. J. Parasitol. 77:528–539.

5. Fernandez, J. and G. W. Esch. 1991. The component community structure of larval trematodes in the pulmonate snail *Helisoma anceps.* J. Parasitol. 77:540–550.

6. Snyder, S. D. and G. W. Esch. 1993. Trematode community structure in the pulmonate snail *Physa gyrina.* J. Parasitol. 79:205–215.

7. Boerger, H. 1975. A comparison of the life cycles, reproductive ecologies, and size-weight relationships of *Helisoma anceps, H. campanulatum* and *H. trivolvis* (Gastropoda, Planorbidae). Can. J. Zool. 53:1812–1824.

8. Huffman, J. E. and B. Fried. 1990. *Echinostoma* and echinostomiasis. Adv. Parasitol. 29:215–269.

9. Doss, M. A. and M. M. Farr. 1969. Subjects: Trematoda and Trematoda diseases Part 11: hosts: genera A-L. Index Catalogue of Medical and Veterinary Zoology, U.S.D.A. U.S. Gov. Print. Office, Washington, D.C.

10. Dronen, N. O., Jr. and H. T. Underwood. 1977. The life cycle of *Cephalogonimus vesicaudus* (Digenea: Cephalogonimidae) from *Trionyx spiniferus* from Texas. Proc. Helm. Soc. Wash. 44:198–200.

11. Holliman, R. B. and J. E. Fisher. 1968. Life cycle and pathology of *Spirorchis scripta* Stunkard, 1923 (Digenea: Spirorchiidae) in *Chrysemys picta picta.* J. Parasitol. 54:310–318.

12. Barbour, R. M. 1971. Amphibians and reptiles of Kentucky. The University of Kentucky Press, Lexington, Kentucky.

13. Fried, B., S. Sheuermann, and J. Moore. 1987. Infectivity of *Echinostoma revolutum* miracidia for laboratory-raised pulmonate snails. J. Parasitol. 73:1047–1048.

Trans. Ky. Acad. Sci., 55(1–2), 1994, 36–41

Effects of Sodium Chloride on Beta-hemolytic Streptococci

Bola Fashola[1] and Larry P. Elliott[2]

Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

Abstract

Beta-hemolytic streptococci Lancefield group A, B, and C were isolated from the upper-respiratory tracts of patients and used to study the effects of NaCl on these isolates. The MIC of NaCl was determined for each of these 8 clinical isolates. Group A streptococci were inhibited at a concentration of 7.2% NaCl while group C streptococci were inhibited at 7.0% concentration. Group B streptococci were more resistant, and inhibition of growth occurred at 12.0% NaCl concentrations. Bactericidal concentrations of NaCl were also performed on the isolates and were 9.0% for group A, and 8.0% for group C. NaCl did not demonstrate any bactericidal activity toward the group B streptococci tested. Scanning electron microscopic studies showed no apparent effect on the external structure of streptococci treated with NaCl when compared to non-treated cells. Despite the lack of observable changes in the external structure of treated cells, fine structural alterations were observed with transmission electron microscopic studies. NaCl causes gross abnormalities, such as condensation of nucleoid DNA and some loss of ribosomes followed by dissolution of cell contents resulting in bacterial "ghosts" comprising an empty cell wall and capsule.

Introduction

Streptococcus pyogenes (group A streptococcus) has been recognized to be an important causative agent of bacterial pharyngitis, particularly in children 5–10 years of age. Early diagnosis and prompt treatment of streptococcal pharyngitis can limit the duration of symptoms, reduce infectivity, and prevent subsequent sequelae, such as rheumatic fever. Although the frequency of group A streptococcal infections and their sequelae has declined in the last few decades, during the latter half of the decade of the 1980s, there have been resurgences of this disease, not only in North America but also in Europe and other parts of the world (7). Beginning in 1984 there was a reemergence of rheumatic fever and shortly after, the appearance of a toxic shock-like syndrome due to group A streptococci.

While penicillin G is used clinically for treatment, salt water is the indigenous home remedy used world-wide for treatment of streptococcal pharyngitis. Despite the popularity of using sodium chloride as a home remedy, there is a paucity of information on the susceptibility of beta-hemolytic streptococci to sodium chloride.

The purposes of this study were as follows: (1) to determine if beta-hemolytic streptococci groups A, B, and C are susceptible to sodium chloride; (2) to determine susceptibility of the fresh isolates to sodium chloride as MICs or MBCs; and (3) to evaluate the effects of sodium chloride on the morphology and fine structure of these streptococci.

Materials and Methods

Bacteria

Eight strains of beta-hemolytic streptococci were randomly selected from upper-respiratory clinical isolates obtained from Greenview Hospital in Bowling Green, Kentucky. These streptococci were Lancefield groped by latex agglutination reagents (Streptex, Wellcome Reagents Div., Triangle Park, North Carolina). Of these 8 strains, 3 were identified as *Streptococcus pyogenes* (group A), 3 of *Streptococcus agalactiae* (group B), and 2 as *Streptococcus* (group C).

Determination of NaCl tolerance. The minimum inhibitory concentration (MIC) of the streptococci was determined using a broth macrodilution method (2, 6). Serial doubling dilutions of NaCl were prepared in 1.0 ml of Tryptic Soy Broth (TBS) (Difco Laboratories, Detroit). These tubes were inoculated with an overnight streptococcal culture in TSB which

[1] Present address: Humana Hospital, Greenbrier Valley, Davis Stuart Road, Ronceverte, West Virginia 24970.

[2] Address reprint requests to: Dr. L.P. Elliott, Department of Biology, Western Kentucky University, 1526 Russellville Rd., Bowling Green, Kentucky 42101-3576.

had been diluted to a concentration of 10^2–10^3 cfu/ml and into the control tubes without NaCl. After incubation at 37°C for 18–24 hr, the MIC was measured as the lowest concentration of NaCl at which no growth was visible. Before sampling for minimum bactericidal concentration (MBC) the tubes were shaken and 0.1 ml samples from turbid tubes were spread over the surface of Tryptic Soy Agar plates (Difco). The plates were then incubated at 37°C for 24 hr. MBC was considered the lowest concentration of NaCl which reduced the inoculum by 99.9% within 24 hr.

Electron Microscopy

Samples were removed from the MIC tubes after exposure to a concentration of sodium chloride that allowed sufficient growth of cells to be processed for scanning electron microscopy (SEM). The broth cultures were centrifuged at 4,000 × g for 10 min. The resulting pellets were washed twice, each time for 15 min in a 0.2 M cacodylate buffer (pH 6.5). The washed cells were then fixed in a 1% (v/v) solution of glutaraldehyde prepared in the above buffer. Fixation was performed overnight at 5°C. After fixation, the cells were again centrifuged and the pellets washed in cacodylate buffer for two consecutive 15-min periods. The fixed cells were then dehydrated in a graded series of ethanol. One drop of the cells suspended in 100% ethanol was added to each polylysine-coated coverslip (9, 13). The thin layer of cells was air dried, coated with a gold-palladium alloy (Au 60%, Pd 40%) and examined in a ISI Super IIIA SEM.

For transmission electron microscopy (TEM), cells were obtained, washed, pelleted, and fixed in glutaraldehyde as described above. After being washed twice in 0.2 M cacodylate buffer the cells were post fixed with 1% OsO_4 (2 hr) and then covered with melted agar tempered to 55–57°C. The cell-agar mixture was left to solidify and then cut into 2 mm^3 blocks. The cell-agar blocks were dehydrated in a graded series of ethanol prior to infiltration. A volume of Spurr low viscosity embedding plastic was added to the 100% ethanol cell suspension in a 1:3 mixture. After 2 hr, an amount of Spurr plastic sufficient to make a 2:2 mixture of plastic and ethanol was added and kept overnight. This was followed by a 3:1 infiltration mixture for 2 hr. Following infiltration and embedding in Spurr resin, cells were polymerized in BEEM capsules for 8 hr at 70°C. Ultrathin sections were cut with an Sorval MT2B ultramicrotome by using glass knives and mounted on copper grids. Sections were examined with Zeiss EM9 S-2 transmission electron microscope.

TABLE 1. Minimum inhibitory concentrations and minimum bactericidal concentrations of sodium chloride for various streptococcal isolates.

Clinical strains	MIC value(s) (g/ml) of NaCl	MBC value(s) (g/ml) of NaCl	Number of strains tested
Lancefield Group A	7.2	9.0	3
Lancefield Group B	12–13	25.5*	3
Lancefield Group C	7.0	8.0	2

* Cell viability was observed.

RESULTS

Minimum Inhibitory Concentrations

Table 1 shows the MICs of sodium chloride for the streptococci tested in TSB. The MIC of NaCl for *S. pyogenes* was 7.2. For comparison purposes, the MIC for NaCl for *Streptococcus* group C was 7.0, whereas for *S. agalactiae* 2 strains were 12.0 while one was 13.0. For groups A and C the MBC ranged from 8–9 g/ml; however, for group B NaCl did not have any bactericidal activity.

Cell Morphology

The appearance of all 8 streptococcal strains observed with SEM showed no obvious differences in their external morphology when comparing control and experimental organisms (Fig. 1a). Thus only a representative transmission electron micrograph is presented. The cells appeared to have retained turgidity, hence, the spherical morphology of the cells was maintained.

Definite changes in cells treated with NaCl were observed with the TEM. All streptococcal strains were observed but only representative transmission electron micrographs are shown. The appearance of group A streptococci in the absence of NaCl is shown in Fig. 1b. The nucleoid (arrow) is central, composed of fine, filamentous DNA. The cytoplasm contained darkly staining ribosomes which gave the cell a rough appearance. After exposure to an NaCl concentration of 6.5 g/ml for 18–24 hr, condensation of the DNA occurred, caus-

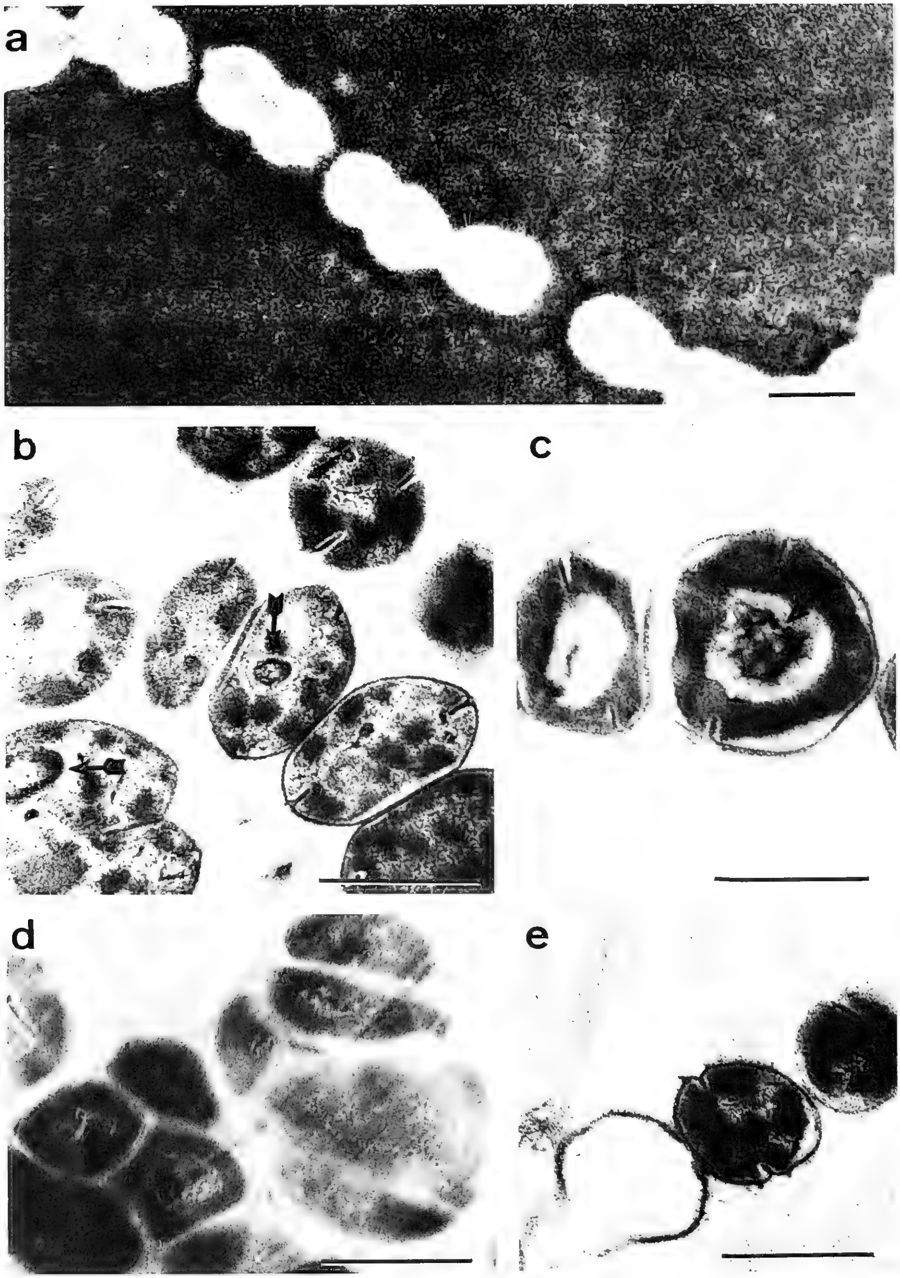


FIG. 1. Groups A and C streptococci. (a, scanning electron micrograph; b, c, d, and e, transmission electron microscopy). a, Group C no NaCl exposure. Bar, 1 μm; b, c, d, and e, Group A exposed to 6.5% NaCl. Bars = 0.5 μm.

ing an expansion of the clear zone and resulting in prominence of the nucleoid region (Fig. 1c). Affected cells also exhibited abortive attempts at cell division (Fig. 1d). These failures were in the form of membrane formation at the plane of division. The formed membranes appeared to lack orientation in their extension. This process resulted in the occurrence of several incomplete divisions leading to large, multisegmented, and misshapen cells. The final

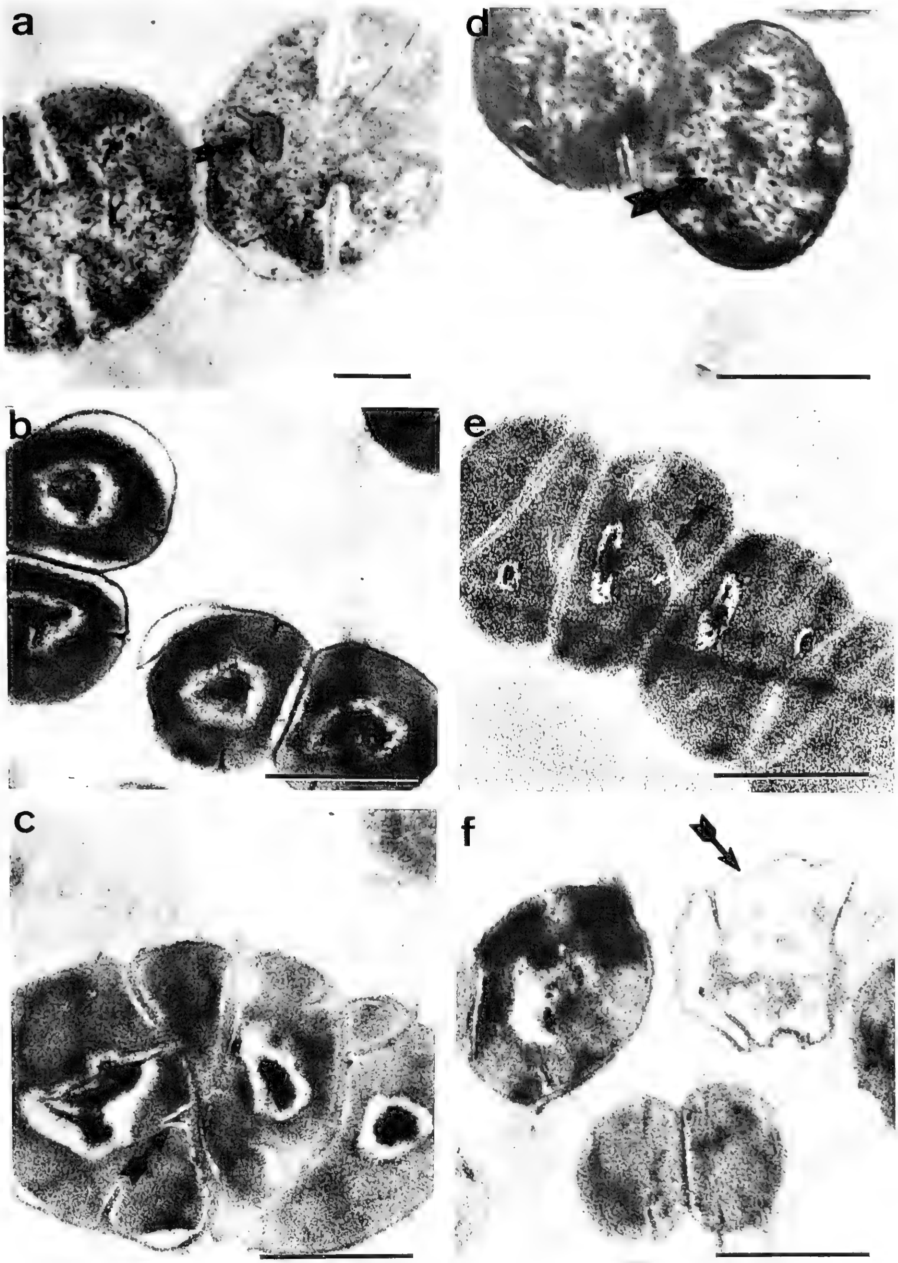


FIG. 2. Groups B and C streptococci. (a–e, transmission electron microscopy). a, Group B no NaCl exposure. Bar, 0.1 μm; b and c exposed to 11.5% NaCl. Bars, 0.5 μm; d, Group c exposed to no NaCl. Bar 0.5 μm; e and f exposed to 6.5% NaCl. Bars, 0.5 μm.

stage observed in these cells was the dissolution of the entire cytoplasmic contents, resulting in bacterial ghosts composed of intact cell walls lacking any organized internal structure (Fig. 1e).

Similar results were obtained with group B streptococci except that the treated cells were exposed to NaCl 11.5 g/ml for 18–24 hr (Fig. 2a, b, c). Similar results were obtained with group C streptococci treated with 6.5 g/ml for

18–24 hr. Bizarre defects were noted within these cells associated with cleavage sites (Fig. 2e) and ghost formation (arrow). The control cells of each group were interesting (Fig. 2a, d) since the group B streptococci had invagination of the plasma membrane (2a, arrow) and group C (2d, arrow) showed an unrestricted and filamentous form of the nucleoid material.

DISCUSSION

These results clearly demonstrate that NaCl inhibits Lancefield groups A, B and C streptococci and can cause gross morphological alterations to these cells. From a survey of 100 Western Kentucky University students, 52% stated that they gargle with salt water containing an average salt content of 2.4%. Our data suggest that concentrations of 7.2% NaCl should be used in order for inhibition of growth of group A streptococci to occur. A percentage 2.4 generally used for gargling falls far below the concentration required for inhibition of the group A streptococci that causes "strep" throat. This could be a reason for the resurgence of group A streptococcal infections in Europe and the USA. Kaplan (7) discussed the increase in severe streptococcal infections and their sequelae. Perhaps too many people are trying to treat streptococcal pharyngitis themselves, rather than seeing a physician for early diagnosis and prompt treatment. If people from all over the US and world are using salt water to gargle for a home remedy to control "strep" throat this delay in killing the streptococci could result in more severe infections.

Obviously, successful treatment of group A streptococci is aided by rapid detection and identification of the streptococci. Although Facklam et al. (4) recommend serological grouping for identifying streptococci they realized cost could keep some laboratories from pursuing this approach. Thus, they (4) recommended a battery of 5 tests for presumptive identification of pathogenic streptococci. Since 79.2% of their group B streptococci tested grew in the presence of 6.5% NaCl and 1.9% of their group A tested were salt tolerant, perhaps less emphasis should be placed on growth in 6.5% NaCl broth as a means of identification. An alternative procedure is to test for hydrolysis of L-pyrrolidonyl-β-naphthylamide (PYR). Group A streptococci and enterococci hydrolyze PYR (14); these microbes could then be differentiated by performing a bacitracin test. Recently Nadler (10) pointed out the difficulties in diagnosing streptococcal pharyngitis by the traditional culture methods and reviewed the methodologies that detect antigen directly in clinical samples. It is her belief that rapid tests can be performed more accurately and reliably in the physician's office or small laboratory, provided proper controls are run.

It was interesting to note that the bactericidal concentration of NaCl for group C streptococci was 8.0%, for group A 9.0% and when concentrations as high as 25.5% were used against B streptococci the microbes remained viable. Thus the response of streptococci to high osmolarity is a fundamental microbiological question. One common mechanism of adaptation to osmotic stress (osmoregulation) is the accumulation of inorganic and/or organic solutes in the cytoplasm to restore turgor in microbes (3). In gram-negative rods, glycine betaine often serves as an osmoprotectant. Little is known about the tolerance of gram-positive cocci or gram-positive rods to high concentrations of NaCl in growth medium. Sakaguchi (11) has found that glycine betaine gives osmotolerance to hyperosmolarity in *Pediococcus soyae* or in *Lactobacillus acidophilus,* betaine accumulation results in osmotolerance (5). The answer to what determines the ability of gram-positive cocci, particularly streptococci, to grow in an environment of osmotic stress may prove to be an excellent area for future research utilizing molecular biological techniques (8).

ACKNOWLEDGMENT

We thank the Faculty Research Committee of Western Kentucky University for a grant to help support this research.

LITERATURE CITED

1. Amako, K. 1977. Scanning electron microscopy of *Streptococcus.* J. Ultra. Res. 58:34–40.

2. Baron, E. J. and S. M. Finegold. 1990. Bailey & Scott's diagnostic microbiology. C.V. Mosby Co., St. Louis, Missouri.

3. Csonka, L. N. 1989. Physiological and genetic responses of bacteria to osmotic stress. Microbiol. Rev. 53: 121–147.

4. Facklam, R. R., J. F. Padula, L. G. Thacker, E. C.

Wortham, and B. J. Sconyers. 1974. Presumptive identification of group A, B, and D streptococci. Appl. Microbiol. 27:107–113.

5. Hutkins, R. W., W. L. Ellefson, and E. R. Kashket. 1987. Betaine transport imparts osmotolerance on a strain of *Lactobacillus acidophilus*. Appl. Environ. Microbiol. 53: 2275–2281.

6. Jones, R. N., A. L. Barry, T. L. Gavan, and J. A. Washington. 1985. In Manual of clinical microbiology. American Society for Microbiology, Washington, D.C.

7. Kaplan, E. L. 1991. The resurgence of group A streptococcal infections and their sequelae. Eur. J. Clin., Microbiol. Infect. Dis. 10:55–57.

8. Le Rudulier, D., A. R. Strom, A. M. Dandekar, L. T. Smith, and R. C. Valentine. 1984. Molecular biology of osmoregulation. Science 224:1064–1068.

9. Mazia, D., G. Schatten, and W. Sale. 1975. Adhesion of cells to surfaces coated with polylysine. J. Cell Biol. 66:198–200.

10. Nadler, H. L. 1989. Group A streptococcal detection. Diagnostic and Clin. Testing 27:34–41.

11. Sakaguchi, K. 1960. Betaine as a growth factor for *Pediococcus soyae*. VIII. Studies on the activities of bacteria in soy sauce brewing. Agric. Chem. Soc. Jpn. 24:489–496.

12. Weiss, R. L. 1984. A polylysine method for scanning electron microscopy. J. Electron Micros. 1:95–96.

13. Wellstood, S. A. 1987. Rapid, cost-effective identification of group A streptococci and enterococci by pyrrolidoyl-β-naphthylamide hydrolysis. J. Clin. Microbiol. 25:1805–1806.

Trans. Ky. Acad. Sci., 55(1–2), 1994, 42–45

Wood Duck Use and Availability of Natural Cavities in Western Kentucky

MARK P. VRTISKA[1] AND ROBERT B. FREDERICK

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

We estimated the availability and use of natural cavities suitable as nest sites for wood ducks (*Aix sponsa*) at the Sloughs Wildlife Management Area, Henderson and Union counties, Kentucky, in April–June 1988. The estimated density of suitable natural cavities was 1.26 ± 0.11 (SE) cavities/ha based on 62 0.5-ha plots. American Sycamore (*Platanus occidentalis*) contained the most cavities (30.8%), followed by ash (*Fraxinus* spp.) (25.6%), and maple (*Acer* spp.) (12.8%). Although used and unused cavities had similar mean values for the characteristics measured ($P > 0.05$), entrance width and entrance length exhibited less variance ($P < 0.05$) in used sites than in unused sites, and cavity depth exhibited greater variance ($P < 0.01$) in used sites than in unused sites. The results suggest that wood ducks might avoid cavities with larger entrance sizes and with intermediate depths (12–40 cm) in an attempt to avoid predation.

INTRODUCTION

Previous investigations of wood duck (*Aix sponsa*) nest sites have concentrated on man-made structures, although most wood ducks nest in natural cavities (1). In addition, little is known about the availability of natural cavities suitable for wood duck nesting (1). Information on the availability of such cavities might influence forest management practices (2) and the deployment of artificial nesting structures (3, 4), the primary management strategies for maintaining local populations of nesting wood ducks. We report the availability of natural cavities and their use by nesting wood ducks in a bottomland forest in western Kentucky.

MATERIALS AND METHODS

The study was conducted at the Sloughs Wildlife Management Area (WMA) on the Jennyhole and Highland Creek units, located in Henderson and Union counties, Kentucky. These units lie adjacent to each other and are located 6.4 km west of Smith Mills, Kentucky, and 2.4 km northeast of Uniontown, Kentucky. This area is typical bottomland hardwood forest consisting primarily of oak (*Quercus* spp.), ash (*Fraxinus* spp.), hickory (*Carya* spp.), hackberry (*Celtis* spp.), and American sycamore (*Platanus occidentalis*) (5).

National Wetland Inventory maps of the Jennyhole and Highland Creek units were obtained, and areas classified as upland, saturated, or temporarily flooded (6) were divided into rectangular 0.5-ha plots. Sixty two plots were chosen randomly to sample 5% of the study area (5), and only plots with ≥0.25 ha of forest habitat were selected. Overwater sites were excluded due to inaccessibility and difficulty in determining plot boundaries.

From April through June 1988, plot boundaries were established and marked, and all trees in the plot ≥28 cm diameter breast height (DBH) were searched for cavities (2). Criteria used to designate a cavity as suitable for wood duck nesting were: entrance width and entrance length ≥6.5 and 9.0 cm, respectively (7), width of interior near cavity bottom ≥12.5 cm (8), length of interior near cavity bottom ≥18.0 cm (8), cavity depth ≤445 cm (8), and cavity height above ground ≥1.8 m (8). When trees could not be climbed due to safety considerations, cavities were considered suitable if entrance size and height above the ground appeared suitable (no precise measurements were taken). The number of entrances to each cavity, tree species or genera, and DBH were also recorded. The distance to nearest water and distance to nearest forest canopy opening ≥0.1 ha (2) were recorded for all suitable cavities. A cavity was considered used by wood ducks if a hen, eggs, egg membranes, or down were present. Additional nest sites outside the sample plots were measured

---

[1] Present address: Dept. of Wildlife and Fisheries, P.O. Drawer LW, Mississippi State, Mississippi 39762.

TABLE 1. Means and standard deviations of variables measured at tree cavities used and unused as wood duck nest sites, Sloughs Wildlife Management Area, April–June 1988.

Variable	Used (N = 9[a])	Unused (N = 10[a])
Diameter breast height (cm)	135.7 ± 42.8	148.9 ± 42.8
Entrance width (cm)	8.0 ± 0.8[b]	8.9 ± 2.0
Entrance length (cm)	10.7 ± 1.3[b]	10.9 ± 3.3
Number of suitable entrances	1.8	2.0
Height of cavity entrance (m)	10.0 ± 2.8	8.1 ± 3.8
Depth of cavity (cm)	25.1 ± 26.6[c]	23.4 ± 8.3
Width of interior bottom (cm)	16.7 ± 3.5	16.1 ± 3.1
Length of interior bottom (cm)	22.0 ± 3.7	22.3 ± 3.6
Distance to nearest water (m)	60.4 ± 52.1	50.6 ± 49.4
Distance to nearest forest opening (m)	44.0 ± 39.1	50.6 ± 49.4

[a] Only cavities for which all characteristics could be measured were included.
[b] Variances significantly different ($P < 0.05$).
[c] Variances significantly different ($P < 0.01$).

and included in the preference analysis, but excluded from density estimates. Where cavities could be measured, possible differences between used and unused cavities were tested using *t* tests (9). Preferences for certain nest site characteristics might not be evident when only differences among means are analyzed, so we also tested for differences in variances by using *F* tests (10) as suggested by McCallum and Gehlbach (11).

RESULTS

Thirty nine suitable cavities were located within plots, and the estimated density of natural cavities suitable for wood duck nesting was 1.26 ± 0.11 (SE) cavities/ha in non-flooded, forested habitat. Sycamores contained the greatest number of suitable natural cavities (30.8%), followed by ash (25.6%), and maple (12.8%). Cavities were also found in hickory and hackberry (N = 4 each), and in oak, sweetgum (*Liquidambar* spp.), catalpa (*Catalpa* spp.), and a dead snag (N = 1 each).

Nine natural cavities used by wood ducks were discovered during the study, 8 in sycamores and 1 in an ash. All cavities were located on the main stem of the tree and most were normal (1, 5) cavities, with only 1 of the bucket (1, 5) variety.

There were no differences between means of used and unused cavities for any of the variables measured (*t* tests, $P > 0.05$) (Table 1). There were differences between used and unused cavities in the variances of entrance width ($F = 6.76$, $P < 0.05$), entrance length ($F = 5.87$, $P < 0.05$), and cavity depth ($F = 10.36$, $P < 0.01$) (Table 1). Entrance width and entrance length exhibited less variance for used cavities than for unused cavities, with used-cavity entrances clustered in the 7–9 cm width and 9–13 cm length range (Fig. 1). Variance in cavity depth was larger for used cavities than for unused cavities; suitable cavities that were very shallow (≤10 cm deep) or very deep cavities (≥40 cm deep) were all used (Fig. 2). Other characteristics had similar variance between used and unused cavities ($P > 0.05$).

Two (20%) of the unused cavities contained identifiable hair, feathers, or eggs of other species; 1 contained an eastern gray squirrel (*Sciurus carolinensis*) and the other contained a common flicker (*Colaptes auratus*). Only 3 of the cavities used in preference analyses

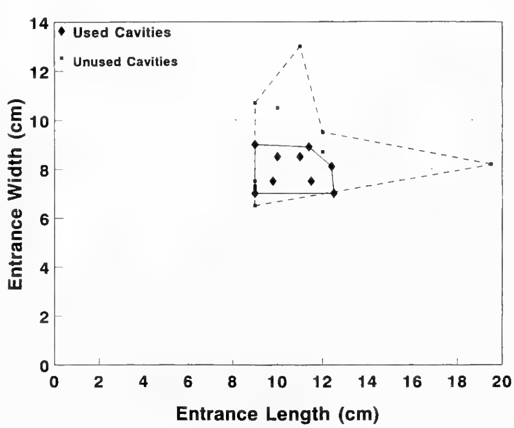


FIG. 1. Variation in entrance width and entrance length of cavities used and not used by wood ducks, Sloughs Wildlife Management Area, April–June 1988.

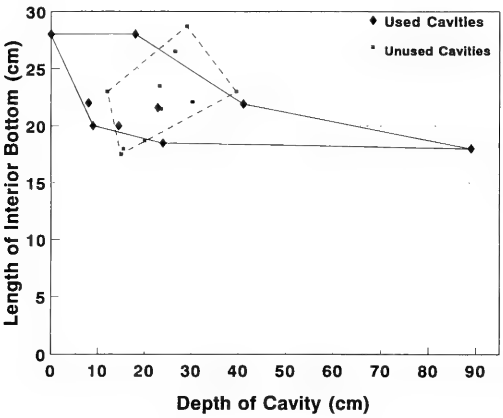


FIG. 2. Variation in cavity depth and interior bottom length (chosen for convenience) of used and unused cavities, Sloughs Wildlife Management Area, April–June 1988.

were within the 0.5-ha plots; 1 used and 2 unused.

DISCUSSION

The density of cavities suitable for wood duck nesting was higher on our study site in Kentucky (1.26/ha) than reported in Mississippi (0.67/ha and 0.21/ha), Missouri (0.33/ha), or Wisconsin (0.65/ha), but lower than sites in Minnesota (4.2/ha) and New Brunswick (5.50/ha) (4 and 12, 14, 3, 2, 13, respectively). Estimated density of natural cavities was similar to a nearby site in Indiana (1.23/ha) (7). The large numbers of sycamores, ash, and maple probably accounted for the relatively high number of suitable nesting cavities at Sloughs WMA. These tree species are important cavity producers throughout most of the range of the wood duck (1).

The true density of suitable natural cavities might differ slightly from our estimate. Some plots were searched during and after leaf-out, making observations of cavities difficult. Also, because safety considerations prevented climbing some trees, not all cavities could be precisely measured to determine their suitability as nest sites for wood ducks. Although some unmeasured cavities might have been misclassified, we do not feel any bias was introduced that would change our estimate of suitable cavity density. Only measured cavities were used in preference analyses.

Although there was no difference between means of used and unused cavities for any of the characteristics measured, there was a difference in variances between used and unused cavities for 3 characteristics. In their study of flammulated owls (*Otus flammeolus*), McCallum and Gehlbach (11) showed how differences among variances can reveal preferences for certain nest characteristics that are missed if only differences among means are tested. Specifically, when means are not different but used sites exhibit a smaller variance for a particular character, selection for a middle range of the measured character is suggested. We contend if used sites exhibit a greater variance, avoidance of or exclusion from the middle range is suggested. Our data suggest a possible preference for cavities with entrance sizes 7–9 cm wide and 9–13 cm long (Fig. 1). All used cavities and only 30% of unused cavities fell into this range (Fig. 1). Most of the unused cavities outside the range had wider or longer entrances, thus wood ducks might actually be avoiding cavities with larger openings. Smaller entrance sizes may prevent raccoons (*Procyon lotor*), the main predator of wood duck nests (15), from entering a cavity. Large entrance sizes might attract raccoons, excluding wood ducks (5). Because our sample sizes were small, however, any conclusions about wood duck preferences for certain cavity characteristics are tentative. In other studies (7, 8), wood ducks were found using cavities with entrances even smaller than the suggested minimum size.

All measured cavities <12 cm or >40 cm deep were used by wood ducks, but only 28% of cavities 12–40 cm deep were used (Fig. 2). The possible selection by wood ducks of cavities with a particular depth may relate to predator avoidance or cavity availability. Shallow cavities may enhance detection of predators ascending the tree or simply permit an easier, quicker escape by the nesting female when predators are detected (5). Conversely, a nest in a cavity greater than 40 cm deep would be beyond the reach of raccoons unable to enter the cavity (5). There might be, however, disadvantages of using very shallow or very deep cavities. Cavities too shallow could increase the chance of predation, and cavities too deep might make nest exodus by ducklings difficult. Natural cavities 12–40 cm deep are sometimes used by other species (16, 17), so perhaps wood ducks are excluded from using cavities intermediate in depth. Kilham (18) reported that a pileated woodpecker (*Dryocopus pileatus*) did not enter a cavity being used by a wood duck. The extent and outcome of such competitive interactions are unknown, however, and warrant further investigation.

Because so many suitable cavities were unused, the density of natural cavities suitable for wood duck nesting did not seem to be a major limiting factor of the population of wood ducks at Sloughs WMA. This might not be true, however, in other areas of Kentucky and the eastern United States. To determine the need for cavity management, including the deployment of nest boxes, future studies of wood ducks should include estimates of the density of suitable natural cavities. To fully understand the relationship between cavity availability on wood duck population dynamics, preference for certain cavity characteristics by wood ducks and competition with other species for these cavities must be considered.

ACKNOWLEDGMENTS

We are grateful for the assistance provided by the staff of the Sloughs WMA, and E. Earhardt and C. J. Lacefield in the collection of field data. The Kentucky Department of Fish and Wildlife Resources provided funding and logistical support. We thank G. Ritchison for a critical review of an earlier draft of this manuscript.

LITERATURE CITED

1. Soulliere, G. J. 1990. Review of wood duck nest-cavity characteristics. Pp. 153–162. In L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor (eds.) Proc. 1988 North Am. Wood Duck Symp., St. Louis, Missouri.

2. Gilmer, D. S., I. J. Ball, L. M. Cowardin, J. E. Mathisen, and J. H. Riechmann. 1978. Natural cavities used by wood ducks in north-central Minnesota. J. Wildl. Manage. 42:288–298.

3. Soulliere, G. J. 1988. Density of suitable wood duck nest cavities in a northern hardwood forest. J. Wildl. Manage. 52:86–89.

4. Lowney, M. S. and E. P. Hill. 1989. Wood duck nest sites in bottomland hardwood forests of Mississippi. J. Wildl. Manage. 53:378–382.

5. Vrtiska, M. P. 1991. Nest productivity, brood survival, and habitat use of wood ducks (*Aix sponsa*) at the Sloughs Wildlife Management Area, Kentucky. M.S. Thesis. Eastern Kentucky Univ., Richmond, Kentucky. 105 pp.

6. Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31, U.S. Fish Wild. Serv., Off. Biol. Serv. Habitat Preserv. Program, Washington, D.C. 103 pp.

7. Robb, J. R. 1986. The importance of nesting cavities and brood habitat to wood duck production. M.S. Thesis. Ohio State Univ., Columbus, Ohio. 153 pp.

8. Bellrose, F. C., K. L. Johnson, and T. V. Meyers. 1964. Relative value of natural cavities and nesting houses for wood ducks. J. Wildl. Manage. 28:661–676.

9. SAS Institute Inc. 1985. SAS user's guide: statistics. Version 5 ed. SAS Institute Inc., Cary, North Carolina. 956 pp.

10. Sokal, R. R. and F. J. Rohlf. 1969. Biometry: the principles and practice of statistics in biological research. W.H. Freeman and Company, San Francisco, California. 776 pp.

11. McCallum, D. A. and F. R. Gehlbach. 1988. Nest-site preferences of flammulated owls in western New Mexico. Condor 90:653–661.

12. Strange, T. H., E. R. Cunningham, and J. W. Goertz. 1971. Use of nest boxes by wood ducks in Mississippi. J. Wildl. Manage. 35:786–793.

13. Prince, H. H. 1968. Nest sites used by wood ducks and common goldeneyes in New Brunswick. J. Wildl. Manage. 32:489–500.

14. Weier, R. W. 1966. A survey of wood duck nest sites in Mingo National Wildlife Refuge in southeast Missouri. Pp. 91–108. In J. B. Trefethen (ed.) Wood duck Management and research: a symposium. Wildl. Manage. Inst., Washington, D.C.

15. Bellrose, F. C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania.

16. Sanderson, H. R. 1975. Den-tree management for gray squirrels. Wildl. Soc. Bull. 3:125–131.

17. Belthoff, J. R. and G. Ritchison. 1990. Nest-site selection by Eastern screech-owls in central Kentucky. Condor 90:982–990.

18. Kilham, L. 1959. Behavior and methods of communication of Pileated Woodpeckers. Condor 61:377–387.

Trans. Ky. Acad. Sci., 55(1–2), 1994, 46–54

A Recent Re-evaluation of the Bivalve Fauna of the Lower Green River, Kentucky

ANDREW C. MILLER AND BARRY S. PAYNE
Waterways Experiment Station, Corps of Engineers,
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

AND

LARRY T. NEILL
Tennessee Valley Authority, P.O. Box 1010, Muscle Shoals, Alabama 35660

ABSTRACT

A survey to assess community characteristics, density, and population demography of abundant species of freshwater bivalves (mussels in the family Unionidae and the Asian clam *Corbicula fluminea* (Muller, 1774)) was conducted at selected locations between river miles (RM) 101.5 and 155.0 in the Green River, Kentucky, in June and July 1992. Two locks and dams in the study area, No. 3 at RM 108.5 and No. 4 at RM 149.0, ceased operating in 1981 and 1965, respectively, effectively eliminating commercial navigation traffic in this river reach. Mussels were scarce except for a moderately dense bed immediately downriver of Dam No. 3 and a low-density bed downriver of Dam No. 4. Mean density downriver of Dam No. 3 was 7.0, 16.0, and 6.6 mussels/sq m, species diversity (H′) was 1.63, 2.59, and 1.90, and evidence of recent recruitment (% individuals <30 mm total shell length) was 7.9, 15.4, and 3.0%, respectively, at the upper, mid, and lower sections of the bed. When results were compared with those obtained by a 1968 study, it was apparent that the mussels have not been greatly affected by closure of the locks and cessation of commercial navigation traffic. Unionid species richness, species diversity, relative species abundance, and community composition are similar, although mean shell length of *Megalonaias nervosa* (Rafinesque, 1820) and *Pleurobema cordatum* (Rafinesque, 1820) are slightly greater (i.e., evidence of reduced recent recruitment) than they were 24 years ago.

INTRODUCTION

In 1968, Williams (1) investigated the mussel fishery along 306 miles of the Green River between its confluence with the Ohio River and the Taylor-Green County line, Kentucky. Mussels were collected with a brail, by diving, and by hand-picking. The objectives were to determine the extent of existing beds and assess mussel species composition, population density, harvest, recruitment, and reproduction.

In the summer of 1992, our divers used quantitative and qualitative methods to collect freshwater bivalves (mussels in the family Unionidae and the Asian clam *Corbicula fluminea* (Muller, 1774)) at selected locations between RM 101.5 and 155.0, which included beds immediately downriver of Dam No. 3 (RM 108.5) and Dam No. 4 (RM 149.0). The upper one-third of our sampling took place within Area III of Williams, which included 149 river miles between Dam No. 4 and the mouth of the river.

The purpose of this paper is to present data from our 1992 survey, and to compare results with those obtained by Williams. The presence of these 2 data sets, separated by 24 years, provides an opportunity to use quantitative and qualitative data on bivalves to investigate possible changes in habitat and water quality in this river reach. The importance of bivalves as an assessment tool has been recognized by academicians and federal and state biologists since the early 1970s. The techniques used by Williams in 1968 and ourselves in 1992 are not exactly the same. However, where appropriate, data can be compared and conclusions can be drawn.

Other studies of the Green River include that by A. E. Ortmann and W. J. Clench, who collected at seven sites upriver of Mammoth Cave between 1921 and 1925 (2); the work of William J. Clench and Peter Okkelberg (3); and Stansbery (4) who collected at Munfordville. These workers collected upriver of our study area. Isom (5) summarized results of previous studies, and the Academy of Natural Sciences (6) collected mussels downriver of RM 67.5. Most recently, Cochran and Layzer (7) collected at sites upriver of our study area and in the Barren River. Only the study by Williams provided detailed data from the area we surveyed that can be used to assess long-term trends in the unionid community.

STUDY AREA

The Green River originates south of Danville in central Kentucky. It flows southwest to Campbellsville, in a westerly, then northwesterly direction until it joins the Ohio River upriver of Evansville, Indiana (Fig. 1). The lower one-third is low-gradient with steep, tree-lined banks and is approximately 70 m wide. The bottom consists of sand, gravel, and silt, with occasional patches of bedrock and clay. Although Williams indicated that mussels could be affected by brine from local oil fields, Isom (5) found no evidence of this in the early 1970s.

Locks and dams were constructed in the Green River in the 1830s; Locks and Dams 1 and 2 are still functional. Lock and Dam No. 1 is located at RM 9.1, near Spotsville, Henderson County, and Lock and Dam No. 2 is located at RM 63.1, near Rumsey in McLean County. Lock and Dam No. 3, near Skilesville, Muhlenberg County, was closed because of lack of commercial traffic and placed in caretaker status on 1 October 1981. Presently, water runs over Dam No. 3, and since the lock is not in operation, commercial traffic has been eliminated from this pool. Lock No. 4, near Woodbury, Butler County, was closed in 1965 after the dam was breached and normal pool elevation could not be maintained. Water now runs through the breach in the dam that partially constricts river flow.

METHODS

Mussels were collected between RM 101.5 and 155.8 by a dive crew equipped with surface-supplied air and communication equipment. Qualitative methods were used at 17 low-density sites (there were usually no more than 2 mussels/sq m). At these sites, 2 divers each worked for 10 to 15 min and collected all mussels encountered by touch. At 3 sites with moderate density (at RM 101.5, 105.5, and 107.4 where densities were estimated to be between 3 and 5 mussels/sq m) 3 divers spent about 60 min collecting using a slightly different method. Each diver placed 5 mussels in one nylon bag, and 20 mussels in each of three nylon bags. The three divers spent about 60 min and collected approximately 200 mussels at each site. Actual numbers varied slightly since dead mussels or rocks were occasionally taken. This was of no consequence since data were used to determine unionid community composition. *Corbicula fluminea* was eliminated from these samples.

Quantitative methods were used to collect Unionidae and *C. fluminea* at ten sites downriver of Dam No. 3 (RM 108.5) and at 4 sites downriver of Dam No. 4 (RM 149.0, Fig. 1). Based on mussel density, distance to the dam, and substratum characteristics, the 10 sites were separated into upper (Sites 1–4), mid (Sites 5–8) and lower sections (Sites 9–10). At each site, ten 0.25 sq m quadrats were positioned approximately 1 m apart and arranged in a 2 × 5 matrix. A diver excavated all sand, gravel, shells, and live bivalves to a depth of 10–15 cm within the quadrat. Sediment was brought to the surface in a 20 liter bucket, transported to shore, and screened through a sieve series (finest screen with apertures of 6.4 mm). All live bivalves were picked from sediments, identified, and total shell length was measured to the nearest 0.1 mm with a dial caliper. The majority of the collected mussels were processed in the field and returned to the river unharmed. A few individuals were taken for vouchers.

Species diversity was calculated with Shannon's index (H') using natural logarithms (8). Evenness was calculated with the modified Hill's ratio, which is relatively unaffected by species richness (8). Bivalve nomenclature is consistent with Williams et al. (9).

RESULTS

Five bivalve species were common to abundant in the bed immediately downriver of Dam No. 3 (Table 1). *Megalonaias nervosa* (Rafinesque, 1820) comprised more than half the assemblage in the upper section of the bed but was substantially less at the mid and lower sections. *Pleurobema cordatum* (Rafinesque, 1820), *Elliptio crassidens* (Lamarck, 1819), and *Amblema plicata plicata* (Say, 1817) increased in abundance moving downriver. To-

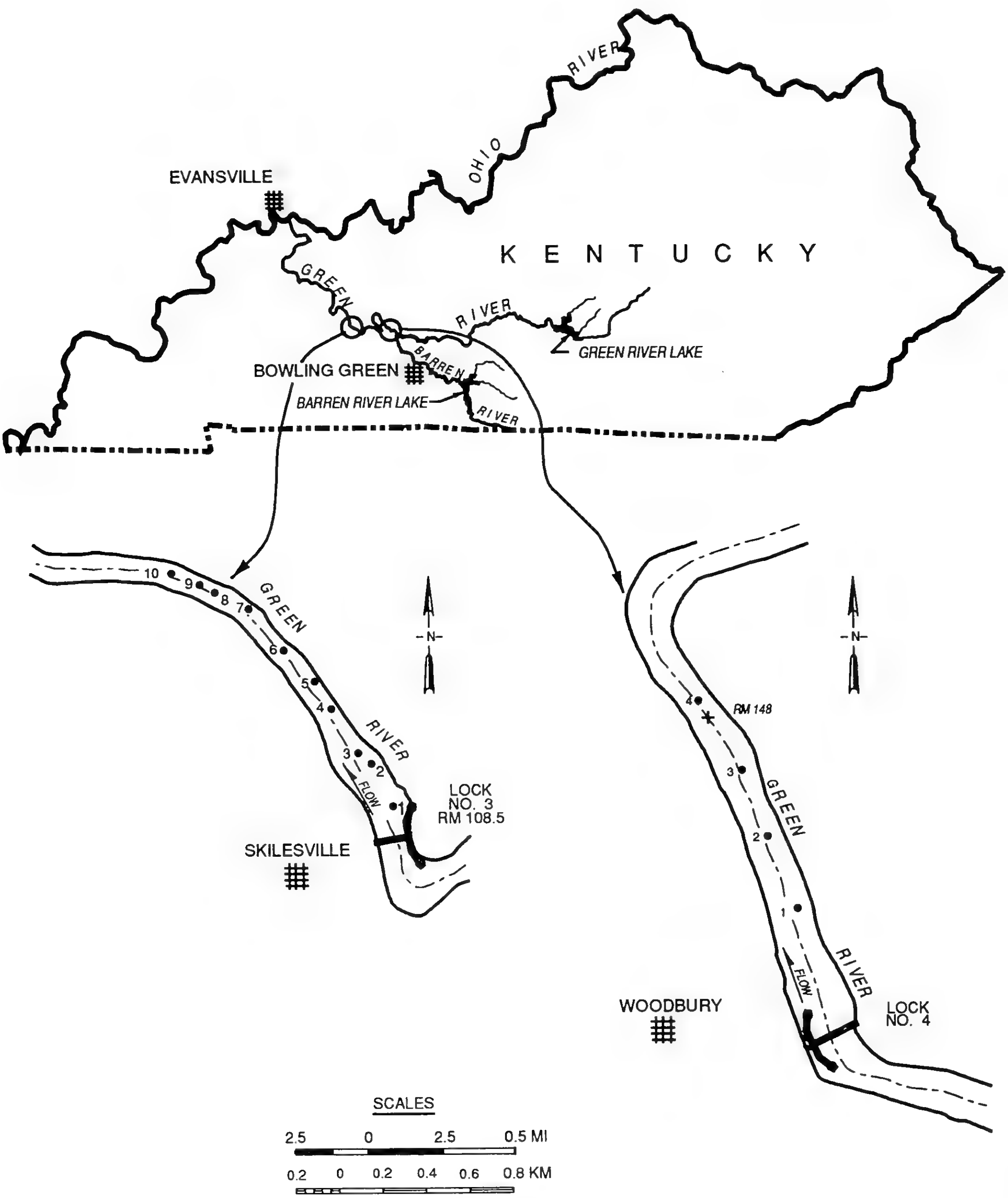


FIG. 1. Collecting sites immediately below Dam Nos. 3 and 4 in the Green River, Kentucky.

tal species richness and species diversity (a function of evenness and richness) were greater in the center as compared with the upper and lower sections of the bed. Evidence of recent recruitment to the bivalve community, expressed as a percentage of all individuals and species (even small species such as *Truncilla* spp. and *C. fluminea*) less than 30 mm shell length, was substantially greater in the mid-section as compared with the upper and lower sections of the bed. Total density of Unionidae was significantly higher in the mid-section (16.0 individuals/sq m) than in the upper and lower sections (7.0 and 6.6 individuals/sq m, respectively, $P < 0.01$). *Corbicula fluminea* was not found at the lower section of the bed and was uncommon at the upper and mid-sections.

Fifteen species of bivalves, including *C. fluminea,* were obtained in 40 quantitative samples collected immediately downriver of Dam No. 4 (Table 1). *Corbicula fluminea* numerically dominated and comprised 58% of the bivalve fauna; other species were each less than 10%. Diversity and evenness were similar at both beds. The per cent of individuals less than 30 mm total shell length downriver of Dam No. 4 was higher than in the bed downriver of Dam No. 3 (65.8% as compared with 3.0 to 15.0%), due mainly to the presence of many small *C. fluminea.* Downriver of Dam No. 4, total density of *C. fluminea* (4.6 individuals/sq m) was higher, and total density of Unionidae (3.3 individuals/sq m) was lower than at the bed downriver of Dam No. 3.

Corbicula fluminea had only minimal effects on community parameters in the bed downriver of Dam No. 3 although greater effects downriver of Dam No. 4 (compare species diversity, evenness, and evidence of recent recruitment, Table 1). Downriver of Dam No. 4 species diversity calculated for just Unionidae was 1.4 times greater than calculated when both Unionidae and *C. fluminea* were considered. Evidence of recent recruitment for only Unionidae (excluding *C. fluminea*) was about one third (21.2% as compared with 65.8%) of the value determined for all bivalves.

Although species richness was higher downriver of Dam No. 3 than downriver of Dam No. 4, bivalve species (unionids plus *C. fluminea*) were collected at about the same rate at both beds (Figs. 2, 3). This similarity reflects the approximately equal evenness of species downriver of Dam Nos. 3 and 4 (Table 2). Fifteen species of bivalves were identified downriver of Dam No. 4 after 78 individuals were collected, and after 100 individuals had been collected downriver of Dam No. 3.

Due to the low density of mussels in the quantitative samples, only 3 populations were collected in sufficient number to allow analysis of size demography. Size demography was examined only for dominant bivalve populations immediately downriver of Dam No. 3. The population of *M. nervosa* consisted almost entirely of large and relatively old mussels, with 44 of 47 individuals collected ranging from 13 to 16.5 cm in length (Fig. 4). The largest specimen was 18 cm long, and approached the maximum recorded size for this species. Not a single individual less than 10 cm in length

TABLE 1. Summary statistics for bivalves (Unionidae and *Corbicula fluminea*) collected at a bed located immediately downriver of Dam No. 3 (RM 108.5) and 4 (RM 149.0), Green River, Kentucky, 1992. In the bed downriver of Dam No. 3, means with the same superscript are not significantly different ($P > 0.05$).

	Downriver of Dam No. 3			Downriver of Dam No. 4
	Upper Section	Mid Section	Lower Section	
Percent abundance of common species				
M. nervosa	55.3	11.4	3.0	7.6
P. cordatum	2.6	15.4	24.2	1.3
E. crassidens	7.9	8.8	33.3	2.5
A. p. plicata	5.3	4.8	12.1	16.7
C. fluminea	7.9	11.9	—	58.2
Community parameters (including *C. fluminea*)				
Total samples	20	50	20	40
Total species	10	21	10	15
Total individuals	38	227	33	79
Diversity (H′)	1.63	2.59	1.90	1.64
Evenness	0.53	0.85	0.82	0.43
Dominance	0.31	0.09	0.17	0.3
% Individuals <30 mm	7.89	15.42	3.00	65.80
% Species <30 mm	10.00	28.57	10.00	26.70
Community parameters (excluding *C. fluminea*)				
Total species	9	20	10	14
Total individuals	35	200	33	33
Diversity (H′)	1.48	2.53	1.90	2.30
Evenness	0.67	0.84	0.83	0.87
Dominance	0.36	0.09	0.17	0.10
% Individuals <30 mm	0.00	4.00	3.03	21.21
% Species <30 mm	10.0	25.00	10.00	21.43
Total density				
Unionidae				
Mean individuals/sq m	7.0[b]	16.0[a]	6.6[b]	3.3
Standard error	1.2	1.3	1.7	1.3
Corbicula fluminea				
Mean individuals/sq m	0.6[a]	2.2[a]	0.0[a]	4.5
Standard error	0.4	0.7	0.0	1.4

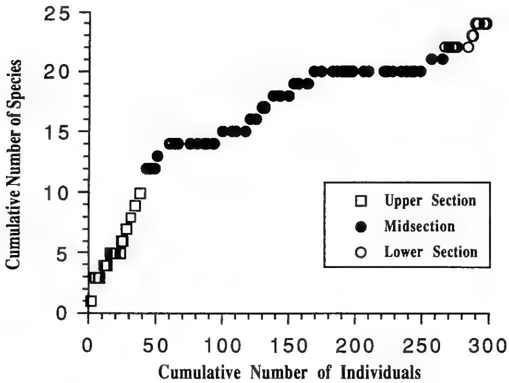


FIG. 2. The relationship between cumulative number of bivalve species versus cumulative number of individuals for quantitative samples taken at the mussel bed immediately downriver of Dam No. 3.

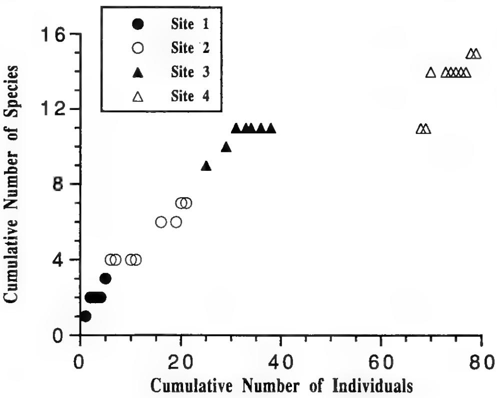


FIG. 3. The relationship between cumulative number of bivalve species versus cumulative number of individuals for quantitative samples taken at the mussel bed immediately downriver of Dam No. 4.

was collected, indicating poor recruitment to this population.

Likewise, the *P. cordatum* population was represented almost entirely by relatively large, old mussels (Fig. 4). All but one of the 22 individuals measured between 7 and 9 cm long. The smallest individual collected was approximately 5 cm in length, and no recent recruits (i.e., individuals less than 3 cm in length) were found. The population of *C. fluminea* was represented by a cohort ranging from 4 to 14 mm (16 of 30 individuals) and a cohort ranging from 16 to 30 mm (14 of 30 individuals) (Fig. 4). Maximum length of the remaining individuals was 30 mm.

DISCUSSION

During the summer and early fall of 1968, Williams (1) collected mussels in 3 sections of the Green River. A reach designated by him as Area III extended from the river mouth to Dam No. 4, a distance of 149 miles that included most of our study area. He reported that mussels were uncommon throughout this area except immediately downriver of dams where they were much more common. He collected 130 individuals and 19 species of unionids, downriver of Dam No. 3; we collected 268 individuals and identified 23 species of unionids (Table 2). He collected 89 individuals and identified 19 species downriver of Dam No. 4; we collected 33 individuals and identified 14 species of unionids.

Isom (5) reviewed data collected by Williams and determined that *Lampsilis cariosa* was probably not identified correctly and was probably *Lampsilis cardium* (Rafinesque, 1820). *Lampsilis luteola* was probably *Lampsilis radiata* (Gmelin, 1791). These minor changes do not alter overall community structure as described by Williams. His complete list for Area III includes 844 individuals and 29 species. When results obtained with our quantitative and qualitative methods are combined, we collected 872 individuals and identified 25 species of unionids. Some species that we found *Leptodea fragilis* (Rafinesque, 1820) and *Truncilla truncata* (Rafinesque, 1820) were not collected by Williams but were probably present in 1968. We did not collect *Cyclonaias tuberculata* (Rafinesque, 1820) and *Obovaria olivaria* (Rafinesque, 1820) that comprised less than 1% of the Williams collection. It is likely that any collector will miss a few of the least common species. Regardless, when results of both surveys are compared, it is apparent that species richness and basic community structure (i.e., dominance of thick-shelled species such as *M. nervosa, P. cordatum, E. crassidens,* and *A. p. plicata*) remained largely unchanged since 1968. Based on data collected by Williams, species diversity and evenness were 2.07 and 0.56; with our data these parameters were 2.43 and 0.67 (Table 2). Lower species diversity in data of Williams was the result of comparatively high percentages of the two most abundant species (*M.*

TABLE 2. Percent species abundance for Unionidae (*Corbicula fluminea* has been excluded from this table) collected at mussel beds downriver of Dam No. 3 (RM 108.5) and 4 (RM 149.0) using quantitative methods and between RM 155.8 and 101.5 using qualitative methods. Also included are data collected in 1968 by Williams (1) between Green River Mile 149.0 and 0.0 using divers and a brail.

		Present survey			
Species	Williams (1)	Downriver of Dam No. 3	Downriver of Dam No. 4	RM 155.8–101.5	Total
Megalonaias nervosa	36.02	17.91	18.16	21.54	20.30
Amblema p. plicata	24.64	6.34	6.05	31.52	22.82
Elliptio crassidens	12.56	12.68	6.05	12.61	12.38
Pleurobema cordatum	6.16	16.42	3.04	2.45	6.77
Ptychobranchis fasciolaris	2.96	3.36	3.04	0.00	1.15
Fusconaia undata[1]	1.66	0.00	0.00	0.00	0.00
Quadrula p. pustulosa	1.66	9.33	6.05	4.38	5.96
Fusconaia ebena	1.54	1.49	0.00	0.35	0.69
Potamilus alatus	1.54	0.74	0.00	4.20	2.98
Elliptio dilatata	1.42	5.97	0.00	0.88	2.41
Ellipsaria lineolata	1.42	7.09	3.04	3.33	4.48
Lampsilis ovata	1.42	0.00	0.00	0.00	0.00
Quadrula quadrula	1.18	2.23	3.04	4.20	3.55
Pleurobema coccineum	0.95	0.00	0.00	0.00	0.00
Pleurobema plenum	0.83	0.00	0.00	0.00	0.00
Ligumia recta	0.59	0.38	0.00	0.00	0.12
Obliquaria reflexa	0.59	8.58	21.20	4.20	6.19
Quadrula nodulata	0.59	1.12	3.04	1.23	1.26
Tritogonia verrucosa	0.47	0.38	3.04	0.87	0.80
Obovaria subrotunda	0.36	0.74	0.00	0.00	0.23
Actinonaias ligamentina	0.24	1.12	0.00	0.52	0.69
Cyclonaias tuberculata	0.24	0.00	0.00	0.00	0.00
Obovaria olivaria	0.24	0.00	0.00	0.00	0.00
Fusconaia subrotunda	0.12	0.00	0.00	0.00	0.00
Lampsilis cariosa[2]	0.12	0.00	0.00	0.00	0.00
Lasmigonia costata	0.12	0.00	0.00	0.00	0.00
Lampsilis luteola[3]	0.12	0.00	0.00	0.00	0.00
Obovaria retusa	0.12	0.00	0.00	0.00	0.00
Truncilla donaciformis	0.12	0.38	0.00	0.00	0.12
Lasmigonia c. complanata	0.00	0.00	3.04	5.26	3.56
Arcidens confragosus	0.00	0.00	0.00	0.70	0.46
Leptodea fragilis	0.00	0.38	3.04	0.70	0.69
Truncilla truncata	0.00	0.74	18.16	0.87	1.49
Fusconaia flava	0.00	0.38	0.00	0.17	0.23
Pleurobema rubrum	0.00	1.49	0.00	0.00	0.46
Quadrula metanevra	0.00	0.74	0.00	0.00	0.23
Total individuals	844	268	33	571	872
Total species (H′)	29	23	14	19	25
Species diversity	2.07	2.50	2.3	2.16	2.43
Evenness	0.56	0.77	0.97	0.63	0.67

[1] Now listed under *F. flava* (9).
[2] Probably *Lampsilis cardium* (5).
[3] Probably *Lampsilis radiata* (5).

nervosa and *A. p. plicata*, Table 2). This is likely the result of sampling methods; sampling by hand and use of the brail will bias collections toward large-sized individuals.

In the present study, abundant unionid populations had a much higher percentage of large individuals than did populations in the late 1960s. Data from Williams indicate that approximately 80% of the *P. cordatum* population consisted of individuals 50 to 70 mm long, with only 20% of the population larger than 70 mm. This contrasts with the results of the present study in which 95% of the population was larger than 70 mm. The maximum length recorded by Williams was approximately 80 mm, and the maximum length we ob-

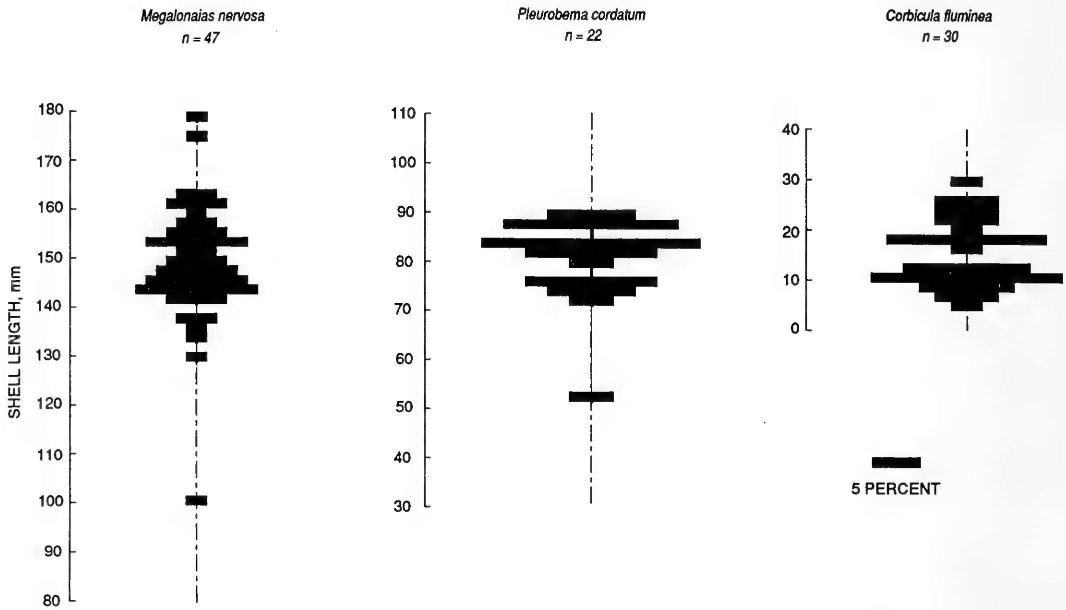


FIG. 4. Length-frequency histograms for *Megalonaias nervosa, Pleurobema cordatum,* and *Corbicula fluminea* collected in quantitative samples at the mussel bed immediately downriver of Dam No. 3.

served was 90 mm. Comparison of results of the present study with data from Williams yielded a similar contrast for *M. nervosa.* Williams reported that approximately 50% of the *M. nervosa* population consisted of individuals greater than 125 mm (maximum shell length = 150 mm); the remaining 50% ranged from 50 to 125 mm. In the present study 98% of the *M. nervosa* population was greater than 125 mm, with a maximum size of 180 mm. Our quantitative technique (diver-collected total substratum samples) ensures collecting individuals at least 10 mm long. Methods used by Williams (collecting by hand or brail) are more likely to under-represent small-sized individuals. Had Williams taken total substratum samples, his estimates of average shell length would likely have been even less. It is not possible to determine if this increase in average shell length of dominant unionids sampled in 1992 (reduced evidence of recent recruitment) when compared with data from Williams is the beginning of a trend, or simply the result of annual variation that is commonly seen in some unionid populations (16).

In populations with reasonably strong recent recruitment, it is not unusual to collect several *M. nervosa* less than 10 cm long. This usually includes some individuals representing recruits of the last one to three years that are 1 to 4 cm long (10). In populations of *P. cordatum* with substantial recent recruitment, a considerable number of individuals less than 5 cm in length are expected, including individuals less than 3 cm long (10).

In a large (n > 100) sample of a dense *C. fluminea* population with complex age structure, 3 to 5 cohorts are typically observed, with the length of the largest cohort averaging 25 to 35 mm (11). The full expected size range of *C. fluminea* was represented in this low density population in the Green River. However, this population was heavily dominated by a cohort of small, recent (either spring or summer 1992) recruits.

We found extremely low unionid densities immediately downriver of Dam No. 4. Density at this location was less than 4 individuals/sq m, whereas density downriver of Dam No. 3 ranged from 7 to 16 individuals/sq m. Williams did not provide density estimates at beds downriver of these dams. Upriver of Dam No. 4 (outside our study area), he reported total densities as high as 61 individuals/sq yd (80/sq m). In areas other than immediately downriver of dams, Williams reported that total density of unionids was low and ranged from 0 to 1.5/sq yd (1.9/sq m). It is not possible to determine whether densities have changed between 1968 and 1992, but it is likely that they have always been low compared with other mussel beds. For example, at a bed immediately downriver of Kentucky Dam in the lower Tennessee River, Miller et al. (12) reported that Unionidae ranged from 9.2 to 128.0 individuals/sq m, and *C. fluminea* ranged from 6.0 to 26.4 individuals/sq m.

In gravel-bed rivers, dams cause the area immediately downriver to degrade (13). Degradation is greatest near the dam and decreases downriver at a decelerating rate. In the Green River, erosive action of high-velocity water below dams was a consequence of normal operation and created conditions suitable for moderately dense mussel populations. Breaching the dams had little effect on substratum stability and mussel beds. Cold, hypolimnetic releases from dams in large rivers can greatly reduce or eliminate mussels and other benthic organisms immediately downriver (14, 15). However, dams along the lower Green River in our study area release surface water and do not negatively affect bivalve molluscs.

When Williams surveyed the Green River in 1968 he reported that the lower river was heavily used by commercial towboats. Since navigation locks were built in the 1830s, commercial vessels had used the river for over 100 years prior to his survey. During the 24 years between completion of Williams' survey and our own, the reach downriver of Dam No. 3 has been free of commercial vessels. Results of this recent re-evaluation of this reach of the lower Green River indicate that failure of dams and cessation of commercial navigation traffic had little effect on unionid species richness, diversity, relative species abundance, and community composition.

ACKNOWLEDGMENTS

Divers were Larry Neill, Robert Warden, Robert T. James, and Jeff Montgomery of the Tennessee Valley Authority. Jim Baker, Eric Pearson, Chuck Boston, Deborah Shafer, Erica Hubertz, and Sarah Wilkerson assisted. The authors thank Mr. Jim Baker, Mr. Terry Siemsen, and an anonymous reviewer for constructive criticism on an early draft of this paper. The study was funded by the U.S. Army Engineer District, Louisville. The Chief of Engineers granted permission to publish this information.

LITERATURE CITED

1. Williams, J. C. 1969. Mussel Fishery Investigations, Tennessee, Ohio and Green Rivers. Project Completion Report for Investigations Projects Conducted Under the Commercial Fisheries Research and Development Act of 1964. U.S. Fish and Wildlife Service and Kentucky Department of Fish and Wildlife Resources.

2. Ortmann, A. E. 1926. The naiades of the Green River drainage in Kentucky. Ann. Carnegie Mus. 17:167–188.

3. Clench, W. J. and H. van der Schalie. 1943. Notes on naiades from the Green, Salt, and Tradewater rivers in Kentucky. Pap. Mich. Acad. Sci. Arts. Lett. 29:223–228.

4. Stansbery, D. H. 1965. The naiad fauna of the Green River at Munfordville, Kentucky. Ann. Rept. Amer. Malacol. Union 1965:13–14.

5. Isom, B. G. 1974. Mussels of the Green River, Kentucky. Trans. Ky. Acad. Sci. 35:55–57.

6. Academy of Natural Sciences of Philadelphia. 1983. Aquatic Baseline Studies of the Green River, Martin Creek and Richmond Slough 1981–1982. Contract DE-AC05-78OR03054 for the International Coal Refining Company, Allentown, Pennsylvania.

7. Cochran, T. G. and J. B. Layzer. 1992. Effects of commercial exploitation on unionid populations in the Green and Barren rivers, Kentucky. Presented at the 40th Annual Meeting of the North American Benthological Society, 26–29 May 1992, Louisville, Kentucky.

8. Ludwig, J. A. and J. F. Reynolds. 1988. Statistical ecology, a primer on methods and computing. John Wiley & Sons. New York, New York.

9. Williams, J. D., M. L. Warren, K. S. Cummings, J. L. Harris, and R. J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18:6–22.

10. Miller, A. C. and B. S. Payne. 1992. The effects of commercial navigation traffic on freshwater mussels in the upper Mississippi River: 1990 studies. Technical Report EL-92-23, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

11. Payne, B. S., A. C. Miller, P. D. Hartfield, and R. F. McMahon. 1989. Variation in size demography of lotic populations of *Corbicula fluminea* (Muller). Nautilus 103: 78–82.

12. Miller, A. C., B. S. Payne, and R. Tippit. 1992. Characterization of a freshwater mussel (Unionidae) community immediately downriver of Kentucky Lock and Dam in the Tennessee River. Trans. Ky. Acad. Sci. 53: 154–161.

13. Neill, C. R. 1987. Sediment balance conservations linking long-term transport and channel processes. Pp.

225–240. In C. R. Thorne, J. C. Bathurst, and R. D. Hey (eds.) Sediment transport in gravel-bed rivers. John Wiley & Sons, New York, New York.

14. Pfitzer, D. W. 1954. Investigations of water below storage release reservoirs. North American Wildlife Conference 19:271–282.

15. Miller, A. C., L. Rhodes, and R. Tippit. 1984. Changes in the naiad fauna of the Cumberland River below Lake Cumberland in Central Kentucky. Nautilus 98: 107–110.

16. Payne, B. S. and A. C. Miller. 1988. Growth and survival of recent recruits to a population of *Fusconaia ebena* (Bivalvia: Unionidae) in the lower Ohio River. Am. Midl. Nat. 121:99–104.

NOTE

***Lesquerella globosa* Rediscovered in Jessamine County, Kentucky.**—*Lesquerella globosa* (Desv.) S. Wats, a candidate for federal review (C2), and a Kentucky endangered species, has been rediscovered in Jessamine County. This species was reported in the Jessamine Creek Gorge and described as infrequent along roadsides by McFarland during his M.S. thesis research (McFarland, J. W., 1946, The Vascular Plants of Jessamine County, Kentucky, University of Kentucky), but could not be located in subsequent studies (Campbell, J. and Meijer, W., 1989, Trans. Ky. Acad. Sci. 50:27–45). A small population was found recently in the vicinity of the intersection of Grows Mill and Jessamine Station roads east of Wilmore. In 1990 and 1991, single specimens were found. In May 1993 8 specimens were found after a thorough search. Seven spindly plants were found growing in dense grass between the road ditch and the fence. Persistence of the population here is probably made possible by frequent mowing of the road right-of-way. The eighth specimen, a more vigorous one, was found north of Jessamine State Road on the bank of an intermittent stream tributary to Jessamine Creek.

Only 13 extant populations of *L. globosa* are known in Kentucky, primarily from Franklin County, and most of these are small. The status of this newly found population seems very precarious.

Appreciation is extended to Julian Campbell of the Nature Conservancy and Margaret Shea of the Kentucky State Nature Preserves Commission for their cooperation in this survey.—**John Brushaber**, Department of Biology, Asbury College, Wilmore, Kentucky 40390.

Trans. Ky. Acad. Sci., 55(1–2), 1994, 56–61

ACADEMY AFFAIRS

The Seventy-Ninth Annual Business Meeting of the Kentucky Academy of Science

Hill Chapel, Georgetown University
Georgetown, Kentucky
23 October 1993

Introduction

President Charles Boehms brought the meeting to order at 11:05 a.m. He introduced David Hartman who presented a brief summary of the Treasurer's Report.

Charles Boehms thanked and presented David Hartman a plaque in recognition for his faithful service to the Academy during his term in office.

He recognized and thanked Barbara Rafaill of Georgetown College for her hard and fruitful execution of her duties as Chairwoman of the Local Arrangements Committee.

Resolutions

Joe Winstead, Chairman of the Nominations, Elections and Resolutions Committee was introduced by President Boehms to present the resolutions previously approved by the Board. The resolutions were as follows:

Resolution 1

Resolution of the Kentucky Academy of Science

Thereby be it resolved that the membership of the Kentucky Academy of Science extend their most profound thanks and appreciation to the administration, staff and student body of Georgetown College for their hospitality and support in hosting the 79th Annual Meeting of the Academy. Further be it resolved that the Academy extends special recognition to Dr. William Crouch, President of Georgetown College; Dr. Charles Boehms, Senior Vice-President and Academic Dean; Dr. Barbara Rafaill, Chairperson of the Local Arrangements Committee; and members of the Local Arrangements Committee for their enthusiasm and efforts towards the success of the Kentucky Academy of Science in conducting the Annual Meeting. Be it known the support and cooperation of Georgetown College in this endeavor is a typical example of the long tradition of contribution to scientific excellence in the Commonwealth of Kentucky.

Resolution 2

Resolution of the Kentucky Academy of Science

Thereby be it resolved that the Kentucky Academy of Science in its 79th year extends the deepest thanks and appreciation to the Toyota Motor Manufacturing, USA, Company for their support and cooperation in helping to sponsor and host the 1993 Annual Meeting of the Academy in Georgetown. Further be it resolved that the Academy recognize Toyota Vice President Jim Wiseman, Helen Littrell, Assistant Manager of Public Affairs and Kathy Clark, Specialist in Administration and Planning for their efforts, help and interest in assuring that the 79th Annual Meeting continued the legacy of service to the sciences of the Commonwealth. Be it known that the membership of the Kentucky Academy of Science applaud the Toyota Manufacturing, USA, Company for corporate citizenship and positive partnership in support of education, arts, sciences, and economic development of the state of Kentucky by the management and workers through their collective efforts and involvement in serving as leaders in the state community.

Resolution 3

Resolution of the Kentucky Academy of Science

Thereby be it resolved by action of the membership of the Kentucky Academy of Science during the 79th Annual Meeting held on the campus of Georgetown College that Dr. Burtron H. Davis, Associate Director of the Kentucky Center for Applied Energy Research be commended for his efforts and diligence in the planning, organization and conduction of the Industrial Sciences Section presentations on 22 October 1993. Furthermore let it be known that this program is a significant advancement in the bringing together of applied science, higher education and secondary education within the Commonwealth of Kentucky through the work of Dr. Davis as the participants represent practicing scientists from private industry, state government and higher education interacting with secondary school students. Through his contributions Dr. Davis has furthered the aims and goals of the Academy in serving as a catalyst for the synthesis of basic research, applied research and technology with the educational and training program within Kentucky.

Resolution 4

Resolution of the Kentucky Academy of Science

By action of the membership of the Kentucky Academy of Science who represent the broadest spectrum of science and technology within the Commonwealth of Kentucky thereby let it be known:

Whereas, The scientific community of the state is excited and enthused about positive reform in educational systems at the elementary and secondary school level and

Whereas, The move toward performance assessment will inherently demand improved student competence in scientific literacy and will demand increased depth of training for science teachers and

Whereas, These changes will involve more hands on experiences and continuation of synthesis of scientific learning, practice, and application by both students and teachers and

Whereas, Improvements gained will increase the demand and needs for advanced placement offerings within every school district it is resolved that teacher training and certification must not be allowed to show any reduction or dilution of content in any sub discipline of the basic sciences as the reforms will require teachers and mentors well versed in specific disciplines as well as with the ability to integrate information into conceptual frameworks.

Be it also resolved that the above statements be forwarded to all appropriate elected state government leaders and appointed officials charged with the planning, implementation and conduction of the public education system within Kentucky.

Each of these resolutions was submitted as a motion and approved by the KAS members.

ELECTION RESULTS

Joe Winstead thanked the individuals who volunteered to stand for election on being nominated. The results of the election were:

Governing Board Member-at-Large: Dr. Wimberly Royster of the KSTC.

Governing Board, Biological Sciences Division: Dr. Gerald Faust, Morehead State University, Biological Sciences Representative.

Vice-President, Dr. William Bryant, Morehead State University.

Charles Boehms stated that the Operations Manual for KAS will be upgraded by a committee made up of former KAS presidents. Efforts will be made to reconcile it with the constitution, or if necessary, recommend constitutional revision.

Two Board members, Burtron Davis and Ray Hammond, are rotating off the Board. They will be presented with Certificates of Appreciation for their service to the Board.

Charles Boehms presented Dr. Donald Sands of the UK Chemistry Department who spoke on Kentucky undergraduate chemistry curriculum reform. Dr. Sands called for cooperation among undergraduate institutions to bring about change in the chemistry curriculum.

Larry Elliot opened discussion on the problem of communication between section chairpersons and secretaries and those in charge of arrangements for the annual meeting. Barbara Rafaill suggested that the responsibilities of section representatives be clearly spelled out.

Paper competition awardees ($100) names were read by Larry Elliot.

Charles Boehms passed the President's gavel to Larry Elliot. As per tradition, outgoing President Boehms presented a check for $100 to the KAS.

TREASURER'S REPORT

Kentucky Academy of Science
1993

Starting Balance (January 1, 1993)		$78,280.38
Income (below)	+29,329.07	
Expenses (below)	−14,961.66	
Ending Balance (September 30, 1993)		$92,647.79

Income—1993

Membership Dues		$4,507.00
Regular	$4,507.00	
Life (61) 1993		
Institutional Memberships		5,250.00
Corporate Memberships		5,150.00
Library Subscriptions		2,901.80
Page Charges and Abstracts		2,787.00
Annual Meeting—1993		5,956.00
Exhibits	525.00	
Registration and Banquet	5,431.00	
Interest Income		2,027.27
Bank	1,066.18	
CD	961.09	
Griffith Memorial Trust		0.00
Endowment Fund Gifts		25.00
Life Membership		0.00
Gift		500.00
Miscellaneous (refund)		225.00
Total		$29,329.07

Expenses—1993

KJAS		$ 2,500.00
KJAS-AAAS—1993 (travel)		1,500.00
NAAS—dues		120.00
Printing		6,611.37
Transactions	$5,290.91	
Newsletter (Secr.)	1,148.34	
Other (Exec. Secr.)	172.12	
Professional Services (CPA)		525.00
Annual Meeting 1992		0.00
Printing	0.00	
Annual Meeting 1993		685.81
Printing & postage	685.81	
Transfer to Endowment Fund		55.00
Gifts	55.00	
New Life Member	0.00	
Treasurer		11.60
Postage	11.60	
President-Elect		56.67
Flowers	56.67	
President		241.00
Travel	241.00	
Executive Secretary		2,138.87
Postal Services	350.00	
Secretarial Services	686.55	
Office Supplies	76.32	

Travel	998.00	
Misc	28.00	
Meetings, Executive and Board)		130.50
Miscellaneous		385.84
Corp. Fees	8.00	
Bond	106.50	
Bad check	50.00	
P.O. Box (1992 + 1993)	98.00	
Third Class permit	75.00	
Awards	48.34	
Total		$14,961.66

Kentucky Academy of Science Foundation

Endowment Fund—1993

Starting Balance (January 1, 1993)		$25,635.99
Life Memberships (61)	$21,350.00	
Endowment	4,285.99	
Income		+ 914.26
Transfer from KAS		
Gifts	55.00	
Direct Gifts to Endowment	100.00	
Interest		
Bank Account	118.53	
CD	640.73	
Expenses		0.00
Ending Balance (September 30, 1993)		$26,550.25
Life Memberships (61)	$21,350.00	
Endowment	5,200.25	

Botany Fund—1993

Starting Balance (January 1, 1993) (Principal—$13,562.49; Interest—$1,033.51)		$14,596.00
Income		+410.89
Interest—Bank Account	$ 90.53	
CD	320.36	
Expenses		−900.00
Grant—Walker	350.00	
—Calie	550.00	
Ending Balance (September 30, 1993) (Principal—$13,562.49; Interest—$544.40)		$14,106.89

Marcia Athey Fund—1993

Starting Balance (January 1, 1993) (Principal—$54,886.02+469.84p; Interest—$2,881.35)		$58,237.21
Income		+1,788.47
Interest—Bank Account	$154.59	
CD	1,633.88	
Expenses		−1,700.00
Grant—Calie	$1,000.00	
—Ritchison	700.00	
Ending Balance (September 30, 1993) (Principal—$54,886.02+469.84p; Interest—$2,969.82)		$58,325.68

Mentor Fund—1993

Starting Balance (January 1, 1993)		$ 3,251.55
Income		+ 360.71
Interest	68.47	
App. Ed. Lab.	292.24	
Ending Balance (September 30, 1993)		$ 3,612.26

Executive Committee

President
Larry P. Elliott
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6002
FAX (502) 745-6471

President-elect
Robert Creek
Department of Biology
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1539
FAX (606) 622-1022

Vice President
William S. Bryant
Thomas Moore College
Cresent Hills, KY 41017
(606) 344-3370
FAX (606) 344-3345

Past President
Charles N. Boehms
Department of Biology
Georgetown College
Georgetown, KY 40324
(502) 863-8087
FAX (502) 868-8888

Secretary
Peter X. Armendarez
Department of Chemistry and Physics
Brescia College
Owensboro, KY 42301
(502) 685-3131
FAX (502) 686-4266

Treasurer
Julia H. Carter
Wood Hudson Cancer Research Laboratory
931 Isabella Street
Newport, KY 41071
(606) 581-7249
FAX (606) 581-7249

Executive Director (ex-officio)
J. G. Rodriquez
Department of Entomology
University of Kentucky
Lexington, KY 40546-0091

(606) 257-4902
FAX (606) 323-1120

Editor, TRANSACTIONS (ex-officio)
Branley A. Branson
Department of Biological Science
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1537
FAX (606) 622-1020

Editor, NEWSLETTER (ex-officio)
Vincent A. DiNoto, Jr.
Physics and Astronomy Department
Jefferson Community College, Southwest Campus
1000 Community College Dr.
Louisville, KY 40272
(502) 935-9840 x280, 236
FAX (502) 935-9840 x296

Division Representative and At-Large Members

Wimberly C. Royster
KY Science and Technology Council, Inc.
P.O. Box 1049
Lexington, KY 40588
(606) 233-3502

Gerald L. DeMoss
College of Applied Science and Technology
Morehead State University
UPO 721
Morehead, KY 40351
(606) 783-2158

James E. Gotsick
Morehead State University
UPO 1335
Morehead, KY 40351
(606) 783-2988

Kimberly Ward Anderson
University of Kentucky
Chemical Engineering
157 Anderson Hall (Tower)
Lexington, KY 40506-1146
(606) 257-3153

Blaine R. Ferrell
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 645-6006

Patricia K. Doolin
Research and Development Department
Ashland Petroleum Company
Box 391
Ashland, KY 41114

David E. Hogan
Psychology Department
Northern Kentucky University
Highland Heights, KY 41076

Valena Hurt
Biology Division
Hazard Community College
Hazard, KY 41701

AAAS/NAAS Representative
J. G. Rodriquez (see Executive Director)

Chairperson, KJAS
Valgene L. Dunham
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-3696

Section Representatives

Section	Chairperson	Secretary
Anthropology	James Hopgood Anthropology Northern Kentucky University Highland Heights, KY 41099-2200 (606) 572-5252	Cara Richards Anthropology Transylvania University Lexington, KY 40508 (606) 233-8176
Botany and Microbiology	Barbara Rafaill Department of Biological Science Georgetown College Georgetown, KY 40324 (502) 863-8087	Nancy Dawson Department of Biology Western Kentucky University 1526 Russellville Road Bowling Green, KY 42101-3576 (502) 745-6501
Chemistry	Robert K. Berry Chemistry Department Maysville Community College Maysville, KY 41056 (606) 759-7141 Ext 155	Larry D. Bigham Science Department Paducah Community College Paducah, KY 42002 (502) 554-9200 Ext 185

Section	Chairperson	Secretary
Geography	Stuart Foster Department of Geography & Geology Western Kentucky University 1526 Russellville Road Bowling Green, KY 42101-3576 (502) 745-5976	Wayne Hoffman Department of Geography & Geology Western Kentucky University 1526 Russellville Road Bowling Green, KY 42101-3576 (502) 745-4555
Geology	Deborah Kuehn Department of Geography & Geology Western Kentucky University 1526 Russellville Road Bowling Green, KY 42101-3576 (502) 745-5984	Kenneth Kuehn Department of Geography & Geology Western Kentucky University 1526 Russellville Road Bowling Green, KY 42101-3576 (502) 745-3082
Physics	Rico Tyle Science Department Franklin-Simpson High School Franklin, KY (502) 586-3273	Vince DiNoto Natural Science Division Jefferson Community College, SW 1000 Community College Dr. Louisville, KY 40272 (502) 935-9840 Ext 280
Physiology, Biophysics, Biochemistry, Pharmacology	Suzanne Byrd Department of Biological Sciences Eastern Kentucky University Richmond, KY 40475 (606) 622-1712	Chang Wang Human Nutrition Research 213 Atwood Research Building Kentucky State University Frankfort, KY 40601 (502) 227-6097
Science Education	Robert Boram Department of Physical Sciences Lappin Hall 104 Morehead State University Morehead, KY 40351 (606) 783-2931	Peter V. Lindeman Division of Biological Science and Related Technology Madisonville Community College 2000 College Drive Madisonville, KY 42431 (502) 821-2250 Ext 2197
Psychology	Terry Barrett Psychology Department Murray State University Murray, KY 42071 (502) 762-2851	Jeff Smith Department of Psychology Northern Kentucky University Highland Heights, KY 41076 (606) 572-5317
Sociology	J. Allen Singleton Department of Political Science 113 McCreary Eastern Kentucky University Richmond, KY 40475-3122 (606) 622-4395	Steve P. Savage Department of Sociology Keith 223 Eastern Kentucky University Richmond, KY 40475-3122 (606) 622-1644
Zoology and Entomology	Guenter Schuster Department of Biological Science Eastern Kentucky University Richmond, KY 40475 (606) 622-1016	Gordon K. Weddle Biology Department Campbellsville, College Campbellsville, KY 42718 (502) 789-5328
Computer Science	Sylvia Clark Pulliam Computer Science Department Western Kentucky University 1526 Russellville Road Bowling Green, KY 42101-3576 (502) 745-6186	Richard A. Rink Department of Mathematics, Statistics, and Computer Sci. Eastern Kentucky University Richmond, KY 40475 (606) 622-1935

Section	Chairperson	Secretary
Mathematics	Carroll Wells Mathematics Department Western Kentucky University 1526 Russellville Road Bowling Green, KY 42101-3576 (502) 745-6218	Russel Brengelman Mathematics Department UPO 1222 Lappin Hall Morehead State University Morehead, KY 40351 (606) 783-2178
Engineering	Nick Stamatiadis Department of Civil Engineering University of Kentucky Lexington, KY 40506-0046 (606) 257-8012	Kaveh Tagavi Department of Mechanical Engineering University of Kentucky Lexington, KY 40506-0046 (606) 257-2739
Scientific Information	Jean Almand Science Library Western Kentucky University 1526 Russellville Road Bowling Green, KY 42101-3576 (502) 745-6079	Elaine Moore Helm Craven Library Western Kentucky University 1526 Russellville Road Bowling Green, KY 42101-3576 (502) 745-6122
Agriculture	Matthew E. Byers Atwood Research Facility Kentucky State University Frankfort, KY 40601 (502) 227-6253	Elmer Gray Department of Agriculture Western Kentucky University 1526 Russellville Road Bowling Green, KY 42101-3576 (502) 745-5961
Industrial Science	Patricia Doolin Research and Development Ashland Petroleum Co. P.O. Box 391 Ashland, KY 41114 (606) 327-6541	Burtron H. Davis Center for Applied Energy Research 3572 Iron Works Pike Lexington, KY 40511 (606) 257-0251
Molecular and Cell Biology	John M. Rawls, Jr. Morgan School of Biological Science 101 Morgan Building University of Kentucky Lexington, KY 40506-0225 (606) 257-8641	Claire R. Rinehart Department of Biology Western Kentucky University 1526 Russellville Road Bowling Green, KY 42101-3576 (502) 745-6006

Local Arrangements Committee

Georgetown College

Barbara Rafaill, Chairperson
Theo Leverenz
Sally Merrigan
Dennis Dedrick
William Harris
Mark Johnson
David Fraley
Ginger Glass

Leigh Anne Hiatt
Bart Dickinson
Rick Kopp
Julie Mann
Steve Cook

Toyota Motor Manufacturing

Helen Littrell
Kathy Clark

Trans. Ky. Acad. Sci., 55(1–2), 1994, 62–91

PROGRAM, ANNUAL MEETING

Kentucky Academy of Science
79th Annual Meeting

Georgetown, Kentucky

Program Summary

Thursday Evening Activities at the
Asher Science Center

Thursday, 21 October 1993

1:00–4:00 p.m.
Executive Board Meeting, Private Dining Room—Cralle Student Center

4:00–8:00 p.m.
Registration, Lobby

6:00–7:30 p.m.
Interest Sessions
Thornton Educational, Room 102; Products, Co. (Physiology Experimentation with Computer Interfacing); Planetarium Show, Planetarium

7:30–8:00 p.m.
Section Chairperson and Secretary Meeting, Room 112

8:00–9:30 p.m.
Reception, Lobby

Friday, 22 October 1993

7:30 a.m.–5:00 p.m.
Registration, Lobby—Cralle Student Center

8:00 a.m.–5:30 p.m.
Poster Exhibits, Grill—Cralle Student Center

8:00 a.m.–5:30 p.m.
Vendor Exhibits, Hall of Fame Room—Cralle Student Center

8:00 a.m.–12:00 noon
Sectional Meetings
Section C—Chemistry, Room 218; Section D—Geography, Room 14; Section G—Physiology and Biophysics, Room 219; Section H—Science Education, Room 33; Section K—Zoology and Entomology, Room 32; Section M—Mathematics, Room 132; Section Q—Agriculture Science, Room 131

9:00 a.m.–9:30 a.m.
Refreshments, Hall of Fame Room—Cralle Student Center; Lobby—Asher Science Center

12:00 noon–1:00 p.m.
Lunch, On your own; line service available Cralle Student Center

1:00 p.m.–2:15 p.m.
Plenary Session, John L. Hill Chapel
Presiding: Charles N. Boehms—President, Kentucky Academy of Science
Welcome: Dr. William H. Crouch, Jr., President, Georgetown College
Announcements: Dr. Barbara L. Rafaill, Chairperson, Local Arrangements Committee
Plenary Presentation: *Toyota Technology—Using Technology to an Advantage*—Mr. Doug Friesen, Manager of Assembly, Toyota Motor Manufacturing, Georgetown, Kentucky

2:15 p.m.–2:45 p.m.
Refreshments (beverages only), Hall of Fame Room—Cralle Student Center; Lobby—Asher Science Center

2:45 p.m.–5:00 p.m.
Sectional Meetings
Section B—Botany and Microbiology, Room 15; Section C—Chemistry, Room 218; Section D—Geography, Room 14; Section E—Geology, Room 17; Section G—Physiology and Biophysics, Room 219; Section H—Science Education, Room 33; Section I—Psychology, Room 133; Section J—Sociology, Room 26; Section K—Zoology and Entomology, Room 32; Section M—Mathematics, Room 132; Section Q—Agriculture Science, Room 131

5:00 p.m.–7:00 p.m.
Presidents Reception, Toyota Motor Manufacturing (hosted by Toyota Motor Manufacturing)

7:30 p.m.–9:15 p.m.
Annual Awards Banquet, Cralle Student Center
Teaching and Learning in the Information Age: K.E.T.S. in the Classroom—Mr. Michael Bidwell, District Technology Coordinator, Shelby County Public Schools

Saturday, 23 October 1993

7:30 a.m.–12:00 noon
Registration, Lobby—Cralle Student Center

8:00 a.m.–2:00 p.m.
Poster Exhibits, Grill—Cralle Student Center

8:00 a.m.–2:00 p.m.
Vendor Exhibits, Hall of Fame Room—Cralle Student Center

8:00 a.m.–9:30 a.m.
Sectional Meetings
Section A—Anthropology, Room 33; Section F—Physics, Rooms 112 and 128; Section I—Psychology, Room 133; Section K—Zoology and Entomology, Room 32; Section L—Computer Science, Room 218; Section M—Mathematics, Room 132; Section N—Engineering, Room 17; Section Q—Agricultural Science, Room 131

9:30 a.m.–10:00 a.m.
Refreshments, John L. Hill Chapel (beverages only)

10 a.m.–11:00 a.m.
Annual Business Meeting, John L. Hill Chapel

11:00 a.m.–12:00 noon
Sectional Meetings, Rooms same as above

12:00 noon–1:00 p.m.
Lunch, On your own; line service available Cralle Student Center

1:15 p.m.–end
Sectional Meetings, Rooms same as above

Note: KJAS

Each spring the Kentucky Junior Academy of Science holds an Annual Spring Symposium. The 59th Symposium was held at Western Kentucky University on 23–24 April 1993. Activities at this meeting included the presentation of Science Projects by KJAS members, Science Bowl competition and Lab Skills competition. The winners of each division of the Science Projects presentations are invited to present their work at the annual meeting of the Kentucky Academy of Science. A KJAS precedes the title of each of the papers given by these young scientists.

COMMUNITY COLLEGES SCIENCE FACULTY

Room 112

Friday, 22 October 1993

10:00 a.m.
General Session, Room 112

10:30 a.m.
Break-out Sessions
Biology, Room 112; Chemistry, Room 202; Physics, Room 128

ANTHROPOLOGY SECTION

James F. Hopgood and Phyllis Passariello
Co-Chairpersons
Room 33

Saturday, 23 October 1993
James F. Hopgood—Presiding

8:00 a.m.
Medieval Castles in a Modern Society: Another Tragic Breakdown in the Time-Honored Anglo-Saxon Jury System
Jim-Murray Walker—Eastern Kentucky University

8:15 a.m.
The Contribution of Refugee Studies to Anthropology
Mary Carol Hopkins—Northern University

8:30 a.m.
Applying Concepts from Anthropology in a Occupational Therapy Program
Angela Scoggin—Eastern Kentucky University

8:45 a.m.
Film Making Among the North Carolina Cherokees
Sharlotte Neely—Northern Kentucky University

9:00 a.m.
Analysis of Newspaper Reports of Child Fatality. Cara Richards—Transylvania University

9:15 a.m.
An "Open" History of a "Closed" Peasant Community. Tim Murphy—Northern Kentucky University

9:30 a.m.
Refreshments, John L. Hill Chapel

10:00 a.m.
Annual Business Meeting, John L. Hill Chapel

11:30 a.m.
Peasant Subculture in China
Andy Kipnis—Northern Kentucky University

Saturday, 23 October 1993
James F. Hopgood—Presiding

11:45 a.m.
Asian Studies Development Program, Phase II: China Field Studies
James F. Hopgood—Northern Kentucky University

12:00 noon
Anthropology Section Business Meeting

BOTANY AND MICROBIOLOGY SECTION

Landon McKinney—Chairperson
Barbara Rafail—Secretary
Room 15

Friday, 22 October 1993
Landon McKinney—Presiding

2:45 p.m.
KJAS
The effects of sodium chloride on the transpiration of pinto beans
Linda Rymarquis—Notre Dame Academy. Sponsored by Sisters Mary Ethel Parrott and Mary Judith Averbeck

3:00 p.m.
The disproof of Beer's Law (for bacteria) and a method of translation from photospectrometer absorption to bacterial population
Christopher Brown—duPont Manual. Sponsored by Barbara Fendley.

3:15 p.m.
The Distribution and Habitat of Coastal Plain Plants on the Cumberland Plateau
Ronald Jones—Eastern Kentucky University

3:30 p.m.
Botanical Survey of the London Ranger District, Daniel Boone National Forest
Julian Campbell and Richard Abbott—The Nature Conservancy and Berea College

3:45 p.m.
The Status of Kentucky's St. John's Worts (*Hypericum* Sect. *Ascyrum*)
Ross C. Clark—Eastern Kentucky University

4:00 p.m.
Sulfur in *Liquidambar orientalis* from Turkey
J. E. Winstead—Western Kentucky University

4:15 p.m.
Light and Electron Microscopic Investigations of a Freshwater, Biflagellated Green Algae (Euglenophyta)
Nancy Dawson—Western Kentucky University

4:30 p.m.
The Northern Kentucky University Diatom Herbarium
M. Steinitz Kannan—Northern Kentucky University

4:45 p.m.
Effects of Mulch Color on Vegetative Growth of Okra
Edith Greer, Catherine Mahl, Karan Kaul, and Michael Kasperbauer—Kentucky State University

5:00 p.m.
Botany and Microbiology Business Meeting

CHEMISTRY SECTION

Ted Shields—Chairperson
Room 218

Friday, 22 October 1993
Ted Shields—Presiding

8:00 a.m.
Water Quality of the Big Sandy River
Steven Berger, Timothy Lavender, and John G. Shiber—Prestonsburg Community College

8:30 a.m.
Glass Transition Temperature for PET
Beverly Campbell and Wei-Ping Pan—Western Kentucky University

9:00 a.m.
Refreshments, Lobby—Cralle Student Center

9:15 a.m.
Applications of TG-FTIR in the Thermoanalysis Laboratory
Jiangling Liu, Yongchi Li, and Wei-Ping Pan—Western Kentucky University

9:30 a.m.
The Effects of Chlorine on Boiler Corrosion
Marian Lee Upchurch, Hai-Bin Coa, Brian Bixler, and Wei-Ping Pan—Western Kentucky University

9:45 a.m.
Progress on Transition Metal Catalyzed Peptide Synthesis
Richard Reznik, Brian Gillispie, Glenn Kelley, and Masangu Shabangi—Asbury College

10:00 a.m.
Nickel Catalyzed Peptide Synthesis
Glenn A. Kelley and Richard Reznik—Asbury College

10:15 a.m.
Zinc Catalyzed Peptide Synthesis
Brian S. Gillispie and Richard Reznik—Asbury College

10:30 a.m.
Synthesis, Characterization, and Reactivity of a Urea Derivative Coordinated to Cobalt (III)
Billy Helton, Miranda Prewitt, Lee Roecker, Anthony C. Willis, and Alan M. Sargeson—Berea College

10:45 a.m.
Analysis of First-Order Kinetic Data by a Differential Technique
Shing Mirn Lee, Li Jing Sun, Koorosh Zaerpoor, and Lee Roecker—Berea College

11:00 a.m.
The Kinetics and Mechanisms of Carbon/Sulfur Cleavage and Formation Reactions of Thioelther Ligands Coordinated to Cobalt (III)
Berekt Berhane, Liwen Liu, and Lee Roecker—Berea College

11:15 a.m.
KJAS
Determination of the Cell Cycle Stage in Which Cyclosporine-A Inhibits Proliferation of W62 T-lymphocytes
Joshua Denny—duPont Manual. Sponsored by Barbara Fendley

11:30 a.m.
The Study of Lewis Acid/Alumina Complexes on Diels-Alder Reaction
Hunter R. Barber, Julie Tan and Ann Hoffelder—Cumberland College

11:45 a.m.
Photo Assisted Atomic and Molecular Processes
Elizabeth Rittenberry, Kenneth M. Sando, Thomas Donan, and Ann Hoffelder—Cumberland College

12:00 noon
Lunch, On your own

1:00 p.m.
Plenary Session, John L. Hill Chapel

2:15 p.m.
Refreshments, Lobby—Cralle Student Center

2:30 p.m.
Relative Rates of Reaction of Halodiazirines with Azide Ion in the S Reaction
Jennifer L. Jones, Xavier Creary, and Ann Hoffelder—Cumberland College

2:45 p.m.
The Determination of the Number of Hydroxyl Groups on the Surface of Alumina
Douglas Smith, Julie Tan, and Ann Hoffelder—Cumberland College

3:00 p.m.
Blood Serum Ion Alteration in Channel Catfish as a Function of Acute Temperature Changes
Jeff Stidam, John T. Riley, and Jeff Kent—Western Kentucky University

3:15 p.m.
Determination of Coal Sulfur Forms Using Thermal Analytical Techniques

L. Michelle Lewis, R. Forsythe, M. Guo, B. Wang, and D. Zhang—Western Kentucky University

3:30 p.m.
The Capability of Microorganisms Isolated from Eastern Kentucky Mine Drainage Sites to Remove Sulfur from Coal
Shirley Thomas and John T. Riley—Prestonsburg Community College and Western Kentucky University

3:45 p.m.
Chemistry Section Meeting

GEOGRAPHY SECTION

James M. Bingham—Chairperson
Stuart A. Foster—Secretary
Room 14

Friday, 22 October 1993
James M. Bingham—Presiding

11:00 a.m.
Latitudinal Variation of Consecutive Day Precipitation
Glen Conner—Western Kentucky University

11:15 a.m.
The Ascent of Wind Power
Mary M. Snow—Western Kentucky University

11:30 a.m.
Kentucky Winds and Renewable Energy: A Summarization of Wind Power Potential in the Commonwealth
Richard K. Snow—Western Kentucky University

11:45 a.m.
Transportation Facilities Analysis of Warren County, Kentucky
James L. Davis—Western Kentucky University

12:00 noon
Lunch

1:00 p.m.
Plenary Session, John L. Hill Chapel

2:15 p.m.
Refreshments, Lobby—Cralle Student Center

2:45 p.m.
Inverse Relationship between Monthly Wind Velocities and Precipitation in the United States and Pacific Basin
Conrad T. Moore—Western Kentucky University

3:00 p.m.
A New Approach to Measuring Segregation
Mark Lowry II and Stuart Foster—Western Kentucky University

3:15 p.m.
Developing "Mercosur"; Can Argentina and Brazil Replicate the European Common Market?
David J. Keeling—Western Kentucky University

3:30 p.m.
Kentucky's Journey to Work 1970–1990: A Comparative Analysis
Wayne Hoffman and James Bingham—Western Kentucky University

3:45 p.m.
The Discovery and Exploration of Side's Cave, Hart County, Kentucky, 1991–1992
James Wells and Christopher G. Groves—Western Kentucky University

4:00 p.m.
Recent Cave Exploration in the Central Kentucky Karst
Christopher G. Groves and James R. Wells—Western Kentucky University

4:15 p.m.
Determining Groundwater Flow Directions, Monitoring Locations and Sampling Frequencies at Hazardous Waste Sites on Karst Terrane without Installing Monitoring Wells
Nicholas Crawford—Western Kentucky University

4:30 p.m.
Water Conservation Systems Developed Centuries B.C., Part I: The Falaj System of Oman
L. Michael Trapasso—Western Kentucky University

4:45 p.m.
Geography Session Meeting

GEOLOGY SECTION

Graham Hunt—Chairperson
Deborah Kuehn—Secretary
Room 17

Friday, 22 October 1993
Deborah Kuehn—Presiding

1:00 p.m.
Plenary Session, John L. Hill Chapel

2:15 p.m.
Refreshments, Lobby—Cralle Student Center

2:30 p.m.
Outwash, Lacustrine and Alluvial Deposits of the Mile 605 Area, Ohio River
Graham Hunt—University of Louisville

2:42 p.m.
Economic Geology of the Georgetown Quad, GQ-605, Ky
Graham Hunt—University of Louisville

2:54 p.m.
Acroporid Reefs of Johnston Atoll, Pacific Ocean
Graham Hunt—University of Louisville

3:06 p.m.
The Einunnfjellet Dome, Norway—A Glimpse into an Orogen
Beth McClellan—Western Kentucky University

3:18 p.m.
KJAS
Investigating the Groundwater of Specific Formations Used as Well Water Sources for the Presence of Lead in Lewis County
Sheri Gilbert—Lewis County High School. Sponsored by Sheree Robinson

3:30 p.m.
Gravity Anomalies and Geometry
Carmen Painter—Western Kentucky University

3:42 p.m.
Development of a Geographic Information System for Karst Groundwater Research
Kyle Bearden—Western Kentucky University

3:54 p.m.
Some Petroogic and Chemical Characteristics of a Transgressive Pet Deposit in San Salvador, Bahamas
Margaret Chair—Western Kentucky University

4:06 p.m.
Prospects for Utilization of Ultrafine and Micronized Coals
Kenneth W. Kuehn—Western Kentucky University

4:18 p.m.
Paleontology and Identification of a Newly Exposed Roadcut West of Auburn, Kentucky
Deborah Kuehn and Michael Sykes—Western Kentucky University

4:40 p.m.
Geology Section Business Meeting

PHYSICS SECTION

John Christopher—Chairperson
Vincent DiNoto—Secretary
Rooms 112 and 128

Saturday, 23 October 1993
John Christopher—Presiding

9:00 a.m.
Chaos in a Dynamical System/Chaos in a Mathematical Model: The Bouncing Ball Problem
Chris M. Graney and Nyeita Irish—Jefferson Community College, Southwest Campus

9:15 a.m.
An Enhanced Model for the Bouncing Ball Problem
Nyeita Irish and Chris M. Graney—Jefferson Community College, Southwest Campus

9:30 a.m.
The Morehead Radio Telescope
Ben Malphrus, Jack Whidden, Russ Brengelman, David Cutts, V. Rajaravivarma, Rodney Stanley, and Eric Thomas—Morehead State University

9:45 a.m.
Evolution of a Coagulating System
B. R. Anderson and H. R. Kobraei—Murray State University

10:00 a.m.
Microscopic Treatment of Vapor Phase Nucleation
H. R. Kobraei and B. R. Anderson—Murray State University

10:15 a.m.
Section Business Meeting

10:30 a.m.
Break

10:45 a.m.
Determination of Temperature and Velocity of Rocket Plumes by Laser Induced Fluorescence
Stephen H. Cobb—Murray State University

11:00 a.m.
PRISM
Led by Gary Boggess, Dean of Science, Murray State University

12:00 noon
Lunch, On your own

1:00 p.m.
The Development of a Pump Laser for Rocket Borne LIDAR
Matt Lowry, Roger Scott, Richard Hackney, and Karen Hackney—Western Kentucky University NASA/Kentucky Space Grant Consortium Space

1:15 p.m.
Science Opportunities for Students and Faculty
Karen Hackney, Richard Hackney, Thomas Bohuski, and Roger Scott—Western Kentucky University

1:30 p.m.
An Astronomy and Space Science Workshop to Support KERA Objectives
Roger Scott, Richard Hackney, Karen Hackney, R. Tyler, M. Smith—Western Kentucky University

1:45 p.m.
Data Acquisition and Experiment Control in the Surface Physics Laboratory at Western Kentucky University
Islamshah Amlani, Todd Stinson, Douglas Harper—Western Kentucky University

2:00 p.m.
Elastic Response of a Thin Aluminum Tube to Shock Loading
Islamshah Amlani and Douglas Harper—Western Kentucky University

2:15 p.m.
The JOVE Program: NASA/University JOINT VENTURES in Space Research
Maria Falbo-Kenkel, Raymond C. McNeil, and David J. Schneider—Northern Kentucky University

2:30 p.m.
Break

2:45 p.m.
Tests of Conformal Gravity: Galactic Rotation Curves
Maria Falbo-Kenkel—Northern Kentucky University

3:00 p.m.
Ultraviolet Spectrophotometry of a Sample of B Supergiants in the Small Magellanic Cloud
Raymond C. McNeil—Northern Kentucky University

3:15 p.m.
Experimental and Theoretical Analysis of Natural Very Low Frequency "Whistlers" Generated by Lighting
David J. Schneider—Northern Kentucky University

3:30 p.m.
A Magnetic Field Test Facility

J. Doug Smith and W. S. Wagner—Northern Kentucky University

PHYSIOLOGY, BIOPHYSICS AND PHARMACOLOGY

Dexter Speck—Chairperson
Room 219

Friday, 22 October 1993
Dexter Speck—Presiding

8:00 a.m.
Models for Primary Production with Emphasis on Kentucky Lake Reservoir
Julie Bennett, H. R. Kobraei, and B. R. Anderson—Murray State University

8:15 a.m.
Experimental Primary Production in Kentucky Lake Reservoir
Alesia Townsend, H. R. Kobraei, and B. R. Anderson—Murray State University

8:30 a.m.
Uterine Microvascular Response to Serotonin in the Normotensive and Hypertensive Rat
Julie Hornung, Nancy L. Alsip, and Eleanor Asher—University of Louisville

8:45 a.m.
Blood Flow of Rat Reproductive Organs During the Estrous Cycle Before and After Administration of Human Chorionic Gonadotropin (hCG)
J. B. Miller, A. E. Jimenez, J. C. Passmore, and C. V. Rao—University of Louisville

9:00 a.m.
Refreshments, Lobby—Cralle Student Student

9:30 a.m.
Effect of Magnesium Intake on Bone Loss Associated with Energy Restriction
C. Wang, C. J. Lee, and A. Babalmoradi—Kentucky State University

9:45 a.m.
Down Regulation of Drug Detoxifying Enzymes in Embryonal Carcinoma Cells Cultured with Retionic Acid
S. Vogelpohl, E. Meier, S. Ebert, J. Pullman, D. Wilkening, and J. Carter—Wodd Hudson Cancer Research Laboratory

10:00 a.m.
Conformational Analysis of Lipid-Bound and Non-Lipid-Bound Apolipoprotein Ai by Limited Proteolysis
Erika Hayden and Linda Roberts—Centre College

10:15 a.m.
Vascular Response to Nitric Oxide Synthase Blockade in Pregnant and Non-Pregnant Rats
A. L. Forsberg and R. T. Dowell—University of Kentucky

10:30 a.m.
Purification and Characterization of a Deoxyrinonuclease from Etiolated Soybeans
V. L. Dunham and C. Xu—Western Kentucky University

10:45 a.m.
Toxicity of Glyceollin to *Fusarium solani* and Correlation with Pathogenicity on Soybeans
Manoj Warrier and Margaret G. Richey—Centre College

11:00 a.m.
In Vitro Endopolygalacturonase Activity and Pathogenicity of *Fusarium solani* on Soybeans
Kristine DeStefano and Margaret G. Richey—Centre College

11:15 a.m.
Resonant Power Frequency Magnetic Fields Alter Growth of Radish Seedlings
Stephen D. Smith—University of Kentucky, Bruce R. McLeod—Mountain State University and Abraham R. Liboff—Oakland University

11:30 a.m.
Testosterone and Estradiol Concentrations in the Blood Plasma of Paddlefish Before and After Injection with LHRH Analog
Richard J. Onders, Steven D. Mims, and Julia A. Clark—Kentucky State University

12:00 noon
Lunch, On your own

1:00 p.m.
Plenary Session, John L. Hill Chapel

2:15 p.m.
Refreshments, Lobby—Cralle Student Center

2:30 p.m.
Dehydration Effects on Osmoregulation by Adult and Larval Bullford, *Rana catesbeiana*
Endang Widiastuti and John J. Just—University of Kentucky

2:45 p.m.
Phenylalanine and P-hydroxybenzoic Acid in Combination Therapy in the Treatment of Sickle Cell Disease
Felix O. Akojie—Paducah Community College and Leslie W-M. Fung—Loyola University

3:00 p.m.
Aflatoxin—DNA Interactions
Suzanne Byrd—Eastern Kentucky University

3:15 p.m.
Physiology, Biophysics and Pharmacology Section Business Meeting

ATTENTION:
Following the Business Meeting there will be a workshop entitled, "Integrative Studies in Human Physiology and Medicine: A Case History Involving Diabetes Mellitus" conducted by Richard T. Lyons—Jefferson Community College.

SCIENCE EDUCATION

Benjamin Malphrus—Chairperson
Robert Boram—Secretary
Room 133

Friday, 22 October 1993
Benjamin Malphrus—Presiding

9:00 a.m.
Refreshments, Lobby—Cralle Student Center

9:30 a.m.
Learning the Methodology of Science by Dissecting Journal Articles
Peter V. Lindeman—Madisonville Community College

9:45 a.m.
Bottle Biology
Kim Alexander and Robert Creek—Eastern Kentucky University

10:00 a.m.
Tissue Culturing Using the "Wisconsin Fast Plants"
Robert Creek and Kim Alexander—Eastern Kentucky University

10:15 a.m.
"Introduction to Chemistry" Course at Western Kentucky University Using an Armchair Laboratory
Lowell W. Shank, Stephanie L. Hammons, and Amanda J. Ayer—Western Kentucky University

10:30 a.m.
Success as Perceived by Community College Students
John G. Shiber—Prestonburg Community College

1:00 p.m.
Plenary Session, John L. Hill Chapel

2:15 p.m.
Refreshments, Lobby—Cralle Student Center

2:45 p.m.
Usefulness of a Nature Trail in Teaching Biology Students
Pamela S. McLaughlin and Peter V. Lindeman—Madisonville Community College

3:00 p.m.
An application of TQM Principles to the Classroom: An Investigation and Analysis
Alan D. Smith and Paul M. Majorsky—Robert Morris College

3:15 p.m.
A Procedure for Integration of Science and Computer Instruction in a Secondary Science Classroom
Cloyd J. Bumgardner—Calloway County High School and Kim Worley—Somerset Community College

3:30 p.m.
Administration of a Biology Teaching Curriculum Designed to Achieve Kentucky Education Reform Act Valued Outcomes in the Secondary Science Classroom
Cloyd J. Bumgardner—Calloway County High School

3:45 p.m.
Health Care Needs and Management: Survey and Implications
Alan D. Smith—Robert Morris College

4:00 p.m.
Homemade Videotape of an Experiment on the Chemical Analysis of an Alloy
C. C. Wilkins, N. W. Hunter, and S. J. Redden—Western Kentucky University

4:15 p.m.
Science Education Business Meeting

PSYCHOLOGY SECTION

Jeffrey Smith—Chairperson
Tery Barrett—Secretary
Room 133

Friday, 22 October 1993
Jeffrey Smith—Presiding

2:30 p.m.
KJAS
Reaction Time: How Musical Stimuli and Tempo Affect Human Reaction Time
Matthew Carper—duPont Manual High School. Sponsored by Barbara Fendley

2:45 p.m.
Behavioral Effects of Late Embryonic Exposure to Cocaine and Ethanol on the Young Chick
Isaac Caton, John Dose, and James Zolman—University of Kentucky

3:00 p.m.
Embryonic Exposure to Coadministration of Ethanol and Cocaine on Acquisition and Extinction Behavior in the Young Chick
John Dose, Isaac Caton, and James Zolman—University of Kentucky

3:15 p.m.
Effect of the Opiate Buprenorphine on Amphetamine Reward in Rats
Ronya Gibson, James Rowlett, and Michael Bardo—University of Kentucky

3:30 p.m.
The Effects of Brain Lesions on Spatial Learning Assessed with a 1-day Morris-water-maze Procedure
Russell Brown, Philip Kraemer, and Stephen Schef—University of Kentucky

3:45 p.m.
Timing an Interval Does not Require Attention, If You Are a Pigeon
Karen Roper and Thomas Zentall—University of Kentucky

4:00 p.m.
It's Not What You Are, but Who You Hang Around with
Lou Sherburne and Thomas Zentall—University of Kentucky

4:15 p.m.
Using Teacher's Expectations to Break the Vicious Cycle of Failure with the Reading Disabled Child
Robert T. Simpson and L. Gibbs—Western Kentucky University

4:30 p.m.
Effects of Haloperiodol on Cocaine-induced Behavioral Sensitization
Sonia Fields, Kristin Rase, and Bruce A. Mattingly—Morehead State University

4:45 p.m.
SCH23390 Blocks the Behavioral, but not the Neurochemical Effects of Repeated Quinpirole Treatments

Steve McDonald, Tracye Ellison and Bruce A. Mattingly—Morehead State University

5:00 p.m.
Hallucinations in Normals: Exploring Reports Across Sensory Domains
Terry R. Barrett—Murray State University

5:15 p.m.
Adult Child Coresidence
Lorraine C. Basso—Murray State University

Saturday, 23 October 1993
Jeffrey Smith—Presiding

8:00 a.m.
The Effects of Individual Difference Variables on the Relationship between Verbal Praise and Performance
Shalonda L. Cawthon—Murray State University

8:15 a.m.
The Impact of Ergonomics on Consumer Attitudes
Peter Batsakee, Matt Shank, and Jeffrey Smith—Northern Kentucky University

8:30 a.m.
The Effects of Shift Work on Illness
Traci Hamlin—Murray State University

8:45 a.m.
The Effects of Workload on the Identification of Motorcycles
Kevin Martin, Peter Batsakes, Cyndia McDaniel, Lisa Gloeckler, and Jeffrey Smith—Northern Kentucky University

9:00 a.m.
Gender and Spatial Ability: A Piece of the Puzzle
Kevin R. Newman—Murray State University

9:15 a.m.
Refreshments, John L. Hill Chapel

10:00 a.m.
Annual Business Meeting, John L. Hill Chapel

11:15 a.m.
Prosecuting the Offender: Does it Promote the Healing Process after Rape?
Hope B. Patterson—Murray State University

11:30 a.m.
Sex Differences in EMG Biofeedback Training
Sarah Scott and Jack Thompson—Centre College

11:45 a.m.
Religious Motivation and Fear of Death
Janet M. Shreves—Murray State University

12:00 noon
Lunch, On your own

1:30 p.m.
The Relationship of Stress and Sleepwalking
Nicole P. Swanson—Murray State University

1:45 p.m.
Reducing Homophobia among University Students
Dana A. Westerman—Murray State University

2:00 p.m.
An Evaluation of Rehabilitation Procedures in Occupational Therapy
Kelly R. Young—Murray State University

2:15 p.m.
Attention Deficit Disorder: The Effectiveness of Classroom Intervention
Susan B. Buckman—Murray State University

2:30 p.m.
Psychology Section Business Meeting

Sociology Section

J. Allen Singleton and Steve Savage
Co-Chairpersons
Room 26

Friday, 22 October 1993
J. Allen Singleton—Presiding

2:45 p.m.
The Politics of Campaigning for Collegiate Student Office
April Ramsey (Undergraduate) and J. Allen Singleton—Eastern Kentucky University

3:00 p.m.
The Controversy over Spotlight Hunting in Clay County
Ernie Ferguson (Undergraduate) and J. Allen Singleton—Eastern Kentucky University

3:15 p.m.
U.S.–Cuban Relations
Will Grant (Undergraduate) and J. Allen Singleton—Eastern Kentucky University

3:30 p.m.
Trail Drives of Appalachian Kentucky
J. Allen Singleton—Eastern Kentucky University

3:45 p.m.
Uses of Public Assistance to Preserve Middle Class Status
Cynthia Huffman, Mary Ann Long (Undergraduates) and Steve Savage—Eastern Kentucky University

4:00 p.m.
Sociology Section Business Meeting

Zoology and Entomology Section

Monte P. Johnson—Chairperson
Guenter Schuster—Secretary
Room 32

Friday, 22 October 1993
Monte P. Johnson—Presiding

9:30 a.m.
KJAS
The Use of Potassium Chloride to Control the Zebra Mussel and the Possible Effects on the Aquatic Ecosystem
Matthew Graul—Henderson County High School. Sponsored by Susan Mueller

9:45 a.m.
Embryological Development of the Fathead Minnow (*Pimephales promelas*)

W. K. Dorsey and B. A. Ramey—Eastern Kentucky University

10:00 a.m.
In vitro Culture of *Microplitis croceipes* Teratocytes and the Effects of Teratocyte Secretory Products
Eric J. Schepers, Douglas Dahlman and Deging Zhang—University of Kentucky

10:15 a.m.
Microplitis croceipes Teratocyte Secretory Product(s) Blocks *In vitro* Metabolic Processes of Fat Body Tissue of *Heliothis virescens*
Deging Zhang and D. L. Dahlman—University of Kentucky

10:30 a.m.
Effects of Temperature and Dosage on Mortality of Three Stored-product Insect Species Exposed to Insecto®
Burr H. Settles and Paul A. Weston—Kentucky State University

10:45 a.m.
Stimulation of Oviposition in the Angoumois Grain Moth
Patti L. Rattlingourd, Paul A. Weston, and Jacqualine Perkins—Kentucky State University

11:00 a.m.
Toxic and Anti-feedant Effects of Fractions from *Zanthoylum bungeanum* Extract on Larvae of *Sitotroga cerelella* (Oliver)
Ziaosong Ge and Paul A. Weston—Kentucky State University

12:00 noon
Lunch, On your own

1:00 p.m.
Plenary Session, John L. Hill Chapel

2:15 p.m.
Refreshments, Lobby—Cralle Student Center

2:30 p.m.
Local Variation in the Timing of Maturation in Female Painted Turtles (*Chrysemys picta*)
Peter V. Lindeman—Madisonville Community College

2:45 p.m.
Phylogeny of *Plethodon doralis* and *Plethodon cinereus*: Distribution and Systematic Data
S. Marcus Kirtley, Teresa R. Forsyth, and Bill J. Forsyth—Indiana University Southeast

3:00 p.m.
Zoology and Entomology Business Meeting

3:15 p.m.
Leafhoppers and Treehoppers on Pin Oak
Monte P. Johnson and Paul H. Kreytag—University of Kentucky

3:30 p.m.
Phylogeny of *Plethodon doralis* and *Plethodon cinereus*: Allozyme Variation
Teresa R. Forsyth and S. Macrus Kirtley—Indiana University Southeast

3:45 p.m.
Ontogenetic Changes in Growth Efficiency in Laboratory-Reared Water Snakes of the Genus *Nerodia*
Roy M. Scudder-Davis—Berea College

4:00 p.m.
Diet of Kentucky's Threatened Spotted Darter, *Etheostoma maculatum* (Pisces: Percidae)
Richard K. Kessler—University of Louisville

4:15 p.m.
In vivo and in vitro Effects of Light on Ommatidial Morphology in the Cockroach, *Leucophaea maderae*
Channon Yule and Blaine R. Ferrell—Western Kentucky University

4:30 p.m.
Effects of Complete Feed and Supplemental Feed with and without Organic Fertilization on Pond Production of the Freshwater Prawn, *Macrobrachium rosenbergii*
J. H. Tidwell, C. D. Webster, W. Knight, and L. R. D'Abramo—Kentucky State University

4:45 p.m.
Benthic Macroinvertebrates Associated with Various Diets and Fertilizer Regimes Fed to Freshwater Prawns, *Macrobrachium rosenbergii,* in Artificial Ponds: Preliminary Results
Sankie J. Hill, Jr., John Sedlacek, Paul Weston, and James Tidwell—Kentucky State University

5:00 p.m.
Kentucky's Butterflies: Should any Species be Listed as Endangered or Threatened? Charles V. Covell, Jr.—University of Louisville

Saturday, 23 October 1993
Monte P. Johnson—Presiding

8:15 a.m.
An Inexpensive Pre-positioned Electrofishing Sampler for Habitat Assessment of Stream Fish
Gordon K. Weddle and Richard K. Kessler—Campbellsville College

8:30 a.m.
Reaction of Elk (*Cervus elaphus*) to Seismic Activity in South-central Montana
Steven C. Thomas—Eastern Kentucky University

8:45 a.m.
Rest Site and Denning Habits of Raccoons (*Procyon lotor*) in Central Kentucky
Charles L. Elliott and Jeff Norment—Eastern Kentucky University

Saturday, 23 October 1993
Monte P. Johnson—Presiding

9:00 a.m.
Seasonal Prevalence of Three Digenetic Trematode Cercariae in the Snail, *Hellisoma trivolvis*, at Owsley Fork Reservoir
Ronald B. Rosen, Jose M. Ilagan, Jessica K. Starnes, Marichelle Asuncion, Manuel L. San, and Melissa E. Denton—Berea College

9:15 a.m.
Effectiveness of a Constructed Wetland for Acid Mine Drainage Reclamation
A. J. Grant and B. A. Ramey—Eastern Kentucky University

9:30 a.m.
Refreshments, John L. Hill Chapel

10:00 a.m.
Annual Business Meeting, John L. Hill Chapel

COMPUTER SCIENCE SECTION

Richard A. Rink—Chairperson
Room 218

Saturday, 23 October 1993
Richard A. Rink—Presiding

8:15 a.m.
Microcomputer COBOL Compilers
Sylvia Clark Pulliam—Western Kentucky University

8:30 a.m.
Developing Appropriate Material for the SCI and C52 Closed Laboratory Courses
Carol W. Wilson—Western Kentucky University

8:45 a.m.
The Changing High School Computer Science Curriculum
Carol W. Wilson—Western Kentucky University

9:00 a.m.
Deadlock Detection in a Database System: An Algorithm of Complexity O(N)
John Crenshaw—Western Kentucky University

9:30 a.m.
Refreshments, John L. Hill Chapel

10:00 a.m.
Annual Business Meeting, John L. Hill Chapel

11:30 a.m.
Fuzzy Logic: Who? When? Why? and How?
Art Shindhelm—Western Kentucky University

11:45 a.m.
Computer Science Business Meeting

MATHEMATICS SECTIONS

Carroll G. Wells—Chairperson
Russell M. Brengelman—Secretary
Room 132

Friday, 22 October 1993
Russell Brengelman—Presiding

11:00 a.m.
A Computer Simulation of the Heart
Joe Zanchi, Student—Centre College

11:20 a.m.
Geometry Acclivities for the Classroom
Carroll Wells—Western Kentucky University

11:40 a.m.
Summer Science Camp Math
Ann Heard and Chris Leverenz—Georgetown College

12:00 noon
Lunch, On your own

1:00 p.m.
Plenary Session, John L. Hill Chapel

2:00 p.m.
Refreshments, Lobby—Cralle Student Center

2:40 p.m.
Calculus Reform Across Kentucky
Report on the NSF Calculus Institute
Darrell H. Abney—Maysville Community College
Calculus Using Mathematica
Chris Christensen—Northern Kentucky University
Laboratory Calculus at U.K.
Carl Eberhart—University of Kentucky
Communications for Math and Science
Paul Eakin—University of Kentucky

4:00 p.m.
Forestry in the Northwest
Edward C. Korntved—Morehead State University

4:20 p.m.
Data Compression Using Fractal Surfaces
Bruce Kessler—Western Kentucky University

4:40 p.m.
Mathematics Problem Solving, Student Motivation and Learning Theories
Russell M. Brengelman—Morehead State University

Saturday, 23 October 1993
Russell Brengelman—Presiding

8:00 a.m.
Utilization of Graphing Calculators in Discrete Mathematics Courses
Robert J. Lindahl—Morehead State University

8:20 a.m.
Prototyping Neural Networks
James Porter—Western Kentucky University

8:40 a.m.
A Class of Harmonizable Isotropic Random Fields
Randy Swift—Western Kentucky University

9:00 a.m.
PASS: An Accountability Project
Kathy Mouwers and Ramona Meador—Owensboro Community College

9:20 a.m.
It Ain't Necessarily So with Apologies to George Gershwin
John Spraker—Western Kentucky University

9:40 a.m.
Refreshments, John L. Hill Chapel

10:00 a.m.
Annual Business Meeting, John L. Hill Chapel

11:00 a.m.
Fair Division
Walter Feibes—Bellarmine College

11:20 a.m.
An Introduction to the Numerical Solution of Schrodinger-Type Equations Using Finite Element Methods
Mark Robinson—Western Kentucky University

11:40 a.m.
Solving O.D.E's
Kari Kelton, Student. Western Kentucky University

12:00 noon
Lunch, On your own

1:20 p.m.
Calculus Reform Across Kentucky
Report on the NSF Calculus Institute
Darrell H. Abney—Maysville Community College
Calculus Reform at WKU
Barry Brunson—Western Kentucky University
Calculus Using DERIVE and Graphing Calculators
Rodger Hammons—Morehead State University
Using the Harvard Calculus Textbook
Kathy Mowers and Karin Chess—Owensboro Community College
Open Discussion on Calculus Reform

3:00 p.m.
A Linear Programming Algorithm that Combines Continuous Variable and Combinatorial Techniques
David Atkinson—Western Kentucky University

3:20 p.m.
Generating Functions for a Class of Complex Sequences
James Barksdale—Western Kentucky University

3:40 p.m.
Section Business Meeting

ENGINEERING SECTION

Issam Harik—Chairperson
David Allen—Secretary
Room 17

Saturday, 23 October 1993
Issam Harik—Presiding

9:00 a.m.
A New Finite Element Model for Analysis of Slab-Girder Bridges
Meiwen Guo and Issam E. Harik—University of Kentucky

9:15 a.m.
Bridge Piers Subjected to Ship Impact
Michael W. Whitney, Issam E. Harik, and David L. Allen—University of Kentucky

9:30 a.m.
Refreshments, John L. Hill Chapel

10:00 a.m.
Annual Business Meeting, John L. Hill Chapel

11:15 a.m.
Cohort Analysis on Accident Rates of Older Drivers
Polepalli Vinary Kumar and Nidiforous Stamatiadis—University of Kentucky

11:30 a.m.
KJAS
Factors Affecting the Production and Action of Quicksand
Ellen Air—Notre Dame Academy. Sponsored by Sisters Mary Ethel Parrott and Mary Judith Averbeck

11:45 a.m.
Engineering Business Meeting

AGRICULTURAL SCIENCES SECTION

Robert J. Barney—Chairperson
Matthew E. Byers, Secretary
Room 131

Friday, 22 October 1993
Matthew E. Byers—Presiding

9:15 a.m.
The Horticulture Research Program at Kentucky State University: An Introduction
Desmond R. Layne—Kentucky State University

9:30 a.m.
Street Tree Inventory Using CIS Graphics
James E. Martin—Western Kentucky University

9:45 a.m.
Vegetable Yields Using Three Soil Management Strategies: 1993
Debra H. Hilborn, George F. Antonious, and Matthew E. Byers—Kentucky State University

10:00 a.m.–12:00 noon
Statewide Research Symposium
A presentation of ongoing agricultural research being conducted by the various universities in Kentucky. Presentations will be made by pertinent agricultural administrators. Open discussion will follow.

1:00 p.m.
Plenary Session, John L. Hill Chapel

2:15 p.m.
Refreshments, Lobby, Cralle Student Center

2:45 p.m.
Effects of Dietary Protein Level on Growth and Body Composition of Channel Catfish Reared Cages
Laura Goodgame Tiu, Carl D. Webster, James H. Tidwell, and Eddie B. Reed—Kentucky State University

3:00 p.m.
Animal Waste Management Systems in the Barren River Area: Soil and Plant Interactions with Animal Waste Application
O. W. Dotson, Ray Johnson, Bryan Kessler, Jason Slaton, and David Stiles—Western Kentucky University

3:15 p.m.
Comparison of Mineral Element Analyses by NIRS and Wet Lab Methods
Bryan Kessler, Linda Brown, and David Stiles—Western Kentucky University

3:30 p.m.
Break

3:45 p.m.
Plant and Soil Analyses Following High Rates of Application of Livestock Manure
Ray Johnson, Thomas Dotson, Alvin Bedel (Undergraduate), O. W. Dotson, David Stiles, and Jon Barrow—Western Kentucky University

4:00 p.m.
Runoff of Agricultural Chemicals
Nekiya Baker (Undergraduate), George F. Antonious, Debra J. Hilborn, and Matthew E. Byers—Kentucky State University

4:15 p.m.
The Effect of Promisulfuron and Nicosulfuron on the Growth of Johnsongrass, *Sorghum halepense*
James P. Worthington—Western Kentucky University

4:30 p.m.
Using Tension Lysimeters to Monitor Agricultural Chemical Infiltration
Dawn Green (Undergraduate) and Matthew E. Byers—Kentucky State University

4:45 p.m.
Effects of Soybean Cultivars and Planting Dates on Biomass Production
Aslam Tawhid and Elmer Gray—Western Kentucky University

Saturday, 23 October 1993
Matthew E. Byers—Presiding

8:00 a.m.
Effect of Synthetic DeOderase on Water Quality in Recirculating Aquaculture Systems
Wanda Knight (Undergraduate) and James H. Tidwell—Kentucky State University

8:15 a.m.
Effects of Large Animal Production Units on Stream Water Quality: Fish Community Assemblages
Robert Hoyt, Jon Barrow, Jason Slaton, and David Stiles—Western Kentucky University

8:30 a.m.
Effects of Large Animal Production Units on Stream Water Quality: Water Quality Parameters
Thomas Dotson (Undergraduate), David Stiles, O. W. Doston, Jason Slaton, and Alvin Bedel—Western Kentucky University

8:45 a.m.
Monitoring Constructed Wetlands in Kentucky
Frank S. Young, III (Undergraduate), George F. Antonious, and Matthew E. Byers—Kentucky State University

9:00 a.m.
Effects of Fertilization and Mowing on Persistence of Indian Mockstrawberry and Common Blue Violet
Elmer Gray and Neysa M. Call (Undergraduate)—Western Kentucky University

9:15 a.m.
Mixing Municipal Solid Waste Materials for Composting
Luther B. Hughes, Jr., Robert M. Schneider, Karen E. Prow (Undergraduate), Robert H. Austin, Jr., and Elmer Gray—Western Kentucky University

9:30 a.m.
Refreshments, John L. Hill Chapel

9:45 a.m.
Temperature Changes During Municipal Solid Waste Composting
Karen E. Prow (Undergraduate), Elmer Gray, Robert M. Schneider, and Luther B. Hughes, Jr.—Western Kentucky University

10:00 a.m.
Comparisons of Composts for Growing Vegetables in Containers
Brian Lacefield (Undegraduate), Ashlam Tawhid, and Elmer Gray—Western Kentucky University

10:15 a.m.
Stimulation of Oviposition in the Angoumois Grain Moth
Patti L. Rattlingourd, Paul A. Weston, and Jacqualine Perkins—Kentucky State University

10:30 a.m.
Effect of Different Colored Plastic Mulches on Insect Pests of Okra
M. M. Williams (Undergraduate), J. D. Sedlacek, P. L. Rattlingourd, B. D. Price, and J. D. Sedlacek—Kentucky State University

10:45 a.m.
Insect Populations in On-Farm Stored Corn During the First Year of Storage
J. D. Sedlacek, P. A. Weston, B. D. Price, and P. L. Rattlingourd—Kentucky State University

11:00 a.m.
Effect of Insecticide and Fungicide Treatment on Several Quality Parameters of Stored Shelled Corn
Bryan D. Price, John D. Sedlacek, and Paul A. Weston—Kentucky State University

11:15 a.m.
Agriculture Business Meeting

Sectional Posters

Posters were available for viewing for the duration of the meeting. Presenters were requested to be at their posters to facilitate discussion of their research at the following times: Friday, October 22 from 2:15 p.m. to 3:00 p.m. Saturday, October 23 from 9:00 a.m. to 10:00 a.m. and 11:00 a.m. to 12:00 noon.

1. Response of Tissue Porphyrin Metabolites to Altered Zinc Status and Toxic Metal Exposure
   M. Panemangalore and F. N. Bebe—Kentucky State University
2. Effect of Copper Status, Lead (Pb) and Cadmium (Cd) Exposure on Ceruloplasmin Activity in Adult Rats

M. Panemangalore, K. Mahal, F. N. Bebe, and E. Allaudin—Kentucky State University

3. Monitoring ppb Levels of Lead in Water from Drinking Fountains by Atomic Absorption Spectrophotometry
Robert Warford, David Fraley, and Kevin McGill—Georgetown College
4. Two-lined Salamanders, *Eurycea cirrigera*, Detect Chemical Deposits of Predatory Salamanders
Paul V. Cupp, Jr.—Eastern Kentucky University and Glenn Marvin—University of Oklahoma
5. Local Enhancement in Pigeons: Delayed Reinforcement Effects
Lynn A. Berberich, Carol Mokas, and David E. Hogan—Northern Kentucky University
6. MOVER—A Computer Simulation Model for Teaching and Investigating Two-dimensional Animal Movement Behavior
Paul A. Weston—Kentucky State University and James R. Miller—Michigan State University
7. Bacteria from Hypersaline Lagoons in the Galapagos Islands
Bettie Palmison and Miriam Steinitz Kannan—Northern Kentucky University
8. Predicting Student Performance in Liberal Arts Chemistry
David Fraley and David Forman—Georgetown College
9. Molecular Structure of Siloxene
B. J. Stigall—Murray State University, and James L. Meeks and Larry Bigham—Paducah Community College
10. Educating the Northern Kentucky Community about Psychopathology
Perilou Goddard, Deanne Auer, Beverly Lenicky, Angela Gumm, Sarah Ranso, James Thomas—Northern Kentucky University, and Earl Kreisa—Mental Health Association of Northern Kentucky
11. A Biotin Assay Using Time Resolved Fluorescence
Dawn Garrett—King College, and Angela Fultz, Sylvia Daunert, Leonidas Bachas—University of Kentucky
12. Are All Computer Hard Drives Created Equal?
B. J. Stigall—Murray State University and James L. Meeks—Paducah Community College
13. Survey of Kentucky Elder Citizen Perceptions of the Dental Profession's Ability to Serve Them Effectively
Arthur Van Stewart and Suzanne Meeks—University of Louisville
14. A Study of Homeless Facilities and Shelters to Determine Extent of Professional Dental Services Provided
Eric T. Veal and Arthur Van Stewart—University of Louisville
15. Impact on New OBRA-mandated Dental Reporting System on State Licensing and Ratings of Nursing Home Facilities in Kentucky
Bryan G. Harness, Arthur Van Stewart—University of Louisville and Julia McKee—Cabinet for Human Resources
16. Site-directed Mutagenesis of Southern Bean Mosaic Virus Protease
Alan J. Simmons and Claire A. Rinehart—Western Kentucky University

HHMI Biological Sciences Undergraduate Inititative
University of Kentucky
John M. Rawls, Jr., Director

17. Phenylalanine and p-hydroxybenzoic acid in Combination Therapy in the Treatment of Sickle Cell Disease
Felix D. Akojie and Leslie W-M. Fung—Paducah Community College
18. Localization of a Methylation Signal
Brandon McGrath, Padmaja Mummaneni and Mitchell Turker
19. Characterization of a Transgene-Induced Mutation That Alters Motor Neuron Function in Mice
Stephen L. Wang and Braett T. Spear
20. Role of Jasmonic Acid on Wound-Induced Alkaloid Increases in Nicotiana Plants
Alice Taylor, Pierce Fleming, Roger Anderson, and David Hildebrand
21. Conformation-Activity Relationships of the Heat-Stable STp Enterotoxin
Matthew H. Wilson and Judith G. Shelling
22. Regulation of Phytoalexin Biosynthesis: Resection Analysis of a Sesquiterpene Cyclase Gene Promoter
Jeffery W. Morrison, Shaohui Yin, and Joe Chappell
23. Molecular Cloning and Characterization of the Chick NMDA Receptor
Amina Shalash, Brian Davis, and Laurie Garner
24. The Physiological and Cellular Control of Hatching in the Fathead Minnow (*Pimephales promelas*)
Juanita Combs, Tracy Livingston Longley, and John J. Just
25. The Synergistic Inhibition of T-lymphocytes by Dexamethasone and Prostaglandin E2
Brad Sparks and Lucinda Elliott
26. The Protective Proteins of the Fly, *Phormia regina*
John F. Lamon III and Gerald A. Rosenthal

PRESIDENTS OF THE KENTUCKY ACADEMY OF SCIENCE

1914–1915 Joseph H. Kastle
1915–1916 N. F. Smith
1916–1917 A. M. Miller
1917–1918 R. C. Ballard
1918–1919 J. E. Barton
1919–1920 Paul P. Boyd
1920–1921 W. H. Coolidge
1921–1922 George D. Smith
1922–1923 Lucien Becker
1923–1924 W. R. Jillson
1924–1925 Cloyd M. McAllister

1925–1926	Austen R. Middleton
1926–1927	W. G. Burroughs
1927–1928	W. D. Valleau
1928–1929	G. D. Buckner
1929–1930	Frank L. Rainey
1930–1931	V. F. Payne
1931–1932	Anna A. Schnieb
1932–1933	George Roberts
1933–1934	John S. Bangson
1934–1935	Alfred M. Peter
1935–1936	J. S. McHargue
1936–1937	Robert T. Hinton
1937–1938	L. Y. Lancaster
1938–1939	W. R. Allen
1939–1940	A. W. Homberger
1940–1941	Charles Hire
1941–1942	G. B. Pennebaker
1942–1943	J. T. Skinner
1943–1944	L. A. Brown
1944–1945	L. A. Brown
1945–1946	Paul Kolachov
1946–1947	Ward Sumpter
1947–1948	Alfred Brauer
1948–1949	Morris Scherago
1949–1950	W. E. Blackburn
1950–1951	E. B. Penrod
1951–1952	Harvey B. Lovell
1952–1953	Thomas Herndon
1953–1954	C. B. Hamann
1954–1955	R. H. Weaver
1955–1956	J. G. Black
1956–1957	A. M. Wolfson
1957–1958	William M. Clay
1958–1959	William B. Owsley
1959–1960	Pete Panzera
1960–1961	H. H. LaFuze
1961–1962	Charles Whittle
1962–1963	Lyle Dawson
1963–1964	R. A. Chapman
1964–1965	C. B. Hamann
1965–1966	John M. Carpenter
1966–1967	Robert M. Boyer
1967–1968	Paul G. Sears
1968–1969	Orville Richardson
1969–1970	Lloyd Alexander
1970–1971	Karl Hussung
1971–1972	Louis Krumholz
1972–1973	Marvin W. Russell
1973–1974	Donald Batch
1974–1975	Ellis V. Brown
1975–1976	Frederick M. Brown
1976–1977	Charles Payne
1977–1978	Charles Kupchella
1978–1979	Sanford L. Jones
1979–1980	Rudolph Prins
1980–1981	John Philley
1981–1982	Ted M. George
1982–1983	J. G. Rodriguez
1983–1984	Gary Boggess
1984–1985	Joe Winstead
1985–1986	Charles V. Covell
1986–1987	Larry Giesmann
1988	William P. Hettinger, Jr.
1989	Richard N. Hannan
1990	Debra K. Pearce
1991	W. Blaine Early, III
1992	Douglas L. Dahlman
1993	Charles N. Boehms

MEETING LOCATIONS OF THE KENTUCKY ACADEMY OF SCIENCE

1914, 1915	State College (presently University of Kentucky)
1916–1928	University of Kentucky
1929	Berea College
1930	Centre College
1931	Transylvania University
1932	Eastern Kentucky State Teachers College
1933	University of Kentucky
1934	Berea College
1935	University of Kentucky
1936	Western Kentucky State College
1937	University of Louisville
1938	Morehead State Teachers College
1939	Murray State Teachers College
1940	University of Kentucky
1941	Eastern Kentucky State Teachers College
1942	University of Kentucky
1943	University of Louisville
1944	University of Kentucky
1945	No Annual Meeting
1946	University of Louisville
1947	Western Kentucky State College
1948	University of Kentucky
S1949	Cumberland Falls State Park
F1949	Eastern Kentucky State College
1950	University of Louisville
1951	University of Kentucky
1952	Georgetown College
S1953	Ashland
F1953	University of Kentucky
S1954	Berea College
F1954	University of Louisville
S1955	Cumberland Falls State Park
F1955	Kentucky State College
S1956	Kentucky Dam Village
F1956	Eastern Kentucky State College
S1957	Western Kentucky State College and Mammoth Cave National Park
F1957	Berea College
S1958	Natural Bridge State Park
F1958	University of Kentucky
S1959	Lake Cumberland State Park
F1959	Western Kentucky State College
S1960	Murray State College

F1960	University of Louisville
S1961	Morehead State College
F1961	University of Louisville
1962	Eastern Kentucky State College
1963	University of Kentucky
1964	Morehead State College
1965	University of Kentucky
1966	Kentucky Wesleyan College
1967	University of Louisville
1968	Western Kentucky University
1969	Murray State University
1970	Georgetown College
1971	Eastern Kentucky University
1972	Morehead State University
1973	Transylvania University
1974	Centre College
1975	University of Louisville
1976	University of Kentucky
1977	Western Kentucky University
1978	Eastern Kentucky University
1979	Northern Kentucky University
1980	Transylvania University
1981	Murray State University
1982	Ashland Oil Inc., Ashland
1983	University of Louisville
1984	Kentucky State University
1985	Morehead State University
1986	Lexington, Kentucky (with SSMA)
1987	Western Kentucky University
1988	Eastern Kentucky University
1989	University of Kentucky
1990	Northern Kentucky University
1991	Owensboro, Kentucky
1992	Ashland Community College
1993	Georgetown College

1994 Annual Meeting
3–5 November 1994
Paducah, Kentucky
Host: Paducah Community College

ABSTRACTS OF SOME PAPERS PRESENTED AT ANNUAL MEETING, 1993

AGRICULTURAL SCIENCES

Animal waste management systems in the Barren River area of Kentucky: soil and plant interaction with animal waste applications. O. W. DOTSON,* RAY JOHNSON, BRYAN KESSLER, JASON SLATON, and DAVID STILES, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

A preliminary survey was conducted on farms with animal enterprises in the Barren River area. Much of the area possesses karst topography, which presents unique problems associated with animal waste management. Though these farms may contain large areas for waste application, a series of factors may result in heavy applications over smaller areas. This study was developed to survey soil composition of those fields where heavy application occurred and those where little or no application occurred. Also, species differences were studied. Parameters studied were percentages of organic matter, and ppm of phosphorus, potassium, magnesium, calcium, sodium, pH, sulfur, zinc, manganese, iron, and copper. On farm A most parameters studied were not greatly different but organic matter (OM) was 3.5% (0–15 cm depth) with the heavy application and 2.4% on the light. P and K were 65 and 285, respectively, for the light application as opposed to 39 and 118 for low. On farm B similar figures for OM, P, and K were, respectively, 3.8, 45, and 207 and 3.3, 36, and 58 for heavy and light applications. The above data are representative of production units with cattle (ruminants). In general, similar values for the parameters under study were found on swine enterprises for OM and most of the macro elements. Even with 95 kg^{ha-1} of nitrogen, only 0.21% nitrate was observed in the plant tissue. However, and possibly due to diet composition, higher levels were observed for Zn, Cu, and Fe in the soil where swine waste was applied. Frequent analyses of stream water adjacent to this unit would indicate no impact on stream water quality. In our survey, animal waste management is a concern to the producer. Considerable differences were observed from farm to farm and even on the same farm. Soil composition appeared to be influenced by source of animal waste applied.

Comparison of composts for growing vegetables in containers. BRIAN D. LACEFIELD,* ASLAM TAWHID, and ELMER GRAY, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

Sustainability of society is enhanced when recurring waste products are effectively substituted for diminishing natural resources. The present study is an ongoing effort to evaluate common waste products as soil amendments for growing food crops in containers. The materials included soil (S), leaf mulch (L), wood mulch (W), N-viro soil (V), and chicken manure (C). Each of the 40 plastic barrel sections (58 cm diam, 38 cm depth) contained ca. 60 liter of one of the following mixtures (percent by volume): S(100); S(50), L(50); S(50), W(50); S(50), L(25), W(25); S(50), L(25), C(25); S(50), W(25), C(25); S(50), L(25), N(25); and S(50), W(25), N(25). The four mixtures not including C or V were supplemented with 56.0 N, 24.5 P, and 46.5 K, all expressed in kg ha^{-1}. Fifteen different food crops were grown in these mixtures in 1993. Seed or fruit yields, plant height, and biomass productions indicated that some mixtures were equal or superior to soil only. There were many examples of interactions between mixtures and crops and between mixtures and cultivars within crops. Preliminary results indicated that using waste compost in containers has strong potential for urban gardeners.

Comparison of mineral element analyses by NIRS and wet laboratory methods. BRYAN KESSLER, LINDA BROWN, and DAVID STILES,* Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

This study was conducted to estimate correlation between mineral element analyses of various grasses completed via wet laboratory chemistry and estimation via Near Infrared Reflectance Spectroscopy (NIRS). Universal equations were used to evaluate the spectra observed. Warm season grasses (bermuda grass and sudan grass) and cool-season grasses (tall fescue, rye, wheat) were studied. The following observations of NIRS analyses, wet laboratory analyses, and simple correlations, respectively, were observed: nitrogen 2.61%, 2.42%, and 0.94; phosphorus 0.40%, 0.17%, and 0.88; calcium 0.59%, 0.51%, and 0.37; potassium 2.50%, 2.05%, and 0.67; and magnesium 0.21%, 0.26%, and −0.13. The correlations and data for nitrogen analyses were acceptable. The correlations and analyses for the other mineral elements merit further study and perhaps development of more narrow-based equations for greater confidence in NIRS analyses.

Effects of large animal production units on stream water quality: fish community assemblages. ROBERT D. HOYT,* Department of Biology, JON BARROW, JASON SLATON, and DAVID STILES, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

An intensive swine rearing facility in southern Kentucky has proposed using animal wastes as pasturage fertilization. This study attempted to describe any impacts of this practice on fish fauna in Buck Creek, less than 1 mile from the rearing facility. Sampling station I was located just above the upstream runoff effluent while station II was located just below the downstream effluent. Samples were taken on 26 Oct 1992, and 3 Jun 1993, using electrofishing gear. Twenty of 21 species were taken at station II; 16, at station I. Twenty species were observed in fall collections; 17, in spring. Simpson's and Shannon's diversity indices identified the greatest diversity at station II in spring followed by I fall, II fall, and I spring. In spring, station I was impacted by orangethroat darters, which made up 60% of the community; in fall they dropped to 24%. Station II in fall was impacted by stoneroller minnows, bluntnose minnows, and common shiners, which made up 80% of the total; in spring, these species dropped to 46%. Jaccard and Sorenson coefficients showed seasonal communities to be more closely related; Renkonen and Morisita indices showed station relationships to be stronger. Stoneroller minnows, bluntnose minnows, and common shiners are all omnivores. Their increased presence in fall (after the growing season) suggested that nutrient enrichment of the water promoted an algal flora responsible for their increased presence.

Effects of large animal production units on stream water quality: water quality parameters. THOMAS DOTSON,* DAVID STILES, O. W. DOTSON, JASON SLATON, and ALVIN BEDEL, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

A 14 mo study was conducted on a stream associated with a 219 ha watershed where 12,000–17,000 head of swine are raised. The animal waste, from a second stage anaerobic lagoon, was spread on pasture/forage fields. An average of 70 kg of nitrogen, 13.3 kg of phosphorus, and 73 kg of potassium were applied per hectare per year. The samples collected during six time periods from the mainstream and inlet streams had various levels at different times but flow was diluted to the point this was not observed to any great extent in the main stream flow. Nitrate was observed to increase from 0.4 mg/liter to 2.2 mg/liter; the safe drinking standard is 10 mg/liter. Considering the animal concentration and the application of animal waste to pasture (good management practice to reduce possible run off), the observed water quality appeared to be good prior to the stream arriving at the drainage of this watershed (upstream) and after all drainage entered the stream (downstream). Upstream and downstream samples, respectively, were observed for the following parameters mg/liter; total solids 390 and 380; ammonia N-O,O; calcium 63 and 58; phosphorus 0.04 and 0.06; copper 0 and 0; iron 0.28 and 0.31; zinc 0.068 and 0.071; nitrate-N 0.4 and 2.2 (safe drinking water standard 10); pH 7.85 and 7.59; and dissolved oxygen 8.15 and 8.58. Inlet drainage streams from the watershed were not greatly affected by the animal production unit.

Effect of primisulfuron and nicosulfuron on growth of Johnson grass (*Sorghum halepense*). JAMES P. WORTHINGTON, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

Johnson grass is a major problem weed in corn in Kentucky. Primisulfuron (Beacon) and nicosulfuron (Accent) can be very effective for control of the grass when properly applied. Our study sought to determine the effect of time and application timing on performance of primisulfuron and nicosulfuron for control of Johnson grass in corn. Nicosulfuron and primisulfuron were applied postemergence at full rates of 35 g and 40 g a.i./ha, respectively, in the first week of June in 1988, 1989, 1990, and 1991 and as split applications of half rate each in the first week of June and near the end of June 1989 and 1991. The two-row corn plots (1.5 × 7.6 m) were planted 11–16 May each year. Johnson grass was 25–40 cm tall for early postemergence and 15–45 cm for late postemergence applications. Nitrogen was applied at 150 kg/ha each year, and residual herbicides were applied to control annual grass and broadleaf weeds. Visual ratings of treatments compared to adjacent check plots were used to evaluate Johnson grass control at 21 and 42 d after application of early postemergence treatments (DAT). Rainfall was much below normal in 1988 and much above in 1989. There were four replications of each treatment and data analyzed as a split-plot design, using time in years as the subplots. There were no significant differences between treatments and years in Johnson grass control except in 1988, when nicosulfuron provided more control (82.5%) than primisulfuron (58.1%). Johnson grass was under moisture stress when the herbicides were applied; there was considerable regrowth in the primisulfuron treated plots. Control of Johnson grass was significantly greater at 42 d after treatment (DAT) than at 21 DAT. There was a highly significant interaction between time after treatment and herbicide; control using primisulfuron was lower than when using nicosulfuron in four out of five years at 42 DAT.

Effects of soybean cultivars and planting dates on biomass production. ASLAM TAWHID* and ELMER GRAY, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

Soybean (*Glycine max*) is highly valued as a source of edible oil and as a source of organic nitrogen. Soybean cultivar development and cultural practices are directed toward seed production rather than forage or green manure production. The objective of the present study was to determine the effects of cultivar maturity differences and planting dates on biomass production. The experimental design was a split-plot with four replications. The three planting dates (2 Jun, 16 Jun, and 6 Jul) were mainplots and the five cultivars were split-plots. The cultivars and their maturity groupings and areas of adaptation were McCall (OO, Minnesota), A2506 (II, Iowa), FFR 561 (V, Kentucky), Perrin (VIII, South Carolina), and Laredo (undesignated maturity, forage cultivar). Experimental units were 45 m^2 (3×15 m). Seeds were inoculated and broadcast at the rate of 175 kg ha^{-1} and covered by disking. Cultivars were harvested at the early bloom stage. Average biomass production (oven dry basis) decreased progressively (2.92, 2.45, and 2.08 metric tons ha^{-1}) for the planting dates. Highest biomass yield (5.88 metric tons ha^{-1}) was produced by Laredo at the first planting. For shorter growth periods (1 or 2 mo) the earlier maturing cultivars were equal or superior to the later maturing cultivars; however, when all cultivars were compared at the early bloom stage, later maturing cultivars produced more biomass. Soybean stands and yields were reduced by inadequate seed covering by disking, by insufficient soil moisture at germination (especially the second planting), and by competition with Johnson grass and pigweed. These preliminary results indicate that soybean is a good source of green manure production during summer.

Fertilization and mowing on persistence of Indian mockstrawberry and common blue violet in a tall fescue lawn. ELMER GRAY* and NEYSA M. CALL, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

Research was conducted from 1990 to 1992 at Bowling Green, Kentucky, to determine the influence of soil fertilization and mowing on persistence of Indian mockstrawberry, *Duchesnea indica*, and common blue violet *Viola papilionacea*, in an old, weakened tall fescue lawn. Fertilization treatments included F0 = none applied; F1 = spring and fall application of 0.49 kg N, 0.21 kg P, and 0.41 kg K 100 m^{-2}; and F2 = spring and fall application of twice the F1 rate. Mowing treatments were M0 = not mowed; and M1 and M2 = mowing heights of ca. 4 and 6 cm, respectively, at biweekly intervals. Persistence of both weeds was influenced more by mowing than by fertilization. Survival of Indian mockstrawberry was greatest when mowed at 6 cm and not fertilized and lowest when highly fertilized and not mowed. Blue violets were virtually eliminated by either mowing treatment and did not respond to fertilization. Mowing and fertilization effectively reduced survival of Indian mockstrawberry and common blue violet in the tall fescue lawn.

Herbicide leaching in vegetable culture. MATTHEW E. BYERS and DAWN GREENE,* Kentucky State University, Frankfort, KY 40601.

The use of herbicides to control weeds on erodible lands may reduce the need for tillage and contribute to a sustainable agricultural system. But herbicides are perceived to potentially affect groundwater. The purpose of this study was to determine if clomazone (2-(2-chlorophenyl)methyl-4, 4-dimethyl-3-isoxazolidinone), a selective herbicide, would leach under the experimental conditions. Clomazone was applied at 1.5 kg/ha to plots (3.7×22 m) on a 10% slope, with Lowell silt loam soil, on 29 May 1993, to which pepper transplants were planted. Plots in 1993 had either fescue strips every row (F1), fescue strips every other row (F2), and minimum tillage (MT) as soil treatments. Clomazone was monitored by using tension lysimeters located at the top, middle, and bottom of each plot; within each location these were placed at three depths: 1, 2, and 5 ft. Samples were drawn monthly. Sampling followed rigorous QA/QC procedures. Extraction was done with a liq/liq process using hexane. Analysis was by GC-NPD and GC-MS. Clomazone was found <0.7 ppb, <0.2, and <0.1 PPB for 1, 2, and 5 ft during the June sampling (1st sampling post-application). By 29 July all levels diminished to <0.2 PPB; clomazone levels in F2 > F1 > MT, overall. Although leaching occurred, concentrations were very low. Impact at measured concentrations to exposed subsoil organisms is unknown.

Horticulture research program at Kentucky State University: pawpaw as a fruit crop. DESMOND R. LAYNE,* Kentucky State University, Frankfort, KY 40601.

The horticulture research program at Kentucky State University began in June 1990. From its inception, the development of pawpaw (*Asimina triloba*) as a commercial fruit crop has been a major priority. Pawpaw is the largest fruit native to the United States. In addition to the excellent nutritive value of its fruit, an alkaloid (asimicin) found in the bark has both pesticidal and anti-cancer properties. Pawpaw germplasm has been collected during a nationwide contest and from numerous collection trips throughout southeastern U.S. Currently, superior plants identified from the wild, plants from the contest, and commercial cultivated varieties are being evaluated in the field and greenhouses at the KSU research farm. Demonstration plantings have been established at grower farms with the help of the KSU Cooperative Extension Program. Research projects are underway to address some of the important concerns in developing pawpaw as a new commercial fruit crop. These include determining heritabilities for commercially important traits, characterizing morphological and molecular variation in the germplasm collection, developing improved methods of vegetative propagation, developing weed control recommendations, determining factors affecting seed germination, determining seedling dormancy requirements, and studying physiology of seedling development. Future research projects will investigate reduced input strategies for fruit production by limited-resource farmers.

Monitoring of constructed wetlands in Franklin County, Kentucky. FRANK S. YOUNG III,* MATTHEW E. BYERS, and GEORGE F. ANTONIOUS, Kentucky State University, Frankfort, KY 40601.

Kentucky's topography, clayey soils, and karst topography contribute to non-point source pollution from on-site sewage treatment. Wetlands are an alternative for homeowners where conventional on-site treatment may fail. The current study design included monitoring two 2-bed and two 1-bed constructed wetland systems. Systems consist of trenches excavated at a level grade, lined with 30-mil plastic, and filled with #2 and #57 aggregate; the beds' walls were supported by railroad ties. Beds were covered with organic mulch, and emergent macrophytes were planted. Systems were sampled monthly, starting at the discharge end, with the port closest to the septic tank sampled last. Samples were transported to labs in a cooler in 10 min. Dissolved oxygen (DO), pH, and temperature were recorded on site. Testing included biochemical oxygen demand (BOD-5 d), total suspended solids (TSS), ammonia, nitrate, and phosphate. Fecal coliform (FC) assays were performed by the Cabinet for Human Resources lab. Presented data were from site-G, a representative system. Site-G BOD(5), FC, DO, and ammonia mean levels in effluent were 102 mg/liter, 12,018 col./dl, 0.46 mg/liter, and 34.79 ppm, respectively. Performance of site G has been poor. System water levels were too high and saturated the mulch cover. This resulted in low dissolved oxygen throughout the bed, which likely inhibited nutrient and pathogen removal.

Plant and soil analyses following high rates of application of livestock manure. RAY E. JOHNSON,* THOMAS DOTSON, ALVIN BEDEL, O. W. DOTSON, DAVID STILES, and JON BARROW. Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

This study was conducted on a Pembroke silt loam (fine-silty, mixed, mesic, Typic Paleudalf) on the Western Kentucky University Farm. Corn (*Zea mays*) was grown to maturity, with tissue collected at early ear-fill stage and at maturity. Soil samples were collected when corn plants were about 30 cm tall and in early February 1993. Dairy-cow solid manure was added at rates to supply 0, 168, 336, 672, and 1,344 kg ha^{-1} of total N, referred to as the 0, 1×, 2×, 4×, and 8× rates, respectively. One plot received only urea to supply 168 kg ha^{-1} of N. Corn grain yields were 8,223–10,154 kg ha^{-1}, with no significant treatment response. Total plant dry matter production was 11,254–16,035 kg ha^{-1}, with a consistent positive response to increasing manure rates. Corn husk tissue, collected at early ear-fill stage, showed a consistent increase in percentage composition of N, P, and K, and a consistent decrease in tissue concentration of Ca and Mg, with increases in manure application rates. Similar but less consistent and less pronounced trends were noted with mature whole-plant analyses. Tissue contents of S, Mn, Zn, and Cu showed little variation among treatments. Soil nitrate levels (0–30 cm depth) when corn plants were ca. 30 cm tall indicated an adequate available N level for optimum corn yields at all manure application rates. The levels of "available" soil P, K, and Mg increased significantly with increasing manure application rates. This response was most evident with exchangeable soil K levels. Soil Ca levels showed no response to treatment. Soil nitrate levels in February 1993 were very low at the 0–15 cm and 15–30 cm sampling depths for all treatments, and at the 30–60 cm and 60–90 cm depths for all except the two highest manure application rates.

Street tree inventory using GIS graphics. JAMES M. MARTIN, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

Street tree inventories are valuable management tools in hundreds of American cities. Data collected generally include location, species, DBH, condition, maintenance required, damage to hardscape, and interference with utility lines. This information facilitates tree planting, removal, and maintenance programs and determines the value of a resource often taken for granted. There are many computer programs to process these data; dBase works very well. Once entered, many valuable bits of management information can be easily retrieved. For example, lists can be prepared of trees in need of immediate maintenance, trees causing damage to curbs, and trees that are the dominant species. An enhanced management tool being used in the Bowling Green, Kentucky, inventory is Geographical Information System (GIS) graphics. The added value of this system is that it generates maps that effectively pinpoint the location of trees that fit particular criteria. Data collectors assigned identification numbers to each tree inventoried and marked its location on aerial photos of the city. This information was entered into the GIS program. The result is that maps can be generated that highlight trees fitting into a particular category such as those ready for removal. This helps in seeking bids and instructing crews about maintenance activities.

Temperature changes during municipal solid waste composting. KAREN E. PROW,* ELMER GRAY, ROB-

ERT M. SCHNEIDER, and LUTHER B. HUGHES, Department of Agriculture, Western Kentucky University, Bowling Green, KY 42101.

Composting is an effective way to deal with most products currently being deposited in Kentucky landfills. Our study is an effort to show that, during composting of municipal solid waste products, temperatures can be used as an index for decomposition rate, and that the final product can then be used as an effective soil amendment. The materials used include N-VIRO soil (treated sewage sludge), commercial wood pallets, yard brush, and leaves. Fifteen windrows were compiled at the compost site at Western Kentucky University. These windrows (20′ long, 9′ wide, and 3.5′ high) were aerated once every 10–15 d using a 24′ windrow mixer. Temperatures were read every other day beginning 11 Jun. Two temperature readings were taken at a depth of 2′ and at points located approximately ⅓ of the length from each end of the windrow. Two samples were taken from each windrow every 4 wk. The samples were ground and prepared for chemical analysis. All the materials eventually gained optimal temperature (90–140° F) for composting. Some of the materials attained this level of composting more rapidly than others. Mixtures of these materials complemented one another as they created products that were more readily composted.

Vegetable yields using three management strategies: 1993. DEBRA J. HILBORN,* GEORGE F. ANTONIOUS, and MATTHEW E. BYERS, Kentucky State University, Frankfort, KY 40601.

The need to conserve top soil is known. However, availability of soil-conserving alternatives, how these practices compare to each other in effectiveness, and effect on crop yield are not well known. Research in 1991 showed that a 1-foot-wide stand of living fescue (T1) effectively reduced soil erosion and chemical movement. In 1993, T1, a reduced level of living fescue (T2), and minimum till (MT: with vetch intercropped) were studied to determine influence on yield of tomato and green pepper (green pepper and green pepper: tomato intercropped). Eighteen plots (22 × 3.7 m) on a 10% slope in Franklin County, Kentucky, were used. There were 9 plots with 10 rows of green pepper (crop treatment #1) and 9 plots with 5 rows (every other row) of green pepper intercropped with 5 rows (every other row) of tomato (crop treatment #2). Each crop treatment was replicated thrice for each soil treatment. The lowest average yield of marketable tomato per harvest was in T1, 18.89 fruits per 7.4 m of row. Yield number of T2 and MT were similar (22.54 and 24.21 fruits per 7.4 m of row, respectively, $P = 0.05$). This effect was reversed for the green pepper. Yield number was highest in T1 (15.59), followed by MT (14.10) and T2 (10.87) for fruits per 7.4 m of row. Intercropped green pepper with tomato produced a higher yield response overall relative to green-pepper-only plots.

BOTANY AND MICROBIOLOGY

Bacterial from hypersaline lagoons of the Galápagos Islands. BETTIE OGREN-PALMISON* and MIRIAM STEINITZ-KANNAN, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41099.

Sergio, Bainbridge, and the Salt Mine are three hypersaline lagoons in the Galápagos Islands. Sergio is a shallow lagoon on Espumilla Beach, Santiago Island, with an ion concentration of 64.6 mSiemens; sea water averages an ion concentration of 53 mSiemens. Bainbridge is a crater lake with an ion concentration of 143–145 mSiemens. The most saline of the three systems is the Salt Mine, with more than seven times the ion concentration of sea water at 394 mSiemens. Sergio and Bainbridge contain abundant plankton, including brine shrimp; however, plankton tows in the Salt Mine contained no zooplankton. Bacteria have been isolated and cultured from cores that were extracted from these lagoons. Although the exact taxonomic grouping of the isolated bacteria has not yet been established, some isolates may belong to the archaebacteria family Halobacteriaceae.

Status of Kentucky's St. John's Worts (*Hypericum* Sect. *Ascyrum*). ROSS C. CLARK, Department of Biological Sciences, Eastern Kentucky University, Richmond, KY 40475.

Examination of living material and herbarium specimens has revealed that misdetermination of *Hypericum stragalum* as *H. hypericoides* commonly occurs in Kentucky. Status, synonymy, and geographic distribution of plants of these taxa and *H. stans* will be discussed.

CHEMISTRY

Nickel-catalyzed peptide synthesis. GLENN KELLEY* and RICHARD REZNIK, Department of Chemistry, Asbury College, Wilmore, KY 40390.

Research was continued on the use of Ni (II) as a catalyst in the formation of simple peptides from amino acids. Attention was directed at amino acids thought to be present in the region of the active site of urease, a nickel-containing metalloenzyme. Results show that amino acids other than glycine can form peptides in the presence of Ni (II).

Progress on transition metal catalyzed peptide synthesis. RICHARD REZNIK,* DAVID GANTZ, BRIAN GILLISPIE, GLENN KELLEY, and MASANGU SHABANGI, Department of Chemistry, Asbury College, Wilmore, KY 40390.

Last year it was reported that Ni (II) could catalyze the formation of simple peptides from glycine. Further investigation has shown that other transition metals can catalyze the reaction, although dependence on pH is different. The sodium ion does not appear to catalyze the reaction under the conditions studied. Amino acids other than glycine have been studied, and they also give simple peptides. These results support the hypothesis that this is a general reaction that could have been involved in the chemical evolution of metalloenzymes.

Water quality of the Big Sandy River, Kentucky. TIMOTHY LAVENDER and STEVEN BERGER, Division of Biological Sciences & Related Technologies, Prestonsburg Community College, Prestonsburg, KY 41653.

In late fall 1992, a pilot study was undertaken to determine water quality of a 2.25 km stretch of the Big Sandy River in Floyd County, Kentucky, with respect to dissolved oxygen, salinity, and iron, manganese, and chlorine content. The results of the analyses of 41 samples collected showed that average levels of the three elements, plus those of dissolved oxygen and salinity, were within normal ranges for river water. The most recent report on the quality of Kentucky's waterways, however, indicates that this portion of the Big Sandy River, also known as the Levisa Fork, supports neither swimming due to agricultural/municipal input nor aquatic life as a result of heavy metal contamination from "unknown" sources. In view of this, it seems appropriate to recommend further, more comprehensive study of the river here, especially with regard to toxic metals, i.e., lead, cadmium, mercury, etc., in both water and sediment. Such work would seek to identify which specific heavy metals are present in this area, their concentrations, and their possible sources.

Zinc-catalyzed peptide synthesis. BRIAN GILLISPIE* and RICHARD REZNIK, Department of Chemistry, Asbury College, Wilmore, KY 40390.

The zinc ion has been found to catalyze formation of simple peptides from amino acids. The results demonstrate that metals other than Ni (II) can catalyze this reaction. As in the case of nickel, pH is a key parameter in determining the extent of conversion. Initial tests with glycine revealed that zinc (as $ZnSO_4$) was active in formation of simple peptides. Later tests looked at catalytic effect with the amino acids aspartic acid, histidine, methionine, and serine.

ENGINEERING

Chemical vapor deposition of thin solid films. H. A. MARZOUK,* J. S. KIM, J. Y. KIM, and P. J. REUCROFT, Department of Materials Science and Engineering; R. J. JACOB, Nano Probe Lab of the Markey Cancer Center and Department of Microbiology and Immunology; and J.D. ROBERTSON and C. ELOI, Department of Chemistry, University of Kentucky, Lexington, KY 40506.

Chemical vapor deposition (CVD) technology has expanded considerably in the last few decades. The estimated market for this technology is expected to exceed 3 billion dollars in 1993 in the U.S. market alone. A very versatile technology, it can be used to fabricate any metal, non-metal, or compound. It can be used to coat surfaces having different shapes and sizes. It also produces coatings with excellent conformal step coverage. The exponential growth of this technology manifests itself in two broad areas: (a) the microelectronics industry, where it is used for interlayer dielectrics, masking, passivation, gate interconnects, load resistors, contact barriers, metallization, and anti-reflection coatings; and (b) it is also used in the metallurgical coating industry to provide protective coatings for tools or parts where severe problems of erosion, friction, or hot corrosion dominate. It is especially widely used in the coating of cutting tools. In this presentation the results of several CVD projects will be discussed: (a) deposition of pure Cu films on Si(100), glass and polyimide, the main application of such films being in the multilayer interconnects in ultra-large-scale-integration (ULSI) circuity; (b) fabrication of ZnO films on glass, the main application of such films being in surface acoustic wave devices, transparent conducting materials, solar cells, and gas sensors; (c) fabrication of Al_2O_3 films on Si(100) and glass, the main application lying in the advantages Al_2O_3 holds over SiO_2 as a dielectric insulator for semiconductor device applications. These include being a better barrier for alkali ions, higher radiation resistance, and a higher dielectric constant.

GEOLOGY

Acroporid reef corals of Johnston Atoll, Pacific Ocean. GRAHAM HUNT, Department of Geography/Geosciences, University of Louisville, Louisville, KY 40292.

Johnston Atoll is 800 km southwest of the Hawaiian coral reefs and over 1,500 km from other shallow water reefs to the south and west. This relatively small atoll is (a) an arc-shaped rim in the northwest quadrant that partially surrounds a shallow lagoon of about 3 fathoms (Stage 3 of Darwin), (b) an open structure to the southeast at about 20 km distance from the rim, (c) a surface area of 21,000 ha above a depth of 90 m, (d) depauperate of shallow water stony corals (33 species and 16 genera) with the genus *Acropora* the dominant scleractinian, and (e) northwest of the NW–SE trending Line Islands that may have a tectonic and volcanic history similar to Hawaii. The Johnston Atoll "table *Acropora*" was collected from the northwest rim and is referred to *Acropora cytherea*. The coral is ramose with branches of axial corallites larger in diameter than the numerous radial corallites. This genus is one of the most important of the hermatypic corals and may represent more than 40% of the living scleractinians. Some oxygen isotope ratio studies of corals may be used for a better understanding of ocean-temperature differences in the interpretations of global-climates. Coloration changes of corals may be interpreted as due to (a) local changes in ecological conditions and/or (b) changes in species caused by natural selection in the process of evolution.

Economic geology of the Georgetown Quadrangle, GQ-605, Kentucky. GRAHAM HUNT, Department of Geography/Geosciences, University of Louisville, Louisville, KY 40292.

Surface mapping of the Georgetown Quad may indicate potential resources of economic importance at depth. Surface drainages of the area appear to follow NW- and NE-striking geologic structures that may provide economic traps below the surface of the Quad. Four NW-striking quarry pits were mined in the Lexington Limestone for building stone and road metal. NE-striking exposures of barite and galena are found in Carter Coords sections 11 and 12, U-60 and section 10, T-59. Structure contours drawn on members of the Lexington units show several structural "noses" of highs and lows that may form favorable prospects for ground water and/or hydrocarbon accumulation at depth. Subsurface data of a Knox Test, total depth 1,100 ft, Walnut Hall Farm Well No. 1, Carter Coords section 2, T-60, indicate several potential porous and permeable zones in the St. Peter Sandstone and Knox Dolomite. A new emphasis may be placed on the interpretation of geologic maps in the future for the economic development and sustainability of subsurface resources of Kentucky.

Outwash, lacustrine, and alluvial deposits of the Mile 605 area, Ohio River, Kentucky and Indiana. GRAHAM HUNT, Department of Geography/Geosciences, University of Louisville, Louisville, KY 40292.

Pleistocene deposits of outwash and lacustrine sands and gravels that may have been deposited by meltwater streams in front of the margin of an active glacier were examined in three correlative localities of the Mile 605 area of the Ohio River, referred to here as the (1) Interpretive Center, (2) Big Eddy, and (3) Quarry sections. Samples were collected from the three sections for mechanical analysis. These sieve analyses provided data on different size ranges of correlative samples of the sections. Results of these analyses may be displayed as a series of graphic cumulative curves. This curve is a graphic "signature" of that particular sample. Signature curves of modern detrital sediments may be produced, e.g., cross-bedded dune sands. It may be concluded that sediments of a similar environment of deposition will have similar signature curves.

HEALTH SCIENCES

Impact of new OBRA-mandated dental reporting system on state licensing and ratings of nursing home facilities in Kentucky. ARTHUR VAN STEWART and BRYAN G. HARNESS, Department of Orthodontic, Pediatric, and Geriatric Dentristry, University of Louisville, Louisville, KY 40292; and JULIA McKEE, Cabinet for Human Resources, Frankfort, KY 40601.

The guarantee of appropriate health services to residents of long-term care facilities is the shared responsibility of federal and state agencies. Increased emphasis on monitoring compliance was expected after the 1987 Omnibus Budget Reconciliation Act became effective in 1988. Three earlier studies conducted within the Commonwealth concluded that OBRA has had little positive effect on quality of dental services provided. Our study examines the role that the state licensing authority plays in monitoring dental services being provided to people living in Kentucky's 300+ nursing homes. The investigators worked directly with representatives of the Cabinet for Human Services to determine (a) the frequency with which facilities had failed to comply with dental care service requirements, (b) the number of site visiting teams which had reported any dental service deficiencies, and (c) to what degree the awarding of "superior" ratings to individual nursing homes was influenced by the quality of dental services being provided by licensed facilities.

Study of facilities and shelters for the homeless to determine extent of professional dental services provided. ARTHUR VAN STEWART and ERIC T. VEAL, Department of Orthodontic, Pediatric, and Geriatric Dentistry, University of Louisville, Louisville, KY 40292.

Due to a sluggish economy, expanding societal problems, and several other factors there is a large homeless population across America, including Kentucky. Shelters and social service agencies/facilities generally offer food, a place to sleep, and other basic necessities. Selected homeless shelters also offer some types of medical services. This study expands on an earlier homeless study by examining the dental service activities of 110 nationally homeless shelters identified as having a strong medical service component. A four-page, 18-item questionnaire was developed and sent to each facility listed by the U.S. Department of Health & Human Resources in their *1993 Directory of Health Care for the Homeless.* The goal of the survey was to determine (a) the number of facilities providing dental services, (b) the organizatonal structure of their dental support programs, (c) the types of clinical services being provided, and (d) the program's plans to expand or improve dental services in the future. The presentation will summarize the preliminary findings derived from 37 completed questionnaires returned to the investigators in 1993. Major conclusions and recommendations emerging from the study will be reviewed.

Survey of Kentucky elder citizen perceptions of the dental profession's ability to serve them effectively. ARTHUR VAN STEWART* and SUZANNE MEEKS, Urban Center on Aging, % Department of Orthodontic, Pediatric, and Geriatric Dentistry, University of Louisville, Louisville, KY 40292.

As a result of changing demographics in the U.S.A., Canada and other western countries, there is increasing interest in health care services for older people. Earlier studies revealed common dental conditions and service problems associated with an older ("geriatric") population. Other studies have reported dentist and dental student attitudes towards the provision of care to older persons. This presentation reports the findings of a 1993 study of 145 older adults drawn from the greater Louisville area. The respondents included 71% women and 29% men, which is a typical gender profile for older populations. The mean age of the respondents was 73.08 yr. Other demographic data include (a) place of domicile, (b) estimatedannual earnings, and (c) highest level of formal education. Our study examined (a) preference for gerontologic training among students, (b) senior citizen gender preference for dental practitioners, (c) knowledge and use of dental hygiene therapists, and (d) basic skills and understanding that senior citizens would like to see developed among dental students and dental practitioners. A series of Chi Square analyses produced several statistically significant findings $P < 0.01$. Other findings, although not so statistically well supported, offer additional insights into current and future relationship between senior citizens and members of the dental profession.

MATHEMATICS

Fair division. WALTER FEIBES, Rubel School of Business, Bellarmine College, Louisville, KY 40205.

The general problem for allocation of fixed resources among several parties is considered. The resources are of different types and are differently valued by the parties. This allocation is usually accomplished by means of some sort of negotiation. As the number of parties is increased the allocation process becomes increasingly complex and a need arises to find a formalized negotiation procedure. Specifically, the problems of dividing an estate and dividing an encyclopedia are used to illustrate four different negotiation procedures; the "naive procedure," the "randomization procedure," the "auction procedure," and the "Steinhaus fair-division procedure." The outcomes of these procedures are then compared with respect to fairness and with their effect of encouraging honest evaluations by the parties. These four, and possible other approaches, can be applied to many other problems such as settling business disputes, a fair way for partners to dissolve a business, and divorce settlements. Finally, the fair division problem, which does not have one unique correct solution, draws upon a modicum of probability, mathematics, economics, ethics, and creative reasoning. For students it can serve as an excellent example of an interdisciplinary approach to problem solving in the real world.

Generating functions for a class of complex sequences. JAMES B. BARKSDALE, JR., Department of Mathematics, Western Kentucky University, Bowling Green, KY 42101.

Let P^∞ denote the vector space of polynomials over the complex field C. Now, consider the class of complex sequences described by $S = \{\langle P(n)\rangle_{n=0}^{\infty} \mid P \in P^\infty\}$. This paper presents a characterization and a formulation of closed-form expressions for the generating functions of this class S of complex sequences. The characterization of such generating functions is embodied in the statement of the following principal theorem of the presentation: For each $P \in P^\infty$ there exists a unique $Q \in P^\infty$ such that $g(z) = 1/(1 - z)\cdot Q[z/(1 - z)]$ is the generating function for the complex sequence $\langle P(n)\rangle_{n=0}^{\infty}$.

MOLECULAR & CELL BIOLOGY

Characterization of a transgene-induced mutation that alters motor neuron function in mice. STEPHEN L. WANG* and BRETT T. SPEAR, Department of Microbiology and Immunology, University of Kentucky College of Medicine, Lexington, KY 40536.

Previous transgenic mice studies have demonstrated that microinjected DNA can act as an insertional mutagen by integrating within and disrupting endogenous genes. Dr. Spear's lab identified a transgenic line, A4, with an unusual phenotype. When two hemizygous A4 mice are mated, average sized litters are produced. The pups develop normally until 14 d of age when 25% of the offspring exhibit a severe hind limb spastic paralysis; moreover, the onset of spasticity is accompanied by a severe wasting phenotype which results in death 4–7 d after the onset of disease. Affected pups do not appear to be paralyzed as they still respond to stimuli in their hind limbs, suggesting that motor neurons rather than sensory neurons are affected. Mating experiments and Southern analysis indicate that the phenotype is carried in an autosomal recessive manner, with only transgene-homozygous mice exhibiting the described phenotype. Preliminary data also show a high degree of motor neuron degeneration in affected pups. As a result of these observations, we hypothesize that the transgene in A4 mice has disrupted a gene for normal development or function of motor neurons. To understand the molecular nature of the observed phenotype, it is essential to identify the disrupted gene. This objective was pursued through the inverse polymerase chain reaction (IPCR), a procedure to amplify unknown DNA flanking known DNA. Two sets of oligonucleotide primers were synthesized and trial IPCRs successfully amplified a "target" flanking sequence in plasmid DNA; however, numerous attempts to amplify the flanking A4 genomic DNA were unsuccessful.

Conformation-activity relationships of the heat stable STp enterotoxin. MATTHEW H. WILSON* and JUDITH G. SHELLING, Department of Biochemistry, University of Kentucky, Lexington, KY 40536.

STp is a member of a class of heat-stable enterotoxins (ST). The ST peptides produced by *Escherichia coli* vary in length from 18 (Stp; porcine form) to 19 (STh; human form) amino acids. This class of enterotoxins is the major killer of infants in the third world, due to its mediation of chronic diarrhea, and is responsible for 40% of the cases of traveller's diarrhea. Yet the mechanism by which the ST toxins work, and the structure-function relationships involved in their biological activity, remain to be discovered. Structural studies on the STp peptide were performed using high resolution two-dimensional ^1H nuclear magnetic resonance (2D NMR) spectroscopy in a solvent mixture of 65% deuterated-trifluoroethanol (TFE) and 35% H_2O. Structural studies under these conditions, which mimic a membrane environment, have revealed some stable secondary and tertiary structure. Our studies involved the use of COSY and NOESY experiments, which reveal through bond and through space interactions, respectively. In conjunction with similar NMR studies on other ST analogs and with computational modeling (distance geometry followed by simulated annealing), this information will be used to model a ST "template" incorporating the 3D arrangement of amino acid side chain and backbone elements required for binding. This template will then be used as the basis for designing a therapeutic inhibitor of its toxicity.

Localization of a methylation signal. BRANDON McGRATH,* PADMAJA MUMMANENI, and MITCHELL TURKER, Department of Pathology, University of Kentucky, Lexington, KY 40506.

De novo methylation (i.e., new methylation) is a heritable, epigenetic event required for embryonic viability. The origin of the de novo methylation signal is not known. Recently, our laboratory has identified an 800-base-pair region located upstream of the mouse *aprt* (adenine phosphoribyltransferase) gene that apparently provides a de novo methylation signal. Fragments from this region will be studied to further delineate the sequence from which the methylation signal emanates. To examine this particular sequence further, we created several plasmid constructs. The base construct used lacked the 1.4 kbp upstream region containing the methylation center. We then inserted into the base construct DNA fragments suspected to have de novo methylation signals. The new plasmid constructs were then transfected into Del TG3 cells lacking the *aprt* gene and the upstream region. Transfected cells were selected in azaserine/adenine media (AzA), which selects for *aprt* expression. The transfectants were then collected and methylation in the upstream region was examined by southern blot analysis. The results are currently being analyzed.

Molecular cloning and characterization of the chick NMDA receptor. AMINA SHALASH,* BRIAN DAVIS, and LAURIE GARNER, Department of Anatomy and Neurobiology, University of Kentucky, Lexington, KY 40517.

The N-methyl-d-aspartate or NMDA receptor is part of a family of receptors responding to the amino acid glutamate. Glutamate receptors represent the predominant excitatory neurotransmitter system. The NMDA receptor, ubiquitous in the central nervous system of mammals, is thought to be involved in pain transmission in the spinal dorsal horn. It also plays an integral role in neuronal and visual cortical plasticity during development. A chick brain cDNA library was screened with a rat NMDA probe; possible NMDA clones were isolated. After conversion of DNA to a plasmid, the clones were sequenced and analyzed. By use of the cloned NMDA receptor, riboprobes were made for use in in situ hybridization; by use of in situ hybridization, the NMDA messenger RNA was localized in the dorsal horn of a normal chick spinal cord. Through drug manipulations to alter neural activity, the levels of gene expression in the dorsal horn of affected chick spinal cords can be monitored with in situ hybridization.

Physiological and cellular control of hatching in fathead minnows (*Pimephales promelas*). JUANITA COMBS,* TRACY LIVINGSTON LONGLEY, and JOHN J. JUST, School of Biological Sciences, University of Kentucky, Lexington, KY 40506.

Hatching is a vital process in all animals; therefore, it is of interest how embryos escape from their proteinaceous egg cases or their shells. Most aquatic vertebrates have hatching gland cells that release an enzyme that digests the proteinaceous egg case and makes hatching possible. Without hatching gland development, hatching cannot occur. Fathead minnows normally hatch within 4–6 d after fertilization. Our results show that hypoxia induces hatching. Fathead embryos are placed in water bubbled with three oxygen concentrations: 100% oxygen, air (21% O_2 or 150 mm HgO_2), and 100% nitrogen. When 100 young embryos (3–4 d after fertilization) were placed in these described conditions for 2 h, they failed to hatch presumably because they lacked the hatching gland cells. When older embryos (4–5 d after fertilization with developed melanophores) were exposed for 1 h to the above conditions, 64% (150/234) of the embryos hatched in N_2, 19% (35/182) hatched in air, but only 12% (27/220) hatched in O_2. After the first hour some embryos were switched from O_2 to N_2 or air, and from air to N_2; the remaining embryos were left on their respective conditions. Of those switched from O_2 to N_2, 71% (48/68) hatched; 82% (28/34) hatched when moved from air to N_2; and none of the embryos (0/25) hatched when moved from O_2 to air. The embryos left in air hatched at 8% (4/50) while those in O_2 hatched at 6% (5/80). The normal O_2 pressure in water (150 mm Hg) is slowly decreased by embryos when they are placed in a closed system. The O_2 pressure at which 22 embryos hatched ranged between 93–40 mm Hg with the average being 67.7 mm Hg. Since hatching enzymes are released by exocytosis from the hatching glands, we postulated that, like the release of many enzymes, this discharge is controlled by an increase in intracellular calcium levels. To assess calcium's role in the hatching process, experiments are being conducted using various calcium ionophores.

Protective proteins of the fly *Phormia regina*. JOHN F. LAMON III* and GERALD A. ROSENTHAL, T. H. Morgan School of Biological Sciences, University of Kentucky, Lexington, KY 40506.

The fly *Phormia terranovae* responds to disease-causing bacteria with inducible protective proteins known as diptericins. Upon addition to agar inoculated with *Escherichia coli*, a zone of clearing is created by these antibiotic proteins. The diptericins provide a system for studies of non-protein amino acid incorporation and biological activity. However, due to prohibition of importation of *P. terranovae*, *P. regina* was selected to continue these studies.

The protective proteins of *P. regina* are isolated by grinding the larvae and centrifuging. The resulting extract is purified by exposure to 100°C for 4 min followed by repetitive extraction of the pellet. The supernatant solutions are fractionated (40%–70%) with $(NH_4)_2SO_4$ and the pellet applied to a CM-cellulose column. Protective protein 1 (PP1) and PP2 are anionic and wash from the column with 10 mM glycylglycine (pH 8.5). PP3 is obtained by gradient elution with a linear gradient of 25 mM to 400 mM ammonium acetate (pH 7.1). The appropriate fractions are subjected to gel filtration chromatography (G-200) in which $PP3_A$ and $PP3_B$ are separated. $PP3_A$ is gel filtrated as above to yield $PP3_{a1}$ and $PP3_{a2}$. PP3B is purified with CM-cellulose employing a 25 mM to 400 mM gradient of ammonium formate (pH 6.5) and Sephadex G-200. PP1 was purified as described for PP3 above except a DEAE-cellulose column was employed to produce $PP1_A$ and $PP1_B$. The six protective proteins of *P. regina* are constitutive rather than inducible. They may function by binding to bacteria and agglutinating them. A polyclonal antibody against certain PPs, as part of an ELISA, will verify bacterial binding and specificity.

Regulation of phytoalexin biosynthesis: resection analysis of a sesquiterpene cyclase gene promoter. JEFFERY W. MORRISON,* SHAOHUI YIN, and JOE CHAPPELL, Department of Agronomy, University of Kentucky, Lexington, KY 40546.

To determine the mechanisms by which plants activate their anti-microbial defenses, we studied the elicitor regulation of a chimeric gene comprised of the 5′ flanking region of a gene encoding the sesquiterpenoid 5-epi-aristolochene synthase fused to the β-glucuronidase gene. Cellulase stimulated an expression of the chimeric gene electroporated into tobacco protoplasts. Analysis of 5′ deletions suggests that elicitor inducibility is due the region from nucleotide position −206 to −262 relative to the transcription start site. Removal of this region results in the loss of elicitor inducible gene expression.

Role of jasmonic acid on wound-induced alkaloid increases in tobacco plants. ALICE TAYLOR,* PIERCE FLEMING, ROGER ANDERSEN, and DAVID HILDEBRAND, Department of Agronomy, University of Kentucky, Lexington, KY 40546.

There is evidence that jasmonic acid (JA) and/or methyl jasmonate (MJ) are important signal transducers in plants for altering production of metabolites and function as regulatory molecules. JA/MJ can cause wide and varied physiological and biochemical changes in a diverse range of plants such as poppies, tomatoes, and beans. A number of approaches were used to extract and quantitate JA/MJ including use of O-(2,3,4,5,6-pentafluorobenzyl)-hydroxylamine hydrochloride (PFB) to improve efficiency of recovery of JA/MJ from leaf tissue of tobacco (*Nicotiana tabacum*). The working hypothesis is that JA/MJ are mobile signals that are induced in plants upon wounding of leaves and move to roots where they stimulate alkaloid biosynthesis. Wounding of leaves and injection of MJ into leaves of field-grown tobacco plants increased the formation of alkaloids in roots. Leaves were wounded both attached to intact plants and detached. JA/MJ increased in both intact and detached leaves 2–4 hr after wounding; JA/MJ were undetectable in intact leaves 6–12 hr after wounding. Radiolabelled JA was used to follow movement through the plants.

Synergistic inhibition of T-lymphocytes by dexamethasone and prostaglandin E2. LUCINDA ELLIOTT and BRAD SPARKS,* Department of Immunology, University of Kentucky, Lexington, KY 40507.

There is increasing evidence that neural hormones such as glucocorticoids and ecosinoids such as prostaglandins can modulate immune function. Dexamethasone (DEX), a synthetic glucocorticoid, and prostaglandin E2 (PGE2), an ecosanoid, have been demonstrated to inhibit the in vitro proliferative response of T-lymphocytes to mitogens. However, these studies were conducted with high pharmacological concentrations of these compounds, which would not be realized in vivo. Elliott and coworkers demonstrated that low physiological concentrations of DEX and PGE2 alone are ineffective, but when added together cause a synergistic inhibition of the proliferative response of T-lymphocytes that had been stimulated by anti-CD3 monoclonal antibody(mAB). Additionally, the anti-proliferative effect of DEX and PGE2 was shown to be correlated with a synergistic inhibition of interleukin-2 (IL-2) secretion by stimulated T-lymphocytes. The purpose of our study was to further characterize these findings by determining the effects of the physiologic concentrations of DEX and PGE2 on the induction and stability IL-2 mRNA by anti-CD3 mAB stimulated T-lymphocytes. RNA was extracted from stimulated T-lymphocytes by phenol extraction. Various amounts of RNA were loaded on formaldehyde gel for Northern analysis. Autoradiography indicated that at least 40 μg of RNA were required in order to form a band of IL-2 mRNA on film. Work in progress is anticipated to support the hypothesis that exposure of T-lymphocytes to DEX and PGE2 at physiologic concentrations will cause synergistic down regulation of steady-state levels of IL-2mRNA.

Aflatoxin-DNA Interactions. SUZANNE BYRD, Eastern Kentucky University, Richmond, KY 40475.

The non-covalent and covalent binding of the naturally-occurring plant toxins, aflatoxins B_1, B_2, G_1, and G_2 were studied by comparing the stereospecificity and binding affinities to double helical DNA. Aflatoxin B_1 is a highly carcinogenic compound while the related mycotoxins, aflatoxins B_2, G_1, and G_2, are only mildly carcinogenic. The B and G analogs of aflatoxin are extremely similar structurally, but while the B analogs possess a planar cyclopentanone ring attached to the coumarin ring system, the G analogs contain a slightly puckered lactone ring at the same site. It was determined that all the compounds under review interacted with the DNA double helix through the process of intercalation, while the binding affinities between these compounds varied as much as tenfold. Apparently, the primary reason for the difference in toxicity and carcinogenicity of the aflatoxins is in their affinity for DNA rather than a difference in the mode of binding. The covalent binding of aflatoxins to DNA were analyzed by comparing the sequence specificity of the epoxide forms of aflatoxin B_1 and G_1 to a number of restriction fragments from the plasmid pBR322. The sequence specificities of the two compounds were nearly identical for the highest affinity binding sites, but measurable differences were detected at the secondary binding sites. Apparently, differences in the carcinogenic and mutagenic capacities of the various aflatoxins are due to a variety of factors.

PHYSICS

A magnetic field test facility. J. DOUG SMITH* and W. S. WAGNER, Department of Physics and Geology, Northern Kentucky University, Highland Heights, KY 41099.

Recently a considerable amount of information has appeared in local and national media concerning health effects of electromagnetic radiation—more specifically 60 hz magnetic fields—on biological systems. The purpose of this research was to set up a test facility to investigate the effects of 60 hz magnetic fields on some biological systems. A six turn, 1 meter diameter wire loop has been constructed. Current in the loop—and thus the magnetic field within the loop—is controlled by a rheostat and a variable auto transformer connected to a 120 volt 60 hz source. The magnetic field at various locations within the loop has been measured with a gaussmeter and compares favorably to the calculated theoretical values. Testing of biological systems subjected to this controllable magnetic field is currently in progress.

Experimental and theoretical analysis of natural very low frequency "whistlers" generated by lightning. DAVID J. SCHNEIDER, Department of Physics and Geology, Northern Kentucky University, Highland Heights, KY 41099.

Dr. Dennis Gallagher from NASA's Marshall Space Flight Center and I are working on two ways to enhance the "traditional" avenues of analyzing whistler data. The first technique is to use weather satellites to narrow the possible location(s) of the lightning causing the whistler. This technique can be further complemented by using a lightning detection array network to further narrow the geographic region of possible lightning generated whistlers. Independent determination of whistler origins will lead to a better understanding of Earth-ionosphere waveguide physics. Therefore, if all three techniques—whistler sonogram recordings, weather satellite data, and lightning detection—are used to analyze simultaneously recorded whistlers around the Earth, a more detailed picture of this natural phenomenon is possible. We are in the process of implementing the program described above at NKU. Whistler data collection will take place around the autumnal equinox, the winter solstice, and the vernal equinox. The data will complement this past year's data collection at 12 sites across North America. These new data will be analyzed by the techniques described above and will also be digitized for theoretical fit to a custom nonlinear curve fitting program. This research is sponsored by Northern Kentucky University and the NASA/JOVE program.

Tests of conformal gravity: galactic rotation curves. M. K. FALBO-KENKEL, Department of Physics and Geology, Northern Kentucky University, Highland Heights, KY 41099.

In ongoing research with Demos Kazanas of the Goddard Space Flight Center and Phillip Mannheim of the University of Connecticut, I am investigating the Schwarzschild-like solution to the field equations of conformal gravity with a view towards explaining the behavior of galactic rotation curves. According to Newtonian physics the rotational velocity of stars and gas about a galaxy's center should decrease as a function of radial distance from the center of the galaxy. However, the majority of galactic rotation curves measured to date do not exhibit such behavior. An explanation for this is obtained by considering deviations in the usual Newtonian form for the gravitational potential. One such deviation in the Newtonian gravitational potential is provided in the framework of conformal gravity. Currently, luminosity data in radio and optical wavelengths of 10 galaxies are being used to determine the shape of galactic rotation curves. By fitting these data to the Schwarzschild-like solution obtained by Kazanas and Mannheim one can test the theory as an alternative description of gravitational interactions. To date we have produced a preliminary fit for NGC 3198. The theoretical model predictions seem to agree well with the data. As more and better data become available from such sources as the Ultraviolet Imaging Telescope (UIT) and the Hubble Space Telescope (HST), we will incorporate them in our study. This research is supported in part by a NASA/JOVE fellowship.

The JOVE program: NASA/university joint ventures in space research. M. K. FALBO-KENKEL, RAYMOND C. McNEIL,* and DAVID J. SCHNEIDER, Department of Physics and Geology, Northern Kentucky University, Highland Heights, KY 41099.

The NASA/university joint ventures (JOVE) program was established by NASA in 1989 as a means of involving research associates at smaller institutions in NASA research programs. A brief description and history of the JOVE program and an outline of the participation in this program by Northern Kentucky University are given.

Ultraviolet spectrophotometry of a sample of B supergiants in the Small Magellanic Cloud. RAYMOND C. McNEIL, Department of Physics and Geology, Northern Kentucky University, Highland Heights, KY 41099.

A study of the ultraviolet spectra of the B supergiants in the Small Magellanic Cloud (SMC) has been undertaken, in collaboration with Richard P. Fahey and George Sonneborn of NASA Goddard Space Flight Center and with support from NASA, as a means of addressing some questions regarding the nature and evolution of massive stars. Both new and archival spectra obtained with the International Ultraviolet Explorer (IUE) are being used. A classification system based on morphology of the ultraviolet spectra will be established and spectrophotometric parameters characterizing the sample of SMC supergiants will be defined. These parameters, and the spectra themselves, will then be studied to see if they might provide the means for distinguishing pre- and post-red supergiants. Our results will also be used to examine the interstellar extinction properties of the SMC and to search for regional variations. Finally, by comparison with LMC (Large Magellanic Cloud) or galactic data, it should be possible to study the effects of metallicity on UV spectral morphology and, for the hotter supergiants, on stellar winds and mass loss.

PHYSIOLOGY, BIOPHYSICS, BIOCHEMISTRY, & PHARMACOLOGY

Dehydration effects on osmoregulation by adult and larval bullfrog, *Rana catesbeiana*. ENDANG LINIRIN WIDIASTUTI,* and JOHN J. JUST, School of Biological Sciences, University of Kentucky, Lexington, KY 40546.

Since amphibian skin offers no resistance to water loss, amphibians should possess other physiological mechanisms that help them survive during dehydration periods. During hydration periods adult anurans store dilute urine in the urinary bladder. The volume of urine stored averages 5.7 ± 0.7% of the adult body weight and has an average osmotic pressure of 62.3 ± 8.1 mOsm/kg H_2O. The body weight of dehydrated adults decreased by up to 30%; further dehydration could be fatal. During dehydration the osmotic pressures of urine and plasma increased, and the urine volume decreased. The average urine osmotic pressure increased from 62.3 to 254.0 mOsm/kg H_2O, while average plasma osmotic pressure increased from 192.8 to 264 mOsm/kg H_2O. During dehydration the ratio of the urine and the plasma osmotic pressures increased from about 0.32 to near its theoretical maximum (1.0). Thus during dehydration adult anurans use the urinary bladder as a major osmoregulatory organ. Tadpoles lacking urinary bladders maintained a constant osmotic pressure of about 180 mOsm/kg H_2O when placed in saline solution ranging from 10–200 mOsm/kg H_2O. They became isoconformers when placed in solutions above 200 mOsm/kg H_2O. In 225 mOsm/kg H_2O tadpoles are able to osmoregulate for about 6 hr, after which time they become isoconformers. On the other hand, model tadpoles made of cellophane dialysis bags equilibrated with the hypertonic saline within minutes. Tadpoles cannot survive in hyperosmotic medium of 250 mOsm/kg H_2O or higher. We are currently trying to discover what physiological mechanisms are available for tadpole osmoregulation in hyperosmotic conditions.

Down regulation of drug detoxifying enzymes in embryonal carcinoma cells cultured with retinoic acid. S. VOGELPOHL,* E. MEIER, S. EBERT, J. PULLMAN, D. WILKENING, and J. CARTER. Wood Hudson Cancer Research Laboratory, Newport, KY 41071.

Gamma-glutamyl transpeptidase (GGT) and glutathione S-transferase P (GST-P) are Phase II (drug-detoxifying) enzymes used widely as markers for preneoplastic and neoplastic cells in rodent bioassays. The purpose of our study was to determine if expression of these enzymes is reduced in cultured mouse embryonal carcinoma (F9.22) cells induced to differentiate in the presence of retinoic acid (RA). Cells were plated at 1×10^5 cells/ml. F9.22 cells and their differentiated counterpart, HR9 cells, were grown in medium composed of 90% Eagle's minimal essential medium with Hank's salts containing 10% fetal bovine serum or 1% GMS-X (Gibco) serum substitute (containing insulin, 1.0 g/liter, sodium selenite, 0.67 mg/l, transferrin 0.55 g/liter, and ethanolamine 0.2 g/liter) at 37°C. in an atmosphere of 95% air and 5% CO_2. Cells were grown with or without all-*trans* retinoic acid (0.1 μM) for up to 7 d. RA was added following cell attachment (usually 2–3 hr). GGT was assayed by the method of Nafatalin et al. (Clin. Chim. Acta 26:293. 1969); GST-P was assayed by the method of Habig et al. (J. Biol Chem. 249:7130. 1974) using 1-chloro-2,4-dinitrobenzene as the substrate. Protein was assayed by the Lowry method. Specific activities of GGT and GST-P were higher in F9.22 embryonal carcinoma cells than in HR9 cells. Following exposure to RA, the specific activities of both drug detoxifying enzymes were significantly reduced in F9.22 cells. Morphology of F9.22 treated with RA was similar to HR9 cells and growth rate was reduced. Experiments are in progress to determine if the down regulation of GGT and GST-P is a direct effect of exposure to RA or the result of cellular differentiation.

Experimental model for studying therapeutically delayed wound contraction. H. JOSEPH,* G. ANDERSON, J. BARKER, G. TOBIN, F. ROISEN, and L. WEINER. Departments of Anatomy, Physiology, and Surgery, University of Louisville, Louisville, KY 40292.

Large skin wounds contract to help close the area. "Contraction" often causes loss of function of the hands or feet by binding skin, joints, and musculature together in a fibrous scar, making them immobile. To avoid this, wounds are surgically covered with a skin graft or skin flap. This must be done within 3–5 d after wounding or contraction initiates. When other medical emergencies take priority and graft or flap coverage cannot be done during the first 3–5 d, it would be beneficial to *prevent* contraction until the graft or flap can be done. The present study determined if the hairless (hr/hr) mouse is a suitable animal model in which to study wound contraction and evaluate potential treatment modalities which can inhibit wound contraction. Paired symmetrical wounds (1 cm^2) were made on the dorsum of 17 adult hairless mice. Wound area (mm^2) was measured (n = 8) on days 1, 3, 7, 10, and 15 utilizing computerized planimetry (Sigmaplot, Optimas). Wounds were biopsied on days 2, 5, and 10 and stained with hematoxylin and eosin and Gormouri's Trichrome. Inflammatory cells (mm^2), dermal fibroblasts (mm^2), and granulation tissue thickness (mm) were counted on day 5. Drug (Colchicine(C) 10^{-6} M, Pen(P) 10^{-5} M or C with P) or saline (S) was injected (n = 9) into the wounds on days 1–5; each animal served as its own control. Wounds were biopsied and granulation tissue thickness was measured. On days 3, 5, 7, 10, and 15 wounds (n = 8) contracted to 40 + 3.4, 36 + 4.0, 12 + 7.5, 9 + 3.9, 0 (closed) per cent of their original area, respectively. On day 5, inflammatory cells in granulation tissue per mm^2 (n = 4) were 43 ± 2. Fibroblasts in granulation tissue per mm^2 (n = 1) (multiple sections) was 12 + 2. Granulation tissue thickness was 0.80 + 0.04, 0.78 + 0.02, 0.19, 0.3 + 0.08 mm in control/(S), (C), (P) or (C) with (P), respectively. The hr/hr mouse is a reliable in vivo model in which to study wound contraction at the gross and cellular level. The effect of potential therapeutic modalities that can inhibit contraction can be measured quantitatively. (P) effectively inhibits the proliferation of granulation tissue (0.05).

In vitro endopolygalacturonase activity and pathogenicity of *Fusarium solani* on soybeans. KRISTINE DESTEFANO* and MARGARET G. RICHEY, Department of Biochemistry and Molecular Biology, Centre College, Danville, KY 40422.

Sudden death syndrome (SDS) is a systemic wilt disease in soybeans that can cause the death of the plant. SDS is caused by several strains of *Fusarium solani*, a filamentous fungus. Qualitative enzyme assays on eight pathogenic and four non-pathogenic strains of *F. solani* indicated that pathogenicity was correlated with the production of endopolygalacturonase with optimum activity at pH 4.0 (Endo-PG_4), an extracellular cell wall-degrading enzyme. Quantitative in vitro assays for Endo-PG_4 were conducted to determine if variation in pathogenicity among these strains (ranging from highly virulent to avirulent) was due to variation in the production of Endo-PG_4. In general, it was found that the highly virulent strains produced the most Endo-PG_4 and the less virulent/avirulent strains produced little, if any, Endo-PG_4. These results indicate that production of Endo-PG_4 may be necessary for pathogenicity in *F. solani*.

Testosterone and estradiol concentrations in blood plasma of paddlefish before and after injection with LHRH analog. RICHARD J. ONDERS,* STEVEN D. MIMS, and JULIA A. CLARK, Aquaculture Research Center, Kentucky State University, Frankfort, KY 40601.

Blood samples were collected from paddlefish, *Polyodon spathula*, before and at intervals after injection with Luteinizing Hormone Releasing Hormone Analog (LHRHa); des-GLY^{10}, [D-Ala^6] LHRH ethylamide. Two trials were conducted in different geographic locations and at opposite positions in the spawning season (late season vs. early season). Samples were analyzed by radioimmunoassay to determine blood plasma concentrations of testosterone and estradiol. Blood plasma from males in the late season trial indicated a spike in testosterone levels after injection, with concurrent decreases in estradiol. Blood plasma from females in the late season trial indicated increasing and decreasing patterns for both estradiol and testosterone. Hormone levels in paddlefish from the early season trial were initially higher than in fish from the late season trial. Hormone levels from blood plasma of fish sampled 3 wk after spawning had returned to baseline levels. Ovulation and spermiation success rate for LHRHa-injected paddlefish was 100%.

Toxicity of glyceollin to *Fusarium solani* and correlation with pathogenicity on soybeans. MANOJ WARRIER* and MARGARET G. RICHEY, Department of Biochemistry and Molecular Biology, Centre College, Danville, KY 40422.

Glyceollin, a secondary metabolite of soybeans produced in response to stress and/or infection, has been found to be toxic to invading microorganisms, including fungi. Certain strains of *Fusarium solani*, a filamentous fungus, have been found to cause sudden death syndrome (SDS), a severe wilt, in soybeans. In order for the fungus to successfully infect and spread throughout the plant, it must be able to tolerate or detoxify glyceollin. In vitro agar toxicity assays were conducted on several pathogenic and nonpathogenic strains of *F. solani* to determine if pathogenicity was correlated with the ability to tolerate glyceollin. Preliminary data indicated that there was considerable variation among the pathogenic strains in the ability to tolerate glyceollin. In vitro liquid culture assays were conducted on selected strains to determine if tolerance was due to detoxification of glyceollin.

Vascular response to nitric oxide synthase blockade in pregnant and non-pregnant rats. A. L. FORSBERG* and R. T. DOWELL, Tobacco and Health Research Institute and Department of Physiology, University of Kentucky, Lexington, KY 40506.

Hemodynamic adjustments occur, as pregnancy progresses. Blood pressure (BP) decreases, heart rate (HR), cardiac output (CO), and uterine blood flow (UBF) all increase. EDRF (or NO) has been implicated in the above hemodynamic changes. This study was performed to elucidate the role of EDRF in regional organ blood flow, specifically UBF. Two groups of rats, 1) late-pregnant (P) (day 15–19, term = 21 days, n = 5) and 2) age matched non-pregnant (NP) (n = 6) were anesthetized and surgically prepared for blood flow determinations using radioactive microspheres. Control blood flow and hemodynamic measurements were determined prior to a 30 min infusion of N,ω-nitro-1-arginine (1-NNA), a nitric oxide synthase (NOS) inhibitor. At the end of the infusion a second set of measurements were made. Infusion of 1-NNA increased BP by 28% in P and 39% in NP rats. Peripheral vascular resistance (PVR) also increased (P—206%, NP—202%). Heart rate, CO, and SV were reduced by the following percentages: HR— P—5%, NP—14%; CO— P—59%, NP—60%; and SV— P—61%, NP—44%. Regional blood flow to all organs decreased; however, the decrease in UBF in the pregnant condition was not statistically significant (P—37%, NP—86%, $P = 0.05$). Additionally, the overall decrease in organ blood flow, including UBF, reflects the actions of 1-NNA to decrease CO. However, the cause of the discrepancy between P and NP UBF remains unclear. Because the inducible form of NOS (iNOS) is minimally inhibited by 1-NNA, we speculate that a component associated with pregnancy stimulates iNOS induction.

PSYCHOLOGY

Educating the Northern Kentucky community about psychopathology. PERILOU GODDARD,* DEANNE AUER, BEVERLY LENICKY, ANGELA GUMM, SARAH RANSOM, and JAMES THOMAS, Department of Psychology, Northern Kentucky University, Highland Heights, KY 41099; and EARL KREISA, Mental Health Association of Northern Kentucky, Covington, KY 41011.

In fulfillment of a Science Education Partnership Award funded by the National Institute of Mental Health, psychology faculty members and students at Northern Kentucky University have formed an alliance with leading psychopathologists and with the Mental Health Association of Northern Kentucky to help members of the region's adult community develop understanding of and appreciation for basic research that underlies our knowledge about mental and addictive disorders. By combining scientific knowledge, educational expertise, and community involvement, we hope to (a) reduce the stigma associated with these disorders by increasing individuals' understanding of their etiology, (b) increase citizens' support of basic research into these disorders by giving them a better idea of where their tax dollars go when they are used for psychopathology research, and (c) impart to the public a sense of the excitement that researchers feel when they make new discoveries about the origins and treatment of these disorders. In the first year of this 3-yr project, we have recruited scientists specializing in various areas of psychopathology research and have obtained state-of-the-art information from them about their specialty areas. We are translating this research into an adult-learning curriculum consisting of modules adaptable to community group meetings of different compositions and lengths. As the project continues, we shall train educators to present this curriculum to community groups, evaluate the programmatic and educational goals of the project, and disseminate the teaching modules and training programs to other mental health associations and other interested organizations.

SCIENCE EDUCATION

Administration of a biology teaching curriculum designed to achieve Kentucky Education Reform Act valued outcomes in the secondary science classroom. CLOYD J. BUMGARDNER, Calloway County High School, Murray, KY 42071.

A teaching model has been developed to help high school students master the core concepts of biology and anthropology. This curriculum model requires students to role play as health-care professionals while designing treatment regimens for patients with multiple communicable and hereditary diseases. The treatment regimens prepared by students are derived from knowledge gleaned during classroom discussions of these types of diseases and may be extended from traditional treatments to include methods of prevention. Also included in this curriculum is exposure to some cultural and genetic considerations that may influence the spread of contagious diseases. The students participating in this exercise demonstrate their mastery of the subject matter by answering peer- and teacher-posed questions regarding genetic and cultural considerations of the patient's condition and by presenting their ideas in class. In addition to helping students master the subject matter, this teaching model helps students achieve specific valued outcomes designated in the Kentucky Education Reform Act.

Procedure for integrating science and computer instruction in the secondary science classroom. CLOYD J. BUMGARDNER,* Calloway County High School, Murray, KY 42071; and KIM WORLEY, Computer Systems Manager, University of Kentucky, Somerset Community College, Somerset, KY 42501.

Enactment of the Kentucky Education Reform Act of 1990 paved the way for integrating science and technology instruction utilizing micro-computers in the public school system. However, many students and teachers may not have been extensively exposed to micro-computer applications in academically oriented courses. Accordingly, student opinions of computer effectiveness as an instructional tool may be invaluable in supplying direction when initially designing an effective science curriculum at the building level. High school science students without extensive exposure to computer-assisted instruction were presented with anatomy and human physiology topics in lecture and worksheet formats. The students reviewed this and other new material using interactive instructional computer programs. Student opinions of the effectiveness of this instruction for learning, potential for achieving specific KERA valued outcomes, and alternative teaching strategies were sampled using a short questionnaire. This diagnostic procedure may be used to assist teachers and computer specialists in the development of a science curriculum where computer-aided instruction focussed on teaching for learning is the goal.

Success as perceived by community college students. JOHN G. SHIBER, Division of Biological Sciences & Re-

lated Technologies, Prestonsburg Community College, Prestonsburg, KY 41653.

Over 800 biology students from Prestonsburg Community College (PCC) completed a questionnaire on what signifies success in college, and the type of instruction that is most meaningful and effective. About 79% said that achieving well and learning 75% or more of the course material is most important to feel successful. To guarantee such success, 83% indicated good personal discipline (attending class regularly, knowing how to take notes, having good study habits, etc.) as essential. About 84% also believe teachers' knowledge of course material and ability to get it understood play a very important role in their success. A significant 11%, however, said teachers should "dilute" and make the course material easier for everyone (including the teacher!). Yet, 95% expressed a preference for serious, but friendly, teachers who are willing to guide them in learning. Instructors are continually lured into using a myriad of learning tools available in the "educational-media market," sometimes at the expense of their individual teaching skills. Those who cannot explain concepts effectively and/or achieve good rapport with students may find such tools especially convenient and helpful. But this study reveals that learning "tools", per se, are not necessarily what students want, or learn best with. On the contrary, PCC students stated a clear preference for lectures, note-taking, and reading in the textbook over all other instructional methods as being most helpful to their success. About 82% of students surveyed believe their own attitude towards the course and the instructor greatly influences their success. Indeed, when asked to describe their general attitude upon enrolling in the investigator's classes and the grades they expected to earn by semester's end, 84% described themselves as enthusiastic, optimistic, and/or serious. Of these, 63% expected to get an A, 20% a B, and 1% a C. The 15% who expressed indifference or even pessimism also expected to get As and Bs. Interestingly, 91% of the surveyed students' grades were successful: 47% As, 29% Bs, and 17% Cs (only 2% Ds & 6% Es), suggesting a strong correlation between initial student attitude and ultimate success in a community college biology course. Although grade-point average (GPA) is important to PCC students, most seemed to realize that without an integration of the above-mentioned qualities in courses, teachers, and themselves, their time is wasted and, hence, the GPA is rendered meaningless and irrelevant.

ZOOLOGY & ENTOMOLOGY

Diet of Kentucky's threatened spotted darter, *Etheostoma maculatum*. RICHARD K. KESSLER, Water Resources Laboratory and Department of Biology, University of Louisville, Louisville, KY 40292.

A stomach flushing technique was used to assess the diet of the threatened spotted darter, *Etheostoma maculatum*, in Russell Creek, Kentucky. Forty-four individuals were collected for food-habit analysis in July and October 1991; they represent the first recorded occurrence of the species in Russell Creek. Spotted darters consumed mainly chironomid larvae in both months but also ate water mites, mayflies (mainly Heptageniidae and Oligoneuriidae), stoneflies, and caddisflies (mainly Hydropsychidae). Interseasonal variation in total number of prey consumed, frequency of prey taxa in the diet, and mean relative abundance of items in the diet was observed. Feeding substantially increased in October (avg. # items/stomach = 16.5 versus 7.5 for July). A shift in prey taxa was noted as chironomids, water mites, and stoneflies increased while mayflies and caddisflies decreased in October. More prey taxa (orders) were consumed in July ($n = 7$) versus October ($n = 5$). Further study of the prey relationships of *E. maculatum* is needed so that food preferences can be established and potential interspecific interactions can be identified.

Phylogeny of *Plethodon dorsalis* and *Plethodon cinereus*: Allozyme variation. TERESA FORSYTH* and S. MARCUS KIRTLEY, Department of Biology, Indiana University Southeast, New Albany, IN 47150.

Plethodon dorsalis and *P. cinereus* are closely related species of the Plethodontidae, the woodland salamanders. The range of *P. dorsalis* (zig-zag salamander) includes Kentucky and Indiana; that of *P. cinereus* (red-backed salamander) includes Indiana. This study shows some genetic similarities/differences in terms of allozyme expression between these two species. Of particular interest is the phylogenetic position of a variant form intermediate in appearance and commonly found in areas of range overlap in Indiana. Ten enzyme systems were analyzed using 10 specimens of each species and 6 specimens of the intermediate variant form. Analyses of these systems showed allelic differences within and between the two species, common alleles shared by both species, and alleles found in the intermediate form shared most frequently by *P. dorsalis*. Enzyme systems used were aspartate aminotransferase, esterase, general protein, glucose dehydrogenase, glutamate dehydrogenase, isocitrate dehydrogenase, lactate dehydrogenase, malate dehydrogenase, malic enzyme, and superoxide dismutase. Unbiased estimates of the average heterozygosity and genetic distance between these two species determined from these data and additional enzyme systems data establish strong phylogenetic relationships between *P. dorsalis* and the intermediate variant. Phylogenetic relationships between *P. cinereus* and the intermediate variant are of the same magnitude as the genetic relationships between the two bona fide species.

Phylogeny of *Plethodon dorsalis* and *Plethodon cinereus*: distribution and systematic data. TERESA FORSYTH, BILL FORSYTH, and S. MARCUS KIRTLEY,* Department of Biology, Indiana University Southeast, New Albany, IN 47150.

Plethodon dorsalis and *P. cinereus* are closely related species of the Plethodontidae. One genus of the family, *Plethodon*, the woodland salamanders, is widespread throughout forests of eastern North America. *Plethodon cinereus* has a wider range, stretching into southeastern Canada. Both species range south into Tennessee. The ranges of the species studied here overlap in Indiana and Tennessee. In areas of overlap such as Cagles Mill Lake in Indiana, an intermediate form has long been recognized. The striped pattern on the back appears as a combination of the zigzag pattern of *P. dorsalis* and the straight line pattern of *P. cinereus*. Our study uses systematic data to designate intermediates as members of one species or the other or to determine possible hybrid status. Systematic data, collected for 20–30 specimens, included the following observed data and measurements: total length, tail length/total length, snout–vent length/total length, head width, number of costal grooves, number of costal grooves between the oppressed limbs, sex, and mental gland anatomy. Coloration and pattern were noted for each specimen and photographically documented.

Trans. Ky. Acad. Sci., 55(1–2), 1994, 92–94

DISTINGUISHED SCIENTIST AND OUTSTANDING TEACHER AWARDS, 1993

Distinguished College/University Scientist Award

The recipient of the 1993 Distinguished College/University Scientist Award is Dr. Miriam Steinitz-Kannan, Professor of Biological Science at Northern Kentucky University. Dr. Kannan received her B.A. from Rider College and the Masters and Doctorate from Ohio State University. In 1979, Dr. Kannan joined the faculty at Northern Kentucky University as a part time Assistant Professor teaching microbiology and, at her request, was given a little space to do research. It did not take long for the department to realize that they had acquired an excellent teacher and a potentially outstanding researcher.

Dr. Kannan began her early work in tropical limnology where she studied Ecuadorian lake communities. During her studies she became one of the world's leading experts on diatoms. She has established at Northern the second largest tropical diatom collection in the United States. Her current interest involves using diatoms from lake sediment as an indicator of climatic changes in the area. Dr. Kannan will use this new tool, "paleodiatomology," to study the past and future impact of El Nino—the current that creates global weather changes. This has attracted professional interest from around the world as reflected by a recent collecting trip to the Galapagos Islands that was funded by the National Geographic Society. She has also obtained long term funding from the National Science Foundation Climate Dynamic program for the El Nino studies. Dr. Kannan's ability to obtain research funding has been exceptional. Her success rate would be enviable at many larger schools. Her work has resulted in many publications in international journals, one of which is the prestigious *Nature*. She also has published a book on *The Lakes of Ecuador*. She has presented her work at several international and national meetings and at the Kentucky Academy of Science Annual Meetings.

Dr. Kannan's recognition as a scholar of international and national importance is evident in many ways. One of her research peers states that, "Dr. Kannan is maturing into a researcher of national quality. Her contributions to our understanding of tropical limnology, equatorial diversity, and the history of climatic changes are increasingly being rewarded by name recognition among her peers." In addition she was invited to make a presentation at the AAAS meeting. She serves as a member of the advisory task force for scientific research and international relations for the Ecuadorian Museum of Natural Science. She was also elected to the advisory board of the Charles Darwin Foundation for the Galapagos Islands which consist of 70 internationally known scientists, administrators, and members of royalty from many countries. Although internationally recognized it is also equally important to note that Dr. Kannan is held in the same high esteem by her colleagues at Northern Kentucky University. In the spring of 1993 the Northern Kentucky University Board of Regents selected Dr. Kannan as the recipient of its Regents Professorship Award which is the most prestigious award that the University can make to a member of its faculty.

It might appear that this internationally known scholar would have little time to devote to teaching. On the contrary, she is considered to be an enthusiastic, dedicated teacher whose teaching evaluations are among the highest in the department. The excitement she exhibits in class tends to be contagious and students soon realize they are in for a treat. Dr. Kannan has continually involved undergraduate students in her research, both in the laboratory and the field. Since coming to Northern she has provided financial support through her grants for more than twenty undergraduate students thereby giving them the opportunity to be involved in a first class research program. It is through this interaction of teaching and research that Dr. Kannan has had the greatest impact on her students. As one of her students stated, "Dr. Kannan has earned the reputation in the department as one who is genuinely interested in her students' education and personal development. Her advice is sought by students at all levels, before and after graduation." Yes—Dr. Kannan has come a long way since 1979 when she requested, "a little space to do some research."

It is with great pleasure that the Kentucky Academy of Science recognizes this gifted researcher and dedicated teacher by bestowing upon her the Distinguished College/University Scientist Award for 1993.

Industrial Scientist Award

Mr. Estel M. Hobbs, Director of Ashland Petroleum Company's Automotive and Product Application Laboratories, is the 1993 recipient of the Industrial Scientist Award. Mr. Hobbs has his Bachelor degree from Eastern Kentucky University and his Masters from Purdue University. He has done post-graduate studies at Marshall University.

Mr. Hobbs started his professional industrial career as a chemist in the Texaco Research & Development Department in Texas. Later he returned to Kentucky where he joined Ashland Oil as a research chemist in the petroleum Research & Development Department. Later he was promoted to Manager of Petroleum Research & Development where he led the department in many new processes and product developments. During these years he was involved in several of Ashland's innovative programs such as the H-Coal process and the development of carbon fibers, "Carboflex," for which the research department received "The New Product of the Year" award from the State of Kentucky. Mr. Hobbs was promoted to Director of the Automotive and Product Application Laboratories which are responsible for the technical support of both Ashland's petroleum refineries but also provide technical support for the Valvoline Oil Company products.

In addition to his technical leadership, Mr. Hobbs has been involved in a number of technical and professional organizations including the KAS in which he was a director. He also is very active in community affairs.

It is with great pleasure that the Kentucky Academy of Science presents Mr. Estel Hobbs the Industrial Scientist Award for 1993.

OUTSTANDING COLLEGE/UNIVERSITY SCIENCE TEACHER AWARD

The Outstanding College/University Science Teacher award for 1993 is presented to Dr. Bruce A. Mattingly, Professor of Psychology at Morehead State University. Dr. Mattingly received his bachelor's degree from Morehead State University and his Masters and Doctorate from the University of Kentucky. In 1980 Dr. Mattingly joined the faculty of the Department of Psychology at Morehead State University.

Dr. Mattingly believes that good teaching and progressive research complement one another in the classroom. He maintains an excellent research program which translates into an enthusiasm in the classroom that fosters an environment which motivates students to learn. His classroom presence is dynamic while demonstrating a level of comfort with his material which allows him flexibility in his lecture. One supporter described him as being a very charismatic teacher who fosters independent thought or more simply put, "He wants us to think." A number of students in his introductory courses each year transfer into a psychology major/minor or volunteer to work in his lab. His presentations are tailored to the student's level of understanding, whether it is a beginning undergraduate or advanced graduate student. Another supporter stated, "He has the ability to broaden a student's knowledge base while nurturing an independent curiosity in the student so that he/she can generate research ideas." This is reflected by the fact that he has as many as 5–10 students volunteering each semester to work on projects. Dr. Mattingly does not simply use their "hard labor" but spends time with each of them in order to provide them with the theoretical rationale and background to conduct the project. He is noted for his patience and understanding when students have trouble with their work but always provides a positive and enthusiastic attitude that is so necessary to motivate students. This leads to a type of mentoring which is the basis for exceptional academic achievement by students. Once the projects are completed, Dr. Mattingly puts forth an enormous effort to prepare many of the students to present their work at meetings such as the KAS and the Mid-American Undergraduate Psychology Research Conference. His students have often won awards at these meetings.

Dr. Mattingly's research centers around the development of behavioral sensitization to the direct dopamine agonist apomorphine and has resulted in several publications. His research efforts were recognized by his peers at Morehead State when he was named the recipient of their Distinguished Research Award. He has won the Richard M. Griffith Memorial Research Award presented by the Psychology section of the KAS seven times.

Dr. Mattingly is also active outside the classroom. He serves on various committees and was elected this year by the University faculty as its Faculty Regent. He serves as a mentor and resource person for 15 at-risk students. One of Dr. Mattingly's supporters summed up the justification for this award by stating, "Dr. Mattingly is a person who is extremely talented in both teaching and research and maintains a firm commitment to both. His moral and ethical standards, both in and out of the classroom, are a model for all students."

The Kentucky Academy of Science is pleased to recognize Dr. Bruce A. Mattingly as its 1993 Outstanding College/University Science Teacher.

OUTSTANDING SECONDARY SCHOOL SCIENCE TEACHER

The 1993 recipient of the Outstanding Secondary School Science Teacher Award is Mrs. Barbara Fendley, coordinator of the Mathematics, Science and Technology Magnet program at duPont Manual Magnet High School. Mrs. Fendley has her Bachelor degree from Murray State University and her Masters of Secondary Education and Secondary Principalship from the University of Louisville.

Mrs. Fendley is a master teacher who combines expert knowledge of subject matter with dedication and commitment to her students. High expectations are set for her students and she provides the knowledge and skills necessary for them to reach their objectives. As one supporter put it, "the greatest gift Mrs. Fendley brings to her students is her ability to motivate them toward learning." This reflects her philosophy of education in that she feels that all students can learn if given the proper attention and teacher motivation. A theme that ran through many of her support letters was that it was an adventure and joy to walk into her classroom. Her students are excited and alive. They work with one another, engrossed in research, but at the same time pursuing individual work. She emphasizes hands-on learning using performance-based activities. She generates enthusiasm and excitement in her students because she helps them to learn science that is meaningful to them but also challenging to them.

Mrs. Fendley believes in practicing what she teaches. She not only sets high expectations for her students but also for herself. She has attended several workshops on molecular biology and tissue culturing which has resulted in new courses in microbiology and molecular genetics. She is active in state and national organizations where she has given several presentations and workshops.

Mrs. Fendley and her students have been active in the KJAS. They have participated in the Spring Symposium where they have won group honors as well as individual honors. Many of her students have won honors in various other science competitions. Mrs. Fendley has received several honors during her teaching career, some of which are: duPont Manual Teacher of the Year, Sigma Xi Outstanding Science Teacher, Outstanding Biology Teacher of KY, and Tandy Technology Outstanding Science Teacher National Finalist.

Without Mrs. Fendley's dedicated professionalism many students would not have been motivated to pursue a career in science. But probably more important are those students who were not interested in science, let alone a career, but because of Mrs. Fendley's teaching they found that science was an exciting part of learning and at the end of the course left saying, "That wasn't so bad, in fact, is was fun."

Mrs. Fendley is well deserving of this award. As one of her colleagues said, "I used to think I was an excellent teacher, but next to her I am a good teacher."

The Kentucky Academy of Science is pleased to recognize Mrs. Barbara Fendley as its 1993 Outstanding Secondary School Science Teacher.

NEWS

Annual Meeting

The meeting for 1994 will be sponsored by the Paducah Community College. It will be held at the Executive Inn, Paducah, 3–5 November 1994.

Instructions for Contributors

Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

Manuscripts may be submitted at any time to the Editor. Each manuscript will be reviewed by one or more persons prior to its acceptance for publication, and once accepted, an attempt will be made to publish papers in the order of acceptance. Manuscripts should be typed double spaced throughout on good quality white paper $8^1/_2 \times 11$ inches. NOTE: For format of feature articles and notes see Volume 43(3–4) 1982. The original and one copy should be sent to the Editor and the author should retain a copy for use in correcting proof. Metric and Celsius units shall be used for all measurements. The basic pattern of presentation will be consistent for all manuscripts. The Style Manual of the Council of Biological Editors (CBE Style Manual), the Handbook for Authors of the American Institute of Physics, Webster's Third New International Dictionary, and a Manual of Style (Chicago University Press) are most useful guides in matters of style, form, and spelling. Only those words intended to be italicized in the final publication should be underlined. All authors must be members of the Academy.

The sequence of material in feature-length manuscripts should be: title page, abstract, body of the manuscript, acknowledgments, literature cited, tables with table headings, and figure legends and figures.

1. The title page should include the title of the paper, the authors' names and addresses, and any footnote material concerning credits, changes of address, and so forth.

2. The abstract should be concise and descriptive of the information contained in the paper. It should be complete in itself without reference to the paper.

3. The body of the manuscript should include the following sections: Introduction, Materials and Methods, Results, Discussion, Summary, Acknowledgments, and Literature Cited. All tables and figures, as well as all literature cited, must be referred to in the text.

4. All references in the Literature Cited must be typewritten, double spaced, and should provide complete information on the material referred to. See Volume 43(3–4) 1982 for style.

5. For style of abstract preparation for papers presented at annual meetings, see Volume 43(3–4) 1982.

6. Each table, together with its heading, must be double spaced, numbered in Arabic numerals, and set on a separate page. The heading of the table should be informative of its contents.

Each figure should be reproduced as a glossy print either 5×7 or 8×10 inches. Line drawings in India ink on white paper are acceptable, but should be no larger than $8^1/_2 \times 11$ inches. Photographs should have good contrast so they can be reproduced satisfactorily. All figures should be numbered in Arabic numerals and should be accompanied by an appropriate legend. It is strongly suggested that all contributors follow the guidelines of Allen's (1977) "Steps Toward Better Scientific Illustrations" published by the Allen Press, Inc., Lawrence, Kansas 66044.

The author is responsible for correcting galley proofs. He is also responsible for checking all literature cited to make certain that each article or book is cited correctly. Extensive alterations on the galley proofs are expensive and costs will be borne by the author. Reprints are to be ordered when the galley proofs are returned by the Editor.

CONTENTS

TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

Volume 55
Numbers 3–4
September 1994

Official Publication of the Academy

The Kentucky Academy of Science

Founded 8 May 1914

All manuscripts and correspondence concerning manuscripts should be addressed to the Editor. Authors must be members of the Academy.

The TRANSACTIONS are indexed in the Science Citation Index. Coden TKASAT. ISSN No. 0023–0081.

Membership in the Academy is open to interested persons upon nomination, payment of dues, and election. Application forms for membership may be obtained from the Secretary. The TRANSACTIONS are sent free to all members in good standing.

Annual dues are $25.00 for Active Members; $15.00 for Student Members; $35.00 for Family; $350.00 for Life Members. Subscription rates for nonmembers are: domestic, $45.00; foreign $50.00; back issues are $30.00 per volume.

The TRANSACTIONS are issued semiannually in March and September. Four numbers comprise a volume.

Correspondence concerning memberships or subscriptions should be addressed to the Secretary. Exchanges and correspondence relating to exchanges should be addressed to the Librarian, University of Louisville, Louisville, Kentucky 40292, the exchange agent for the Academy.

INDUSTRIAL AFFILIATES

Associate Patron

Ashland Oil, Inc.

Fellow

Brown & Williamson Tobacco Corporation

Sustaining Member

Air Products & Chemicals, Inc.
ISP Chemicals, Inc.

Member

Corhart Refractories Corporation
MPB, Inc.
United Catalysts, Inc.

Associate Member

3M Tape Mfg. Division-Cynthiana Plant
All-Rite Pest Control
Westvaco
Wood Hudson Cancer Research Laboratory, Inc.

INSTITUTIONAL AFFILIATES

Fellow

University of Kentucky

Sustaining Member

Morehead State University
Murray State University
Northern Kentucky University
University of Louisville
Western Kentucky University

Member

Campbellsville College
Cumberland College
Eastern Kentucky University

Associate Member

Berea College
Brescia College
Centre College
Georgetown College
Kentucky State University
Kentucky Wesleyan College
Lees College
Midway College
Spalding University
Transylvania University

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

September 1994
Volume 55
Numbers 3–4

Trans. Ky. Acad. Sci., 55(3–4), 1994, 97–101

Flat and Relatively Flat Modules

Paul E. Bland[1]

Eastern Kentucky University
Richmond, Kentucky 40475

Abstract

Let τ be a hereditary torsion theory on Mod-R. If R is a commutative principal ideal ring such that the filter of ideals of R contains the essential ideals of R, then the class of flat modules coincides with the class of torsionfree modules if and only if τ is faithful.

Introduction

If Z denotes the ring of integers, an element x of a Z-module M is said to be torsion if there exists a non-zero integer n such that $nx = 0$. If every element of M is torsion, then M is said to be torsion; and if 0 is the only torsion element of M, M is said to be torsionfree. If **T** and **F** denote the collections of torsion and torsionfree Z-modules, respectively, then $\tau = (\mathbf{T}, \mathbf{F})$ is a torsion theory on Mod-Z, the category of abelian groups. This is the "ancestral" notion of torsion theory as it originated in abelian group theory. With respect to this torsion theory on Mod-Z, it is well known that an abelian group is flat if and only if it is torsionfree. In view of this, it seems reasonable to classify the torsion theories on Mod-R for which a module is flat if and only if it is torsionfree. This paper represents a step in that direction.

Discussion

Throughout this paper, R will denote an associative ring with identity which is not necessarily assumed to be commutative. Mod-R will denote the categories of unitary right R-modules and, unless stated otherwise, all mappings considered will be R-linear or Z-linear homomorphisms. The context of the discussion should make it clear which is being considered.

A torsion theory $\tau = (\mathbf{T}, \mathbf{F})$ on Mod-R is a pair of classes of right R-modules satisfying the following conditions:

1. $\mathbf{T} \cap \mathbf{F} = 0$.
2. If $M \to N \to 0$ is exact with $M \in \mathbf{T}$, then $N \in \mathbf{T}$.
3. If $0 \to M \to N$ is exact with $N \in \mathbf{F}$, then $M \in \mathbf{F}$.
4. For each right R-module M, there exists modules $L \in \mathbf{T}$ and $N \in \mathbf{F}$ such that $0 \to L \to M \to N \to 0$ is exact.

Modules in **T** are said to be torsion and those in **F** are said to be torsionfree. It is well known that **T** is closed under homomorphic images, direct sums and extensions, while **F** is closed under submodules, direct products, and extensions. If **T** is closed under submodules, τ is said to be a hereditary torsion theory on Mod-R. If $R \in \mathbf{F}$, then the torsion theory τ is called faithful. For a right R-module M, $\tau(M)$ will denote the collection of those submodules N of M such that $M/N \in \mathbf{T}$. $\tau(R)$ is usually referred to as the filter of right ideals of R. An element $m \in M$ is said to be a torsion element of M if there is a $K \in \tau(R)$ such that $mK = 0$. If $t_\tau(M)$ is the set of all torsion elements of

[1] This paper was written while the author was on sabbatical leave at the University of Otago in Dunedin, New Zealand.

$$\begin{array}{ccccc} 0 \leftarrow & \mathrm{Hom}_Z(L \otimes_R M, Q/Z) & \leftarrow & \mathrm{Hom}_Z(X \otimes_R M, Q/Z) \\ & \downarrow \alpha_L & & \downarrow \alpha_X \\ 0 \leftarrow & \mathrm{Hom}_R(L, \mathrm{Hom}_Z(M, Q/Z)) & \leftarrow & \mathrm{Hom}_R(X, \mathrm{Hom}_Z(M, Q/Z)) \end{array}$$

M, then $t_\tau(M)$ is a submodule of M. Moreover, M is torsion if $t_\tau(M) = M$ and torsionfree if $t_\tau(M) = 0$. $t_\tau(M)$ is said to be the torsion submodule of M. The reader can consult (2) and (5) for standard results and terminology on torsion theory and (3), (4) or (7) for some recent results on flat and torsionfree modules. *We now assume that* $\tau = (\mathbf{T}, \mathbf{F})$ *is a hereditary torsion theory on* Mod-R.

Definition 1.—A left R-module M is said to be τ-flat if the covariant functor $(\cdot) \otimes_R M$ preserves short exact sequences $0 \to L \to X \to N \to 0$ of right R-modules where $N \in \mathbf{T}$.

Definition 2.—A right R-module is said to be τ-injective if the contravariant functor $\mathrm{Hom}_R(\cdot, M)$ preserves short exact sequences $0 \to L \to X \to N \to 0$ of right R-modules where $N \in \mathbf{T}$.

Note that when $0 \to L \to X \to N \to 0$ is a short exact sequence of right R-modules, $L \otimes_R M \to X \otimes_R M \to N \otimes_R N \to 0$ is always exact Hence, to show that a left R-module is τ-flat, it suffices to show that whenever $0 \to L \to X$ is exact with $\mathrm{coker}(L \to X) \in \mathbf{T}$, $0 \to L \otimes_R M \to X \otimes_R M$ is exact. Similarly, $\mathrm{Hom}_R(L, M) \leftarrow \mathrm{Hom}_R(X, M) \leftarrow \mathrm{Hom}_R(N, M) \leftarrow 0$ is always exact, so to show that M is a τ-injective right R-module we are only required to show that $0 \leftarrow \mathrm{Hom}_R(L, M) \leftarrow \mathrm{Hom}_R(X, M)$ is exact when $\mathrm{coker}(L \to X) \in \mathbf{T}$.

If $\tau = (\mathbf{M}, \mathbf{0})$ is the torsion theory where **M** is the class of all right R-modules, the definition of a τ-flat left R-module reduces to that of a flat left R-module. In this setting, we also see that the definition of a τ-injective right R-module coincides with the usual definition of an injective right R-module. Clearly, a left R-module is τ-flat if and only if $\mathrm{Tor}_1^R(N, M) = 0$ for all $N \in \mathbf{T}$. Similarly, a right R-module M is τ-injective if and only if $\mathrm{EX}_R^1(N, M) = 0$ for all $N \in \mathbf{T}$. It is not difficult to show that a right R-module is τ-injective if and only if whenever L is a submodule of a right R-module X such that $L \in \tau(X)$, each R-linear mapping $f: L \to M$ can be extended to an R-linear map $g: X \to M$.

Definition 3.—If Q denotes the field of rational numbers and M is a left R-module, then $M^+ = \mathrm{Hom}_Z(M, Q/Z)$ is called the character module of M.

Note that when M is a left R-module, M^+ can be made into a right R-module by defining $(fr)(m) = f(rm)$ for each $f \in M^+$ and all $m \in M$. The following theorem establishes a connection between τ-flat left R-modules and τ-injective right R-modules.

Theorem 1.—A left R-module is τ-flat if and only if its character module M^+ is a τ-injective right R-module.

Proof.—Suppose that M is a τ-flat left R-module and let $0 \to L \to X \to N \to 0$ be an exact sequence of right R-modules with $N \in \mathbf{T}$. Then $0 \to L \otimes_R M \to X \otimes_R M$ is exact. Since Q/Z is an injective Z-module, the sequence $0 \leftarrow \mathrm{Hom}_Z(L \otimes_R M, Q/Z) \leftarrow \mathrm{Hom}_Z(X \otimes_R M, Q/Z)$ is exact. But for any right R-module A there is an isomorphism $\alpha_A: \mathrm{Hom}_Z(A \otimes_R M, Q/Z) \to \mathrm{Hom}_R(A, \mathrm{Hom}_Z(M, Q/Z))$ defined by $[\alpha_A(f)(a)](m) = f(a \otimes m)$ for each $f \in \mathrm{Hom}_Z(A \otimes_R M, Q/Z)$ and all $a \in A$ and $m \in M$. This leads to the commutative diagram shown above where the bottom row is exact since the top row is exact.

Hence, $0 \leftarrow \mathrm{Hom}_R(L, M^+) \leftarrow \mathrm{Hom}_R(X, M^+)$ is exact and so M^+ is τ-injective as a right R-module. Since this argument is easily reversible, the theorem follows.

The Generalized Injective Test Lemma.—R. Baer (1) has shown that the ring R is a test module for injective modules. He has shown that a right R-module M is injective if and only if for all right ideals K of R, each R-linear mapping $f: K \to M$ can be extended to an R-linear mapping $g: R \to M$. Using the same techniques as those used to prove The Injective Test Lemma, it can be shown that a right R-module is τ-injective if and only if for all $K \in \tau(R)$, each R-linear mapping $f: K \to R$ can be extended to an R-linear mapping $g: R \to M$. This result is often referred to as the Generalized Injective Test Lemma.

Now suppose that for all essential right ideals $E \in \tau(R)$, each R-linear mapping $f: E \to M$ can be extended to an R-linear mapping $g: R \to M$. We claim this is sufficient to ensure that M is τ-injective. To see this, suppose K is any right ideal of R which is in $\tau(R)$ and let $f: K \to M$ be an R-linear mapping. Via Zorn's lemma, choose J to be a right ideal of R maximal with respect the property $J \cap K = 0$. Then $J \oplus K$ is an essential right ideal of R and so since $K \subseteq J \oplus K$, it follows that $J \oplus K \in \tau(R)$. Next, observe that if $f^*: J \oplus K \to M: x + y \to f(y)$, then f^* is a well defined R-linear mapping which extends f to $J \oplus K$. But $J \oplus K$ is essential in R and so f^* can be extended to an R-linear mapping $g: R \to M$. Consequently, f can be extended to R and so M is τ-injective. Hence, a right R-module M is τ-injective if and only if for all essential right ideals $E \in \tau(R)$, each R-linear map $f: E \to M$ can be extended to an R-linear mapping $g: R \to M$.

The Generalized Injective Test Lemma leads to the following connection between τ-flat left R-modules and right ideals $K \in \tau(R)$.

Theorem 2.—The following are equivalent:

1) M is a τ-flat left R-module.
2) For each right ideal $K \in \tau(R)$, $0 \to K \otimes_R M \to R \otimes_R M$ is exact where $0 \to K \to R$ is the canonical injection.
3) For each essential right ideal $E \in \tau(R)$, $0 \to E \otimes_R M \to R \otimes_R M$ is exact where $0 \to E \to R$ is the canonical injection.

Proof.—1) $\Rightarrow$ 2) and 2) $\Rightarrow$ 3) are obvious. Hence suppose that $E \in \tau(R)$ is an essential right ideal of R. If 3) holds, then $0 \to E \otimes_R M \to R \otimes_R M$ is exact. By using the same argument as in the proof of Theorem 1, we can show that $0 \leftarrow \mathrm{Hom}_R(E, M^+) \leftarrow \mathrm{Hom}_R(R, M^+)$ is exact. Hence, M^+ is a τ-injective right R-module by our observation following The Generalized Injective Test Lemma; and so, by Theorem 1, M is a τ-flat left R-module.

The following two theorems establish additional connections between τ-flat left R-modules and right ideals of R in $\tau(R)$.

Theorem 3.—The following are equivalent:

1) M is a τ-flat left R-module.
2) For each right ideal $K \in \tau(R)$, the canonical mapping $\varphi_K^M: K \otimes_R M \to KM$ defined by $\varphi_K^M(\Sigma_{i=1}^n k_i \otimes m_i) = \Sigma_{i=1}^n k_i m_i$ is an isomorphism.
3) For each essential right ideal $E \in \tau(R)$, the canonical mapping $\varphi_K^M: E \otimes_R M \to EM$ defined by $\varphi_K^M(\Sigma_{i=1}^n e_i \otimes m_i) = \Sigma_{i=1}^n e_i m_i$ is an isomorphism.

Proof.—1) $\Rightarrow$ 2). If $K \in \tau(R)$ and $j: K \to R$ is the canonical injection, consider the commutative diagram

$$\begin{array}{ccc} K \otimes_R M & \xrightarrow{j \otimes 1_M} & R \otimes_R M \\ \downarrow \varphi_K^M & & \downarrow \varphi_R^M \\ KM & \xrightarrow{j\#} & RM = M \end{array}$$

where j# is the canonical injection. Since φ_R^M is an isomorphism, we can write $j \otimes 1_M = \varphi_R^{M\ -1} \circ j\# \circ \varphi_K^M$. If M is a τ-flat left R-module, $j \otimes 1_M$ is a monomorphism. Hence, $\varphi_K^M(k \otimes m) = 0$ leads to $(j \otimes 1_M)(k \otimes m) = 0$ and so $k \otimes m = 0$. Thus, φ_K^M is a monomorphism. Since φ_K^M is clearly an epimorphism, φ_K^M is an isomorphism.

2) $\Rightarrow$ 1). If φ_K^M is an isomorphism, then $j \otimes 1_M$ is a monomorphism since φ_R^{M-1}, j#, and φ_K^M are all monomorphisms. Thus, M is a τ-flat left R-module.

Since 2) $\Rightarrow$ 3) is obvious, the proof will be complete if we can show 3) $\Rightarrow$ 2). Let $K \in \tau(R)$ and choose a right ideal J of R maximal with respect to the property $J \cap K = 0$. Then $J \oplus K \in \tau(R)$ and $J \oplus K$ is an essential right ideal of R. Note that $(J \otimes_R M) \oplus (K \otimes_R M) \cong (J \oplus K) \otimes_R M$ since the tensor product commutes with directs sums. Hence, if we identify $K \otimes_R M$ with its image in $(J \oplus K) \otimes_R M$, then $\varphi_K^M = \varphi_{J \oplus K}^M |_{K \otimes_R M}$. Thus φ_K^M is a monomorphism and consequently, an isomorphism.

Theorem 4.—Let M be a left R-module and suppose that $\pi: F \to M$ is a free left R-module on M with $\ker \pi = N$. Then the following are equivalent:

1) M is τ-flat.
2) $KF \cap N = KN$ for each right ideal $K \in \tau(R)$.
3) $EF \cap N = EN$ for each essential right ideal $E \in \tau(R)$.

Proof.—1) $\Rightarrow$ 2). If $K \in \tau(R)$, $K \otimes_R N \xrightarrow{1_K \otimes j} K \otimes_R F \xrightarrow{1_K \otimes \pi} K \otimes_R M \to 0$ is exact where $j: N \to F$ is the canonical injection. Consider the commutative diagram

$$\begin{array}{ccccccc} & & K \otimes_R N & \xrightarrow{1_K \otimes j} & K \otimes_R F & \xrightarrow{1_K \otimes \pi} & K \otimes_R M \to 0 \\ & & & & \downarrow \varphi_K^F & & \downarrow \varphi_K^M \\ 0 \to & & KF \cap N & \to & KF & \xrightarrow{\theta} & KM \quad \to 0 \end{array}$$

where $\theta: KF \to KM: \Sigma_{i=1}^{n} k_i f_i \to \Sigma_{i=1}^{n} k_i \pi(f_i)$. Note that since F is free, F is a τ-flat left R-module so, by Theorem 3, φ_K^F is an isomorphism. Notice also that θ is an epimorphism since π is an epimorphism. Since $KF \subseteq F$, $\theta = \pi|_{KF}$ and so $\ker \theta = KF \cap N$. Now by Theorem 3, M is a τ-flat left R-module if and only if φ_K^M is an isomorphism for each $K \in \tau(R)$. Hence, suppose φ_K^M is an isomorphism. Let rf be a generator of $\ker \theta = KF \cap N$, so that $\theta(rf) = 0$. But then $\varphi_K^M \circ (1_M \otimes \pi) \circ \varphi_K^{F-1}(rf) = 0$ and so $(1_M \otimes \pi) \circ \varphi_K^{F-1}(rf) = 0$ since φ_K^M is a monomorphism. From this it follows that $\varphi_K^{F-1}(rf) \in \ker(1_M \otimes \pi) = \mathrm{Image}(1_M \otimes j)$. Consequently, there is an element $\Sigma_{i=1}^{n} k_i \otimes g_i \in K \otimes_R N$ such that $(1_M \otimes j)(\Sigma_{i=1}^{n} k_i \otimes g_i) = \Sigma_{i=1}^{n} k_i \otimes g_i = \varphi_K^{F-1}(rf)$. Hence, $\varphi_K^F(\Sigma_{i=1}^{n} k_i \otimes g_i) = rf$ and so $rf = \Sigma_{i=1}^{n} k_i g_i \in KN$. Therefore, $KF \cap N \subseteq KN$ and from this it follows that $KF \cap N = KN$. Thus, if M is a τ-flat left R-module, then $KF \cap N = KN$ for each $K \in \tau(R)$.

2) $\Rightarrow$ 3) is obvious and so let's show that 3) $\Rightarrow$ 1). To show this, consider the commutative diagram given in the proof of 1) $\Rightarrow$ 2) with K replaced by $E \in \tau(R)$. Suppose that E is essential in R and that $EF \cap N = EN$. Since φ_E^M is clearly an epimorphism, we will only be required to show that φ_E^M is a monomorphism. Let $e \otimes m$ be a generator in $\ker \varphi_E^M$. Since $\pi: F \to M$ is an epimorphism, there is an $f \in F$ such that $\pi(f) = m$. Hence, $(1_M \otimes \pi)(e \otimes f) = e \otimes m$ and so $\varphi_E^M \circ (1_M \otimes \pi)(e \otimes f) = \varphi_E^M(e \otimes m) = 0$. Thus, $\theta \circ \varphi_E^F(e \otimes f) = 0$ and so $\theta(ef) = 0$. Hence, $ef \in \ker \theta = EF \cap N = EN$. If $ef = \Sigma_{i=1}^{n} e_i g_i$ where $e_i \in E$ and $g_i \in N$ for each i, then $\varphi_E^{F-1}(ef) = \varphi_E^{F-1}(\Sigma_{i=1}^{n} e_i g_i)$ and so $e \otimes f = \Sigma_{i=1}^{n} e_i \otimes g_i$. Therefore, $e \otimes m = (1_M \otimes \pi)(e \otimes f) = (1_M \otimes \pi)(\Sigma_{i=1}^{n} e_i \otimes g_i) = \Sigma_{i=1}^{n} e_i \otimes \pi(g_i) = 0$ and so φ_E^M is an injection. But by Theorem 3, if φ_E^M is an isomorphism for each essential right ideal $E \in \tau(R)$, M is τ-flat.

Notice that if $\tau = (\mathbf{M}, \mathbf{0})$, the torsion theory in which every module is torsion, $\tau(R)$ contains all the right ideals of R. In this case, Theorems 1 through 4 reduce to standard theorems concerning flat left R-modules. We leave the proof of the following lemma to the reader.

Lemma 1.—If R is a commutative ring, then $(k)F \cap N = (k)N$ if and only if $kF \cap N = kN$ for any R-modules F and N and all principal ideals (k) of R.

Theorem 5.—If R is a commutative ring such that the ideals of $\tau(R)$ are principal, then every torsionfree module is τ-flat.

Proof.—Suppose that M is a torsionfree R-module and let $\pi: F \to M$ be a free module on M with $N = \ker \pi$. By Theorem 4 and Lemma 1, to show that M is τ-flat, it suffices to show that $kF \cap N = kN$ for each $k \in R$ such that $(k) \in \tau(R)$. If $(k) \in \tau(R)$ and $kf \in KF \cap N$, then $f + N \in F/N \cong M$ is such that $(k)(f + N) = 0$. Hence, $f + N$ is a torsion element of F/N. But F/N is torsionfree and so $f + N = 0$. Hence, $f \in N$ which shows that $kf \in kN$. Therefore, $kF \cap N \subseteq kN$ and so $kF \cap N = kN$.

Theorem 6.—If R is a commutative ring such that the ideals of $\tau(R)$ are principal, the class of τ-flat R-modules coincides with the class of torsionfree R-modules if and only if τ is faithful.

Proof.—If the class of τ-flat modules coincides with the class of torsionfree modules, τ is faithful since R is projective and consequently τ-flat.

Conversely, suppose that τ is faithful. Theorem 5 shows that every torsionfree R-module is τ-flat and so it remains only to show that every τ-flat R-module is torsionfree. Let $\pi: F \to M$ be a free module on M with $\ker \pi = N$ and suppose that M is τ-flat. If $f + N$ is a torsion element of $F/N \cong M$, then there is an ideal $(k) \in \tau(R)$ such that $(k)(f + N) = 0$. Hence, $kf \in N$ and so $kf \in kF \cap N = kN$. If $kf = kg$ where $g \in N$, then $(k)(f - g) = 0$ and so $f - g$ is a torsion element of F. But τ is faithful and, consequently, R is torsionfree. Since **F** is closed under submodules and direct products, it follows that every free R-module is torsionfree. Thus, $f = g$ and so $f + N = g + N = 0$. Therefore, M is torsionfree.

The Goldie Torsion Theory.—For a right R-module M, let $Z(M) = \{m \in M | (0:m)$ is an essential right ideal of R$\}$.[2] Z(M) is called the singular submodule of M, and it is not difficult to show that Z(M) is a submodule of M. A right R-module M is said to be singular if $Z(M) = M$ and non-singular if $Z(M) = 0$. The class N of all non-singular right R-modules forms a torsionfree class for a torsion theory (called the Goldie torsion theory) τ_G on

[2] (0:m) denotes the right annihilator of m in R.

Mod-R. If $Z_a(m) = \{m \in M | m + Z(M) \in Z(M/Z(M))\}$, then $t_G(M) = Z_2(M)$ for each right R/module M. If K is an essential right ideal of R, $t_G(R/K) = R/K$ and so $K \in \tau_G(R)$. Thus, the filter of right ideals of R for the Goldie torsion theory contains all the essential right ideals of R. Additional information regarding Goldie torsion theories can be found in (2) and (6).

If $\sigma = (\mathbf{T}_\sigma, \mathbf{F}_\sigma)$ and $\tau = (\mathbf{T}_\tau, \mathbf{F}_\tau)$ are torsion theories on Mod-R, we will write $\sigma \leq \tau$ when $\sigma(R) \subseteq \tau(R)$. If $\sigma \leq \tau$, then $\mathbf{T}_\sigma \subseteq \mathbf{T}_\tau$ and $\mathbf{F}_\tau \subseteq \mathbf{F}_\sigma$.

Theorem 7.—If τ is a hereditary torsion theory on Mod-R such that $\tau_G \leq \tau$, the following are equivalent for a left R-module M:
1) M is flat.
2) M is τ-flat.
3) M is τ_G-flat.

Proof.—1) ⇒ 2) is obvious and 2) ⇒ 3) follows from Theorem 3 and the fact that $\tau_G(R) \subseteq \tau(R)$. Now let's show that 3) ⇒ 1). If M is a τ_G-flat left R-module, $E \otimes_R M \cong KM$ canonically for each essential right ideal $E \in \tau_G(R)$ and $\tau_G(R)$ contains all the essential right ideals of R. Notice next that if we select $\tau = (\mathbf{M}, \mathbf{0})$ in Theorem 3, we see that a left R-module is flat if and only if $E \otimes_R M \cong KM$ canonically for all essential right ideals of R. Putting these two observations together, we conclude that M must be flat.

We can now prove the main result of this paper.

Theorem 8.—Suppose that τ is a hereditary torsion theory on Mod-R such that $\tau_G \leq \tau$. If R is a commutative ring and the ideals in $\tau(R)$ are principal, then the following are equivalent:
1) The class of flat R-modules coincides with the class of τ-torsionfree modules.
2) τ is faithful.

Moreover, whenever one of these conditions holds, $\tau = \tau_G$.

Proof.—By Theorem 6, the class of τ-flat R-modules coincides with the class of τ-torsionfree modules if and only if τ is faithful. But since $\tau_G \leq \tau$, Theorem 7 shows that the class of flat R-modules coincides with the class of τ-flat R-modules. Hence, the class of flat R-modules coincides with the class of τ-torsionfree modules if and only if τ is faithful. But if τ is faithful, τ_G is also faithful and so the class of flat R-modules must also coincide with the class of τ_G-torsionfree modules. Thus, τ and τ_G have the same torsionfree classes and so it must be the case that $\tau = \tau_G$.

We conclude with the following observations. If R is a domain, then every torsion theory $\tau \neq (\mathbf{M}, \mathbf{0})$ on Mod-R is faithful. Hence, if R is a principal ideal domain, by Theorem 8, we see that an R-module is flat if and only if it is Goldie torsionfree. That is, if and only if it is a non-singular module ($Z(M) = 0$). Specializing further to the ring of integers, this tells us that an abelian group is flat if and only if it is Goldie torsionfree. But the Goldie torsion theory on Mod-Z is the usual torsion theory on Mod-Z. Hence, our work leads to the corollary that an abelian group is flat if and only if it is torsionfree in the usual sense.

LITERATURE CITED

1. Baer, R. 1940. Abelian groups which are direct summands of every containing group. Proceedings of the American Mathematical Society, 46:800–806.

2. Golan, J. 1986. Torsion theories. Longman Scientific and Technical, John Wiley and Sons, Inc., New York.

3. Gray, D. 1991. On flatness relative to a torsion theory. Quaestiones Mathematicae 14:471–481.

4. Mbuntum, F. and C. Fomekong. 1988. Relatively coflat modules. Afrika Mathematika 1:127–138.

5. Stenstrom, B. 1975. Rings of quotients. Springer-Verlag, Berlin.

6. Teply, M. 1969. Some aspect of Goldie's torsion theory. Pacific Journal of Mathematics 29:447–459.

7. Xin, L. 1989. Torsionfree modules all of whose proper homomorphic images are torsion modules. Journal of Mathematical Research 9:581–584.

Trans. Ky. Acad. Sci., 55(3–4), 1994, 102–107

Relationships Between Recent Growth and Climate for Rural and Urban *Fraxinus americana* L.

James O. Luken and Douglas Porter
Department of Biological Sciences

and

David B. Agard
Department of Mathematics and Computer Science, Northern Kentucky University
Highland Heights, Kentucky 41099-0400

Abstract

Urban and rural *Fraxinus americana* L. (white ash) trees growing in northern Kentucky and southern Ohio were cored and the rings measured to assess climate/ring-width relationships. Canopy-class trees (maximal ages 43–68 years) from 4 urban and 4 rural sites were sampled. The resulting standardized tree-ring chronology derived from the urban sites was similar to the chronology derived from the rural sites, suggesting a common response to climate variation. Response functions relating monthly climate to variations in tree growth indicated significant positive relationships for winter temperature, winter precipitation, and precipitation in May, June, and July. Beginning in April and ending in September, high temperatures were negatively related to growth, but this response was not well-defined. Although urban and rural stands had similar trends in growth/climate relationships, the tree-ring chronology from urban stands was characterized by more autocorrelation and slightly more non-climatic growth influence. Stresses possibly leading to this result are as yet undefined and are small relative to the effects of annual variations in temperature and precipitation.

Introduction

The eastern deciduous forest is characterized by seasonal variation in climate that dramatically affects the physiological activity of trees (1). Individual climatic factors may assume varied importance depending on the season. For example, precipitation during spring and summer is often related to annual tree growth (2, 3, 4). However, temperature during winter may also have an influence (5).

Historical relationships between seasonal climate and tree growth may be changing as human populations increase and more of the eastern deciduous forest becomes urbanized. In Kentucky, such changes would likely be concentrated in the central and northern parts of the state, where the pace of urbanization is relatively rapid. It is important to understand how human-generated factors influence growth processes. Air pollution in the urban environment is the most likely cause of modified tree growth (6, 7). However, other factors associated with urbanization may also be involved (8).

The purpose of this study was to compare climate/ring-width relationships of *Fraxinus americana* L. (white ash) growing in urban and rural stands. White ash was chosen as a test species because it is a ubiquitous component of forest remnants, because it is relatively sensitive to some air pollutants (e.g., ozone) (9, 10) and because the ring-porous wood anatomy reduces the potential for error during ring observation and measurement. We addressed the following questions: What is the contribution of monthly temperature and precipitation to the annual growth of white ash? Do urban and rural stands differ in their climate/ring-width relationships?

Study Sites and Methods

Eight white ash dominated stands were selected in northern Kentucky and southern Ohio. Four stands (hereafter referred to as urban stands) were located in the northern section of Campbell County, Kentucky and were within the Greater Cincinnati/Northern Kentucky metropolitan area. Four stands (hereafter referred to as rural stands) were located in the southern section of Campbell County and in the southern section of Clermont County, Ohio. All forests sampled in this study were second- or third-growth stands (maximum white ash ages ranged from 43–68 years) and could best be described as mixed hardwoods.

Trees most commonly associated with white ash in the study sites were assessed by centering 10 meter diameter circular plots on trees used for core extraction. All trees (stems> 5 cm diameter) were counted and their stem diameters measured. Importance values [(relative density + relative basal area)/2] were calculated.

Two increment cores were extracted from each of 8–12 canopy-class trees in every stand. Suppressed and damaged trees were avoided. Cores were cross-dated and annual rings were measured following standard procedures (11). Rings produced during the first 5 years of tree growth were ignored. Growth trends related to tree age were assessed and removed by fitting curves (usually negative exponential) to the tree-ring series, using computer programs developed at the University of Arizona Laboratory of Tree-Ring Research (12). The resulting growth indices (13) were then averaged by year within the 4 rural stands to produce a rural chronology and within the four urban stands to produce an urban chronology.

Urban and rural chronologies showed similar sensitivity, a measure of ring-width variation through time (Table 1). First-order autocorrelation, however, was higher in the urban chronology than in the rural chronology. Autocorrelation arises from growth conditions in one year manifesting in succeeding years (13). Such autocorrelation can obscure growth/climate relationships. Therefore, a whitening process was used to remove autocorrelation from the chronologies.

Whitening was achieved by fitting autoregressive Box Jenkins models to the urban and rural chronologies. The resulting serially random residuals were then used in the development of growth/climate relationships rather than using the original growth indices (13).

Climate data for the last 70 years were obtained from the Cincinnati/Northern Kentucky Airport, ca. 24 km from the urban sites and ca. 56 km from the rural sites. These data were organized into 22 variables. The variables were as follows: monthly average temperature for each of 10 months of the current year (January through October) and December of the previous year; monthly total precipitation for each of 10 months of the current year (January through October) and December of the previous year.

Table 1. Characteristics of the rural and urban chronologies.

	Rural	Urban
Interval (years)	1927–1990	1932–1990
Number of trees	34	35
Mean sensitivity	0.19	0.19
First order autocorrelation	0.097	0.385

Correlation functions and response functions (14, 15) were used to describe growth/climate relationships. A correlation function is the series of correlation coefficients (Pearson's r) resulting from relationships between the chronology residuals and the 22 climatic variables. A response function represents a series of regression coefficients where a dependent variable (the series of chronology residuals) is predicted by a set of independent variables (the 22 climatic variables). Because intercorrelation may exist in the climate data, the original climate data were transformed into orthogonal principle components (14). Nine of the 22 eigenvectors were retained for the development of response functions. These 9 vectors represented 68% of the total climatic variance. Amplitudes of the important eigenvectors were used to develop regression equations explaining variance in the urban and rural chronologies. The coefficients from these regression equations were transformed to a final set of coefficients so that the response functions could be readily interpreted in terms of the original 22 climatic variables.

Results

Species composition of urban and rural forests was similar except that urban stands had lower importance of *Acer saccharum,* higher importance of *Fraxinus americana* and fewer tree species (Table 2). Structural characteristics (e.g., density and basal area) of urban and rural forests were not significantly different (rank sum test, $P > 0.05$). Urban stands had a mean stem density of 869 stems/ha and mean basal area of 22.5 m^2/ha; rural stands had a mean stem density of 1038 stems/ha and mean basal area of 24.0 m^2/ha. All urban stands were heavily invaded by the exotic

TABLE 2. Mean importance values and % frequencies of trees in rural and urban stands (n = 4).

Species	Importance		% Frequency	
	Rural	Urban	Rural	Urban
Fraxinus americana	40.0	66.2	100	100
Acer saccharum	32.9	9.5	92	45
Celtis occidentalis	5.6	3.8	26	41
Ulmus rubra	4.7	10.8	33	26
Carya cordiformis	4.6	2.1	26	16
Prunus serotina	4.0	0.3	18	3
Aesculus glabra	2.7	3.6	26	16
Sassafras albidum	1.8	0	10	0
Cercis canadensis	1.4	0	20	0
Cornus florida	0.9	0	26	0
Juglans nigra	0.9	0	5	0
Tilia americana	0.5	0	5	0
Acer negundo	0	1.9	0	5
Quercus rubra	0	1.6	0	16

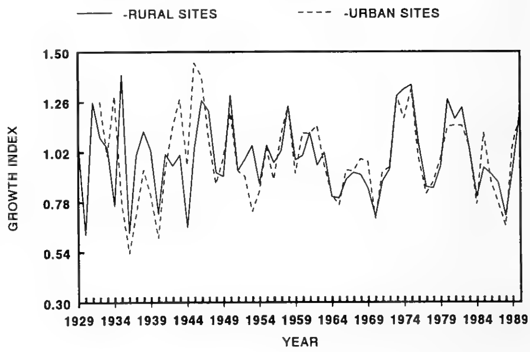


FIG. 1. Standardized tree-ring chronologies of white ash growing in rural and urban stands. The urban chronology is based on 70 cores sampled from 35 trees. The rural chronology is based on 68 cores sampled from 34 trees.

shrub, *Lonicera maackii* (mean density 0.6 shrubs/m^2); rural stands lacked a shrub understory.

Data on soils and stand history were not collected during this study. We assumed that even though variations in site conditions may be important to tree vigor, climate is the important determinant of year-to-year variation in growth. This assumption was supported by the fact that urban and rural chronologies were similar (Fig. 1), with the exception that growth indices in the urban chronology prior to 1950 showed greater deviation from the standardized mean of 1.00. Correlation functions from urban and rural stands (Fig. 2) suggest that tree growth is highest when precipitation is high in May and June, or, in the case of the urban chronology, in December of the previous year. Tree growth is also positively related with high temperatures in January of the current growing year or December of the previous year. High temperatures in June are negatively correlated with tree growth in rural stands; this relationship is less obvious in urban stands (Fig. 2, B and D).

Response functions explained 24.7% (adjusted R^2) of the urban chronology variance and 30.4% of the rural chronology variance. Coefficients of the response functions generally paralleled the trends in the correlation functions: precipitation in January, the previous December, and May, June, and July is positively associated with tree growth (Fig. 3, A and C). Significant positive coefficients for the previous December, January, February, and March, and negative coefficients for spring and summer months indicate the changing influence of temperature during a growing season (Fig. 3, B and D).

DISCUSSION

The development of growth/climate relationships based on tree-ring data depends on the presence of sensitive chronologies (i.e., large year-to-year variation in ring widths associated with variations in climate). Several factors might mitigate the sensitivity of tree-ring series used in this study. First, trees were not selected from stressful sites, but instead represented canopy-class individuals from mesic sites. Second, competitive interactions among trees from these relatively young stands could confound the climate signal (16). In spite of these mitigating factors, it is clear from the sensitivity indices (Table 2) and from the similarities in urban and rural chronologies (Fig. 1) that climate is uniformly affecting the trees in this study.

Strong positive relationships between spring precipitation and tree growth are likely the result of increased stomatal conductance during years when moisture is not limiting (17). Hinckley et al. (18) found that growth of oak trees was dependent on the number of days trees avoided drought by stomatal closure. In addition, Liu and Muller (19) found that canopy trees in Kentucky showed a 23% reduction in radial growth during drought years. High temperatures during the growing season apparently exaggerate the water limitation.

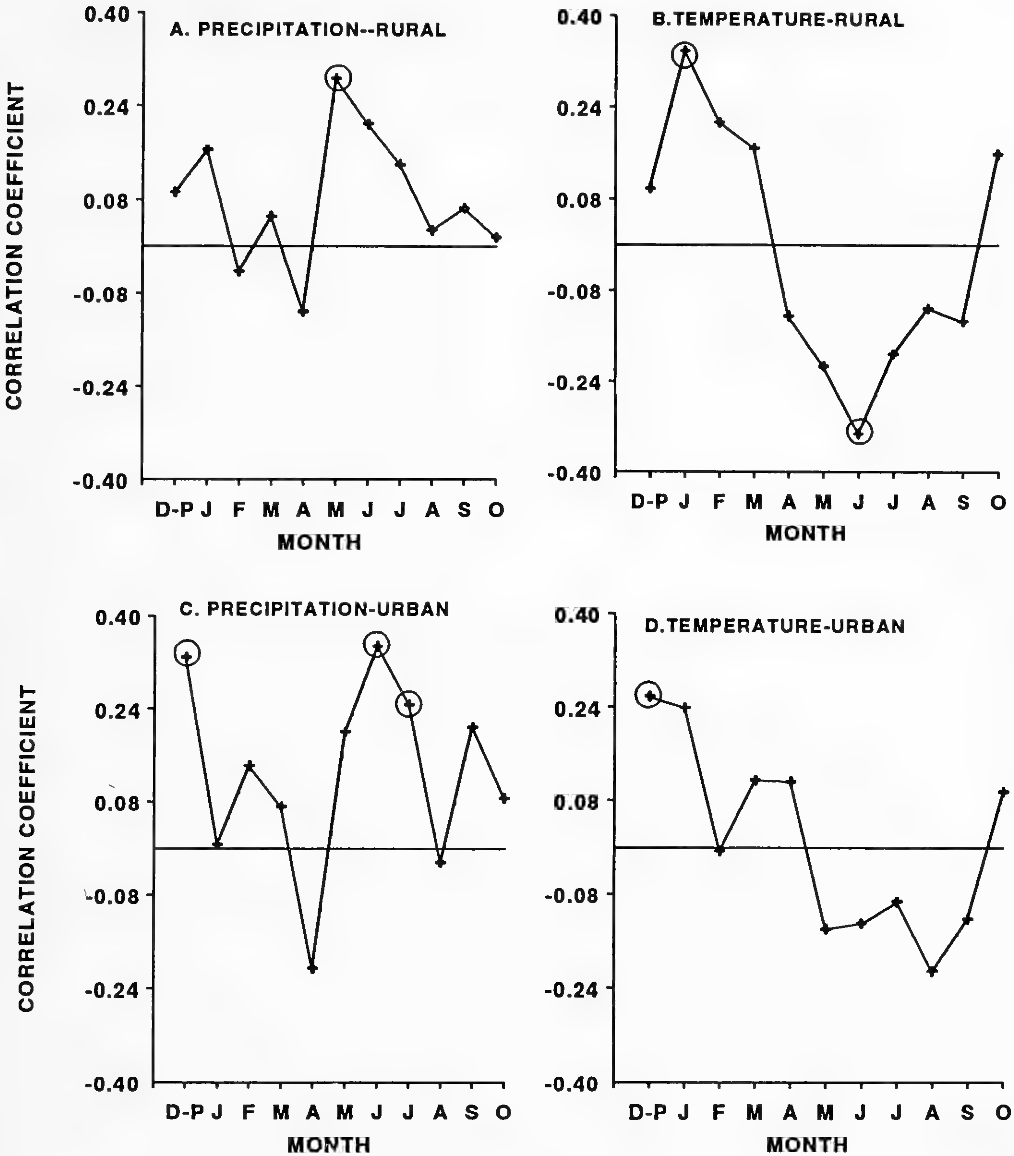


FIG. 2. Correlation functions for postwhitened rural and urban chronologies. Significant ($P < 0.05$) Pearson correlation coefficients are circled. D-P indicates December of the previous year.

Positive associations between tree growth and temperature during months when trees are dormant are less easily explained. It is possible that above-freezing temperatures during these months set in motion a series of physiological processes that in turn allows trees to emerge more quickly from dormancy once the temperature rises to appropriate levels (17). Absence of extensive frost damage to roots during warm winters may also allow trees to emerge faster from dormancy (17).

The response functions likely give the best opportunity for assessing differences between urban and rural stands. Response function trends were similar in urban and rural stands and few differences were noted, with the minor exceptions that significant coefficients were shifted by 1 month. These shifts can be

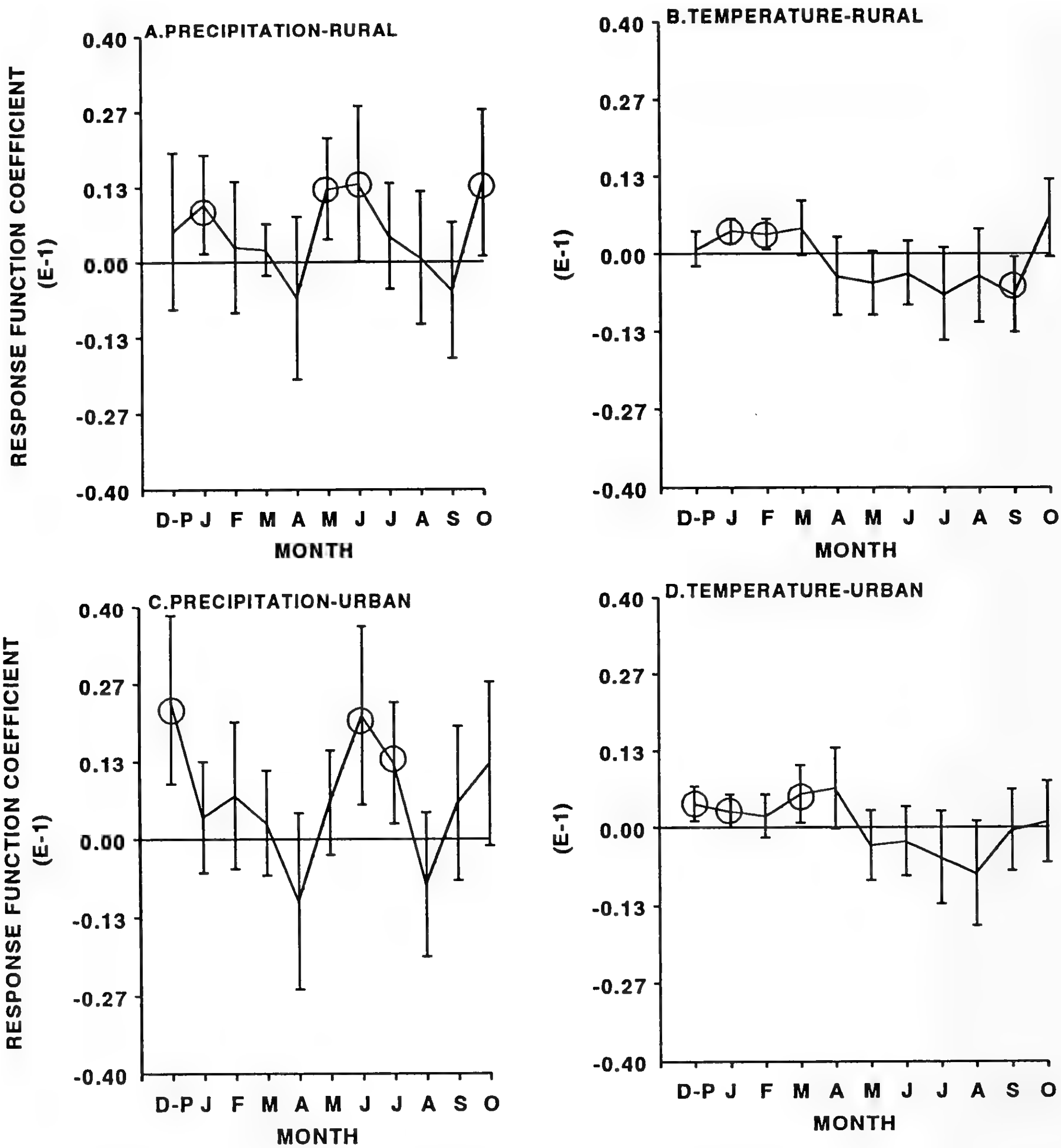


Fig. 3. Response functions for postwhitened rural and urban chronologies. Vertical bars represent the 95% confidence limits. Significant ($P < 0.05$) coefficients are circled. D-P indicates December of the previous year.

explained by large variation in the estimated coefficients. In general, both urban and rural stands are subject to similar climate influences prior to and after bud-break. Still, climate variation explained less of the urban chronology variance and first-order autocorrelation was higher in the urban chronology. A similar response has been found for white oak trees growing in polluted areas (10).

Although specific conditions affecting sampled trees were not measured in this study, previous research suggests that both soil and atmospheric conditions can be modified in the urban environment (8). In the Northern Kentucky region, these urban effects on treegrowth appear small relative to annual variations in temperature and precipitation. The large amount of growth variation that was left unexplained in this study suggests that future research might concentrate on factors other than temperature and precipitation. In addition, it is possible that these factors could be interacting in a complex fashion not considered in the present study.

CONCLUSIONS

Temperature and precipitation in December or January, and precipitation during May, June, or July are important determinants of annual radial growth in urban and rural white ash trees growing in northern Kentucky and southern Ohio. The urban influence was small relative to the controlling effects of temperature and precipitation on growth.

ACKNOWLEDGMENTS

Dr. Calvin Liu (University of Kentucky–Forestry) provided invaluable expertise and technology during ring measurements. This research was conducted while Luken was a NSF/EPSCOR Regional University Visiting Scholar. Further financial support was provided by a Northern Kentucky University Summer Fellowship.

LITERATURE CITED

1. Hicks, D. J. and B. F. Chabot. 1985. Deciduous forest. Pp. 257–277. In B. F. Chabot and H. A. Mooney (eds.) Physiological ecology of North American plant communities. Chapman and Hall, New York.

2. Lyon, C. J. 1936. Tree ring width as an index of physiological dryness in New England. Ecology 17:457–478.

3. Tryon, E. H., M. A. Thompson, and K. L. Carvell. 1957. Effect of precipitation and temperature on increment of yellow poplar. For. Sci. 3:32–44.

4. Cook, R. C. and G. C. Jacoby. 1977. Tree-ring-drought relationships in the Hudson Valley, New York. Science 198:399–401.

5. Fitts, H. C. 1962. The relation of growth ring widths in American beech and white oak to variations in climate. Tree-Ring Bull. 25:2–10.

6. McClenahen, J. R. 1983. The impact of an urban-industrial area on deciduous forest tree growth. J. Environ. Qual. 12:64–69.

7. McClenahen, J. R. and L. S. Dochinger. 1985. Tree ring response of white oak to climate and air pollution near the Ohio River Valley. J. Environ. Qual. 14:274–280.

8. McDonnell, M. J. and S. T. A. Pickett. 1990. Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. Ecology 4:1232–1237.

9. Davis, D. D. and J. M. Skelly. 1992. Foliar sensitivity of eight eastern hardwood tree species to ozone. Water Air Soil Pollution 62:269–277.

10. Pye, J. M. 1988. Impact of ozone on the growth and yield of trees: a review. J. Environ. Qual. 17:347–360.

11. Swetnam, T. W., M. A. Thompson, and E. K. Sutherlan. 1985. Using dendrochronology to measure radial growth of defoliated trees. USDA For. Serv. Ag. Hdbk. No. 639. 39 pp.

12. Graybill, D. A. 1988. Program operating manual for RWLIST, INDEX AND SUMAC. Laboratory of Tree-ring Research, Tucson, Arizona.

13. Fritts, H. C. 1976. Tree rings and climate. Academic Press, New York.

14. Fritts, H. C., T. J. Blasing, B. P. Hayden, and J. E. Kutzbach. 1971. Multivariate techniques for specifying tree-growth and climate relationships and for reconstructing anomalies in paleoclimate. J. Appl. Meteor. 10:845–864.

15. Blasing, T. J., A. M. Solomon, and D. N. Duvick. 1984. Response functions revisited. Tree-Ring Bull. 44: 1–15.

16. Fritts, H. C. and T. W. Swetnam. 1989. Dendroecology: a tool for evaluating variations in past and present forest environments. Adv. Ecol. Res. 19:111–188.

17. Larcher, W. 1980. Physiological plant ecology. Springer Verlag, New York.

18. Hinckley, T. M., P. M. Dougherty, J. P. Lassoie, J. E. Roberts, and R. O. Tesky. 1979. A severe drought: impact on tree growth phenology, net photosynthetic rate and water relations. Amer. Midl. Nat. 102:307–316.

19. Liu, Y. and R. N. Muller. 1993. Effect of drought and frost on radial growth of overstory and understory stems in a deciduous forest. Am. Midl. Nat. 129:19–25.

Trans. Ky. Acad. Sci., 55(3–4), 1994, 108–112

Evaluation of Practical Feed Formulations with Different Protein Levels for Juvenile Red Claw Crayfish (*Cherax quadricarinatus*)

CARL D. WEBSTER,[1] LAURA S. GOODGAME-TIU, AND JAMES H. TIDWELL

Aquaculture Research Center Kentucky State University,
Frankfort, Kentucky 40601

AND

DAVID B. ROUSE

Department of Fisheries and Allied Aquacultures, Auburn University,
Auburn, Alabama 36849

ABSTRACT

A 5-week feeding trial was conducted in aquaria with juvenile (0.022 g) red claw, *Cherax quadricarinatus*, to examine the effects of dietary protein levels on growth and survival. Four practical diets were formulated to contain 25, 35, 45, and 55% protein. Finished diets had analyzed protein percentages of 23, 33, 43, and 52%. A commercial shrimp diet (45% protein) was also fed for comparative purposes. After 5 weeks, final whole body weight and percentage weight gain of red claw fed diets containing 33, 43, and 52% protein were significantly ($P < 0.05$) higher than red claw fed the commercial shrimp diet. No significant differences ($P > 0.05$) were found in final whole body weight and percentage weight gain of red claw fed a diet containing 23% protein compared to red claw fed either the other test diets or the commercial shrimp diet. Percentage survival was not significantly different ($P > 0.05$) among treatments. These results indicate that these diets formulated for the red claw appear to be suitable and that a diet containing 33% may be adequate.

INTRODUCTION

Interest in the culture of the Australian red claw crayfish, *Cherax quadricarinatus*, has increased during the last several years. The red claw shares many of the attractive attributes of marron, *C. tenuimanus*, including a comparatively non-aggressive and non-burrowing behavior. A simplified life-cycle in which relatively advanced juvenile crayfish are released directly from the female, eliminates the requirement for expensive and sophisticated hatcheries for larval rearing (1). An advantage of red claw is a wider temperature tolerance (15–30°C) compared to marron (17–25°C) (2). Greater temperature tolerance may increase the potential of red claw as an aquaculture species in a larger geographical area in the United States, including Kentucky, than marron.

Masser and Rouse (3) stated that a two-phase culture system will be needed for red claw if cultured in the southeastern United States. An intensive, indoor phase would be used in the winter months to spawn adults and raise juveniles to a 0.5–2.0 g stocking size and would be followed by an outdoor phase to raise juveniles to market size (30–50 g).

Formulation of diets suitable for production of red claw in intensive culture requires determination of its nutritional requirements. Lack of such information may impede red claw aquaculture in the United States. Currently, expensive shrimp diets are fed to juvenile red claw (D. B. Rouse, pers. comm.). The purpose of the present study was to evaluate the growth and survival of juvenile red claw fed practical diets containing various percentages of protein.

MATERIALS AND METHODS

Experimental Diets

Four experimental diets were formulated to contain increasing percentages of protein (25, 35, 45, and 55%) (Table 1). Menhaden fish meal was added to each diet as a constant percentage of total protein (51%). A commercial shrimp diet (Zeigler Shrimp diet, Zeigler Bros., Gardners, Penn.) which is commonly

[1] To whom correspondence should be directed.

TABLE 1. Ingredient composition of four experimental diets fed to red claw crayfish reared in aquaria.

Ingredient	Diet (% protein)			
	23%	33%	43%	52%
Menhaden fish meal	19.0	28.0	36.5	44.5
Soybean meal	3.0	15.0	28.0	30.5
Shrimp head meal	13.0	13.0	13.0	10.0
Ground corn	51.0	31.0	11.5	0.0
Soybean lecithin	0.5	0.5	0.5	0.5
Cod liver oil	4.0	4.0	3.0	2.0
Cholesterol (analytical)[1]	0.5	0.5	0.5	0.5
Dicalcium phosphate	3.0	2.0	1.0	1.0
Vitamin and mineral mix[2]	3.0	3.0	3.0	3.0
Casein	0.0	0.0	0.0	5.0
CMC[3]	3.0	3.0	3.0	3.0

[1] Cholesterol (analytical grade) was purchased from Sigma Chemical, St. Louis, MO.

[2] Vitamin and mineral mix provided the following (in mg or IU/kg of diet): A, 5,280 IU; D_3, 2,640 IU; E, 66 IU; B_{12}, 0.11 mg; K, 13.2 mg; riboflavin, 16 mg; pantothenic acid, 42 mg; thiamine, 13.2 mg; niacin, 106 mg; B_6, 13.2 mg; folic acid, 2.6 mg; choline chloride, 618 mg; ascorbic acid, 935 mg; NaH_2PO_4, 10 g; $CaHPO_4$, 20 g; KCL, 10 g; Se, 0.4 mg; Zn, 207 mg; Fe, 72 mg; Mn, 216 mg; Cu, 9 mg; I, 4.5 mg; Co, 1.8 mg.

[3] CMC = carboxymethylcellulose.

used in red claw production (D. B. Rouse, pers. comm.) was also used for comparison with the diets formulated in this study. Chemical composition of the diets is presented in Table 2.

In preparing diets, dry ingredients were first ground to a small particle size (approximately 250 μm) in a Wiley mill. Dry ingredients were then thoroughly mixed with water to obtain a 30% moisture level. Diets were passed through a mincer with die to form 0.4-mm diameter strands and dried (20°C) for 16 hr using a convection oven. After drying, diets were broken and sieved into 4-mm pellets. Cod liver oil was sprayed onto the dried pellets immediately prior to storage. All diets were kept frozen (−15°C) until fed.

Percentage protein of the diets was determined by the Kjeldahl method, percentage fat was determined by acid hydrolysis and percentage moisture was determined by drying a 10-g sample in a convection oven at 95°C until constant weight (4). Due to possible differences between the proximate compositions of the diet ingredients and published values (5), the finished diets were 23, 33, 43, and 52% protein. Actual protein values will be used throughout the rest of this paper. Diets were also analyzed for amino acid composition by a commercial analytical laboratory (Woodson-Tenent Labs, Dayton, Ohio) and are presented in Table 3.

Since neither digestible nor metabolizable energy values are available for red claw, dietary energy values were calculated (based on proximate analysis of diets) from physiological fuel values of 5.65 kcal/g of protein, 4.1 kcal/g of carbohydrate (NFE), and 9.5 kcal/g of lipid as stated by El-Sayed and Teshima (6).

Dried diets were also evaluated for pellet stability in water. Ten grams of pellets of equal length were distributed uniformly on a 100-cm² brass screen (2-mm mesh size) having raised sides. Samples were lowered into static water (approximately 10 cm under the water surface) for 30 minutes and then dried in an oven (100°C) for 24 hr. The residue left on the screen was recorded as dry solids not leached in water. The percentage of dry solids

TABLE 2. Chemical composition (dry-matter basis) of four experimental diets and a commercial shrimp diet fed to red claw reared in aquaria. Percentage moisture, protein, fat, fiber, and ash values are means of two replicates.

	Diet (% protein)				
	23%	33%	43%	52%	Zeigler
% Moisture	10.4	10.7	7.7	7.6	8.8
% Protein	23.3	33.0	43.4	51.6	45.2
% Fat	10.6	10.7	11.1	10.8	11.1
% Fiber	4.5	5.0	5.4	4.6	3.0
% Ash	16.5	18.1	19.7	20.1	14.4
NFE[1]	45.2	33.2	20.4	13.0	26.3
Energy (kcal/100 g diet)[2]	417.7	424.3	431.3	447.4	465.0
P:E[3]	55.8	77.8	100.6	115.3	97.2
Pellet water stability[4]	79 ± 1[ab]	78 ± 2[b]	53 ± 6[c]	75 ± 1[b]	90 ± 0[a]

[1] NFE = 100 − (% protein + % fat + % fiber + % ash).

[2] Energy values are based on physiological fuel values used by El Sayed and Teshima (1992).

[3] P:E = protein to energy ratio; calculated as mg of protein/kcal.

[4] Pellet water stability = percentage of dry solids retained after 30 minutes in static water.

on the screen after 30 min in water to total solids in the pellets was used as a comparative measure of pellet stability in water.

Experimental System and Animal Maintenance

The feeding trial was conducted in 20 37.5-liter acrylic aquaria (50 × 25 × 30.5 cm; L × W × H). Water was recirculated through biological and mechanical filters. The recirculating system was a 2,000-liter vertical screen filter system utilizing high-density polyester screens and polyethylene "bio-balls" to remove particulate materials and provide substrate for nitrifying bacteria (Red Ewald, Inc., Karnes City, Texas). Continuous aeration was provided by a blower and air-stones. All aquaria were cleaned by siphon once daily (1330) to remove uneaten diet. Each aquarium was supplied with water at a rate of 0.5 liter/min. Approximately 4% of the total water volume of the system was exchanged per day.

Chloride levels were maintained at approximately 1,000 mg/liter by addition of food-grade NaCl. Hardness and alkalinity levels were maintained at approximately 400 mg/liter by addition of sodium bicarbonate (baking soda) and analytical-grade calcium phosphate (dibasic; $CaHPO_4$). Black plastic covered the back and sides of all aquaria to minimize disturbances caused by personnel entering the laboratory.

Water temperature was measured daily using an electronic thermometer. Dissolved oxygen was measured twice weekly using a YSI Model 58 (YSI Industries, Yellow Springs, Ohio). Total ammonia, nitrite, total alkalinity, and chlorides were monitored twice weekly using a DR/2000 spectrophotometer (Hack Company, Loveland, Colorado). pH was monitored twice weekly using an electronic pH meter (pH pen; Fisher Scientific, Cincinnati, Ohio). Over the duration of the study these water quality parameters averaged (±SD): water temperature, 27.5 ± 1.1°C; dissolved oxygen, 6.7 ± 0.5 mg/liter; total ammonia, 0.25 ± 0.18 mg/liter; nitrite, 0.03 ± 0.02 mg/liter; total alkalinity, 419.5 ± 51.5 mg/liter; chlorides, 1,065 ± 100 mg/liter; pH, 8.62 ± 0.81.

Juvenile red claw, *Cherax quadricarinatus* (mean individual weight of 0.022 g), were obtained from the research hatchery at Auburn University, Auburn, Alabama and randomly stocked into 20 aquaria at a rate of 15 juveniles per aquarium, with 4 replications per treatment (diet). Individual weight of the juveniles was measured on an electronic scale (Mettler AT261 Delta Range, Mettler Instruments, Zurich, Switzerland) prior to stocking. On day 2, stocking mortalities were replaced. No subsequent replacement of mortalities was performed. Red claw were counted every other week. It was decided prior to the start of the study that if mortality in any treatment reached 50%, the study would be terminated. Red claw were fed to excess twice daily (0800 and 1500) for 5 weeks. Diet was evenly distributed over the bottom of each aquarium to ensure availability to all individuals. Each aquarium had one nylon-mesh substrate structure and 10 tubes (2.5-cm sections of 2.0-cm diameter garden hose) for shelters. At the conclusion of the feeding trial, red claw were individually weighed (wet weight).

TABLE 3. Amino acid composition (% of diet) of diets containing different protein levels fed to juvenile red claw crayfish. Values are means of two replications. Tryptophan levels were not determined.

Amino acid	Diet (% protein)				
	23%	33%	43%	52%	Zeigler
Alanine	0.92	1.53	2.10	2.26	2.35
Arginine	1.14	1.69	2.47	2.90	2.17
Aspartic acid	1.61	2.53	4.15	4.96	3.81
Cystine	0.17	0.24	0.35	0.41	0.38
Glutamic acid	2.66	3.46	5.94	7.00	5.57
Glycine	1.28	1.81	2.37	2.77	2.17
Histidine	0.61	0.83	1.52	1.92	1.33
Isoleucine	0.78	1.22	1.46	1.86	1.52
Leucine	1.66	2.19	2.93	3.72	3.56
Lysine	1.20	1.82	2.48	3.15	2.33
Methionine	0.45	0.64	0.91	1.09	0.75
Proline	1.71	1.30	1.80	2.24	2.31
Phenylalanine	0.85	1.22	1.64	2.00	1.88
Serine	0.76	0.97	1.66	2.09	1.70
Threonine	0.68	0.91	1.54	1.95	1.48
Tyrosine	0.42	0.62	1.41	1.59	0.83
Valine	0.95	1.41	1.77	2.29	2.11

Statistical Analysis

Final individual weight (g), survival (%), specific growth rate (SGR), and weight gain (%) were calculated at the conclusion of the study. Specific growth rate was calculated as follows: SGR (%/day) = $(\ln W_t - \ln W_i/T) \times 100$ where W_t is the weight of the juvenile at

TABLE 4. Final weight, survival, specific growth rate (SGR), and weight gain of juvenile red claw fed diets containing various percentages of protein and a commercial shrimp diet (Zeigler). Values are means ± SE of four replications. Means within a column having different superscripts were significantly different ($P < 0.05$).

Diet (% protein)	Final wt (g)	Survival (%)	SGR	Wt. gain (%)
1 (23%)	0.516 ± 0.011^{ab}	58.4 ± 9.2^{a}	9.28 ± 0.06^{a}	$2{,}301.7 \pm 41.80^{ab}$
2 (33%)	0.597 ± 0.074^{a}	58.3 ± 5.0^{a}	9.63 ± 0.32^{a}	$2{,}611.8 \pm 337.68^{a}$
3 (43%)	0.563 ± 0.056^{a}	50.0 ± 8.1^{a}	9.49 ± 0.29^{a}	$2{,}459.2 \pm 252.84^{a}$
4 (52%)	0.567 ± 0.029^{a}	61.8 ± 5.7^{a}	9.54 ± 0.15^{a}	$2{,}475.6 \pm 132.9^{a}$
Ziegler	0.409 ± 0.017^{b}	71.7 ± 5.0^{a}	8.61 ± 0.11^{b}	$1{,}760.6 \pm 78.5^{b}$

time t, W_i is the weight of the juvenile at time 0, and T is the culture period in days.

Data were analyzed by analysis of variance using the SAS ANOVA procedure (7). Duncan's multiple range test was used to compare differences among individual means. All percentage data were transformed to arc sin values prior to analysis (8).

RESULTS AND DISCUSSION

This is one of the first studies to evaluate prepared diets for juvenile red claw. Red claw juveniles fed experimental diets containing 33, 43, and 52% protein had significantly higher ($P < 0.05$) final individual weights (g) and specific growth rates (SGR) than those fed a commercial shrimp diet containing 45% protein (Table 4). Final body weight and SGR of red claw fed a diet containing 23% protein were not significantly different ($P > 0.05$) than those of red claw fed the other three experimental diets or the commercial shrimp diet. Growth of red claw fed the commercial shrimp diet in the present study was similar to growth rates observed in other studies (D. B. Rouse, pers. comm).

Red claw juveniles fed a commercial shrimp diet had a numerically higher percentage survival (71%) than red claw fed the experimental diets (58, 58, 50, and 61% for red claw fed diets containing 23, 33, 43, and 52% protein, respectively) (Table 4). However, differences in percentage survival were not statistically significant ($P > 0.05$), possibly due to variation within each treatment. Mortalities were associated with several factors including: several (15–20) red claw were found in the biofilter, probably after being removed from the aquarium through the standpipe. Some incidents of cannibalism were observed, but these occurred after week 3 of the study. However, survival values were comparable or greater than values reported in other studies with Australian crayfish (1, 9, 10, 11). Reduced water stability of experimental diets may have been a factor in the reduced survival percentages. Although survival was not significantly different ($P > 0.05$) among treatments, survival was lowest (50%) for red claw fed diet 3 (with poor water stability) and was highest (72%) among red claw fed the commercial shrimp diet (with good water stability). Water stability of diet pellets is an important factor when feeding crustaceans. Greater pellet stability minimizes leaching of water-soluble nutrients which may adversely affect crustacean growth. Fair and Fortner (12) compared growth of freshwater prawn, *Macrobrachium rosenbergii,* fed a water-stable pelleted diet to prawn fed pulverized pellets and reported that prawn fed water-stable pellets had twice the growth rate.

Data indicate that a diet containing 33–52% protein appears suitable for use in rearing juvenile red claw for the first 5 weeks after release from the female. This is in agreement with dietary protein levels reported for other crustaceans. Villarreal (11) reported no differences in growth of marron, *Cherax tenuimanus,* fed for 8 weeks with diets containing between 17–48% protein. Hubbard et al. (13) reported that a diet containing 30% protein was adequate for optimal growth of red swamp crayfish, *Procambarus clarkii.* Freshwater prawn, *Macrobrachium rosenbergii,* have a protein requirement between 32–40% (14, 15, 16). D'Abramo et al. (17) reported that growth of juvenile lobster, *Homarus americanus,* fed a diet containing 30% protein was not different from juveniles fed diets containing higher percentages of protein.

These data indicate that a formulated diet, with a protein level of 33%, appear to be adequate for juvenile red claw. Feeding for longer duration, use of individual rearing containers, and use of a greater quantity of (or a different binder) may be useful in future nutritional studies. Diets used in this study appear to be a starting point for further studies to determine nutritional requirements of red claw.

ACKNOWLEDGMENTS

We thank Karla Richardson for typing this manuscript. This research was partially funded by a grant from the USDA/CSRS to Kentucky State University under agreement KYX-80-92-05A.

LITERATURE CITED

1. Rouse, D. B. and I. Kartamulia. 1992. Influence of salinity and temperature on molting and survival of the Australian freshwater crayfish (*Cherax tenuimanus*). Aquaculture 105:47–52.

2. Semple, G. P., D. B. Rouse, and K. R. McLain. In press. *Cherax destructor, C. tenuimanus,* and *C. quadricarinatus* (Decapoda: Parastacidae). A comparative review of biological traits relating to aquaculture potential. Freshwater Crayfish.

3. Masser, M. P. and D. B. Rouse. 1993. Production of Australian red claw crayfish. Alabama Cooperative Extension Service, ANR-769. Auburn University, Auburn, Alabama.

4. AOAC (Association of Official Analytical Chemists). 1990. Official methods of analysis, 15th ed. AOAC, Inc., Arlington, Virginia.

5. NRC (National Research Council). 1983. Nutrient requirements of warmwater fishes and shellfishes. Nat. Acad. Press, Washington, D.C.

6. El-Sayed, A. F. M. and S. Teshima. 1992. Protein and energy requirements of Nile tilapia, *Oreochromis niloticus,* fry. Aquaculture 103:55–63.

7. Statistical Analysis Systems. 1988. SAS/STAT user's guide, Release 6.03 ed. SAS Institute, Cary, North Carolina 1028 pp.

8. Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

9. Kartamulia, I. and D. B. Rouse. 1992. Survival and growth of marron *Cherax tenuimanus* in outdoor tanks in the Southeastern USA. J. World Aquacult. Soc. 23:169–172.

10. Rouse, D. B. and I. Kartamulia. 1992. Use of sodium chloride to improve survival of the Australian crayfish *Cherax tenuimanus.* Prog. Fish-Cult. 54:118–121.

11. Villarreal, H. 1991. A partial energy budget for the Australian crayfish *Cherax tenuimanus.* J. World Aquacult. Soc. 22:252–259.

12. Fair, P. H. and A. R. Fortner. 1981. The role of formula feeds and natural productivity in culture of the prawn, *Macrobrachium rosenbergii.* Aquaculture 24:233–243.

13. Hubbard, D. M., E. H. Robinson, P. B. Brown, and W. Daniels. 1986. Optimum ratio of dietary protein to energy for red crayfish (*Procambarus clarkii*). Prog. Fish-Cult. 48:233–237.

14. Millikin, M. R., A. R. Fortner, P. H. Fair, and L. V. Sick. 1980. Influence of dietary protein concentration on growth, feed conversion, and general metabolism of juvenile prawn (*Macrobrachium rosenbergii*). Proc. World Maricult. Soc. 11:382–391.

15. D'Abramo, L. R., J. M. Heinen, H. R. Robinette, and J. S. Collins. 1989. Production of the freshwater prawn *Macrobrachium rosenbergii* stocked as juveniles at different densities in temperate zone ponds. J. World Aquacult. Soc. 20:81–89.

16. Tidwell, J. H., C. D. Webster, and J. A. Clark. 1993. Evaluation of distillers dried grains with solubles as an ingredient in diets for pond culture of the freshwater prawn *Macrobrachium rosenbergii.* J. World Aquacult. Soc. 24:66–70.

17. D'Abramo, L. R., D. E. Conklin, C. E. Bordner, N. A. Baum, and K. A. Norman-Boudreau. 1981. Successful artificial diets for the culture of juvenile lobsters. J. World Maricult. Soc. 12:325–332.

Trans. Ky. Acad. Sci., 55(3–4), 1994, 113–117

Mycoflora Associated With On-Farm Stored Corn (Maize) in Kentucky

John D. Sedlacek, Bryan D. Price, and Paul A. Weston

Plant and Soil Science Division, Community Research Service,
Kentucky State University, Frankfort, Kentucky 40601

Abstract

In order to determine the presence and relative abundance of fungi in corn stored on-farm in Kentucky, storage facilities in 24 western counties in the state were sampled during 1989 and 1990. Samples were cultured on 2 types of media: (1) Czapek-Dox broth supplemented with 20% sucrose and (2) sterile distilled water. Plates were incubated at 25°C for 7 days at which time fungi were identified and number of genera and/or species per kernel were enumerated. A total of 14 fungal species were isolated in 1989 and 18 species in 1990. The predominant fungi each year were *Aspergillus* spp., *Penicillium* spp., and *Fusarium* sp. There were several significant differences in percentage of occurrence of the isolates between crop-reporting districts. No significant differences in occurrence were detected between sample locations within bins.

Introduction

Corn, *Zea mays* (L), is a valuable agricultural commodity in the U.S., providing nutrition for humans, pets and livestock. Cornmeal and flour are incorporated into a vast array of food products including, but not limited to, breakfast cereals, bakery products, and snack foods (1). In Kentucky, corn may be stored in on-farm facilities for months awaiting sale or even kept for years as livestock feed (2).

Stored corn is susceptible to losses as a result of invasion by a wide range of insect and microbial pests. Infection by storage fungi may result in reduced germination, discoloration, production of foul odors, chemical and nutritional changes, and an overall reduction in quality leading to economic loss. Mycotoxins may also be produced, endangering the health of humans and livestock (3).

Kentucky is divided into 6 agricultural crop-reporting districts (4). District I is located in extreme western Kentucky while District VI is in the eastern most part of the state. The objective of this study was to determine the composition and relative abundance of mycoflora associated with on-farm stored corn in the 3 western-most crop reporting districts. This study was conducted as a means of determining the scope and severity of fungal infections in that region and to identify areas requiring further research. These districts were chosen because the majority of corn grown and stored in the state is located within these boundaries (4).

Materials and Methods

Stored corn samples were collected in 15 counties in 1989 and 24 (not mutually exclusive) counties in 1990 from 114 total farms in western Kentucky. Samples were obtained from galvanized steel bins varying in size from 1,000–60,000 bu capacity using a 35.6 cm deep bin cup probe sampler at the center and edge of each grain mass at 3 depths: surface, middle, and bottom. Samples were taken irrespective of cardinal direction, 0.3–1 m in from the bin wall. A composite sample was created from the center and the edge samples by combining the samples from the 3 depths in a 0.9 liter mason jar. Thus, 2 samples (i.e., 1 from the center and 1 from the edge) were taken from each bin. In cases where the grain mass was not deep enough to use a cup probe, a scoop sample was taken to fill the mason jar.

Subsamples (25 g) for fungal analyses were taken from each jar and 20 kernels were removed for moisture content determination. Kernels for moisture determination were ground in a Wiley mill through a #20 mesh screen, then dried in an oven at 103°C for 16 hours (5). Per cent moisture was calculated by difference from per cent dry matter. Subsamples were held at approximately −20°C prior to analysis.

Species composition and relative abundance of fungi were determined by placing corn kernels on two types of media in petri dishes. Czapek-Dox broth (Difco Laboratories, Inc., Detroit, Michigan) supplemented with 20%

TABLE 1. Fungi isolated from surface disinfected kernels, range of kernel moisture and average kernel moisture content of on-farm stored shelled corn in western Kentucky.

Isolate	n	MC low (%)	MC high (%)	Mean MC (%) ± SE
Alternaria sp.[b]	13	9.1	14.1	12.3 ± 0.3
Aspergillus candidus	2	11.9	12.2	12.1 ± 0.2
Aspergillus flavus	47	9.1	22.1	13.3 ± 0.3
Aspergillus fumigatus	2	12.3	16.4	14.4 ± 2.1
Aspergillus glaucus	100	9.4	22.1	13.5 ± 0.2
Aspergillus niger	22	10.2	22.0	13.9 ± 0.5
Aspergillus terreus[a]	2	12.1	16.4	14.3 ± 2.2
Chaetomium sp.	7	12.2	15.6	13.5 ± 0.5
Cladosporium sp.[a]	7	9.8	18.4	14.1 ± 1.1
Diplodia sp.	20	9.5	18.0	13.9 ± 0.5
Drechslera sp.[b]	1	—	12.1	—
Epicoccum sp.[b]	1	—	13.3	—
Fusarium sp.	229	9.1	22.1	13.1 ± 0.1
Mucor sp.	8	12.0	22.0	15.0 ± 1.2
Nigrospora sp.	48	9.2	18.0	13.3 ± 0.2
Paecilomyces sp.[b]	1	—	14.0	—
Penicillium spp.	118	9.5	22.1	13.6 ± 0.2
Phoma sp.[b]	1	—	11.1	—
Rhizopus sp.	9	11.9	16.7	13.4 ± 0.6
Syncephalastrum sp.[b]	1	—	12.3	—

[a] = 1989 isolate only, [b] = 1990 isolate only.

sucrose was used to isolate the more osmophilic species of Aspergilli whereas sterile distilled water was used to isolate other species with less fastidious growth requirements. Frey and Legg (6) determined these media to be most efficient in maximizing recovery of fungi from stored corn. Both media were used by pipetting 4.5 ml onto sterile filter paper (Whatman #1) in a petri dish (100 × 20 mm). A total of 20 kernels were plated per sample, 10 each on two plates. Kernels were surface-disinfected by swirling them in a 1% solution of NaOCl (Clorox®) for a period of 1 minute, shaken to remove excess bleach, and immediately plated without rinsing. All plates were incubated in a growth chamber at 25 ± 2°C and >49.0 ± 0.4% relative humidity for 7 days at which time the plates were refrigerated.

Fungi were identified and number of genera and/or species were enumerated as soon as possible after refrigeration. Identifications were made based on examination with dissecting and compound light microscopes. *Aspergillus* species designations are "group species" as classified by Raper and Fennell (7).

Descriptive statistics as well as ANOVA and Fisher's protected LSD test were used to analyze all data (8). Two-way chi-square analyses were used to examine the association between moisture content and fungal species presence (9).

RESULTS

A total of 20 fungal species were isolated from surface disinfected kernels in the survey (Table 1). Mean kernel moisture contents ranged from 12.1% to 15.0% (Table 1). Fourteen fungal genera and/or species were found in 1989 and 18 in 1990. The predominant isolate in 1989 was *Fusarium* species, infecting 98.0% of the bins sampled, 98.9% of the samples, and 75.1% of the kernels cultured (Table 2). *Aspergillus glaucus* and *Penicillium* spp. also appeared in relatively high numbers, occurring in 51.0, 43.2, and 16.9%, and 67.3, 53.4, and 11.9% of the bins, samples, and kernels, respectively. In 1990, the same 3 isolates predominated. *Fusarium* sp. occurred in 100, 96.5, and 73.4%, *A. glaucus* in 55.7, 41.2, and 16.0%, and *Penicillium* spp. in 69.3, 47.6, and 11.3% of the bins, samples, and kernels, respectively.

Several significant differences in occurrence between districts were observed (Table 3). Mean occurrence of *Fusarium* sp. ($P = 0.2150$), *A. glaucus* ($P = 0.1449$), and *Penicillium* spp. ($P = 0.0853$) were not statistically different between districts in 1989. In 1990, Districts I and II had a significantly higher occurrence of *Fusarium* sp. ($P = 0.0001$) and a significantly lower incidence of *A. glaucus* than District III ($P = 0.0001$). Differences in occurrences of *Penicillium* spp. were not significant between districts ($P = 0.4032$). There was significantly more *Nigrospora* sp. in District III than District I in 1989 ($P = 0.0053$). However, in 1990 there was significantly more *Nigrospora* in District I than Districts II and III ($P = 0.0001$).

Fusarium sp. was isolated from all counties sampled in both survey years. In 1989, *Penicillium* spp. was isolated from 14 of 15 counties and *A. glaucus* from 11 of 15. In 1990, *Penicillium* spp. was isolated from 23 of 24 and *A. glaucus* from 18 of 24 counties sampled. There were no significant differences in percentage of occurrence based on sample location (center vs. edge) within the grain bins for any of the fungi (Table 4) ($P > 0.05$).

TABLE 2. Incidence of fungi isolated from surface disinfected kernels of on-farm stored shelled corn in western Kentucky.

Isolate	n	% Bins infected	n	% Samples infected	n	% Kernels infected
			1989			
Fusarium sp.	49	98.0	88	98.9	880	75.1
A. glaucus[s]	49	51.0	88	43.2	880	16.9
Penicillium spp.[s]	49	67.3	88	53.4	880	11.9
Diplodia sp.	49	32.7	88	21.6	880	6.4
Nigrospora sp.	49	28.6	88	21.6	880	4.9
Rhizopus sp.[s]	49	14.2	88	8.0	880	4.3
A. flavus[s]	49	36.7	88	22.7	880	3.6
A. niger[s]	49	16.3	88	12.5	880	3.1
Mucor sp.[s]	49	6.1	88	4.5	880	2.3
Cladosporium sp.	49	12.2	88	8.0	880	1.1
Chaetomium sp.	49	6.1	88	3.4	880	1.0
A. terreus[s]	49	4.1	88	2.3	880	0.2
A. candidus[s]	49	2.0	88	1.1	880	0.1
A. fumigatus[s]	49	2.0	88	1.1	880	0.1
			1990			
Fusarium sp.	88	100.0	170	96.5	1,700	73.4
A. glaucus[s]	88	55.7	170	41.2	1,700	16.0
Penicillium spp.[s]	88	69.3	170	47.6	1,700	11.3
Nigrospora sp.	88	28.4	170	17.1	1,700	5.3
A. flavus[s]	88	25.0	170	17.6	1,700	3.2
Rhizopus sp.[s]	88	5.7	170	2.9	1,700	2.0
Alternaria sp.	88	14.8	170	7.6	1,700	1.9
A. niger[s]	88	12.5	170	7.1	1,700	1.2
Diplodia sp.	88	6.8	170	3.5	1,700	1.1
Mucor sp.[s]	88	5.7	170	2.9	1,700	0.9
Chaetomium sp.	88	6.8	170	3.5	1,700	0.7
Syncephalastrum sp.	88	1.1	170	0.6	1,700	0.5
Paecilomyces sp.	88	1.1	170	0.6	1,700	0.3
Drechslera sp.	88	1.1	170	0.6	1,700	0.2
A. candidus[s]	88	2.3	170	1.2	1,700	0.1
A. fumigatus[s]	88	1.1	170	0.6	1,700	0.1
Epicoccum sp.	88	1.1	170	0.6	1,700	0.1
Phoma sp.	88	1.1	170	0.6	1,700	0.1

[s] = storage fungus.

DISCUSSION

It is not surprising that *Fusarium* sp. was the most predominant isolate in the survey, even though members of this genus are generally considered to be "field" fungi and, thus, do not cause many problems in storage. Field fungi may exist in a dormant state under storage conditions but most die off rather quickly at lower moisture contents commonly encountered in grain bins (10). *Rhizopus* sp. can be a storage fungus, but *Nigrospora* sp. is not. Higher numbers of field fungi may indicate corn stored for a relatively short period of time. This is likely considering many of the samples obtained in the survey were from grain harvested less than a year before sampling. *Penicillium* spp., a major source of "blue-eye," is also very common in corn, with both field and storage species known to infect kernels. Blue eye results from the germ of a kernel becoming infected with the fungus resulting in a bluish-green coloration in that region. *Aspergillus glaucus,* the third most frequent isolate, may also cause "blue-eye" and is perhaps the most prevalent storage fungus in the world (11). *Aspergillus glaucus* is distinguished by its ability to grow at kernel moisture contents as low as 13.5%. There was no detectable association between moisture content and presence/absence of any of the fungal species examined using chi-square analysis ($P > 0.05$).

In regard to differences in occurrence between districts, there is no consistently higher

TABLE 3. Incidence of predominant fungi among the three crop reporting districts sampled. Means followed by the same letter in each row are not significantly different ($\alpha = 0.05$)

Isolate	Mean occurrence/10 kernels		
	Dist I	Dist II	Dist III
	1989		
Fusarium sp.	6.7a	7.4a	8.0a
A. glaucus	0.9a	1.7a	2.1a
Penicillium spp.	1.0a	0.8a	1.6a
Diplodia sp.	1.0a	0.8a	0.4a
Nigrospora sp.	0.0b	0.4ab	0.8a
Rhizopus sp.	1.1a	0.5a	0.0a
A. flavus	0.3a	0.3a	0.5a
A. niger	0.1a	0.5a	0.3a
	1990		
Fusarium sp.	8.1a	8.4a	6.2b
A. glaucus	0.3b	0.8b	2.8a
Penicillium spp.	1.1a	0.9a	1.3a
Nigrospora sp.	1.6a	0.4b	0.1b
A. flavus	0.1a	0.5a	0.3a
Rhizopus sp.	0.0a	0.2a	0.3a
Alternaria sp.	0.1a	0.4a	0.0a
A. niger	0.0a	0.1a	0.2a

TABLE 4. Effect of sampling location within bins on incidence of predominant fungi isolated. Means followed by the same letter in each row are not significantly different ($\alpha = 0.05$).

Isolate	Mean occurrence/10 kernels	
	Center	Edge
	1989	
Fusarium sp.	7.8a	7.2a
A. glaucus	1.9a	1.6a
Penicillium spp.	1.4a	1.0a
Diplodia sp.	0.4a	0.8a
Nigrospora sp.	0.6a	0.4a
Rhizopus sp.	0.2a	0.6a
A. flavus	0.2a	0.5a
A. niger	0.2a	0.4a
	1990	
Fusarium sp.	7.5a	7.2a
A. glaucus	1.8a	1.4a
Penicillium spp.	1.3a	1.0a
Nigrospora sp.	0.4a	0.6a
A. flavus	0.4a	0.2a
Rhizopus sp.	0.4a	0.0a
Alternaria sp.	0.1a	0.3a
A. niger	0.1a	0.1a

occurrence of storage fungi in District III. Barney et al. (2) found that District III had a larger number of farms which fed their corn to livestock and as a result held the corn in the bins for a longer period of time, thus increasing the potential for invasion by storage fungi. It is also surprising that there was no statistical difference based on sample location in the occurrence of storage fungi. Hagstrum et al. (12) found greater numbers of grain insects in the center column of bin-stored wheat compared to edges. One would expect greater numbers of storage fungi in the center column owing to damage to the kernels caused by the insects.

The percentage of bins and samples infected with fungi was consistently greater than the percentage kernels infected. Thus, the fungi isolated were more widely distributed than the kernels were heavily infected. Major storage fungi causing spoilage of grain were isolated from many of the corn samples. This grain will remain mold-free only if grain temperature is kept low or if moisture content is gradually decreased. Therefore, results of this survey emphasize the need for growers and commodity managers to maintain conditions not conducive to fungal germination and growth.

ACKNOWLEDGMENTS

D. E. Legg consulted on early survey protocol. This research was supported by a USDA-CSRS grant awarded to Kentucky State University under agreement KYX-10-86-05P.

LITERATURE CITED

1. Bothast, R. J., R. F. Rogers, and C. W. Hesseltine. 1974. Microbiology of corn and dry milled corn products. Cereal Chemistry 51:829–838.

2. Barney, R. J., D. E. Legg, and J. D. Sedlacek. 1989. On-farm storage facilities and management practices in Kentucky. Bull. Entomol. Soc. Amer. 35:26–33.

3. Sanchis, V., I. Vinas, M. Jimenez, M. A. Calvo, and E. Hernandez. 1982. Mycotoxin-producing fungi isolated from bin-stored corn. Mycopathologia 80:89–93.

4. Kentucky Agricultural Statistics Service. 1991. In Tom Lenz (ed.) Kentucky agricultural statistics 1989–1990. Louisville, Kentucky.

5. AOAC. 1965. Official methods of analysis of the Association of Analytical Chemists, 10th ed. Arlington, Virginia.

6. Frey, S. A. and D. E. Legg. 1988. Isolation techniques for surveying the fungi of stored maize. Trans. Ky. Acad. Sci. 49:131–139.

7. Raper, K. B. and D. I. Fennell. 1977. The Genus *Aspergillus*. Robert E. Krieger Pub. Co., Malabar, Florida.

8. SAS Institute. 1988. SAS/STAT users guide. SAS Institute, Cary, North Carolina.

9. Steel, R. G. D. and J. H. Torrie. 1980. Principles and procedures of statistics, 2nd ed. McGraw Hill, New York, New York.

10. Christensen, C. M. and D. B. Sauer. 1982. Microflora. Pp. 219–240. In C. M. Christensen (ed.) Storage of cereal grains and their products, 3rd ed. American Association of Cereal Chemists. St. Paul, Minnesota.

11. Sauer, D. B., C. L. Storey, and D. E. Walker. 1984. Fungal populations in U.S. farm-stored grain and their relationship to moisture, storage time, regions, and insect infestations. Phytopathology 74:1050–1053.

12. Hagstrum, D. W., G. A. Milliken, and M. S. Waddell. 1985. Insect distribution in bulk-stored wheat in relation to detection or estimation of abundance. Environ. Entomol. 14:655–661.

Trans. Ky. Acad. Sci., 55(3–4), 1994, 118–123

Spatial and Temporal Patterns of Emergence of Periodical Cicadas (Homoptera: Cicadidae) in a Mountainous Forest Region

PAUL J. KALISZ

Department of Forestry, University of Kentucky,
Lexington, Kentucky 40546

ABSTRACT

The 1991 emergence of periodical cicada Brood XIV was sampled in an extensive and non-fragmented forest region on the Cumberland Plateau of Kentucky. On upland sites *Magicicada septendecim* L., *M. septendecula* Fisher, and *M. cassini* Alexander and Moore accounted for 82, 13, and 5%, respectively, of the nymphs emerging from the soil. Daily emergence rates peaked first on upper south slopes, then on ridges, upper north slopes, and lower slopes; there was a 9-day difference between the dates at which emergence rate culminated on upper south slopes and lower slopes. Peak daily emergence rate ranged from 0.5 to 1.7 insects/m^2, and mean cumulative emergence density ranged from 3.7 to 9.3 insects/m^2 among landscape positions. Both peak rate and cumulative density declined in the sequence: ridges > upper north slopes > upper south slopes > lower slopes. Higher P concentration in the 0–10 cm depth was the only difference found in a comparison of properties of soils from which abundant cicadas had emerged and properties of nearby soils from which no cicadas had emerged. The low emergence densities recorded in the present study may be representative of conditions in extensive and non-fragmented forests as contrasted with the higher densities reported by research in forest patches or in forest remnants in agricultural or urban landscapes.

INTRODUCTION

The emergence of periodical cicadas (Homoptera: Cicadidae: *Magicicada* spp.) is locally synchronized among up to 3 species with 13-yr or 17-yr life cycles; populations emerging any 1 year are recognized as "broods" (1, 2). Density per unit ground area and relative species dominance of emerging broods are variable over small distances, presumably in response to gradients in vegetation, microclimate or substrate (3).

Much research on periodical cicadas has been performed in small forest patches or in forest remnants in agricultural or urban landscapes (e.g., 4, 5, 6, 7, 8). Habitat fragmentation, in combination with simplification of ecosystems and introduction of exotic species, results in an abundance of "edge" and in alterations in species interactions and inputs of energy and matter, and may lead to crowding of mobile organisms in forest remnants (9). In the case of periodical cicadas, habitat disturbance has been found to be associated with elevated population levels in or at the edge of forest remnants (6, 10), and with disruption of the spatial segregation of species according to preferred ovipositional habitats (3, 4).

In recent years the range limits of periodical cicadas have receded away from urban areas, and a number of broods have declined in abundance due to land-use changes and practices such as pesticide application (10, 11, 12). Given the rapidity of such changes, and the altered conditions and ecological relationships found in fragmented or disturbed habitats, my objective was to statistically describe the emergence of a brood of periodical cicadas in an extensive and non-fragmented forest region. To achieve this objective, the spatial and temporal patterns of emergence of *Magicicada septendecim* L., *M. septendecula* Fisher, and *M. cassini* Alexander and Moore, the three resident species of 17-yr cicadas, were sampled on a little-disturbed research forest in eastern Kentucky near the center of the Appalachian Plateaus Region (13) of the eastern U.S.A. My intention was to document ecological relationships between cicada emergence density, landscape position and soils as a contribution to understanding the biology of periodical cicadas in extensive and non-fragmented forests, and as a benchmark that may be useful in detecting changes in population size and behavior.

MATERIAL AND METHODS

Study Area.—This study was performed on the University of Kentucky's Robinson Forest in Breathitt County (37°27′N, 83°8′W). Climate is temperate, humid, and continental. Mean annual precipitation is 1,170 mm distributed evenly throughout the year; mean annual temperature is 10°C, with mean daily maxima and minima of 8° and −4°C in January, the coldest month, and 31° and 18°C in July, the warmest month (14).

Sampling for this study was performed within a 1,000-ha area representative of the entire 6,000-ha experimental forest and of the Rugged Eastern Area of the Northern Cumberland Plateau (sensu 15) in general. The latter physiographic area is part of Fenneman's (13) Appalachian Plateaus Region which extends from the Allegheny Plateau in southeastern Ohio and southwestern Pennsylvania along the Cumberland Plateau of eastern Kentucky and Tennessee to northern Alabama, and which is generally >75% forested (15, 16, 17, 18, 19). This region also includes most of the range of periodical cicada Brood XIV (1). The landscape of the study area is intricately dissected; slopes with gradients >30% occupy ca. 80% of the land area and first-order watersheds occupy ca. 50% of the land area. Elevations range from 240 to 490 m above mean sea level, and relief ranges from 115 to 200 m.

Surficial geological materials are horizontally-layered sandstones, siltstones, coals and shales of the Breathitt Formation, Lower and Middle Pennsylvanian Series (20). The most common types of upland soil profiles are classified as fine-loamy, mixed, mesic Typic Hapludults (Shelocta series) and fine-loamy, mixed, mesic Typic Haplumbrepts (Cutshin series) in colluvium; as loamy-skeletal, mixed, mesic Typic Dystrochrepts (Dekalb series) in coarse-textured residuum; and as clayey, mixed, mesic Aquic Hapludults (Latham series) in fine-textured residuum. Soil properties vary in predictable patterns related to the underlying geological material and location in the landscape (21).

The study area lies near the center of Braun's (22) Mixed Mesophytic Forest Region. Forests are dominated by ca. 50 woody species (23) and stand composition is determined by microsite variations controlled primarily by landscape position (21). Stand basal areas generally range from 20–35 m^2/ha, and ages from 50–70 yr.

Field Methods.—The 1991 emergence of Brood XIV was sampled. Nymphs were captured as they emerged from the ground using screen-covered cone traps similar in design to those described by Raney and Eikenbary (24) except that they were closed at the top and had circular ground areas of 0.2 m^2. Sampling was limited to upland areas since bottomlands were small and often disturbed. Ten traps were randomly distributed within each of 20 randomly-located, 0.2-ha sample areas. Sample areas were not statistical "blocks" but were intended to ensure dispersion of the traps throughout the study area while maintaining practical sampling logistics.

Traps were checked every 24 to 48 hr from 13 May until 10 June, and then less frequently until 25 June. Following eclosion, sex and species were recorded for captured individuals. The 2 "dwarf" cicada species were distinguished from one another based on the assumption that all *M. septendecula* had orange bands on the black abdominal sternites and that all *M. cassini* lacked such bands; *M. septendecim* was recognized by its larger size and by the presence of a brown spot between the eye and the base of the wing (3).

After the emergence was over, forest floor (O horizon) and soil samples were collected from beneath two cone traps on each of the 20 sample areas: one from beneath the trap that captured the greatest number of cicadas in the area, and one from beneath the nearest trap that captured no cicadas. Traps were randomly selected in cases where more than one trap satisfied these requirements. Volumetric samples of forest floor and soil with 0.1-m^2 ground area were collected beneath the center of the cage; the 0 to 10 cm soil depth, which corresponded approximately to the A horizon, was sampled.

Species and diameter at 1.4 m above ground (DBH) were recorded by landscape position for all stems >10 cm DBH within each sample area. These data were used to calculate species importance as a percentage of the basal area for each landscape position (Table 1).

Laboratory Methods.—Forest floor (O horizon) samples were dried at 60°C and then ignited at 450°C to determine ash concentration. Soil samples were air-dried and crushed to pass a 2-mm sieve. The >2-mm fraction

TABLE 1. Relative basal areas (%) for stems ≥10 cm DBH on four landscape positions. Absolute basal areas were 27.8, 29.5, 25.6, and 33.7 m^2/ha, respectively, for upper south slopes, ridges, upper north slopes and lower slopes.

Taxon	Upper south	Ridges	Upper north	Lower
Quercus spp.	53	56	49	15
Pinus rigida	10	24	0	0
Carya spp.	10	2	1	2
Acer spp.	6	12	17	15
Liriodendron tulipifera	6	<1	9	11
Tsuga canadensis	2	<1	0	21
Fagus grandifolia	2	1	<1	14
Tilia heterophylla	2	0	8	8
Magnolia acuminata	1	<1	5	8
Other (no. of species)	8 (11)	5 (6)	11 (7)	6 (9)

was added to the stones collected in the field and weighed, and the <2-mm fraction was analyzed as described below. Particle-size analysis was performed using the hydrometer method (25) following removal of organic matter with NaOCl. The following soil chemical analyses were performed: pH (1:1, soil:water); available Ca, Mg, K, and P using the Mehlich 3 extractant (26) and spectroscopic determination; organic C by the Walkley-Black procedure (27); and total N by a Kjeldahl procedure (28).

Data Analysis.—Landscape positions used in this study were similar to Smalley's (15) land-types, with upper and lower slopes divided along a line half-way from the top of the ridge to the stream, and north and south slopes separated by a line connecting azimuths of 315° and 135°. Based on topographic maps, and on measurements of slope gradient and compass bearing at the locations of the 200 traps, landscape position was classified as ridges (average 0% slope gradient, no slope orientation) for 30 traps, as upper south slopes (43% gradient, SW orientation) for 70 traps, as upper north slopes (35% gradient, NE orientation) for 50 traps, and as lower slopes (42% gradient, N orientation) for 50 traps. Mean emergence rate was calculated as the cumulative number of cicada nymphs emerging per unit ground area divided by the number of days since the start of emergence.

Normality (Lilliefors variation of Kolmogorov-Smirnov test) and homogeneity of variance (Cochran's C test) were confirmed for the test variables prior to statistical analysis. Density of emerging cicadas was analyzed using a nested design with sample areas nested within landscape positions. The null hypothesis was that cicada density did not differ among the 4 landscape positions that were sampled. When ANOVA was significant at the $P = 0.05$ level, the Bonferroni procedure was used for mean separation among landscape positions.

Forest floor and soil samples were analyzed using paired t tests at the 0.05-level with 20 replications. The null hypothesis was that the properties of soils from which no cicadas emerged did not differ from those of nearby soils from which many cicadas emerged. Results of forest floor analyses are given on an ash-free basis; results of soil analyses are given on an air-dry basis.

RESULTS

The first periodical cicada was observed May 4, and widespread emergence of nymphs from the soil began May 10; the last nymph was captured May 31, and the last adult was heard June 16. The daily emergence rate culminated first on upper south slopes (day 4 of the emergence period), then on ridges (day 6), upper north slopes (day 8) and lower slopes (day 13) (Fig. 1). Mean daily emergence rate also culminated earlier for males (day 5) versus females (day 7), and for *M. septendecim* (day 5) versus the two "dwarf" species (day 8) (Fig. 1). Although generalized curves describing emergence rate were smooth and had a single clearly-defined peak (Fig. 1), all landscape positions experienced reduced emergence rates between days 10 and 13 (not recognizable on Fig. 1) associated with the occurrence of 27 mm of precipitation and a temperature decrease of ca. 5°C.

The female:male ratio of the sampled population was 55:45. *Magicicada septendecim, M. septendecula,* and *M. cassini,* respectively, accounted for 82, 13, and 5% of the 241 captured cicada nymphs. *Magicicada septendecim* and *M. septendecula* were collected on all landscape positions; *M. cassini* was collected on only a single site on an upper north slope. Although infrequent on the upland forest sites that were sampled, I observed *M. cassini* to

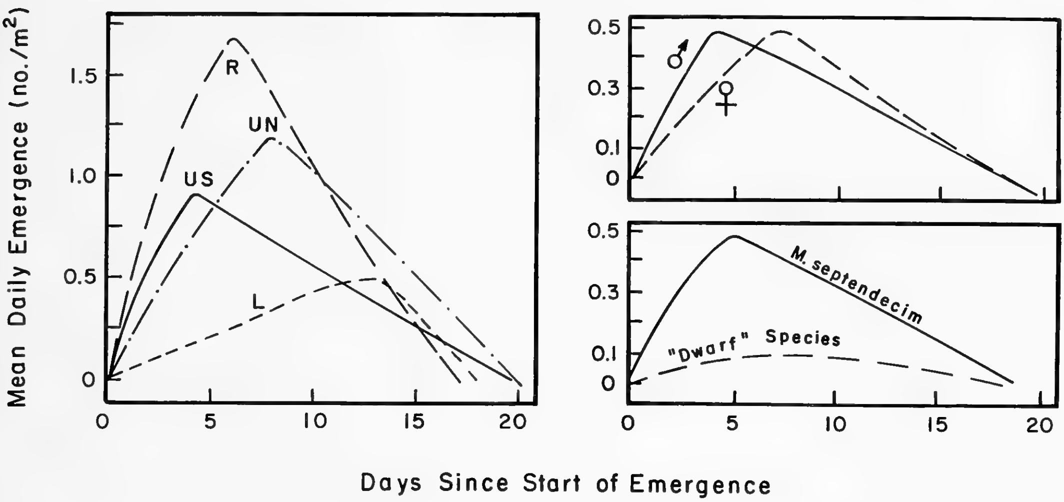


FIG. 1. Temporal patterns of mean daily rate of periodical cicada (*Magicicada* spp.) emergence from soil classified by landscape position (ridges = R, upper north slopes = UN, upper south slopes = US, and lower slopes = L), sex, and cicada species ("dwarf" species = *M. septendecula* and *M. cassini*). Day 0 was 10 May 1991; n = 200 traps.

be the dominant species on disturbed bottomlands on the study area.

Both the maximum daily emergence rate (Fig. 1) and the mean total emergence density (Table 2) declined in the sequence ridges > upper north slopes > upper south slopes > lower slopes. Emergence density was significantly (P = 0.01) greater on ridges compared to lower slopes, and was intermediate on upper north and south slopes (Table 2).

There were few soil differences between areas from which abundant cicadas emerged compared to nearby areas from which no cicadas emerged (Table 3). Phosphorus concentration in the upper 10-cm soil was significantly (P = 0.04) higher on areas with abundant cicadas. Although mean concentrations of C, N, and Ca were also higher in soils from areas with abundant cicadas, these differences were not statistically significant (Table 3).

TABLE 2. Density of periodical cicada emergence from soils on four landscape positions.

Landscape position (n)	$\bar{x}$ ± SE (no./m²)
Ridges (30)	9.3 ± 1.5 *ab**
Upper north slopes (50)	7.9 ± 1.2 *bc*
Upper south slopes (70)	5.3 ± 1.0 *bc*
Lower slopes (50)	3.7 ± 1.2 *c*

* Means marked with different letters were different at 0.05 level.

DISCUSSION

Based on data presented in Barfield et al. (29), relative amounts of incident solar radiation during the period of March through May were 1.0, 0.9, 0.8, and 0.7, respectively, for upper south slopes, ridges, upper north slopes and lower slopes used in this study. Similarly, Hutchins et al. (21), working on the same area used in my study, measured a growing season soil temperature difference of 3°C at a depth of 10 cm when comparing southerly and

TABLE 3. Means and significance levels (P) for paired t tests of 0 horizon mass and selected properties of the mineral soil (0–10 cm depth) between areas from which emerging cicadas were absent and abundant (n = 20).

Property	Cicadas absent	Cicadas abundant[1]	P
0 horizon mass (g/m²)	1,388	1,143	0.35
Coarse fraction[2] (g/kg)	487	574	0.08
Sand[3] (g/kg)	520	530	0.78
Silt[3] (g/kg)	260	260	0.98
Clay[3] (g/kg)	220	210	0.75
pH	4.8	4.7	0.74
C (g/kg)	51	75	0.15
N (g/kg)	2.1	2.3	0.36
P (mg/kg)	4.9	7.6	0.04
Ca ($cmol_c$/kg)	2.6	3.5	0.32
Mg ($cmol_c$/kg)	0.8	0.8	0.75

[1] Statistics (insects/m²) for areas with abundant cicadas were: $\bar{x}$ ± SD, 19.5 ± 14.0; median, 15.0; minimum, 5.0; maximum, 60.0.

[2] Fraction ≥2 mm expressed on a whole-soil basis.

[3] Expressed on a <2 mm basis; sand, ≥0.05; silt, <0.05 and ≥0.002; clay, <0.002 mm.

northerly slopes. Given that emergence of cicada nymphs has been reported to be delayed by low temperatures (1), variability of soil temperature across the landscape likely accounts for observed differences in temporal patterns of peak cicada emergence, including a 9-day lag between the dates of peak emergence on upper south slopes and on lower slopes (Fig. 1).

The results of this study support prior work (3, 4, 5) showing that in upland forests *M. septendecim* is common while *M. septendecula* is widely distributed but scarce. Similarly, the scarcity of *M. cassini* on the study area conforms to prior observations that, in undisturbed forests, this species is only common in bottomlands (3, 4, 5). The dominance of *M. cassini* (16 of 26 captured individuals) on a single upper north slope site was anomalous. This site was, however, similar to bottomlands in that it was a relatively moist hollow and was occupied by such mesophytic tree species as *Tilia heterophylla* (32% of the basal area), *Magnolia acuminata* (15%), *Acer saccharum* (13%), and *Fraxinus americana* (12%). Dybas (3) also reported that *M. cassini* colonized upland areas occupied by mesophytic tree species.

The greatest documented emergence of periodical cicadas, and apparently the highest biomass per unit area ever recorded for terrestrial animals under natural conditions, was 3,750/m^2 and 368 g/m^2 fresh mass estimated on a forested floodplain in Illinois for a population dominated by the 17-yr *M. cassini* (4). In upland forests, emergence densities are typically much lower than this maximum, ranging from ca. 10 to 100/m^2 (e.g., 4, 7, 8, 30). Densities recorded in this study (Table 2) are at or below the lower end of the range of these past estimates. This discrepancy may be methodological rather than real since past density estimates have been based on techniques such as excavating nymphs one or more years before emergence (30), counting emergence holes (4, 8), or counting cast skins (7) rather than on trapping insects as they leave the soil. However, habitat disturbance has been found to be associated with elevated densities of periodical cicadas along forest edges and in forest remnants (6, 10). The relatively low emergence densities (Table 2) of the present study may, therefore, be accurate estimates for extensive and non-fragmented forest regions where the availability of a large and uniform expanse of suitable habitat reduces the tendency for oviposition and the emergence of nymphs from soil to be concentrated in forest edges or forest remnants.

Differences in emergence density among the 4 sampled landscape positions likely result from a number of interacting conditions affecting oviposition and the survival of nymphs in the soil. Differences in soil temperature among landscape positions (21) has already been mentioned. *Magicicada septendecim*, the dominant species on the study area, seems to prefer upland tree species such as oaks and hickories as ovipositional substrates (31). Low emergence density (Table 2) on lower slopes may, therefore, be partly controlled by the scarcity (Table 1) of these preferred species. The higher average emergence densities on ridges, upper north and upper south slopes (Table 2), which were dominated by oaks (Table 1), and lower average emergence densities on lower slopes, which were dominated by a mixed assemblage of mesophytic tree species, may also be related to the finding that root density and abundance are approximately twice as great in soils under oak forests as compared to soils under mesophytic forest types on the study area (32). Given that periodical cicada nymphs spend 17 yr sucking xylem fluid from roots, the combined effect of variability in forest composition and in belowground conditions such as root density and soil temperature could account for patterns of emergence density across the landscape.

The absence of clear differences in properties of soils supporting abundant cicadas and of soils lacking cicadas (Table 3) conforms to the generalization that, if geologic substrate and species of cicada are constant, and if excessively wet and excessively shallow soils are not considered, soil properties do not seem to be related to the occurrence or density of periodical cicadas (8, 10, 33, 34). The small but significant increases in P concentration in soils with abundant cicadas were similar to the differences found when comparing cicada turrets to the surrounding soil; the latter study speculated that elevated P in turrets was due to excretions by the insect itself (8). Considered over the range of well-drained and acid substrates sampled in the present study, cicada emergence density does not appear to be controlled by soil properties.

ACKNOWLEDGMENTS

I thank Rick Wells for help in the field and laboratory. This work was supported by Mc-Intire-Stennis funds and is a contribution of the Kentucky Agricultural Experiment Station, Paper no. 93-8-185.

LITERATURE CITED

1. Marlatt, C. L. 1907. The periodical cicada. U.S.D.A. Bur. Entomol. Bull. 71:1–183.

2. Alexander, R. D. and T. E. Moore. 1962. The evolutionary relationships of 17-year and 13-year cicadas, and three new species (Homoptera, Cicadidae, *Magicicada*). Misc. Publ. Mus. Zool. Univ. Mich. 121:1–59.

3. Dybas, H. S. 1974. The habitats of 17-year periodical cicadas (Homoptera: Cicadidae: *Magicicada* spp.). Ecol. Monogr. 44:279–324.

4. Dybas, H. S. and D. D. Davis. 1962. A population census of seventeen-year periodical cicadas. Ecology 43: 432–444.

5. Dybas H. S. and M. Lloyd. 1962. Isolation by habitat in two synchronized species of periodical cicadas (Homoptera: Cicadidae: *Magicicada*). Ecology 43:444–459.

6. White, J., M. Lloyd, and J. H. Zar. 1979. Faulty eclosion in crowded suburban periodical cicadas: populations out of control. Ecology 60:305–315.

7. Karban, R. 1982. Increased reproductive success at high densities and predator satiation for periodical cicadas. Ecology 63:321–328.

8. Luken, J. O. and P. J. Kalisz. 1989. Soil disturbance by the emergence of periodical cicadas. Soil Sci. Soc. Am. J. 53:310–313.

9. Saunders, D. A., R. J. Hobbs, and C. R. Margules. 1991. Biological consequences of ecosystem fragmentation: a review. Conserv. Biol. 5:18–32.

10. Maier, C. T. 1980. A mole-eye's view of seventeen-year periodical cicada nymphs, *Magicicada septendecim* (Homoptera: Cicadidae). Ann. Entomol. Soc. Am. 73:147–152.

11. Forsythe, H. Y., Jr. 1975. Ovipositional host plants of 17-year cicadas. Ohio Agric. Res. Develop. Cen. Res. Circ. 210:1–19.

12. Kritsky, G. 1988. The 1987 emergence of the periodical cicada (Homoptera: Cicadidae: *Magicicada* spp.: Brood X) in Ohio. Ohio J. Sci. 88:168–170.

13. Fenneman, N. M. 1938. Physiography of the eastern United States. McGraw-Hill, New York, New York.

14. Hill, J. D. 1976. Climate of Kentucky. Ky. Agric. Exp. Stn. Progr. Rep. 221:1–88.

15. Smalley, G. W. 1986. Classification of and evaluation of forest sites on the northern Cumberland Plateau. U.S.-FS Gen. Tech. Rep. SO-60.

16. Kingsley, N. P. 1985. A forester's atlas of the Northeast. U.S.D.A. Forest Service Gen. Tech. Rept. NE-95:1–96.

17. Smalley, G. W. 1979. Classification and evaluation of forest sites on the southern Cumberland Plateau. U.S.-FS Gen. Tech. Rep: SO-23.

18. Smalley, G. W. 1982. Classification and evaluation of forest sites on the mid-Cumberland Plateau. U.S.-FS Gen. Tech. Rep: SO-38.

19. Smalley, G. W. 1984. Classification and evaluation of forest sites in the Cumberland Mountains. U.S.-FS Gen. Tech. Rep: SO-50.

20. McDowell, R. C., G. J. Grabowski, Jr., and S. L. Moore. 1981. Geologic map of Kentucky. U.S. Geological Survey, Reston, Virginia.

21. Hutchins, R. B., R. L. Blevins, J. D. Hill, and E. H. White. 1976. The influence of soils and microclimate on vegetation of forested slopes in eastern Kentucky. Soil Sci. 121:234–241.

22. Braun, E. L. 1950. Deciduous forests of eastern North America. Hafner, New York, New York.

23. Carpenter, S. B. and R. L. Rumsey. 1976. Trees and shrubs of Robinson Forest, Breathitt County, Kentucky. Castanea 41:277–282.

24. Raney, H. G. and R. D. Eikenbary. 1969. A simplified trap for collecting adult pecan weevils. J. Econ. Ent. 62:722–723.

25. Gee, G. W. and J. W. Bauder. 1986. Particle-size analysis. Pp. 383–411. In A. Klute (ed.) Methods of soil analysis. Part 1, 2nd ed. American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin.

26. Mehlich, A. 1984. Mehlich 3 soil test extractant: a modification of Mehlich 2. Commun. Soil Sci. Plant Anal. 15:1409–1416.

27. Nelson, D. W. and L. E. Sommer. 1982. Total carbon, organic carbon and organic matter. Pp. 539–579. In A. L. Page (ed.) Methods of soil analysis. Part 2, 2nd ed. American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin.

28. Bremner, J. M. and C. S. Mulvaney. 1982. Nitrogen-total. Pp. 595–624. In A. L. Page (ed.) Methods of soil analysis. Part 2, 2nd ed. American Society of Agronomy Soil Science Society of America, Madison, Wisconsin.

29. Barfield, B., J. Hill, and J. Walker. 1973. Solar radiation on sloping surfaces in Kentucky. Ky. Agric. Exp. Stn. Progr. Rep. 208:1–16.

30. Scully, N. J. 1942. Root distribution and environment in a maple-oak forest. Bot. Gaz. 103:492–517.

31. Lloyd, M. and J. A. White. 1976. On the ovipositional habits of 13-year versus 17-year periodical cicadas of the same species. New York Entomol. Soc. 89:148–155.

32. Kalisz, P. J., R. W. Zimmerman, and R. N. Muller. 1987. Root density, abundance, and distribution in the mixed mesophytic forest of eastern Kentucky. Soil Sci. Soc. Am. J. 51:220–225.

33. Gossard, H. A. 1917. Distribution of the Ohio broods of periodical cicada with reference to soil. Ohio Agric. Exp. Stn. Bull. 311:551–577.

34. Strandine, E. J. 1940. A quantitative study of the periodical cicada with respect to soil of three forests. Am. Midl. Nat. 24:177–183.

Trans. Ky. Acad. Sci., 55(3–4), 1994, 124–126

Metal Concentrations in Guano from a Gray Bat Summer Roost

MICHAEL J. LACKI

Department of Forestry, University of Kentucky,
Lexington, Kentucky 40546

ABSTRACT

As part of a monitoring effort of gray bat maternity colonies in Jessamine County, Kentucky, guano was collected beneath 2 clusters of gray bats and examined for concentrations of 11 metals. All 11 metals were present in at least trace concentrations. Iron ($\bar{x}$ = 708.3 mg/kg), zinc ($\bar{x}$ = 337.8 mg/kg), manganese ($\bar{x}$ = 75.5 mg/kg) and copper ($\bar{x}$ = 71.4 mg/kg) had the highest concentrations of the metals tested. These data indicate that pollution from metals may represent a previously undescribed threat to the survival of this endangered bat.

INTRODUCTION

The gray bat, *Myotis grisescens,* is a monotypic species restricted in distribution to the limestone karst region of southeastern United States (1). Gray bats received endangered species status in 1976 (2), because 95% of the known population hibernated in only 9 caves, with over half the population in a single cave. Gray bats are restricted to cave habitats for roosting (3).

Gray bats are believed to be declining more rapidly in the northern portions of their range, Kentucky in particular (4). One survey of summer colonies of gray bats in Kentucky estimated a decline of 89% in population size from the previously believed maximum (1). Evidence of successful reproduction of gray bats was reported for a maternity colony in Jessamine County, Kentucky (5), and has since been observed for colonies at 10 other sites in Kentucky (J. MacGregor, pers. commun.).

Several environmental stressors have been described for gray bats (6), with chemical pollution from pesticides well documented (7, 8, 9, 10, 11). Tuttle (6) expressed the need for additional studies on other sources of chemical pollution and their occurrence in gray bat foraging areas. In this paper, I present data that demonstrates exposure of gray bats to possible contamination from metals.

DISCUSSION

Jessamine County, Kentucky, contains 3 caves historically known to contain gray bat summer colonies (1); 2 of these caves are located in Jessamine Creek Gorge, with an active gray bat maternity colony present in one cave (5). The author made 2 trips to this cave in 1993 to obtain samples of guano from gray bats. On 24 March, I stacked flat rocks beneath anticipated roosting locations to ensure that subsequent collection would provide guano of recent origin. Stacks of rock also prevented loss of guano due to a shallow stream on the cave floor. Two male gray bats were present in the cave on this visit.

On 17 June, I counted the number of adult female gray bats emerging from the cave using night vision equipment, illuminating the entrance with 4 Wheat lamps covered with Wratten (#87) filters. Two night vision scopes were required to view the entire entrance to the cave. I entered the cave following completion of the emergence of adult females and collected 2 guano samples, 1 each from beneath separate clusters of young. I placed guano into soil tins lined with aluminum foil and refrigerated the samples later that same evening. I estimated the number of young by measuring ceiling cluster dimensions. A handful (approx. 5–6) of dead young were observed on the cave floor.

Guano samples were dried at 104°C for 72 hours. A 0.1 g subsample was digested in nitric acid, filtered, and raised to 100 ml with distilled water. Total copper (Cu), iron (Fe), zinc (Zn), nickel (Ni), cadmium (Cd), manganese (Mn), and silver (Ag) was measured with a flame atomic absorption spectrophotometer. Total lead (Pb), arsenic (As), and selenium (Se) was measured with a furnace atomic absorption spectrophotometer. A second 0.1 g subsample was digested in permanganate/per-

TABLE 1. Concentrations of metals (mg/kg) in guano from a gray bat summer roost in Jessamine County, Kentucky, June 1993.

Metal	Front cluster	Back cluster
Ag	<5.5	<6.5
As	1.6	1.4
Cd	<5.5	<6.5
Cu	73.6	69.1
Fe	851.1	565.5
Hg	0.15	<0.1
Mn	66.3	84.7
Ni	<14	<16
Pb	3.6	2.7
Se	13.7	15.6
Zn	320.1	355.5

sulfate and sulfuric and nitric acids and processed on a co-vapor atomic absorption spectrophotometer for total mercury (Hg). All metals were measured in mg/kg.

I found all 11 metals present in the guano analyzed (Table 1). Little difference was observed between values for the guano from beneath the front or back cluster of young. In decreasing order, Fe, Zn, Mn, and Cu were present at the highest concentrations, with Hg occurring at trace levels. The number of adult female gray bats emerging from the cave on 17 June was 4,700. Two clusters of young were found inside the cave and I estimated the number of young at 1,800 and 1,400 bats for the front and rear cluster, respectively. This yielded a colony size of 7,900 bats, larger than an estimate of 4,050 obtained in 1990 (J. MacGregor, pers. commun.).

Metal concentrations in gray bat guano demonstrated that some metals were present at high levels, indicating possible pollution sources within the foraging radius of the maternity colony. Concentrations of Fe and Zn in the guano of gray bats exceeded concentrations for these metals in tissues of anurans (i.e., frogs) living in the vicinity of an acid mine seep (12). Iron concentrations in water ≥40 mg/liter have been shown to be lethal to tadpoles (13), but other studies have found no lethal effects on amphibians (14, 15, 16, 17). The biomagnification potential of Fe and Zn remain unknown (12).

It remains unclear how these metals were obtained, presumably by injestion, and whether these concentrations are detrimental to the health status of gray bats. The emergence count indicated that colony size had increased from 1990, but the present estimate was still well below the historic maximum population size of 44,300 bats (1). Further studies are warranted to determine where point sources of metal pollution exist within the foraging radius of this maternity colony and whether these metals biomagnify as they are passed along the food chain.

ACKNOWLEDGMENTS

Financial support for this study was provided through a grant from The Nature Conservancy's (TNC) Rodney Johnson Stewardship Endowment and a grant from Jessamine County. J. R. MacGregor, R. R. Currie, and B. R. Dalton offered helpful advice. This investigation (No. 94-8-10) is connected with a project of the Kentucky Agricultural Experiment Station and is published with the approval of the Director.

LITERATURE CITED

1. Rabinowitz, A. and M. D. Tuttle. 1980. Status of summer colonies of the endangered gray bat in Kentucky. J. Wildl. Manage. 44:955–960.

2. Brady, J., T. Kunz, M. D. Tuttle, and D. Wilson. 1982. Gray bat recovery plan. Fish and Wildl. Ref. Serv., Denver, Colorado.

3. Barbour, R. W. and W. H. Davis. 1969. Bats of America. Univ. Kentucky Press, Lexington.

4. Barbour, R. W. and W. H. Davis. 1974. Mammals of Kentucky. Univ. Kentucky Press, Lexington.

5. MacGregor, J. R. and A. G. Westerman. 1982. Observations on an active maternity site for the gray bat in Jessamine County, Kentucky. Trans. Ky. Acad. Sci. 43: 136–137.

6. Tuttle, M. D. 1979. Status, causes of decline, and management of endangered gray bats. J. Wildl. Manage. 43:1–17.

7. Clark, D. R., Jr., R. K. LaVal, and D. M. Swineford. 1978. Dieldrin-induced mortality in an endangered species, the gray bat (*Myotis grisescens*). Science 199:1357–1359.

8. Clark, D. R., Jr., F. M. Bagley, and W. W. Johnson. 1988. Northern Alabama colonies of the endangered grey bat *Myotis grisescens*: organochlorine contamination and mortality. Biol. Conserv. 43:213–225.

9. Clark, D. R., Jr., C. M. Bunck, E. Cromartie, and R. K. LaVal. 1983. Year and age effects on residues of dieldrin and heptachlor in dead gray bats, Franklin County, Missouri—1976, 1977, and 1978. Environ. Toxicol. and Chem. 2:387–393.

10. Clawson, R. L. 1991. Pesticide contamination of endangered gray bats and their prey in Boone, Franklin,

and Camden Counties, Missouri. Missouri Acad. Sci. Trans. 25:13–19.

11. Clawson, R. L. and D. R. Clark, Jr. 1989. Pesticide contamination of endangered gray bats and their food base in Boone County, Missouri, 1982. Bull. Environ. Contam. Toxicol. 42:431–437.

12. Lacki, M. J., J. W. Hummer, and H. J. Webster. 1992. Mine-drainage treatment wetland as habitat for herpetofaunal wildlife. Environ. Manage. 16:513–520.

13. Porter, K. R. and D. E. Hakanson. 1976. Toxicity of mine drainage to embryonic and larval boreal toads (Bufonidae: *Bufo boreas*). Copeia 1976:327–331.

14. Cooke, A. S. and J. F. D. Frazer. 1976. Characteristics of newt breeding sites. J. Zool. 178:223–236.

15. Beebee, T. J. C. and J. R. Griffin. 1977. A preliminary investigation into natterjack toad (*Bufo calamita*) breeding site characteristics in Britain. J. Zool. (London) 181:341–350.

16. Albers, P. H. and R. M. Prouty. 1987. Survival of spotted salamander eggs in temporary woodland ponds of coastal Maryland. Environ. Pollut. 46:45–61.

17. Freda, J., V. Cavdek, and D. G. McDonald. 1990. Role of organic complexation in the toxicity of aluminum to *Rana pipiens* embryos and *Bufo americanus* tadpoles. Can. J. Fish. Aquat. Sci. 47:217–224.

Trans. Ky. Acad. Sci., 55(3–4), 1994, 127–130

Overwintering Channel Catfish, *Ictalurus punctatus*, and Blue Catfish, *Ictalurus furcatus*, in Cages

LAURA GOODGAME-TIU, CAROL D. WEBSTER,[1] JAMES H. TIDWELL, AND EDDIE B. REED, JR.

Aquaculture Research Center, Kentucky State University,
Frankfort, Kentucky 40601

ABSTRACT

Channel catfish, *Ictalurus punctatus*, and blue catfish, *I. furcatus*, were overwintered in cages. Fish were fed (1% of body weight) every other day, when water temperatures were greater than 3°C. Fish of both species lost weight during the study. Weight loss in blue catfish (25.9%) was significantly ($P < 0.05$) greater than in channel catfish (8.5%). Percentage survival of channel catfish (97%) was significantly ($P < 0.05$) greater than survival of blue catfish (44%). The large differences in survival may be related to parasite-induced mortality in blue catfish. Channel catfish can be successfully overwintered in cages; however, blue catfish may be prone to high mortality and can lose up to 25% of their body weight.

INTRODUCTION

Channel catfish, *Ictalurus punctatus*, normally require 14–20 months to reach marketable size (450 g). Thus, fish must be overwintered during their first year of life (1, 2, 3). Channel catfish consume less food in winter than in summer months (1, 4). If water temperatures fall below 7°C, fish may not feed at all (2, 5). However, withholding food from fish when water temperature is above 7°C often results in weight loss (1, 2).

Blue catfish, *I. furcatus*, possess several attributes that may make them a desirable culture species in temperate regions of the United States. They have a higher dressing percentage than channel catfish (6), are easier to seine (7), and may have a lower optimum growing temperature than channel catfish (8). However, like channel catfish, they require overwintering during their first year of life in order to reach marketable size.

Cage culture offers some advantages over open pond culture in that it allows fish to be reared in ponds that would be difficult to harvest by seine, and permits easy observation of the condition and feeding habits of the fish (9). It would be advantageous to farmers who use cage-culture methods to be able to overwinter fish in cages. There is little information on rearing channel catfish, and no data on rearing blue catfish, in cages during the winter (4, 10). The purpose of this study was to compare growth and survival of channel catfish and blue catfish overwintered in cages.

MATERIALS AND METHODS

Channel catfish and blue catfish fingerlings were randomly stocked on 9 October 1992 into eight 1.25-m^3 floating cages moored over the deepest area (4 m) of a 1.0-hectare pond (mean depth, 2.0 m) on the Agricultural Research Farm, Kentucky State University, Frankfort, Kentucky. Cages were constructed by attaching 1-cm polyethylene mesh to a wooden frame. Cage lids were removable. To prevent loss of sinking feed, polyethylene net (2-mm mesh) was installed on the sides near the bottom (8 cm high) and covering the bottom of each cage. Cages were anchored to a floating dock and spaced at 2-m intervals.

Cages were stocked with either 300 channel catfish (average individual weight, 26.5 ± 1.9 g) or 300 blue catfish (average individual weight, 16.6 ± 0.4 g). Channel catfish were of the Red River strain and were obtained as eggs from the Delta Branch Experimental Station in Stoneville, Mississippi. The eggs were hatched at the Aquaculture Research Center, Kentucky State University, in late May 1992. The blue catfish were spawned from broodstock collected from the Kentucky River and hatched in late June 1992. The differences in stocking size may reflect the differences in hatching dates or early growth between the 2 species, but would be indicative of the size of fish available for overwintering. Fry of both species were stocked in ponds and fed a crum-

[1] To whom correspondence should be directed.

TABLE 1. Composition of an experimental diet fed to channel catfish and blue catfish overwintered in cages.

Menhaden fish meal (67%)	15.00
Soybean meal (44%)	25.00
Wheat flour	13.00
Meat and bone meal	8.00
Ground corn	28.75
Mineral mix[a]	0.10
Vitamin mix[b]	0.10
Choline	0.05
CMC[c]	5.00
Lignosulfonate	5.00
Chemical analysis	
% Moisture	11.20
% Protein[d]	33.70
% Fat[d]	6.50

[a] Mineral mix contained: Mn, 10.0% (as $MnSO_4$); Zn, 10.0% (as $ZnSO_4$); Fe, 7.0% (as $FeSO_4$); Cu, 0.7% (as $CuSO_4$); I, 0.24% (as $CaIO_3$); Co, 0.10% (as $CoSO_4$).

[b] Vitamin mix contained: thiamin (B_1), 1.01%; riboflavin (B_2), 1.32%; pyridoxine (B_6), 0.9%; nicotinic acid, 8.82%; folic acid, 0.22%; cyanocobalamine (B_{12}), 0.001%; pantothenic acid, 3.53%; menadione (K), 0.2%; ascorbic acid (C), 22.1%; retinolpalmitate (A), 4,409 IU/kg; cholecalciferol (D_3), 2,204,600 IU/kg; alpha tocopherol (E), 66.2 IU/kg; ethoxyquin, 0.66%.

[c] CMC = carboxymethylcellulose.

[d] Dry-matter basis.

bled high-protein trout diet (Purina, St. Louis, Missouri) until stocked into cages.

During the present study, fish were fed (ration of 1% body weight) every other day, when temperatures were greater than 3°C. The amount fed was adjusted every 4 weeks, based on an estimated 3:1 feed conversion ratio (2). All fish were offered food more often than would be recommended for channel catfish (2) due to the lack of growth data for blue catfish during winter and so that feed would not be a limiting factor during the study. The study lasted for 182 d, of which fish could possibly be fed 91 d. During the study, fish were fed 60 days and not fed 31 d due to low temperatures. Fish were fed a diet formulated to contain 32% protein (Table 1). Dietary ingredients were processed into 5-mm sinking pellets by a commercial feed mill (Farmers Feed Mill, Lexington, Kentucky). Dietary protein level was determined using macro-Kjeldahl, dietary fat by acid hydrolysis, and moisture by drying to constant weight in a convection oven at 100°C (11).

Temperature and dissolved oxygen were monitored twice daily (0800 and 1630 hr) outside the cages at a depth of 0.75 m with a YSI model 57 oxygen meter (Yellow Springs Instrument Co., Yellow Springs, Ohio). Dissolved oxygen did not decline below 6.0 mg/liter during the study and no aeration was required. Total ammonia nitrogen, phosphorus, nitrite and nitrate were measured once per week with a DR 700 Colorimeter (Hach Co., Loveland, Colorado), and pH was measured weekly using an Accumet 900 pH meter (Fisher Scientific, Cincinnati, Ohio).

Fish were harvested on 9 April 1993 and were not fed for 24 hr prior to harvest. Total number and weight of fish in each cage were determined at harvest. Twenty five fish were randomly sampled from each cage and individually weighed (g) and measured (total length, cm). Ten fish from each cage were homogenized separately in a blender and analyzed for protein, fat, and moisture. Protein was determined using macro-Kjeldahl, fat was determined using ether extraction, and moisture was determined by drying a 10 g sample in a convection oven (100°C) until constant weight (11).

Data (percentage weight gain and survival) were analyzed using the SAS *t* Test procedure (12) for significant differences between channel catfish and blue catfish. All percentages and ratio data were transformed to arc sine values before analysis (13).

RESULTS AND DISCUSSION

Water quality characters for the duration of the study averaged (±SD): morning water temperature, 6.1 ± 3.8°C; afternoon water temperature, 6.3 ± 4.0°C; morning dissolved oxygen, 11.9 ± 2.5 mg/liter; afternoon dissolved oxygen measured 12.3 ± 2.2 mg/liter; total ammonia nitrogen, 0.34 ± 0.05 mg/liter; phosphorus, 5.15 ± 6.53 mg/liter; nitrite, 0.00 ± 0.00 mg/liter; nitrate, 0.14 ± 0.08 mg/liter; pH, 8.02 ± 0.44. All water quality characters were within accepted values for growth (14).

Fish of both species lost weight during the study. Weight loss in blue catfish (25.9%) was significantly ($P < 0.05$) greater than in channel catfish (8.5%) (Table 2). Since fish lost weight during the study, it was not possible to calculate specific growth rates (SGR) and feed conversion ratios (FCR) for channel catfish or blue catfish. Percentage survival of channel catfish (97%) was significantly ($P < 0.05$) greater than survival of blue catfish (44%).

All fish species are poikilotherms and are thus profoundly affected by water temperature. Channel catfish have a reduced metabolic activity and, consequently, reduced food consumption during colder water temperatures. The weight loss of the fed channel catfish reported in the present study is similar to values reported in Lovell and Sirikul (1), 9%, and Robinette et al. (2), 3–8%, for weight loss of non-fed channel catfish overwintered in ponds. This would indicate that the channel catfish in the present study did not consume much food during the study. Burtle and Newton (10) stated that cooler water temperatures contributed to weight loss of channel catfish when reared in cages compared to warmer water temperatures. The water temperatures reported in the present study averaged 6.22°C. This is colder than temperatures reported in studies conducted in more southerly states (1, 2, 10) and most likely contributed to the greater weight loss of our fed fish.

Conflicting results have been reported regarding the growth of blue catfish. Huner and Dupree (10) suggested that blue catfish may be inferior to the channel catfish as a cultured species due to slower growth at sizes less than 1 lb. In contrast, it has been stated that blue catfish may have a lower optimum-growth temperature than channel catfish (8), and thus perform better in cooler climates. Results of the present study indicate that cage-reared blue catfish do not have higher weight gains than channel catfish during winter. This is in agreement with Grant and Robinette (15), who reported that growth of channel catfish was greater than that for blue catfish during the winter when reared in ponds.

The survival of channel catfish in cages was comparable to the survival of channel catfish overwintered in ponds (1, 3, 15). In April, all blue catfish were infested with an external fungus and with *Trichodina* sp.. Channel catfish showed no sign of either parasite. The parasite infestation is suspected of being responsible for the majority of deaths of blue catfish and thus, lower survival percentage compared to channel catfish. Parasite-induced mortality of cage-reared blue catfish during winter may preclude farmers from attempting this culture practice.

Whole body analysis indicated that blue catfish had significantly ($P < 0.05$) higher percentages of moisture (77%) and fat (29%) compared to channel catfish (75 and 21%, respectively); however, percentage protein was not significantly different between species ($P > 0.05$) (Table 2). Lovell and Sirikul (1) reported that non-fed fish had more body fat than fish fed during the winter, indicating that protein was degraded for energy needs. Grant and Robinette (15) reported no difference in percentage protein between the 2 species when overwintered in ponds.

TABLE 2. Growth and body composition of blue and channel catfish overwintered in cages. Means in rows having different letters are significantly different ($P < 0.05$). Percentage protein and fat are expressed on a dry-matter basis.

	Blue	Channel
Initial stocking size (g)	16.6 ± 0.4	26.5 ± 1.9
Harvest weight (g)	12.6 ± 0.46	24.0 ± 0.94
Harvest length (cm)	12.4 ± 0.06	14.5 ± 0.18
Weight gain (%)	−25.9 ± 1.19a	−8.5 ± 0.55b
Survival (%)	43.9 ± 12.62a	97.2 ± 2.19b
Body composition		
Moisture (%)	77.4 ± 0.30a	74.9 ± 0.42b
Protein (%)	59.3 ± 1.37a	57.4 ± 1.29a
Fat (%)	28.6 ± 0.33a	21.4 ± 0.96b

This study indicates that first-year channel catfish can be successfully overwintered in cages with a high percentage of survival and minimal weight loss. However, first-year blue catfish may be prone to high parasite-induced mortality when reared in cages during winter and can lose up to 25% of their body weight. Further research which examines winter feeding regimes for cage-reared channel catfish should be conducted.

ACKNOWLEDGMENTS

We thank Keenan Bishop, Jackie Lamb, Hank Schweickart, Mac Stone, and Louis Weber for their technical assistance, and Karla Richardson for typing this manuscript. This research was partially funded by a USDA/CSRS grant to Kentucky State University under agreement KYX-80-92-05A.

LITERATURE CITED

1. Lovell, R. T. and B. Sirikul. 1974. Winter feeding of channel catfish. Proc. Southeast. Assoc. Game and Fish Comm. 28:208–216.

2. Robinette, H. R., R. L. Busch, S. H. Newton, C. J. Heskins, S. Davis, and R. R. Stickney. 1982. Winter feeding of channel catfish in Mississippi, Arkansas, and Texas. Proc. Southeast. Assoc. Fish and Wildlife Agencies 36: 162–171.

3. Mims, S. D. and J. H. Tidwell. 1989. Winter feeding of fingerling channel catfish in Kentucky. Trans. Kentucky Acad. Sci. 50:174–176.

4. Huner, J. V. and H. K. Dupree. 1984. Nutrition, feeds, and feeding practices. Pp. 141–157. In H. K. Dupree and J. V. Huner (eds.) Third report to the fish farmers. U.S. Fish and Wildl. Ser., Washington, D.C.

5. Webster, C. D., J. H. Tidwell, L. S. Goodgame, J. A. Clark, and D. H. Yancey. 1992. Winter feeding and growth of channel catfish fed diets containing varying percentages of distillers grains with solubles as a total replacement of fish meal. J. Appl. Aquacul. 1:1–14.

6. Dunham, R. A., M. Benchakan, R. O. Smitherman, and J. A. Chappell. 1983. Correlations among morphometric traits of fingerling catfishes and the relationship to dressing percentage at harvest. J. World Maricul. Soc. 14: 668–675.

7. Chappel, J. A. 1979. An evaluation of twelve genetic groups of catfish for suitability in commercial production. Unpublished Ph.D. Dissertation. Auburn University, Auburn, Alabama.

8. Tidwell, J. H. and S. D. Mims. 1990. A comparison of second-year growth of blue catfish and channel catfish in Kentucky. Prog. Fish-Cul. 52:203–204.

9. Schmittou, H. R. 1970. The culture of channel catfish, *Ictalurus punctatus,* in cages suspended in ponds. Proc. Ann. Con. Southeast. Assoc. Game and Fish Comm. 23(1969):226–244.

10. Burtle, G. J. and G. L. Newton. 1993. Winter Feeding Frequency for Channel Catfish in Cages. Prog. Fish-Cult. 55:137–139.

11. AOAC. 1990. Official methods of analysis of the Association of Association of Official Analytical Chemists, Inc., Arlington, Virginia.

12. Statistical Analysis System. 1988. SAS/STAT user's guide. Release 6.03 Edition. SAS Institute, Inc., Cary, North Carolina.

13. Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

14. Boyd, C. E. 1979. Water quality in warmwater fish ponds. Alabama Agricultural Experiment Station, Auburn University.

15. Grant, J. C. and H. R. Robinette. 1992. Commercially important traits of blue and channel catfish as related to second summer, winter, and third summer growth. Aquacult. 105:37–45.

Trans. Ky. Acad. Sci., 55(3–4), 1994, 131–138

Regional Temperature Trends and Variations in the Contiguous United States from 1935 to 1986

L. Michael Trapasso

Department of Geography and Geology, Western Kentucky University, Bowling Green, Kentucky 42101

and

Fahad M. Al Kolibi

Department of Geography, University of Nebraska, Lincoln, Nebraska 68588

Abstract

The temperature trends and variations from 1935 to 1986 were investigated for the contiguous United States as a whole, and for 10 designated regions. A total of 263 stations from the Historical Climate Network (HCN) were utilized. Data from the contiguous United States revealed that annual, summer, and winter temperatures were free of significant positive or negative trends. Nine of the 10 regions displayed negative temperature trends; however, with 2 exceptions, all were statistically insignificant. A reversal of the annual temperature variations between eastern and western regions was also found.

Introduction

A number of atmospheric scientists have de-emphasized the theory of climatic warming by an augmented "greenhouse effect" (1, 2) or have refuted the theory altogether in recent years (3, 4). Yet, arguments of climatic change persist. One argument concerns the existence of proof that a warming has begun (5, 6, 7). Supplying such proof involves a close examination of temperature trends on a variety of spatial and temporal scales. Research concerning temperature trends on global, hemispheric, and continental scales date back for decades and are far too numerous to cite. However, a selected amount of background literature concerning the continental United States is presented below.

Kalnicky (8) in his study about the temperature trends in the contiguous United States, showed that most of the U.S. experienced warming during the years 1931–1960 and cooling in the 1960–1970s. The eastern United States averaged at least 0.5°C cooler from the base period (1931–1960) (8). Only portions of the northwest and west had higher mean temperatures from 1961 to 1970 than in 1931–1960. Summer and winter temperature deviations were similar to annual temperature deviations.

The variability of temperatures in the United States was also examined by Chico and Sellers (9). They studied the variability of the mean monthly temperature in the United States from 1896 through the 1970s and concluded that there was an increase in the interannual variability from 1900 into the 1930s, and this variability decreased from 1930 to 1970. The peak of the interannual variability is found in the decade of the 1930s, and this temporal trend is explained by changes in the variability of winter mean monthly temperature.

Extensive spatial and temporal research was completed concerning the changes in the climate of the contiguous United States from 1958–1977 (10). Three periods were identified when temperature variation patterns followed an east-west mode, and that from 1958 to 1977 the average temperature decreased 0.5°C from the relatively warm interval of the 1920s to the middle 1950s (10). They also found that cooling was greatest in the eastern United States, while the west had warmer mean temperatures of about 0.3°C during this time.

In another approach to the temperature-trend pattern in the continental United States, attempts (11) were made to identify 10 to 20 year temperature and precipitation fluctuations. These authors investigated the temper-

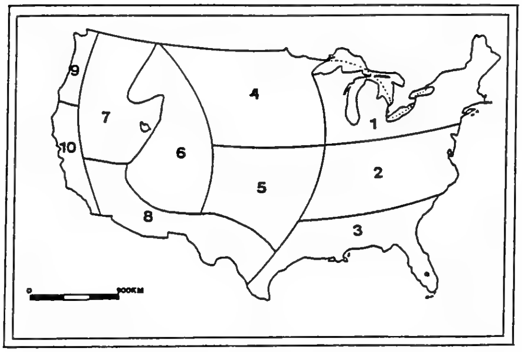


FIG. 1. The ten regions defined by this research.

atures from 1931 to 1982, and attempted to find regions and periods of time in which the climatic characteristics had undergone a clear transition to different climatic characteristics. They identified the largest 10 to 20 year temperature fluctuation across the contiguous United States. Their results showed that over the half century (from 1931–1982) the most important widespread temperature of 10 to 20 year durations, in terms of standardized departure, had been associated with a temperature change of 2°C or more during the years with summer as the greatest fluctuation.

One characteristic of the variability of temperature is having unusual heating, or cooling seasons. A study by Karl et al. (12) concerning temperatures found that the winters of 1975–1983 were unusual and unprecedented in the period from the 1890s to 1983. By "unusual" the authors meant unusually cold or unusually warm. They concluded that an uncharacteristic spell of abnormal winters in the United States occurred from 1975–1976 through 1982–1983, as defined by naturally areal averaged temperatures. Nationally, 6 of 8 winters during this period were either abnormally warm or cold ($z \geq 1.253$) where z is the normalized departure from the long-term mean.

Skeeter et al. (13) found that there is no evidence of any temporal trends in intermonthly temperature variability in the continental United States from 1951 to 1980. However, they also found that the intra-monthly temperature variability was greatest during the winter and least during the summer.

From the cited literature, the temperature trends in the Northern Hemisphere can be summarized as follows: from 1890 to the 1940s there was a positive trend of about 0.6°C (8, 14). Other writers suggested positive figures close to this number. From the middle 1940s until the late 1960s, there was a pronounced decrease in temperature, but his decrease was interrupted by a small rise in 1960 of about 0.03°C. From the late 1960s through 1970s there was a relatively steady situation with respect to temperature trends. From the mid-1970s into the 1980s there was another increase in temperature, but also with a pronounced spatial and temporal variability in the Northern Hemisphere. This variability was correlated to teleconnection of upper atmospheric circulation, and the occurrences of El Niño and La Niña in association with the Southern Oscillation. Others correlate this variability to long and short-term sunspot cycles, and their associated variation of the density of solar radiation.

Karl et al. (15) detected changes in the recent century, but the changes have not been monotonic. Changes tended to be unsteady and of a relatively short period. At best, a decrease in diurnal temperature range seemed to be evident.

The basic pattern of the temperature trends in the United States is relatively different from that of the Northern Hemisphere as a whole. In general, the pattern of the western part of the United States exhibits a trend opposite of that of the Northern Hemisphere, but the eastern United States display relatively similar trends.

In general, the literature concerning temperature trends and characteristics of the contiguous United States, at best, leaves the reader somewhat confused. No one clear-cut conclusion can be drawn. In essence, numerous conclusions can be drawn depending upon what characteristic of temperature is of concern, what sub-periods are observed, and what methodology is used.

The purpose of this study is to analyze 50 years of reliable climate data from the 48 contiguous states and ascertain any and all temperature trends and variations that exist. Since previous research has shown that various geographical regions of the country behave differently with respect to temperatures through time, the continental U.S. is divided into 10 roughly homogeneous regions (Fig. 1). These regions are analyzed separately and compared

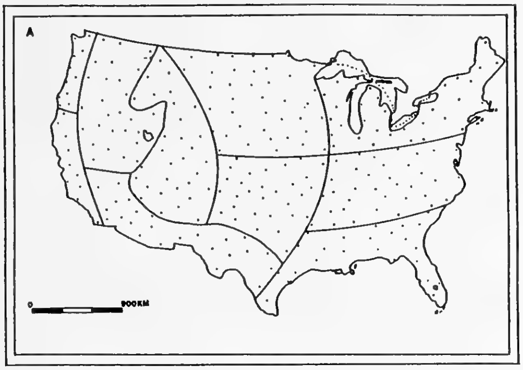


FIG. 2A. The locations of the 263 HCN stations used to analyze the contiguous United States as a whole.

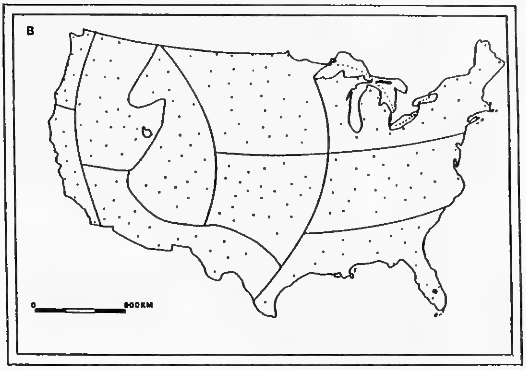


FIG. 2B. Locations of the HCN stations used to analyze the ten regions. With border stations dropped, a total of 205 stations were used.

with the U.S. as a whole. Finally, spatial variations of temperature trends are also investigated.

MATERIALS AND METHODS

Research concerning temperature trends can encounter problems with non-climatic factors that may bias the data. Factors such as urbanization, station relocation, personnel changes, time of observation and instrument changes could affect studies of this type. For this reason only U.S. Historical Climate Network (HCN) stations were used. The HCN is a network of 1,219 long-term stations with records that have been corrected to the extent possible for a number of biases and nonclimatic discontinuities. The authors, concerned with the urbanization bias, took an extra precaution, whereby more than 93% of stations used in this study had urban populations of 5,000 or less according to the 1980 U.S. Census. All together, 263 stations were used when dealing with the contiguous states as a whole. When examining the 10 regions, after border stations were dropped, 205 stations remained in the analysis (Figs. 2A and B, Table 1).

The time period chosen was from 1935 to 1986 or approximately the last 50 years. Though arbitrary, this time period suits the purpose quite well. First of all, 5 decades should be enough time to show at least the beginnings of a temperature trend. Furthermore, the historical time frame seems logical as well. The mid-thirties found the U.S. in the middle of the Great Economic Depression. Industrial growth was at best slow or nonex-

TABLE 1. Data concerning the number of stations utilized in this study.

Region #	Number of Stations per unit Area~ 1:20,000km^2	Border Stations (Dropped)	Stations Studied
1	32	8	24
2	35	9	26
3	23	5	18
4	40	9	31
5	29	7	22
6	31	7	24
7	27	5	22
8	24	6	18
9	11	1	10
10	11	1	10
	Total Stations representing the contiguous U.S. as Whole 263	Total Stations dropped when dealing with the ten regions 58	Total Stations representing the ten regions 205

istent. During the forties, World War II brought about great industrial growth and development. The post-war years saw the United States emerge as an industrial super power. The mid-eighties to the present has seen an economic and industrial slowdown in the U.S. It is reasonable to assume that an increasing temperature trend may be detectable with the increasing industrial activity from 1935–1986.

DEFINING THE REGIONS

For the purpose of this research, the contiguous United States was divided into certain climatic regions. An important concern was how these divisions could be made. Realizing that there are limitations to the homogeneity of these divisions, such as the Great Lakes, the Rocky Mountains and so on, we looked at previous climatic classification schemes. Though there are many climatic classification systems, there is no one standard classification which could divide the country into clear cut areas, each having its own climatic homogeneity. Using the 1968 Trewartha classification (16) emphasized temperature factors. We found that this classification, with little adjustment, rather appropriate for the purposes of this study. Figure 1 shows the division as established by the authors, while Figures 2A and 2B show the distributions of the stations utilized in this study.

Regions are listed and named as follows:

1. Northeastern Region
2. Central Eastern Region
3. Southeastern Region
4. Northern Plains Region
5. Southern Plains Region
6. Mountain Region
7. Basin Region
8. Desert Region
9. Northwestern Region
10. Southwestern Coastal Region

STATION SELECTION

Karl et al. (17) explain the method by which the Historical Climate Network (HCN) data for the United States are corrected for the nonclimatic factors. Even though these corrections are based on assumptions which may have some shortcomings, the HCN data are still considered to be highly dependable. Only HCN stations were used in this study.

METHOD OF SELECTING THE STATIONS

The distribution of stations within each region was kept as equal as possible. To do so, a grid method of selection (13) was attempted; however, applying this method tended to assign regions rather unequal numbers of stations. Thus the grid method was dropped. To assign a sufficient number of stations representing each region in proportion to its area, the following selection process was used: 1. Each region was assigned a minimum of ten stations. 2. The ratio of the number of stations in each region to the approximate area of that region was constant for all the regions. This ratio was one station to each 20,000 km. At times one, or at most two, stations were added to some regions to obtain fair representation. 3. The stations in each region were, as much as possible, equally distributed throughout the region. 4. More than 93% of the total stations selected has an urban population of 5,000 or less, according to the 1980 Census.

RESULTS

After computing monthly means from 1935 to 1986 all data were graphed and variations were observed. Then the annual, winter, and summer trends for the contiguous United States and each of the ten regions were calculated. The summer mean for each year was defined as the average of June, July and August data, while the winter mean was defined as the average of December, January, and February data. Annual means included all 12 months. Linear regression analysis was run for all data sets. Statistical tables and regression analysis graphs were produced to depict the findings.

THE CONTIGUOUS UNITED STATES ANALYZED AS A WHOLE

The mean annual temperature exhibited a slight positive trend for the 48 contiguous United States through time. This, despite the fact that both summer and winter trends were slightly negative. None of the trends are statistically significant (See Table 2). Figure 3A clearly demonstrates the great amount of interannual variability in the data, especially during the winter season, and is in agreement with Karl et al. (11) (Fig. 3B).

Table 2. Statistics concerning the 48 contiguous United States taken as a whole.

Season	Regression Line Slope	Correlation Coefficient	T-test Significance Level	Standard Deviation
Summer	-0.006	-0.13	0.35	0.72
Winter	-0.002	-0.02	0.88	1.74
Annual	+0.002	+0.06	0.68	0.60

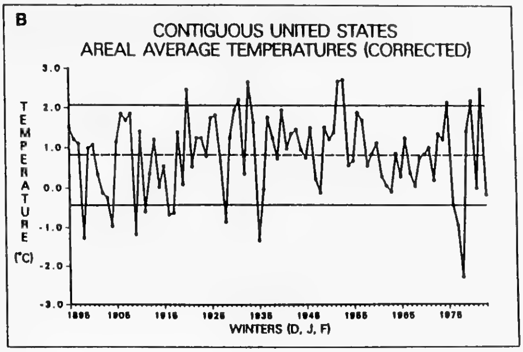


Fig. 3B. Interannual variability in winter temperatures as displayed by Karl et al., 1984.

Summer Temperature Trends and Variations of the Ten Regions

Summer temperatures were free of all statistically significant trends except Region 2, Central Eastern Region (Fig. 4) which displays a negative trend, and a *t* test value 0.012. Significance was defined by the $\alpha = 0.05$ level.

The Central Eastern Region summer variations show one period above the mean, 1935 to 1944, reaching its peak in 1936 recording the highest summer temperature for this region. From 1944 to 1950 and from 1951 to 1954 are 2 consecutive short periods recording below and above the mean variations, respectively. From 1961 to 1976 represents a period of strong negative deviation, where no single year was above the mean temperature. Moreover, the lowest 3 temperatures recorded were during this period. From 1977 to 1986 a period of even fluctuation occurred about the mean line. The standard deviation is 0.8°C and range is 3.2°C.

Winter Temperature Trends and Variations for the Ten Regions

Winter temperatures also lack statistically significant trends except for Region 3, the Southeast Region (Fig. 5) which also displays a negative trend with a *t* test = 0.027.

The Southeastern Region had 2 long alternating periods of above and below the mean deviations and each one was interrupted by a short trend reversal. The period 1936–1956 was a strong deviation above the mean trend line reaching its peak in 1949 with 14.7°C; this was the warmest winter for this reason. This period was interrupted by a brief, weak negative subperiod from 1970–1974. This long period of negative deviation contained the coldest winter for this region, 1977, which recorded 8.3°C, a deviation from the mean of about 2.4°C.

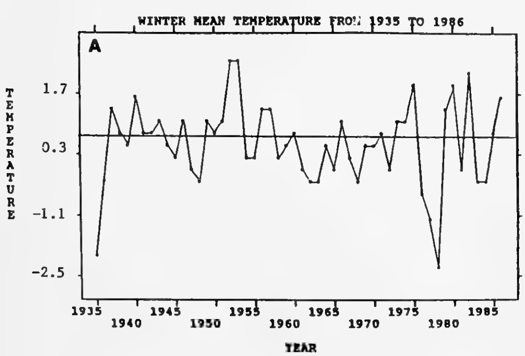


Fig. 3A. Winter mean temperatures for the contiguous United States, showing strong interannual variability.

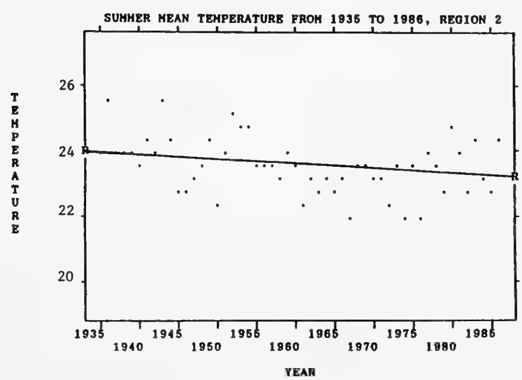


Fig. 4. The Central Eastern Region.

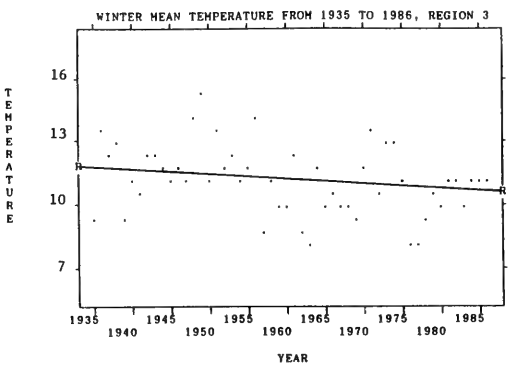


FIG. 5. The Southeastern Region.

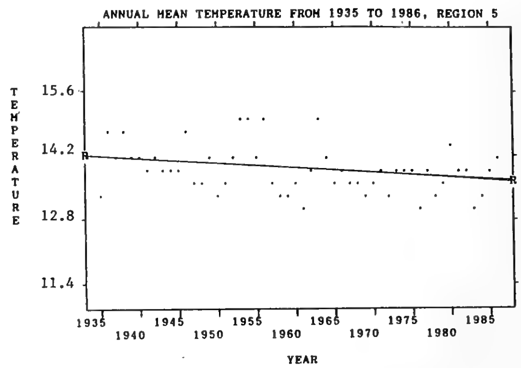


FIG. 7. The Southern Plains Region.

ANNUAL TEMPERATURE TRENDS AND VARIATIONS FOR THE TEN REGIONS

Annual temperature trends were statistically insignificant except for Regions 2 and 5, the Central Eastern and the Southern Plains Regions, respectively. Both Figures 6 and 7, display negative trends. Both data sets yielded an $\alpha = 0.02$.

The Central Eastern Region showed two weak trends above the mean. The periods 1941 to 1946 and 1976 to 1984 are periods of negative deviation reaching the lowest temperature for this region in 1976 which was 1.9°C below the mean. Between these 2 negative periods there is a short period of positive temperatures between 1970–1975.

The Southern Plains Region, 5, contained the following variations (Fig. 7). From the late 1930s to the mid 1940s, annual mean temperatures were either below or right at the mean. The late 1940s through the mid 1960s exhibit the greatest variations in these data, with the greatest extremes. The mid 1960s through to 1980 again shows a period of below the mean to near mean temperature. The last few years show a considerable variation.

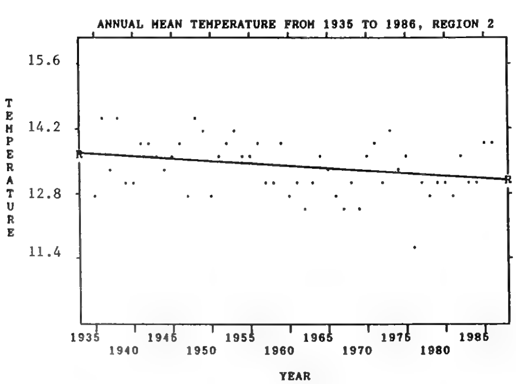


FIG. 6. The Central Eastern Region.

DISCUSSION

TEMPORAL PATTERNS

When comparing this research with the work of others, some interesting similarities and differences are discovered. In general, these previous works are supportive of our findings. However, our study goes one step further by selecting only stations that exhibit little urban growth (i.e., stations surrounded by populations of 5,000 or less). Both our work and that of Karl (15) graph and analyze the data on a regional scale, though the regional boundaries differ. Unlike the work of Karl (15), the analytical techniques differ. Instead of standardizing the data and looking at deviations from the norm, we fit a regression to the data. Here both research projects converge on the same sort of conclusions. Where Karl (15) noted that positive and negative deviations exist through time, our work exhibits a majority of trends that are not statistically significant. These 2 sets of results are derived from the same data characteristic; that is, great variability through time.

The work of Balling and Idso (1) again offers some interesting similarities and differences. We shared the concern of these authors concerning the urbanization bias thus the selection of rather small community stations aids our work in both reliability and accuracy. The majority of the work by Balling and Idso (1)

TABLE 3. Time line from 1935 to 1986 compares highest positive and negative deviations among the ten regions. W = Western group and E = Eastern group.

+	Region #	10	2	7	2	7	7	4	2	4	9	3	1	4	3	1	8	3	1	1	5	1	5	9	9	1	7
+	Group	W	E	W	E	W	W	W	E	W	W	E	E	W	E	E	W	E	E	E	E	E	E	W	W	E	W
YEAR		1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
-	Group	W	W	E	W	E	E	W	W	E	W	W	W	E	W	W	W	W	E	W	W	W	W	E	E	W	E
-	Region #	4	6	3	8	3	1	8	4	1	8	4	9	2	7	9	4	4	3	10	6	9	9	3	1	10	2

+	Region #	8	8	4	5	9	6	7	1	7	2	2	3	2	3	4	10	7	3	7	4	6	4	10	10	3	4
+	Group	W	W	W	E	W	W	W	E	W	E	E	E	E	E	W	W	W	E	W	W	W	W	W	W	E	W
YEAR		1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
-	Group	E	E	E	W	W	E	E	W	E	W	W	E	W	W	W	E	E	W	E	E	E	W	E	W	W	W
-	Region #	5	1	1	4	4	3	2	6	2	9	10	1	6	10	6	2	2	4	2	1	2	8	5	7	9	8

addresses the vital issue of regressing urban growth with temperature changes through time. Here again, our research involved the regression analysis of actual mean temperatures through time, an aspect missing in this and other recent works of this type. These authors further describe a reversal in the temperature trends that occurs between the eastern and western contiguous United States. The negative deviations shown in the southeastern states are also found in our analysis which discovered significant negative trends in our Southeastern and Central Eastern Regions. Our work also suggests the reversal of trends found on either side of the continental U.S. The following section further describes these findings in more detail.

SPATIAL PATTERNS

Due to the meandering pattern of the Upper Air Westerlies, the highest temperature deviation patterns tend to reverse when comparing western regions to eastern regions. The highest positive deviation in eastern regions (i.e., Regions 1–5), indicating a ridge in the jet stream to the east, was mostly (80% of the time) accompanied by the highest negative deviation in a western region (i.e., Regions 6–10). This would indicate a jet stream trough in the west. The reversal of troughs and ridges in the Polar Front Jet essentially assures that the contiguous United States will not likely display uniform temperature deviations throughout. As demonstrated in this research, the ten regions react differently at different times. The time line depicted in Table 3 shows the extent to which this reversal exists.

SUMMARY AND CONCLUSIONS

A number of basic conclusions can be drawn from this research. The first is the complexity of the temperature swings. The authors acknowledge the somewhat tedious reading involved with the data analysis section of this research. With all the periods of trends, subperiods of trends, variations in the trends and exceptions to the variations, the reader is left somewhat confused. Herein lies the first conclusion, that temperature trends in the United States or any subregion are at best, a very complex and changeable phenomenon (see Figs. 3A and 3B).

Another conclusion is drawn when fitting trend lines to the regional data. The trends are statistically insignificant or negative. In a few regions, a significant regional cooling through time was found. Of the temperature trends for the contiguous United States as a whole, the summer and winter temperature trends were negative, while the annual temperature trend was positive—none were significant.

Lastly, in a spatial context a reversal of greatest negative and positive deviations from the eastern regions to the western regions was detected. This makes finding general temperature trends applicable for the entire areal extent of the contiguous United States virtually impossible.

This research, as well as the work of others, clearly demonstrates that the great variability of temperature changes in the contiguous United States prohibits the discovery of a coherent and significant trend through time (i.e., a Greenhouse Effect). The authors recommend that research of this type be ongoing, or at the very least, periodically updated. To state at this time there is no proof of a continental warming is accurate. However, to extrapolate these findings to suggest that there will be no proof of warming trends in the future is premature. Only with more data and updated analysis can the initiation of a coherent and significant trend, if one exists, be found.

LITERATURE CITED

1. Balling, R. C., Jr. and S. B. Idso. 1989. Historical temperature trends in the United States and the effect of urban population growth. J. Geophys. Res. 94:3359–3363.

2. Michaels, P. J. 1991. Global warming and coal: the new synthesis. J. Coal Quality 10:1–11.

3. Bryson, R. A. 1989. Will there be a global greenhouse warming? Environ. Cons. 13:97–99.

4. Lindzen, R. S. 1990. Some coolness concerning global warming. Bull. Amer. Meteorol. Soc. 71:288–299.

5. Kerr, R. A. 1988. Is the greenhouse here? Science 239:559–561.

6. Monastersky, R. 1989. Looking for Mr. Greenhouse. Science New 135:216–221.

7. Abelson, P. H. 1989. Uncertainties about global warming. Science 247:1529–1530.

8. Kalnicky, A. R. 1974. Climatic changes since 1950. Ann. Assoc. Amer. Geogr. 64:100–112.

9. Chico, T. and W. D. Sellers. 1979. Interannual temperature variability in the United States since 1896. Climate Change 2:139–147.

10. Diaz, H. F. and R. G. Quayle. 1980. The climate of the United States since 1895: spatial and temporal changes. Mon. Weather Rev. 108:249–266.

11. Karl, T. R. and W. W. Riebsome. 1984. The identification of 10 to 20 year temperature and precipitation fluctuations in the contiguous United States. J. Climate Appl. Meteorol. 23:950–966.

12. Karl, T. R, et al. 1984. Recent unusual mean winter temperatures across the contiguous United States. Bull. Amer. Meteorol. Soc. 65:1302–1309.

13. Skeeter, B. R., et al. 1988. A climatology of intramonthly temperature variability in the contiguous United States 1951–1980. Phys. Geog. 9:99–119.

14. Reitan, C. H. 1974. A climatic model of solar radiation and temperature change. Quaternary Res. 4:25–38.

15. Karl, T. R., et al. 1989. Time series of regional season averages of maximum, minimum, and average temperature, and diurnal temperature range across the United States: 1901–1987. Historical Climatology Series 4-5, NOAA-NCDC, Asheville, North Carolina. 107 pp.

16. Lyndolph, P. E. 1985. The climate of the earth. Rowman and Allanheld, New York.

17. Karl, T. R., et al. 1988. Urbanization: its detection and effect in the United States climatic record. J. Climate 1:1099–1123.

Trans. Ky. Acad. Sci., 55(3–4), 1994, 139–141

NOTES

***Triatoma sanguisuga* Leconte (Hemiptera: Reduviidae) in Kentucky and West Virginia.**—The natural blood-feeding vector of *Trypanosoma cruzi* (Chagas) in the southeastern United States, *Triatoma sanguisuga* Leconte, has been reported from much wider areas of the nation than *T. cruzi*. According to Blatchly (Nature Pub. Co., 111 pp., 1926) and Usinger (Pub. Health Bull., 288: 83, 1944), *T. sanguisuga* may be found as far north as Maryland, New Jersey and Pennsylvania. Maryland is the only state north of Georgia and the Gulf Coast states in which *T. cruzi* has been found (raccoons) (Walton et al., Am. J. Trop. Med. Hyg. 7:603–610, 1958).

While at Marshall University (Huntington, West Virginia), in the spring and summer of 1965, many efforts were made by myself and several students to collect *T. sanguisuga*. Most of the attempts were made in Cabell and Wayne counties. No bugs or signs of the bugs were observed (Shoemaker, Proc. WV Acad. Sci. 38:15–17, 1966).

A personal correspondence from Richard C. Froeschner, Associate Curator in Charge, Division of Hemiptera, Department of Entomology, United States National Museum, Washington, D.C., stated the following: "Checking the USNM collection of *Triatoma* in response to your letter of May 27, 1965, found no specimens of the genus from West Virginia. Specimens from the adjacent sister states of Pennsylvania, Maryland, Virginia and Kentucky were noted; in other words, collectors should most certainly find it in your state."

Letters were also sent to the biology departments of all of the other colleges in West Virginia inquiring if they had *T. sanguisuga* in their collections. Of the 19 colleges, 5 answered, and 2, Concord College and West Virginia State College, stated that they did have *T. sanguisuga* in their collections. Concord College did not know where the bugs were collected, and West Virginia State College's bugs were collected locally (Nitro, West Virginia) (Shoemaker, loc. cit.).

About 28 years later, around 9:00 A.M., 18 July 1993, I decided to take a Sunday morning stroll in Ashland's Central Park. I had just begun walking around the park when I noticed an insect crawling rapidly across the sidewalk in front of me. I stopped for a closer look and immediately recognized it as an adult male *T. sanguisuga*. Instead of completing my walk, I went instead to Ashland Community College's microbilogy laboratory with the bug carefully wrapped in the cellophane of a cigarette pack. I gently pressed the abdomen of the bug, and forced fresh liquid fecal material out onto a glass slide. After careful microscopic examination of the material, I concluded that no trypanosomes were present.

During subsequent days I examined likely hiding places (hollow trees, animal nests) for the bugs in Central Park, but no more were found. However, I did contact Dr. Ricardo P. Bessin at the University of Kentucky, who informed me that he had several specimens of *T. sanguisuga* that had come from a house in Morgan County, amazingly, also during this past summer (1993). According to Bessin, the bugs had been biting the occupants of the house.

I spoke with Dr. Charles V. Covell and his graduate student, Barry Nicholls, at the University of Louisville Department of Zoology, and they did have 4 *Triatoma* sp. in their collection. Dr. Covell sent them to me for species identification. All of them are *T. sanguisuga* (1 female and 3 males): collected from Trigg Co. (Land Between the Lakes), Bullitt Co., Carter Co. (Carter Caves), and Jefferson Co. (Waverly Park, Louisville).

Dr. J. E. McPherson, Department of Zoology, Southern Illinois University, did not have *T. sanguisuga* in his collection from Kentucky, but did send me a distribution map of the species found in the state of Illinois. As one might expect, most of the bugs were from a 13 county area in the southern part of the state. However, 1 collection was from Henard County, which is near the state's center.

None of the bugs from the universities that I contacted had been examined for the presence of *Trypanosoma cruzi*. If *T. cruzi*, the causative agent of Chagas' disease, is found in *T. sanguisuga* or wild mammals in Kentucky, this potential public health hazard could become an intriguing topic of research.—**Jon P. Shoemaker,** Department of Biological Sciences, Ashland Community College (University of Kentucky), Ashland, Kentucky 41101.

New Localities for Rare or Infrequent Vascular Plants of Kentucky.—The following records provide new information on the distribution of rare or infrequent vascular plants of Kentucky. The majority of new sites are for aquatic and wetland species. The rarity status of these species in Kentucky is based on the recent revision of the Endangered, Threatened, and Special Concern Plants and Animals of Kentucky (Kentucky State Nature Preserves Commission, unpublished document, 1992). References to this 1992 list, as well as additional locality information kindly provided to the author from the databases of the Commission, are abbreviated in the species listings as KSNPC. References to Beal and Thieret, Aquatic and Wetland Plants of Kentucky, 1986, are indicated by the abbreviation B&T. All vouchers are housed at the Eastern Kentucky University Herbarium (EKY).

Glyceria septentrionalis Hitchcock. MADISON CO.: Upland swamp forest with standing water off Duncannon Rd., about 0.5 mi. W. U.S. 421/25, 12 June 1990, *Jones 6353*. The eastern mannagrass occurred in dense stands in shallow water. B&T mapped 2 counties, but it has recently been documented for several additional counties (J. Campbell, pers. comm.). It is under consideration for potential listing by KSNPC.

Gratiola pilosa Michx. Endangered. MCCREARY CO.: Wet meadows below pond on W. side of U.S. 27, just N.

Tennessee state line, 10 August 1991, *Jones 6823.* The hairy hedge-hyssop is known from only 4 counties—Laurel, Wayne, Whitley, and McCreary (KSNPC)—this collection is a new site in the county. Associates at the site included 2 other Kentucky Endangered species (see below).

Hypericum crux-andreae (L.) Crantz. Endangered. MCCREARY CO.: Same site as described for *Gratiola pilosa,* 10 August 1991, *Jones 6821.* This St. Peter's wort is currently known from 3 counties—Pulaski, McCreary, and Whitley (KSNPC). At this new site in McCreary County, just a few plants were observed growing in a wetland meadow.

Juncus nodatus Cov. MCCREARY CO.: Pond off Kingtown Rd., just N. Tennessee state line, 10 August 1991, *Jones 6852.* PULASKI CO.: Large pond near jct. Co. 1003 and KY 192, 22 June 1991, *Jones 6784.* B&T described this rush as infrequent and documented it for 5 counties, all west of Jefferson County. Associates at these south-central Kentucky sites included *Typha angustifolia* L., *Juncus coriaceous* MacKenzie, and *Scirpus purshianus* Fern.

Lobelia nuttallii Roemer & Schultes. Endangered. MCCREARY CO.: Same site as described for *Gratiola pilosa,* 10 August 1991, *Jones 6820.* The species had previously been reported from this county, but this is the only currently known extant population in McCreary County. There is an on-going study of the population biology of this taxon, and new information on its distribution and ecology will soon be available (Steve Walker, pers. comm.).

Lonicera prolifera (Kirchner) Rehder (=*L. reticulata*). Endangered. ANDERSON CO.: Rocky wooded slopes above Gilbert Creek, along KY 513, about 3 mi. E. U.S. 127, 15 May 1991, *Jones 6737.* LINCOLN CO.: Rocky wooded slopes above Cedar Creek, near jct. Boone Rd., 5 July 1993, *Jones 7430.* The only other known site for the grape honeysuckle is one in Franklin County (KSNPC). Two notable associates at the Anderson County site were *Frasera caroliniensis* Walter and *Silene caroliniana* Walter. Just upstream from the Cedar Creek site, 2 other infrequent Kentucky plants, *Monarda clinopodia* L. and *Orbexilum onobrychis* (Nutt.) Rydb., were collected.

Lythrum salicaria L. LINCOLN CO.: In ditches and low meadows along U.S. 150, NW. of Crab Orchard, near jct. of Cedar Creek and Boone Rd., 5 July 1993, *Jones 7438.* B&T mapped 10 counties, all on or near the Ohio River. This south-central Kentucky record is the most southerly extension known in the state for purple loosestrife, a noxious European weed rapidly invading wetlands in the eastern United States.

Ranunculus ambigens S. Wats. Special Concern. MADISON CO.: Same locality as described above for *Glyceria septentrionalis,* 12 June 1990, *Jones 6352.* In B&T, the water-plantain spearwort was documented from 5 counties, all in the northern half of the state. For the last 2 years it has not been observed at this central Kentucky site.

Sagittaria graminea Michx. var. *graminea.* Threatened. KNOX CO.: Shallow shoreline waters of Wilton Lake, off KY 6, 21 July 1982, *Jones 3822,* 13 July 1990, *Jones 6522.* B&T mapped 4 counties, all from the north-central and western part of the state. Associates at this southeastern Kentucky site included *Scirpus pungens* Vahl, *Najas minor* All., and *Eleocharis quadrangulata* (Michx.) Roemer & Schultes.

Scirpus fluviatilis (Torr.) Gray. Threatened. MADISON CO.: Drained basin of Lake Reba, in shallow pools and in ditches, 6 July 1988, *Jones 5446C.* B&T mapped only 2 counties, Henderson and Fulton, both from the far western part of the state, for this species. Chester (Sida 15:157–158, 1992) discussed the distribution of the river bulrush in southeastern U.S. Lake Reba was refilled during 1993 and the current status of the population has not yet been determined.

Scirpus purshianus Fern. MCCREARY CO.: Pond on W. side U.S. 27, just N. Tennessee state line, 10 August 1991, *Jones 6835*; pond off Kingtown Rd., just N. Tennessee state line, 10 August 1991, *Jones 6847.* B&T considered this sedge as rare in the state but it is not listed by KSNPC. The 3 documented counties mapped by B&T were Rowan, Nelson, and Ballard. At these 2 new locations in McCreary County the associates included *Juncus nodatus, Scirpus polyphyllus* Vahl and *Eleocharis quadrangulata.*

Toxicodendron vernix (L.) Kuntze. MCCREARY CO.: Woodlands around 2 ponds, 0.5 mi. ENE jct. U.S. 27 and KY 92, near Pine Knot, 22 June 1991, *Jones* and *Stephens 6779.* The only other known extant site in the state is in Carter County (Bryan, KNPS Newsletter 6(1):3–4, 1991). A detailed account of this site and the associates has already been published (Stephens and Jones, KNPS Newsletter 6(4):9–10, 1991). This species is now under consideration as a potential listing by KSNPC.

Special mention should be made of the McCreary and Madison county sites that each produced several new records. At the McCreary County site near the Tennessee state line there were 3 Endangered species, *Lobelia nuttallii, Gratiola pilosa,* and *Hypericum crux-andreae,* and the infrequent *Scirpus purshianus.* These sites included several wetland habitats, including a large pond, a wetland meadow, and a wet woods. The property is under private ownership, and access is now restricted by locked gates and the posting of no trespassing signs.

A small naturally occurring upland swamp forest off Duncannon Road in Madison County is the site of 2 of the records—*Glyceria septentrionalis* and *Ranunculus ambigens.* Several other wetland habitats occur nearby, including a stand of wet woods and a large pond. This is a remarkable site for the county because of these habitats and the richness of the wetland flora. These areas are entirely surrounded by the Richmond South Industrial Park and on-going development is taking place. Reassurance has been given by the owners that the more fragile and significant regions within the development site will be preserved. As of the summer of 1993, the upland swamp forest was still mostly intact, although several large trees had been toppled by a recent windstorm.

Funds to support this research were provided by grants from the EKU Research Committee, the United States Fish and Wildlife Service, and the Kentucky State Nature Preserves Commission.—**Ronald L. Jones,** Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475.

Trans. Ky. Acad. Sci., 55(3–4), 1994, 142–149

FORUM

The Seamless Web

Branley Allan Branson

Department of Biological Sciences, Eastern Kentucky University,
Richmond, Kentucky 40475

The scientific method did not start with Francis Bacon. In fact, the ability to reason from evidence is, in a very real sense, ancient, at least as old as the origin of highly integrated nervous systems. Two thousand years before Christ, a Babylonian scribe, using cuneiform characters, wrote, "Writing is the mother of eloquence and the father of artists." That spokesperson's voice, coming from the half-million or so clay tablets that have been unearthed, demonstrated the possession of a detailed knowledge of mathematics and engineering, medicine and elemental zoology in those people, elements that had a decidedly modern ring from time to time. Of even greater importance was the fact that those ancient people invented writing, making possible the exponential accumulation of learning that made possible the elimination of errors and, at the same time, introduced the profession of teaching.

One student, all those thousands of years ago, wrote a eulogy for an unnamed teacher, praising him for providing a model of proper behavior, of speech and writing, and for having "focused my eyes on the rules that guide the man of achievement." Thus, from time beyond memory, our youth have been molded and guided by teachers of various sorts, but it is not always the classroom scion who does the teaching, and it is important that any scientist remember that admonition lest we put too much emphasis upon formal classroom exercises while disremembering the prowess of nature to teach.

Teachers do, of course, provide us with direction, help our minds toward potentials. But they can do little more than that; they cannot guide our inductions and deductions when we are abroad on our own. More often than not our abilities to order evidence into formats that are reasonable and to draw conclusions from evidence depends upon our own cognitive skills and upon our insight. The greatest teachers of naturalists, once they have progressed beyond the primer stages of development, may be discovered in all sorts of unexpected places; they are pervasive. Thus, the young Babylonian who extolled the virtues of his teacher only hinted at inchoate attributes of pointing toward ways of seeing, not what was, or should be seen.

Much of my own education has been derived from close encounters with nature. For example, I recall a particularly intense teaching session with a pair of ponderous chuck wallas in the Grand Canyon.

It happened below the Red Wall on a steamy morning in May, deep in the outer gorge. I had come down the trail toward Phantom Ranch studying geological formations, and before me, perhaps 30 feet away, were 2 huge rust-and-black chucks, facing one another near some patches of pink-blossomed prickley pears. This was their ancestral environment, not mine, and their stereotyped senses did not include knowledge of creatures like me, or at least so it seemed. Their powers of recognition—sight, smell, taste—set limits to protected, invisible boundaries. They knew competetors. They eyed one another warily, not moving a muscle or blinking their beady eyes in that ancient landscape.

Intrigued, I slipped the harness of my backpack and slowly lowered myself in the shade to watch. Almost immediately, the action started. With profound grace and precision, the larger of the two articulated a slow double head-bob. The smaller, menaced male did not miss the significance of the formal bow. As the bobbing ceased, the same challenge was iterated by the smaller lizard, and I saw the larger one advance, in that ancient reptilian stance, repeating his challenge as he moved. My observing intrusion upon their primitive world was not recorded by them; they were locked into responses that were older by far than the entire age of man. They were bounded by reptilian genes, restricted to a reptilian universe from which they could not escape. Yet, for all that, we shared many genes and groups of them, but not enough for me to meet their challenge, not could they meet mine. As I shouldered again my pack and made my way down the steep grade, like a peculiar fossil escaping from the hoary strata, I knew that I had just emerged from a primeval incident, and I was delighted.

Further, I contemplated, as I hiked deeper and deeper into time, those ancient impulses, submerged under millions of neurons, nuclei, and processes deep within my brain—a part without which I could not face stress—emerged sometimes from that old reptilian brain and surged through the limbic system to elicit rage or extreme pleasure. I was, I thought, a walking alembic of time myself, a mobile factory of nutrition and support for differing layers of response centers that had developed by accretion, like the sedimentary strata around me in the rocks, only the topmost layer of which contained intelligence—a fog-bound universe that was at once forever lightless and blindingly expansive.

I began to speculate that among the central nervous systems that have been in existence for millions of years, some more loosely knit, some very compact, that all kept their possessors informed about the universe around them, but in a delineating sort of way. All of us, lizards and men, perceive the same things but in different ways, like artists, biologists and lumbermen who contemplate the same pristine forest.

In the over 3 decades that have passed since that brief encounter, I have often mused upon the fat, colorful lizards. Their glistening, bright eyes reflected nothing if not high intelligence, and it was that which bothered me. But why should such an observation take on such great importance? Was it because I was uncomfortable in the sure knowledge of intelligence in organisms that could not read or write?

Hopefully not, for the triumph of intelligence was not something that suddenly appeared, say, in *Australopithecus* on the savannas of Africa. I have seen, and often sensed, intelligence at work in various animals, both in hunters and in would-be prey. The measurement of intelligence in non-human creatures has been one of the undertakings of ethologists. From my own encounters, I sensed the expanding network of neurons from which all intelligence, including our own, was derived. The brains of ancient creatures are imbedded in our brains, their learning ability in our own consciousness. Each time we drift through a woodlot we are cognizant of things known without previous study, or at least of recognition of particulars and generalized schemes like the instinctive members of a foraging wolf pack.

The foraging has been constant—the assumption of an upright posture in a world of tetrapods, the testing and rejecting or acceptance of life-supporting items lasted perhaps more than eight million years, but it started in earnest when the man-apes, living in their antagonistic environments, started using primitive stone tools. The learning and hand-eye coordination changed their brains, not only inexorably enlarging them but also causing different methods of folding to emerge during developmental stages, forcing some of the apelike parts into deeper strata. Juvenilization set in by two million years ago, creating the brain of dreams and conquest that submerged mere instincts.

The billions of cells that were added to the cortex, especially in the frontal lobes, are charged with learning and remembering, more than any other part of the brain. Injury-inducing blows applied to the frontal lobes and the higher intellectual processes required for planning and problem solving and the judgements that tell us the consequences of behavior revert to the level of antecedents. If the blows fall upon the parietal and temporal lobes of the brain, we lose our ability to form or understand words, to express thoughts and sentience, and we are no longer able to remember visual scenes or to execute illustrations of the universe that surrounds us.

The anthropologists, the students of man's emergence, tell us that many of the brain-change patterns are indelibly mapped on the inner surface of the skulls of long-extinct species. Men who survived for hundreds of thousands of years longer than the entire history of modern man had brains and learning abilities that were far less well-developed than those of their product. Or so it would seem.

But skull maps do not tell us much about deep connections and neuronal packing. The instincts of the more primitive intelligence allowed greater latitudes in the environments that sustained those creatures, the learning subjugated natural tendencies more slowly, the forager took what he could get without thinking too deeply about the process.

During over two million years of competition and change, only one species has successfully developed association centers in its cortex that insured the ability to massively change and modify the environmental prerogatives that had defeated most other species that have ever come into being on earth. *Homo sapiens* is a weird, spectral species that has grown further and further removed from nature, though he may yet be forced to retrace some of his steps.

There is an evolutionary axiom that says high degrees of specialization to environments are precursors to extinction, and in many ways man is the most specialized animal in the entire biological history of earth. Yet, in another way man is the most generalized of animals, able to live in many environments, even ones that essentially exclude nearly all other creatures. Man's rationalizing, dreaming, planning brain is the reason.

And it was those things that set me off on tangential thinking about the intelligence I saw burning in the lizard's eyes.

More than that.

The mind that contemplates the intelligence of a lizard has also contemplated its own intelligence and associations while creating cuneiform characters, the startling paintings on Tanzian stone walls, and the great digital computers that rule the earth. The human mind has not only allowed man to escape the constraints of nature, but it has also superimposed constraints upon the rest of nature for which there can be no adaptations by other living beings. And that is why my thoughts kept going back to the chuck walla placidly munching prickly pear flowers in the Grand Canyon, completely trapped by his environmental constraints.

The formidable environment in which we met was a microcosm of the human arena as it interdigitates that of other beings. The eye contact made that patently clear. There was recognition, but recognition that was interpreted at entirely different levels of the universe, almost as if we were excluding one another from the state of history that not only extended back into time before memory itself, but which also made pronouncements about the future. Man's delicate measurements of genetic distancing makes correlations across millions of years, his use of radioisotopic dating carries him into even more remote eras of earth history, his application of biochemical techniques allows him insights into the minutest parts of his own architecture. But at a more primitive level, man and lizard occupy positions that are on equal footing, observation. There is no instantaneous advantage. Learning delineated the gulf between the two systems, in any environment. Like the lizard's eye, man's forms images of the world that he can touch, and the lizard can touch his world, too, but he is restricted to the touch. Another part of man orders and arranges images of parts of the universe he shall never touch, never actually encounter. Even as I contemplated my chuck walla, I knew that somewhere men were fashioning new experiments, new computers, and new mechanical extensions of their biological senses that would cause quantum leaps in learning.

Yet, man tarries in his deserts, often of his own fabrication, contemplating the limitations of ancient lineages that have gone through the sculpturing of time, but he never sees the lizard as an augury of unexpected outcomes.

Man, in his innermost arrangements, is an unexpected outcome himself, I think: in spite of residual reptilian DNA he dreams of building in extraterrestrial space, of taking his limitations with him to the vast deserts of Mars and beyond, of transforming cold and lifeless worlds into new earths where cycles of plundering may be re-established. The dreams go on forever, unlimited by unforeseen constraints. Yet, human dreams have ways of becoming reality, I contemplated further. Anything that can be forced through the sieve of thought can be attempted. And I remembered, too, the foraging across all those thousands of years, the unrelenting competition between tenuously related creatures. How far back in time, or forward, for that matter, must we go before the bonds we refuse to admit are not so obvious, before eye contact between chuck walla and man no longer is disquieting?

We have never been content with simple calibrations of eye-to-target. The freeing of feet from mobility duties, the perfection of hand-and-eye coordination, and the burgeoning growth of the brain during the vast ice ages released more than efficient killing. "Throwing," says William Calvin, "was not a one-step invention. It has aspects such as accuracy and length of throw that may be improved." Killing from a distance was a development we have never relinguished. And that was patently clear in the visual exchange between me and the chuck walla: I could have easily crushed its skull with a single rock. Man has continued to see through the eyes of the hunger, even in this late part of the 20th century, and all the mechanical extensions we have contrived for our organs of perception are only extravagant denouements of Achuelean achievements. But the ability to learn carries with it the ability to learn about things that would destroy us, not the least of which is the adaptation to a narrowly restricted way of life.

We can no longer dream our way free of he exigencies imposed upon us by the twisted coils of genetic codes; dreams may fly to the fartherest extremes of the universe, but they will not carry us with them. Dreams are fire storms in the temporal lobes but in the cold light of wakened perceptions stands the final lesson we must learn, that we, like the lizards that roam their ancient landscapes, are caught in the snares of an incubus. The worst fears of day carry over into the fitful darkness. Awake or sleeping, man searches for solutions to his dilemma, and his unique creativity comes to the surface. As we contemplate how to best harness that creativity, we must inevitably remember that egocentricity is not only another weapon in the arsenal of survival, it is the ultimate guide to the architecture of our higher faculties that not only created reason and science, but also, through the magic of insight, provided us with undistorted views of ourselves. We do not see ourselves as unmitigated miracles of creation but as amalgamations of beasts, including the purely human. We have arrived at this juncture because we are students, not only with the ability to learn to use fire and weaponry, but also what constitutes fire and weaponry. We have built monuments to that ability. Whether those mounments represent graven images remains to be seen, but there is no turning back from the pathway that leads to our uncertain future.

2.

Those of use who hold communion with nature's visible forms, according to William Cullen Bryant's exhortations, must expect responses in various tongues, but what there is to learn from the invisible aspects of nature is couched in an even greater array of languages. "A countryside," said Loren Eiseley, "is above all a biography, the only biography left by time." He was referring to the enormous influence of Sir Charles Lyell on Charles Darwin, an influence as a teacher that led Darwin back to nature as the ultimate teacher, but armed with a new concept, limitless time. Nature may be the greatest teacher on earth, but the lessons it teaches often require enormous concentration and perserverance to understand.

A few nights ago, as I stood in front of our house facing the long, unlighted street that approaches it, I saw a single, dim, yellowish light approaching in the distance, wavering, turning left and right, up and down, like the ghost of some ancient Greek philosopher searching for an educated man. It was eerie, coming onward at a steady pace, grim-reaperish. I was transfixed, rooted to the spot where I stood. Finally, a bicyclist came into view. He was dressed entirely in black, including his helmet. He raised a pale face to glance at me, and then he passed on into the darkness. I did not recognize him, but he gave me the creeps.

For whom was he searching? What was his mission on that rainy, dark night. Those questions will, of course, probably never be answered. In nature, there are many encounters like that, brief, sometimes painfully elidable of proper responses because we are totally ignorant about what we observe. We must grope our way through obfuscation. Like the lone cyclist probing a dark street with little illumination, we must take our evidence in whatever form it is presented.

What evidence? The earth is so packed with the outpourings of evolutionary sequence in the forms of species of plants and animals that evidence would appear to be overwhelming.

That is true, but only if an observer has had the benefit of mentors who taught him how to really see.

Sometimes nature forces conclusions upon observers with such power and drama that those observers are suddenly overwhelmed by the results and wonder why they hadn't understood all along. That occurred for a young Charles Darwin in the Galapagos Islands when he realzied the tremendous importance of isolation to evolution. And it happened to me when I was a young man at Oakland Naval Hospital. I was minimally tutored in medicine, although that was my function at the time, but what occurred was education by natural elements that I did not understand until many years later.

A retired chief petty officer was admitted for treatment in the chest service where I worked. After several days of intensive testing, it was confirmed—histologically, radiologically, and observationally—that he had cancer in both lungs. A perfunctory operation was performed, and it substantiated the previous findings. We could only treat the man's symptoms and try to make him as comfortable as possible.

Like some witch doctor peering into the entrails of a goat, I was, I thought, watching the oncoming results of a disease so beyond medical technology that the practioners had essentially given up ever knowing its causes or cures while within the man's body molecules were at work to insure that the results of millions of years of experimentation would continue unabated. After several months the man's cancer abated then apparently vanished altogether. The only trace of its having been was the ugly scar of exploration. The physicians and surgeons could not explain what had happened.

Now all these years later, even in my later years, I still do not understand entirely, but I do understand that I had witnessed the interactions of the universe's greatest teaching, or, I should say, instructing device, one that was perfected billions of years ago in the primeval ooze where life first started. Desoxyribonucleic acid has been the most potent instructor on earth, and its library influence continues to instruct, generation after generation. Now scientists like Jack Szostak are using that instruction in an attempt to build a cell from the base elements up, following the evolutionary sequence in reverse, perhaps. If they are successful, that cell will contain instructions on how to build another cell like itself. Whether its lineage will evolve to something else there is no way of foreseeing, but it will change, and the offspring of its offspring will change.

Darwin, of course, was also aware that all living things vary, within given populations, from place to place. He may well have learned that in the Galapagos and other islands, but only in part. He was greatly indebted to teachers, contemporary as well as before him. Men like the Compte de Buffon, Jean Baptiste Lamarck, to mention two, certainly thought about variation, and even hinted at natural selection, but it was the great geologist Charles Lyell who described the survival of the fittest, who delineated the effects of physical isolation upon organisms.

Because we are endowed with a thick cerebrum and its attending centers, we expand our learning as we grow and expand ourselves. We learn. Because man transmits knowledge from generation to generation by way of words and sentences, almost in an analgous manner that genetic information is transmitted, learning has evolved to previously unimagined levels. We know the thoughts of entirely vanished civilizations, and we have been able to see how ideas mutate, to diverge into new ideas that undergird the entire substructure of the nearly magical device we call science.

In our learning, we strive to understand not only how living things evolve, but also how life came to be and where it is going. This is a supreme undertaking, not one to be taken lightly or spoken of glibly. Yet, "Like a phantom, it eludes our pursuit," says Loren Eiseley. In that pursuit, we are not dealing with symbolic language, not with the learning of symbols though we use them in our attempts to teach others. In pursuing life we are striving to understand the generative forces of the entire limitless universe, and for this undertaking we require the best energies of all the great teachers who reside in it, including nature herself.

But if societal learning has caused a glut of information to be forwarded through generations, it must be remembered, too, that like the genetic code that transcends generations, only a small percentage of the messages actually make it into the consciousness of successive generations. If, as William H. Calvin once wrote, that we humans "pretty much invented ourselves, imperfections and all, *and we are still inventing ourselves,*" then our learning processes are also seriously flawed. The italics are mine to emphasize how eagerly many of us are willing to misunderstand, misinterpret, or miss entirely the utterances of the great teachers.

Sometimes, in solitary moments of deep contemplation of the undecipherable aspects of the world, individuals put together unique trains of symbols from the immense passage that gave rise to all languages, and through which all the languages of the future must pass, but it is the ideas that are unique, not the symbols. Thus, the contemplative human physiologist Jared Diamond wrote his thoughts concerning the vexing problem associated with the overpopulation of earth by humans: "Archaeologists studying the rise of farming have reconstructed a crucial stage at which we made the worst mistake in human history. Forced to choose between limiting population or trying to increase food production, we chose the latter and ended up with starvation, warfare, and tryanny." After allowing that to sink in, he added, "Hunter-gatherers practiced the most successful and longest-lasting life style in human history."

In that, Diamond may have implied a great deal more than he stated. The evolution of culture came about after the explosive increase in man's brain size rather than gradually emerging with the brain. Intelligence, yes, in the adaptation that has made it possible for man to fit himself into the myriad aspects of the world environment, and that is a unique ability among earth's species.

It also made it possible for man to make the worst mistake in his entire history. Before that, the human animal functioned very much like older animals that depended upon the founder effect, i.e., biological events set in motion by a few individuals that became isolated from larger populations. In effect, however, back in time all populations were essentially founders. New ideas came into vogue, and when such founders got together with other groups fertilization occurred. Out of those meetings came exponential increases and destabilization of old workable genetic constraints. The social animal was born. In two short millenia, human populations have increased from less that a quarter billion people world wide to over five billion.

Teachers may teach, but learning does not necessarily follow.

Social learning is still an uncommon phenomenon on earth, something that has developed, to use on overworked cliché, during the last minute of geologic time, because man himself is very young, gauging by the overall length of time that life has been in existence. We have not retained much of the teaching derivable from earth history. In our symbols, we vastly shorten the contributions made to our lineage by the reptiles and their predecessors, while at the same time we glorify the mammals, and not even all the mammals, emphasizing the glorious contributions of the primates. Yet, we forget that only a short time ago, in the early and mid-19th century, even that glorification was not admissible.

Note that I say "not admissible." It is in the non-verbal part of man's brain, where deep-seated contemplations occur, that the real symbols began to take form and, therefore, where the urge to teach was born. As the world expanded so did the necessity for learning, even though the first instructions were doubtless utilitarian. Still, there are those cliff and cave drawings that speak to us across the gulf of centuries to convey messages that have far outlasted all the mores of those vanished communities.

Like some of my associates, I have sometimes worried over the meanings left behind by writers of past times. I have struggled with cryptic meanings, often to no avail. I have heard some of my associates conclude that, perhaps, those writers meant nothing by what they said. But why would a great mind, fully intending to teach its ideas on the universe, write something that had no meaning? Or, was he writing only for minds perceptive enough to derive meanings?

Some years ago, one of my students, who has by now become internationally famous, attended my course in fisheries ecology. I was earnestly discussing the population dynamics of schooling species, their instantaneous and real mortality rates. The student, at that point in his career, had no intentions of becoming a biologist, not unless he had to admit that medicine was a part of his field. As I got deeper into the subject, expounding upon the complex mathematical model that had been derived to explain the complexities of such populations, the student, intent upon what was being said, suddenly interjected a comment, then flushed deeply: "I don't understand why steps two, three, and five are even necessary, sir."

I peered, incredulously, perhaps, over my glasses at him. "These formulations have been devised by one of the most outstanding population experts in the whole field of fisheries biology, and you think you can answer a theoretical problem like this one by leaving out some of the intermediate steps?"

Still blushing, the young man countered, "Yes, sir. The stuff in the fifth column is canceled out by what you did in the initial calculations. We had some problems like that when I was taking calculus in high school."

I was flabbergasted, of course, but I promptly asked him to come up to the lectern to demonstrate what he was driving at. He not only did that, but he also demonstrated in a perfectly understandable language that even the sluggards in class could understand and use. Those latter students, of course, enjoyed that exercise enormously, not because they learned a great deal or saw the significance of the student's prowess as a teacher, but merely because their instructor had been put in his place by a student. Poetic justice.

A year later, the young man perfected a biochemical technique for measuring genetic distances between species and was at work on a complex statistical design that would not only allow him to test for probability of occurrence, but which would enable him to model the results. That was only the beginning of his work upon the evolutionary sequences of cave fishes and other groups of organisms. Later, he completed his Ph.D. and has since been invited to seminars and symposia around the world to expound upon his work. But the question remains for all of that as to who was teaching whom? Or, were we teaching each other as we went along, giving and receiving instruction in the same way that hunter-gatherers instructed their juveniles? Perhaps our common interests—fishes and evolution, origins and variations, and the power of language—made us receptive to ideas of soaring grandeur through enormous spans of earth time.

Whatever the stimulus, I consider that young man to be one of the most gifted persons I have ever personally known, not only by way of perceptivity and understanding of ideas, but also by way of his ability to translate complexity to simple terms, and to teach others in a palatable way. Much of what I learned from him I have never employed, principally because my interests lie in different directions than his. That does not matter. In a very real way, he altered my value system in the same way that I altered his. Teachers, men, women, or nature, always color the way we think, and that penumbra circles us the rest of our lives, and we transmit the influence to the generation that comes after us. It has always been that way, and it is that process that eventually gave rise to the so-called social mind.

Those of us who are students of evolution have come to know the faces of many instructors, and looking into mirrors we see the face of our own most intimate instructor. We are nothing if not dual personalities, teachers and learners, who create themselves. We live in the dark confines of our heads as well as in the light of stars. Symbols may come to us in the darkness or in the light, but the trick is to recognize them for what they are when they arrive. Evolutionary concepts are as much a matter of mind—a way of looking at things—as they are a matter of scientific endeavors, and cross-fertilization is always near at hand.

A friend and ex-professor of mine, now old and infirm of body but still agile of mind, who has outlived all of his contemporaries and most of his family, drew me and some of my students into a conversation late one evening. We were passing through and stopped to speak with him. He had been writing, working on his memoirs, and thus thoughts of a bygone generation were vivid in his mind.

"I was called into his office," he said, speaking of his long-dead dissertation advisor at the University of Michigan, "out of a clear blue sky. I thought I was in some kind of trouble, you see, and I had an almost overpowering dread. That was the kind of man he was. But I couldn't run." He chuckled at the memory. "I went into his office—it was a horrible mess, papers and books stuck everywhere, on the floor, on chairs, on the desk. I never understood how he could find anything in there, but he always did. He reached into this pile of plunder and pulled out a thick treatise he'd written on the lancelets of the world."

"I was, of course, amazed. I read the title again, then again. It finally dawned on me that he had written that monograph over thirty years ago. Can you imagine that, thirty years? Well, I attempted to hide my amazement, but being a greenhorn I wasn't very successful. I saw confirmation of my lack of success in his face. He told me he'd come across the monograph while he was cleaning out a bookshelf, that he had forgotten about a major piece of work like that for all those years, and I had to ask why he'd never published it. I knew nobody had undertaken to bring order into that group of animals. It was for all practical purposes as fresh then as it was the day he finished it. I could see that."

I was incredulous myself, and I said, "Well, why hadn't he published it?"

He pursed his lips for a moment. "It was odd," he said. "Well, maybe odd is the wrong word. Unique is probably closer to it. Anyway, he said he had never intended the monograph for publication, that he had written it as an example on how to approach the solution of a taxonomic problem, how to use logic so that his students would have a model to study." Then he stared off into a distance that I would never be able to enter, slowly bringing his gaze back to us.

"He was giving it to you for study," I said at last. "He was sort of annointing you with wisdom."

He nodded ever so slowly, without speaking. Then he said, "Wisdom without any recompense whatsoever. Merely for the sake of teaching."

Back on the rain-swept highway, driving toward our destination in the Uinta Mountains of Utah, I contemplated what he had said. Scientists, I thought, may discover all the secrets of the universe, including how life originated and evolved, how man, the dream animal, originated, but it would have all come to naught if the will to teach, the propensity to learn, had failed to materialize at the right time. And in that teaching and learning, we create ourselves anew each generation. That may be the hope of the world: by our creative teaching we may be able to transcend ourselves and become the ultimate student of all that nature has to offer.

If there is any magic on this small planet of ours, it is in education. And it has been that way from the very beginning, since *Homa habilis,* the Clever One, and *Homo erectus* started chipping on stones, building fires, and relaxing aggression long enough to mutter syllabics.

NEWS AND COMMENTS

Westinghouse Science Scholarships

I continue to be chagrined by the conspicuous absence of names of any Kentucky high school seniors on the list of semifinalists and finalists put out by this important annual science talent search. High school seniors from 35 states and Puerto Rico are represented on this year's list—even Arkansas had two students! This is a serious reflection on a state that reputedly is leading the way in educational reform. I hope we are not getting so involved with gingoisms and technology that we fail to actually educate our kids in the fundamentals of science.—Editor.

Annual Meeting

The meeting for 1994 will be sponsored by the Paducah Community College. It will be held at the Executive Inn, Paducah, 3–5 November 1994.

Trans. Ky. Acad. Sci., 55(3–4), 1994, 151–156

INDEX TO VOLUME 55

Instructions for Contributors

Original papers based on research in any field of science will be considered for publication in the Transactions. Also, as the official publication of the Academy, news and announcements of interest to the membership will be included as received.

Manuscripts may be submitted at any time to the Editor. Each manuscript will be reviewed by one or more persons prior to its acceptance for publication, and once accepted, an attempt will be made to publish papers in the order of acceptance. Manuscripts should be typed double spaced throughout on good quality white paper $8^1/_2 \times 11$ inches. NOTE: For format of feature articles and notes see Volume 43(3–4) 1982. The original and one copy should be sent to the Editor and the author should retain a copy for use in correcting proof. Metric and Celsius units shall be used for all measurements. The basic pattern of presentation will be consistent for all manuscripts. The Style Manual of the Council of Biological Editors (CBE Style Manual), the Handbook for Authors of the American Institute of Physics, Webster's Third New International Dictionary, and a Manual of Style (Chicago University Press) are most useful guides in matters of style, form, and spelling. Only those words intended to be italicized in the final publication should be underlined. All authors must be members of the Academy.

The sequence of material in feature-length manuscripts should be: title page, abstract, body of the manuscript, acknowledgments, literature cited, tables with table headings, and figure legends and figures.

1. The title page should include the title of the paper, the authors' names and addresses, and any footnote material concerning credits, changes of address, and so forth.

2. The abstract should be concise and descriptive of the information contained in the paper. It should be complete in itself without reference to the paper.

3. The body of the manuscript should include the following sections: Introduction, Materials and Methods, Results, Discussion, Summary, Acknowledgments, and Literature Cited. All tables and figures, as well as all literature cited, must be referred to in the text.

4. All references in the Literature Cited must be typewritten, double spaced, and should provide complete information on the material referred to. See Volume 43(3–4) 1982 for style.

5. For style of abstract preparation for papers presented at annual meetings, see Volume 43(3–4) 1982.

6. Each table, together with its heading, must be double spaced, numbered in Arabic numerals, and set on a separate page. The heading of the table should be informative of its contents.

Each figure should be reproduced as a glossy print either 5×7 or 8×10 inches. Line drawings in India ink on white paper are acceptable, but should be no larger than $8^1/_2 \times 11$ inches. Photographs should have good contrast so they can be reproduced satisfactorily. All figures should be numbered in Arabic numerals and should be accompanied by an appropriate legend. It is strongly suggested that all contributors follow the guidelines of Allen's (1977) "Steps Toward Better Scientific Illustrations" published by the Allen Press, Inc., Lawrence, Kansas 66044.

The author is responsible for correcting galley proofs. He is also responsible for checking all literature cited to make certain that each article or book is cited correctly. Extensive alterations on the galley proofs are expensive and costs will be borne by the author. Reprints are to be ordered when the galley proofs are returned by the Editor.

CONTENTS