TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

Volume 47
Numbers 1 - 2
March 1986

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.

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 $15.00 for Active members; $7.00 for Student Members; 20.00 family; Life Members $250.

Subscription rates for nonmembers are: domestic, $30.00; foreign, $30.00; 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 exchange should be addressed to the Librarian, University of Louisville, Louisville, Kentucky 40292, the exchange agent for the Academy.

EDUCATIONAL AFFILIATES

Sustaining Member

University of Kentucky

International Machines Corporation

Member

Eastern Kentucky University

Kentucky State University

Morehead State University

Murray State University

Northern Kentucky University

University of Louisville

Western Kentucky University

Associate Member

Alice Lloyd College

Bellarmine College

Berea College

Brescia College

Campbellsville College

Centre College

Georgetown College

Kentucky Wesleyan College

Lees College

Lindsey Wilson College

Spalding College

Thomas More College

Union College

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

March 1986
Volume 47
Numbers 1-2

SURVIVAL, DISPERSAL, AND HOME RANGES OF TRANSLOCATED WILD TURKEYS IN EASTERN KENTUCKY

JOHN P. CARROLL* and M. PETE THOMPSON, Department of Biological Sciences, Eastern Kentucky University, Richmond, KY 40475

*Present address: Department of Biology, University of North Dakota, Grand Forks, ND 58202

ABSTRACT

The survival, dispersal, and home range of wild turkeys *(Meleagris gallopavo sylvestris)* released into unoccupied habitat in eastern Kentucky was investigated. Twenty four turkeys were captured in Virginia and western Kentucky, transported to the study area, and released. Ten of these birds were outfitted with radio transmitters prior to release. Fifty per cent of the radio-tagged turkeys died during the first month after release, with 80% of the losses attributed to great horned owl *(Bubo virginianus)* and gray fox *(Urocyon cinereoargenteus)* predation. No mortality occurred after one month but all birds were ultimately lost due to radio or harness failure. Average maximum movements from the release site during the first 12 weeks post-release ranged from 0.95 -1.75 km. Maximum dispersal was 8.0 km and occurred 6 weeks after release by a juvenile male. The average fall home range size was 197 ha for 2 males and 223 ha for 4 females. Winter and spring home ranges for 3 males averaged 413 ha and 239 ha, respectively. The summer home-range size for a single adult male was 47 ha. The mean three-season home range size for 3 males was 476 ha. Reproduction during the first breeding season after release indicated 3 broods of young turkeys were produced. The evidence suggests the presence of about a one-month adjustment post-release after which released turkeys appear to function as a resident population. It is apparent that the release of wild-trapped turkeys in eastern Kentucky, as undertaken in this study, results in at least short term establishment of a reproducing population.

INTRODUCTION

The eastern wild turkey *(Meleagris gallopavo sylvestris)* has been intensively managed thoughout the eastern United States. Much of this management has involved the restoration of wild turkeys to areas from which they were extirpated. In Kentucky, restoration efforts began in the 1940's and continue through the present. However, few efforts have been made to document the initial activities of turkeys in new habitat, and factors which may influence the relative success or failure of such transplants. In other parts of the southeast several investigations have been conducted. Prestwich (1) studied the survival of wild turkey in central Tennessee. Eichholz and Marchinton (2) reported on the dispersal of 16 wild turkeys in northern Georgia. Bowman, Hill and Burleson (3) studied dispersal of turkeys in North Carolina, and Everett, Speake and Maddox (4) investigated ranges of transplanted turkeys, stocked into occupied habitat in Alabama.

The objectives of this study were to document the survival, dispersal and home range of wild turkeys released into unoccupied Kentucky habitat.

STUDY AREA

The study was conducted on the Mill Creek Wildlife Management Area of the Daniel Boone National Forest in Jackson County, Kentucky. The area is managed by the Kentucky Department of Fish and Wildlife Resources. Elevations range from 385 m to 575 m and the terrain is highly dissected with narrow v-shaped valleys ascending to relatively flat hilltops. The study area is heavily forested in hardwoods (63%) including white oak *(Quercus alba)*, chestnut oak *(Q. prinus)*, scarlet oak *(Q. coccinea)*, northern red oak *(Q. rubra)*, yellow poplar *(Liriodendron tulipifera)* and hickory *(Carya spp.)*. Some stands of softwoods (8%) consisting of shortleaf pine *(Pinus echinata)* and pitch pine *(P. rigida)* are also present. About 17% of the area is in mixed hardwood-pine stands and the remaining 12% consists of clearcut stands which are being regenerated in shortleaf pine. The study area has been described in more detail by Carroll (5).

METHODS

Twenty wild turkeys were captured by rocket-net in Bath County, Virginia of which 8 were outfitted with radio-transmitters. An additional 4 birds were captured in Christian County, Kentucky with oral tranquilizers and 2 of these birds were radio-tagged.

Captured birds were immediately transported to the study area in cardboard boxes for release on the same day as capture. Each bird was aged and sexed (6) and weighed. A numbered aluminum wing tag was also attached to each bird. Telemetry data were collected with Model TRX-24 receivers (Wildlife Materials Inc., Carbondale, IL 62901) and a hand-held 3-element Yagi antenna. Each transmitter was on an individual frequency in the 150-151 mhz range and contained motion and mortality switches similar to those described by Bowman, Hill and Burleson (3) and Everett et al. (7). Transmitter weight ranged from 63 g to 100 g (1.2% to 2.4% of bird weight). Each radio was mounted on the bird's back with nylon braid-coated latex tubing. The tubing was knotted under each wing and securely fastened with metal bands (3,8).

Locations were determined by using triangulation from known stations and in most cases 2 bearings with an intersecting angle between 60° and 120° were used to minimize error (9, 10, 11). Telemetry error of ± 6.15° was calculated for the study area and equipment, and bearings were accurate within 100 m for about 90% of the locations (5).

Each bird was located 2 to 5 times per day during 2 or 3 days each week from release to death or loss of signal. All locations were plotted on a USGS topographic map from which dispersal and home ranges were calculated. The minimum polygon method (12) was used to calculate home ranges.

RESULTS AND DISCUSSION

Known survival of radio-tagged turkeys ranged from 2 to greater than 223 days, as all transmitters eventually failed (Fig.1). Fifty % of the radio-tagged birds died within one month of release with mean survival of 14.2 days (s.d. = 11.2). After the first month post-release no deaths were known to have occurred. Four of the 5 known mortalities were the result of predation by great horned owls *(Bubo virginianus)* and gray foxes *(Urocyon cinereoargenteus)*. The fifth dead turkey showed no outward signs of the cause of death and a subsequent necropsy yielded no information. The initial high rate of mortality among the released birds seems to indicate some kind of relationship with the capture-release process. It could not be determined if the resulting deaths were caused by injuries sustained during handling or from the inexperience of the birds in a new environment, making them vulnerable to predation. Results of other researchers are variable. Prestwich (1) reported 77% mortality within one month of release. He concluded that the proximity of the study area to a suburban development and free ranging dogs caused excess stress and mortality. The results of Bowman, Hill and Burleson (3) indicated less than 10% mortality in the first 2 months after release. Eichholz and Marchinton (2) reported similar low mortality rates. Little and Varland (13) reported mortalities of less than 40% during the first year after release.

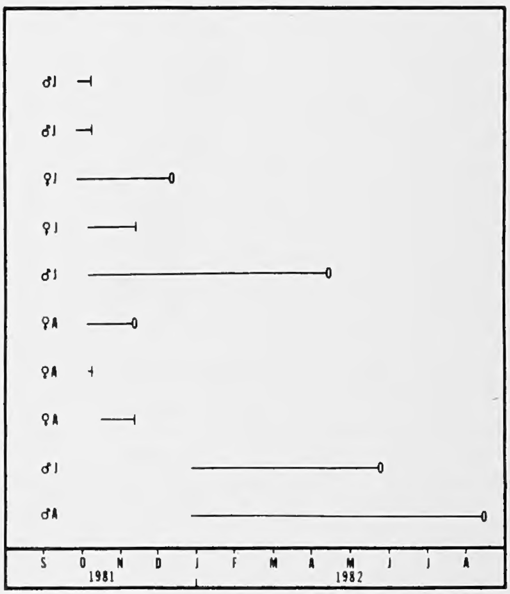


Fig 1. Survival of 10 wild turkeys released in the Mill Creek WMA during 1981-1982. J is juvenile and A is adult. Vertical bar is death of turkey and open circle is loss of signal or transmitter.

Mean maximum movements away from the release sites ranged from 0.95 - 1.75 km during the first 12 weeks post-release. The longest distance moved was 8.0 km by a juvenile male.

The maximum distances moved away from the release sites by individuals occurred during various times in the first 12 weeks. Ultimately, all but one of the surviving turkeys included the release sites as part of their home range. The gradual movements away from release sites reported by Eichholz and Marchinton (2) were not observed during this study, but, the maximum distances moved during the first month

Table 1. SEASONAL HOME RANGES FOR INDIVIDUAL WILD TURKEYS RELEASED INTO THE MILL CREEK WMA, 1981-1982.

	Time (days)	Season	Home Range (ha)
♂ J	10	Fall	217
♂ J	8	Fall	17
♀ J	74	Fall	290
♀ J	30	Fall	183
♂ J	47	Fall	177
	80	W/Sp	132
	188	F/W/Sp	309
♀ A	26	Fall	264
♀ A	2	Fall	-
♀ J	21	Fall	157
♂ A	81	Winter	453
	97	Spring	237
	67	Summer	47
	156	W/Sp	585
♂ J	81	Winter	653
	47	Spring	348
	127	W/Sp	718

J is juvenile and A adult.

were similar between the studies. Bowman, Hill and Burleson (3) found average maximum movements to be 7.0 km and concluded dispersal continued through the first 6 months following release. The lack of dispersal found in this study may reflect the presence of a large mast crop of oaks and dogwood *(Cornus florida)* during the study.

Post-release home range size of the radio-tagged birds surviving more than 2 weeks varied from 157 ha to 653 ha (Table 1). Fall range estimates of 197 ha for males and 223 ha for females were somewhat smaller than those reported by other researchers, but were similar to the findings reported by Raybourne (14) in Virginia. This may be due to the abundant mast crop available during the fall or some behavior changes as a result of the translocation process. The winter ranges for males averaged 413 ha which was larger than the 270 ha estimate cited by Everett, Speake and Maddox (4). The evidence suggests that birds were not restricted by deep snow and cold weather conditions as has been reported in northern regions (15). Instead, it appeared that the birds had to increase their home ranges as the fallen mast was consumed. During the late fall - early winter transition period, a juvenile male shifted its range about 8 km which was the only major shift in home range noted during the study.

The spring gobbler home range sizes (239 ha) were similar to those obtained by Barwick and Speake (16) in Alabama. These home ranges were also comparable to the results of Prestwich (1) and Eichholz and Marchinton (2) for restocked birds.

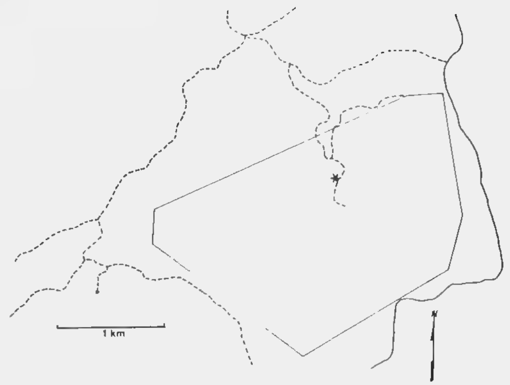


Fig 2. Fall home range (290 ha) of a juvenile female wild turkey released on 29 September 1981 in the Mill Creek WMA. Star is released location.

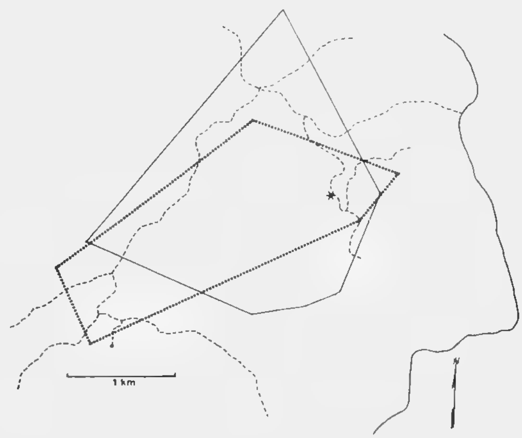


Fig 3. Winter home range (453 ha, solid line) and spring home range (237 ha, dashed line) of an adult male wild turkey released on 26 December 1981 in the Mill Creek WMA. Star is release location.

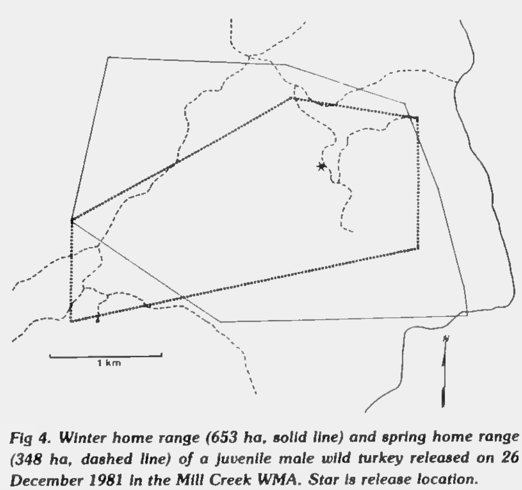


Fig 4. Winter home range (653 ha, solid line) and spring home range (348 ha, dashed line) of a juvenile male wild turkey released on 26 December 1981 in the Mill Creek WMA. Star is release location.

The summer range for one adult gobbler was 47 ha which is smaller than summer ranges reported by other investigators. For example, Barwick and Speake (16) obtained a mean range for gobblers in Alabama of 133 ha, and Bowman, Hill and Burleson (3) reported summer ranges of 542 ha for gobblers in North Carolina.

Ranges for males based on three seasons, with an average size of 476 ha, were within the 224 ha to 1439 ha range given for the eastern wild turkey (4). This probably reflects the intermediate climatic and habitat conditions found in the study area, as well as the condition of mast crop and distribution of mast producing stands throughout the area. These observations support the contentions of Everett, Speake, and Maddox (4) that restocked birds quickly adjust to a new habitat and assume home ranges similar to those of resident birds. The results also indicate a great spatial overlap of ranges in this study (Figs. 2-4), but as noted by Eichholz and Marchinton (2), there were temporal differences in the use of overlapping portions of the home ranges.

Incidental observations of wild turkeys without radios were sparse. Most observations were in the vicinity of the release sites. During the first reproductive season following the release, 4 groups of hens and poults were sighted in the study area and probably represented production of 3 broods. Several gobble counts were conducted during April, 1982, and a maximum of 3 males were heard. All gobbling activity was restricted to the immediate vicinity of the release sites.

SUMMARY

The results of this study indicate that the methods utilized to transplant wild turkeys into unoccupied habitat in eastern Kentucky may be successful. It is apparent there is a short (about one month) period during which many of the released birds succumb to predation. This is probably due to some combination of capture stress and inexperience in new habitat.

The lack of dispersal from release sites and rapid establishment of home ranges similar to those reported for resident turkeys suggests the lack of any long-term effects of the transplant process. Although, the presence of sufficient habitat to support turkeys in the vicinity may be the important factor in how quickly transplanted birds assume roles as a "resident" population.

The subsequent production of 3 broods during the first reproductive season indicates the presence of sufficient habitat components to support turkeys through all four seasons. However, ultimate success of a transplant program can only be measured by the long-term survival of a population in addition to the short-term survival of the released birds.

ACKNOWLEDGEMENTS

The authors thank the Kentucky Division of Fish and Wildlife personnel, especially T. Edwards, E. Gray and G. Wright for their assistance. Eileen Carroll assisted in data collection and analysis, and E. Bertrand and T. Towles assisted with field work. Helpful editorial assistance was provided by B. A. Branson and an anonymous reviewer.

LITERATURE CITED

1. Prestwich, J.L. 1977. A survival study of eastern wild turkey *(Meleagris gallopavo)* on the Cumberland Springs Wildlife Management Area, Tennessee. Tenn. Wildl. Resourc. Agency Tech. Rep. 77-1:1-84.

2. Eichholz, N.F. and R.L. Marchinton. 1975. Dispersal and adjustment to habitat of restocked wild turkeys in Georgia. Proc. S.E. Assoc. Game and Fish Comm. 29:373-377.

3. Bowman, J.A., C.E. Hill and R.Q. Burleson. 1979. Seasonal movements of restocked wild turkeys in North Carolina. Proc. Ann. Conf. S.E. Assoc. Fish and Wildl. Agencies 33:212-223.

4. Everett, D.D., D.W. Speake and W.K. Maddox. 1979. Wild turkey ranges in Alabama mountain habitat. Proc. Ann. Conf. S.E. Assoc. Fish and Wildl. Agencies 33:233-238.

5. Carroll, J.P. 1982. Dispersal, home range and habitat use of translocated eastern wild turkeys *(Meleagris gallopavo sylvestris)* in Jackson County, Kentucky. M.S. Thesis, Eastern Kentucky Univ., Richmond, 79 pp.

6. Larson, J.S. and R.D. Taber. 1980. Criteria of age and sex. Pages 143-202 in S.D. Schemitz (ed.) Wildlife Management Techniques Manual. The Wildlife Society, Washington, D.C.

7. Everett, D.D., D.W. Speake, W.K. Maddox and R.E. Hawkins. 1978. Multi-purpose radio-transmitters for studying mortality, natality and movements of eastern wild turkeys. Proc. Inter. Symp. Biotelemetry 4:155-158.

8. Brander, R.B. 1968. A radio-package harness for game birds. J. Wildl. Manage. 32:630-632.

9. Tester, J.R., D.W. Warner and W.W. Cochran. 1964. A radio-tracking system for studying movements of deer. J. Wildl. Manage. 28:42-45.

10. Heezen, K.L. and J.R. Tester. 1969. Evaluation of radiotracking by triangulation with special

reference to deer movements. J. Wildl. Manage. 33:366-379.

11. Springer, J.T. 1979. Some sources of bias and sampling error in radio triangulation. J. Wildl. Manage. 43:926-935.

12. Mohr, C.O. 1947. Tables of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223-249.

13. Little, T.W. and K.L. Varland. 1981. Reproduction and dispersal of transplanted wild turkeys in Iowa. J. Wildl. Manage. 45:419-427.

14. Raybourne, J.W. 1969. Telemetry of turkey movements. Proc. Annu. Conf. S.E. Assoc. Game and Fish Comm. 22:47-54.

15. Porter, W.F. 1977. Home range dynamics of wild turkeys in southeastern Minnesota. J. Wildl. Manage. 41.434-437.

16. Barwick, L.H. and D.W. Speake. 1973. Seasonal movements and activities of wild turkeys in Alabama. Pages 125-133 in G.C. Sanderson and H.C. Schultz (eds.) Wild turkey management: current problems and programs. Univ. Missouri Press, Columbia.

A SURVEY OF FRESHWATER GASTROPODS IN SELECTED HABITATS OF LAND BETWEEN THE LAKES, KENTUCKY AND TENNESSEE

LUCIANNE BLAIR and JAMES B. SICKEL

Department of Biological Sciences
and Hancock Biological Station
Murray State University, Murray Kentucky 42071

ABSTRACT

A survey of freshwater gastropods and an investigation of their ecological relationships were conducted at 44 collection sites in the Tennessee Valley Authority's Land Between the Lakes in western Kentucky and Tennessee from 14 May to 9 September 1984. Twenty three of the 44 sites supported gastropods. Eight species of gastropods, *Goniobasis laqueata, Physella gyrina, P. integra, P. heterostropha, Helisoma trivolvis, Ferrissia fragilis, Pseudosuccinea columella*, and *Gyraulus parvus*, were found at various locations in 18 streams, one isolated spring, and three small lakes. Each collection site was sampled for species of gastropods and selected water chemistry characteristics, and geological features were noted. The presence or absence of the various snail species in the streams was correlated with the stream's physical characteristics, water chemistry, and underlying geology.

INTRODUCTION

Little work has been done on the freshwater gastropods in western Kentucky, partly, perhaps, because of the confusing taxonomy resulting from the great variability within what is referred to as a species, the need for taxonomic revision in several groups, and the distance from major universities and museums where gastropod research is currently being conducted. As a result, little is known about the ecology and distribution of species occurring in this area. Bickel (1) emphasized the need for collecting and publishing records of mollusks throughout Kentucky. Branson (2) provided a checklist with distribution records, and more recently Branson and Batch (3) summarized the distribution records of aquatic gastropods in Kentucky west of the Kentucky River. Burch (4) gave general distribution information for most of the aquatic gastropods known to occur in Kentucky. These recent papers significantly add to the knowledge of gastropod distribution in western Kentucky, but give little information regarding the ecological relationships of these gastropods; and, with an increasing interest in the endangered species (5), this information is sorely needed.

Only 2 published records of gastropods in LBL could be located, one in which Branson and Batch (3) reported *Lithasia verrucosa* and *Pleurocera canaliculatum* from the shore of Kentucky Lake west of Golden Pond, Kentucky, and a report by Krieger and Burbanck (6) of *Goniobasis semicarinata* (= *Goniobasis laqueata* in this study) collected from Prior Creek by J.B. Sickel. Even less knowledge exists about gastropod ecological relationships in western Kentucky. Literature on gastropod ecology in other regions indicates that several factors are important in determining snail distribution. These factors include alkalinity and pH (7,8), substrate (9,10), vegetation (11), dissolved oxygen (10), temperature (12), and pollution (13).

Land Between the Lakes provides two unique features that may be extremely important in future gastropod research. The land and streams remain relatively undisturbed, and the impoundments that form the east and west boundaries tend to isolate the tributaries forming impediments to migration of small stream gastropods, thus isolating closely related populations. The undisturbed nature of the streams could be important in the conservation of rare species. The isolation of adjacent populations provides opportunities for studies in population genetics.

DESCRIPTION OF THE STUDY AREA

Land Between the Lakes is a national recreation area established in 1965. The area, approximately 65 km long and 12 km across (70,000 ha), is oriented north-south and is surrounded on 3 sides by water. The eastern boundary is formed by the Cumberland River (Lake Barkley) which was impounded in 1964, and the western boundary is formed by the Tennessee River (Kentucky Lake) which was impounded in 1944. A canal connects the 2 lakes and forms the northern boundary. Three counties, Trigg and Lyon counties of Kentucky, and Stewart county of Tennessee, include parts of LBL.

Limestone and chert compose the primary geological formations found in LBL, and these formations determine the groundwater characteristics. St. Louis Limestone and Warsaw Limestone are both Mississippian formations that occur in LBL. Davis et al. (14) stated that water from wells drilled in the St. Louis Formation in western Kentucky was hard to very hard, with 121 mg/1 or greater calcium carbonate, and water from Warsaw Limestone was also hard to very hard.

Fort Payne Formation is also of the Mississippian age. These rocks have been found to be less soluble than the Warsaw Limestone or the St. Louis Limestone. Groundwater from the Ft. Payne Formation is softer and has a lower mineral content (14).

Cretaceous deposits overlie the Mississippian age formations of Land Between the Lakes. The basal unit of these Cretaceous deposits is Tuscaloosa Gravel. The McNairy Formation overlies the Tuscaloosa Gravel. Wells drilled in areas of McNairy Formation have produced soft waters where the underlying unit was thick and moderately hard to very hard waters where the underlying unit was thin (14).

Alluvium deposits are from the Quaternary Period and are composed of silt, sand, and gravel formed from the weathering of the previously mentioned formations. The deposits may also contain various amounts of clay and are present along most stream valleys. These flood plain deposits of alluvium are generally too thin and fine to yield a significant amount of groundwater (14).

Within Land Between the Lakes the streams flowing east to the Cumberland River are separated from those flowing west to the Tennessee River by a divide, approximately centrally located and extending the length of LBL. The short distance between this divide and either of the lake boundaries results in small drainage basins, and many of the streams have only ephemeral or intermittent flow. Several groundwater springs are present and are usually located on or near the few perennial streams in the area. Impoundments of 3 of these perennial streams and of a few embayments adjacent to Lake Barkley have created small lakes. Figure 1 shows the streams of LBL with those surveyed indicated by numbers.

Stehr and Branson (15) showed that intermittent and ephemeral streams are subject to extremes of temperature, water volume, current velocity, and dissolved oxygen levels. Because of these changing conditions, species found in these streams are generally those that can withstand long periods of desiccation. Few freshwater gastropods are able to tolerate these extremes of conditions. Those belonging to the genus *Physella*, however, are able to survive by burrowing deep into the sediments during dry periods (16). In the present study, only the perennial and longest-lived intermittent streams of LBL were selected for collecting. These streams would allow more favorable conditons for mollusk communities to develop.

Eighteen streams, 1 isolated spring, and 3 small lakes were selected for study. Collecting sites on each stream were chosen to reflect the influence of different underlyng geological formations, the presence of springs, and change in stream order. A total of 44 sites was surveyed. To compare conditions between the different stream systems, water chemistry sampling sites were selected at the most accessible points to allow sampling of all sites during a single day.

MATERIALS AND METHODS

The study was conducted from 14 May to 9 September 1984. Three times during the study period, a survey of all chemistry sampling sites was made to compare conditions occurring at each site. These sampling surveys were conducted after at least a week of dry weather to minimize the influence of surface runoff. All of the following water chemistry measurements, with the exception of turbidity, were performed on site.

Dissolved oxygen and temperature were measured using a YSI Model 54 Oxygen-Temperature meter. Conductivity was measured with a Hach Model 2510 conductivity meter, and the pH values were determined with a Hellige Model 605-AHT color comparator and indicator solutions. Concentrations of calcium, total alkalinity, and hardness were determined using a Hack digital titration kit. Standardization of the titration method against a calcium standard solution, prepared as described in Standard Methods (17), gave results within 5% of the expected value. After the above parameters had been analyzed, the water samples were kept on ice and transported to the Hancock Biological Station where turbidity was measured with a Hack Model 16800 turbidimeter.

After the chemical analysis had been completed, physical characters of the streams were noted. These included the depth (m), the velocity (slow, moderate or swift), the approximate area of the site exposed directly to incident sunlight, the primary substrate types, and dominant aquatic vegetation.

Collecting of gastropods at each site was done using a dip net and by hand picking. Collecting was done qualitatively, picking until no new forms of gastropods were found. Specimens from different habitats, for example, pool areas or riffle areas, were kept in separately labeled containers. Collected snails were kept in water and transported back to the Hancock Biological

Station. The snails were first frozen and then perserved in a 5% glycerine-50% isopropyl alcohol solution.

Identification of the gastropods was made using "Freshwater Snails (Mollusca: Gastropoda) of North America" (4), and "Land and Freshwater Shells of North America Part IV Strepomatidae" (18). The identifications were verified by Dr. Billy G. Isom of the TVA laboratory at Muscle Shoals, Alabama. Voucher specimens are deposited in the mollusk museum in the Department of Biological Sciences, Murray State University.

Photographs were made of representative snails from each site and are included in the master's thesis which resulted from this study. Geologic maps of each site are also included in the thesis (19).

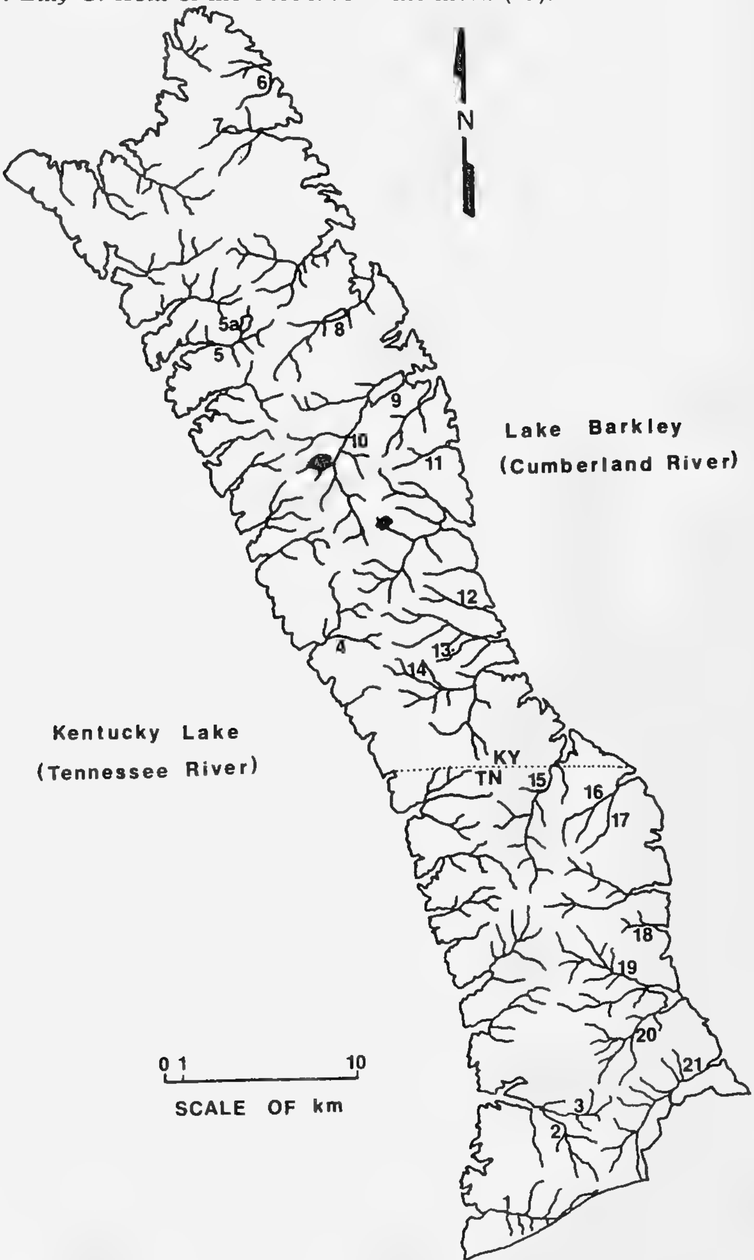


Figure 1. Map of Land Between the Lakes showing surveyed streams. (1.) Lost Creek (2.) South Fork Panther Creek (3.) North Fork Panther Creek (4.) Turkey Creek (5.) Duncan Creek (5a.) Duncan Lake (6.) Unnamed Creek at Clay Bay (7.) Mammoth Furnace Creek (8.) Hematite Lake (9.) Energy Lake (10.) Crooked Creek (11.) Pond Creek (12.) Bacon Creek (13.) Arlt Spring (14.) West Fork Laura Furnace Creek (15.) Prior Creek (16.) Crockett Branch (17.) Crockett Creek (18.) Fox Hollow Creek (19.) Barrett Creek (20.) Brandon Spring Branch (21.) Bear Creek.

RESULTS AND DISCUSSION

Out of the 44 collecting sites, 23 were found to have aquatic gastropods. Eleven of the 21 sites without mollusks were on streams that became dry during the study period. This supports the conclusion of Stehr and Branson (15) that intermittent streams provide poor habitat for aquatic gastropods, even those snails able to withstand short periods of desiccation. Other invertebrates and aquatic vegetation were also usually scarce in these intermittent streams.

Eight gastropod species were found at the 23 collecting sites which supported gastropods. Several habitat characteristics, including calcium level, flow rate, temperature, and geology, showed some relation to the species of gastropods found at particular sites. Table 1 is a summary of the species found in each stream along with selected chemical, physical, and geological characteristics of the streams.

The planorbid snail, *Gyraulus parvus* (Say 1817), was found at 10 collecting sites. All these sites had moderate levels of calcium, hardness, and alkalinity, high levels of turbidity and slow flow. The surface layer of substrate at each site was covered with a layer of silt and organic debris. Most sites also had a relatively warm temperature (20° C or above). Van der Schalie and Berry (12) found that planorbids require warmer water (23-25° C) for reproduction and optimal growth rate.

Species of *Physella* were found at numerous sites with various levels of calcium and other parameters. *Physella integra* (Haldeman 1841), however, was found only at 2 springs which had high levels of calcium and minerals and swift flow. *Physella gyrina* (Say 1821) was found at several sites on streams and lakes. The majority of these latter sites were characterized by the presence of heavy siltation and organic debris, and by slow flow. Where *Physella gyrina* was present in swiftly flowing streams, such as South Fork Panther Creek and Lost Creek, they were found in pool areas or areas of slower flow. These observations support the conclusions of Clampitt (20) who compared the ecology of *Physella gyrina* and *Physella integra*. He found

Table 1. Areas sampled in LBL, species of Gastropods collected, and selected stream characteristics.

					SPECIES							
SAMPLE SITES	Calcium	Flow	Temperature	Geology	*G. laqueata*	*P. heterostropha*	*P. gyrina*	*P. integra*	*G. parvus*	*P. columella*	*F. fragilis*	*H. trivolvis*
Lost Creek	H	R	C	P	A	A	C	R	—	—	C	—
S. Fork Panther Creek	H	R	C	P,W	A	—	C	—	—	—	—	—
N. Fork Panther Creek	L	M	W	P,W	—	—	—	—	—	—	—	—
Turkey Creek	L	M	C	W,P	—	—	—	—	—	—	—	—
Duncan Creek	L	S	W	T	—	C	C	—	C	C	—	—
Clay Bay	M	S	W	T	—	—	C	—	C	—	—	—
Mammoth Furnace Creek	M	S	W	T,L	—	—	—	—	R	—	—	—
Hematite Lake	M	S	W	L,W	—	—	C	—	C	—	—	—
Energy Lake	M	S	W	P	—	—	—	—	C	—	—	—
Crooked Creek	M	M	W	W,P	—	—	—	—	R	—	—	—
Pond Creek	L	S	W	L,W	—	—	—	—	—	—	—	—
Bacon Creek	L	S	W	T,L	—	—	—	—	—	—	—	—
Arlt Spring	L	M	C	T	—	—	—	—	—	—	—	—
W. Fork Laura Furnace Cr.	L	M	W	T	—	—	—	—	—	—	—	—
Prior Creek	H	R	C	W,P	A	A	—	R	—	—	—	R
Crockett Branch	L	S	W	W,L	—	—	—	—	—	—	—	—
Crockett Creek	H	R	C	W,L	A	C	C	—	—	—	—	—
Fox Hollow Creek	M	M	W	L	—	—	—	—	C	—	—	—
Barrett Creek	L	S	C	L	—	—	—	—	—	—	—	—
Brandon Spring Branch	M	S	W	W,L	—	—	C	—	C	—	—	—
Bear Creek	M	M	C	P	—	—	R	—	—	—	—	—

Calcium: H = High levels (80 mg CaCO$_3$/1 and higher)
M = Moderate levels (30-80 mg CaCO$_3$/1)
L = Low levels (30 mg CaCO$_3$/1 and less)
Flow Rate: R = Rapid Flow, M = Moderate Flow, S = Slow Flow
Temperature: C = Moderately Cool (15-19°C)
W = Moderately Warm (20°C and higher)
Geology: T = Tuscaloosa Gravel, P = Fort Payne Formation
W = Warsaw Limestone, L = St. Louis Limestone
Mollusks: A = Abundant, C = Common, R = Rare

Physella integra to be a characteristic inhabitant of rocky lake shores but absent from ponds, while *Physella gyrina* was commonly found in both habitats.

Physella heterostropha (Say 1817) has been reported by Wurtz (13) to be one of the most common and widespread pollution-tolerant species. In this study, it was found in streams of various water chemistry levels, in areas of very low calcium concentration as well as in areas of high concentrations. Sites where *Physella heterostropha* was found also varied from swift to slow flow rate, and from little silt to heavy layers of silt and organic debris. Of the 3 species of *Physella* collected in the study, *Physella heterostropha* appears to be the most generalistic in habitat requirements.

Pseudosuccinea collumella (Say 1817) was found at only one collecting site, Duncan Lake. Baker (21) described *Pseudosuccinea columella* as being found in quiet, stagnant habitats among cattails. These were the conditions present at Duncan Lake. Baker went on to say that although the lymnaeids are widely distributed in the United States, they are habitat restricted.

The ancylid snail, *Ferrissia fragilis* (Tryon 1863), is also widely distributed in the eastern United States, but it is restricted to small bodies of standing water (4). Ancylids are particularly susceptible to desiccation because of their large aperture (22). *Ferrissia fragilis* was found at one spring-fed pool. The pool maintained a constant water level throughout the study period and showed no signs of probable changes in the future.

Helisoma trivolvis (Say 1817) was found at only one spring site. It is common throughout North America (4). Goodrich (23) described *Helisoma trivolvis* as intrinsically adaptive since it lives in a variety of environmental conditions.

Goniobasis laqueata (Say 1829) was found in 4 of the perennial streams which were primarily spring-fed. These streams had several features in common including swift to moderate flow rates, moderate to high levels of calcium, alkalinity, and hardness, moderately low levels of turbidity, moderately low temperatures, and little silt and organic debris.

Some differences were found in the appearance of *Goniobasis laqueata* collected at different sites. Those collected from the South Fork of Panther Creek were the most strongly sculptured, although specimens varied from almost smooth, to those having just spiral lines, to those with strong costae. Color also varied from a light greenish brown to a dark brownish black. *Goniobasis laqueata* collected at the headwaters of South Fork Panther Creek were generally slightly shorter and fatter with less sculpturing. Those collected from the confluence of the North and South forks of Panther Creek were longer and thinner, and had the strongest sculpturing. *Goniobasis laqueata* found at other sites on South Fork Panther Creek showed gradations between the two forms.

Goniobasis laqueata collected from Lost Creek were generally dark in color and had less sculpturing. Those from Lost Creek at Hamm Hollow had the least amount of sculpturing. Those specimens were also found to have a heavy periphyton growth covering the shell.

Goniobasis laqueata found at Crockett Creek were also dark in color. Those snails found upstream showed a moderate amount of sculpturing, but the majority were small in size. Specimens collected downstream were larger but with less sculpturing. *Goniobasis laqueata* from Crockett Creek also showed the most erosion of all gastropods collected during the study.

The population of *Goniobasis laqueata* found at Prior Creek were devoid of any sculpturing and were light brown in color. The majority collected, however, had a dark brown color band that was not observed in specimens from any other creek.

Although no obvious differences between the streams could be concluded as the cause of the variations in *Goniobasis laqueata*, habitat differences have been reported by other investigators to be the cause of shell form changes. In the case of the streams of this study, perhaps the separation and isolation of the populations of *Goniobasis laqueata* have caused the divergence in appearance. In 1921, Goodrich (23) proposed that because *Goniobasis* is purely a creek form, any larger river can act as a barrier permitting the development of small distinct races.

At most collecting sites, a clumped distribution of gastropods was evident. This clumped distribution may have been the result of the habitat diversity and stratification at the collecting sites. Those sites with fewer species of gastropods had fewer habitat types than those sites where several species were found. It is doubtful that all the species of aquatic gastropods in LBL have been found since unsampled areas of streams and isolated ponds may have different habitat types and thus different gastropod species than those found.

Differences in water chemistry between some of the sites was apparently related to the underlying geologic formations, and those differences influence the species of gastropods occurring at the sites (Table 1). Streams in areas of Tuscaloosa Gravel had lower levels of minerals. Arlt Spring, in Tuscaloosa Gravel, showed calcium levels of under 10mg/1 calcium carbonate, while Lost Spring, which was of similar size and flow rate but in an area of Ft. Payne and Warsaw Limestone formations, had much higher calcium levels, 47-94 mg/1.

Streams which were in areas of Warsaw Limestone, St. Louis Limestone or Ft. Payne formations showed moderate to high levels of minerals. Those streams with groundwater springs showed higher levels of calcium than did streams without springs. Intermittent or ephemeral streams that flowed in areas of these formations still contained low levels of minerals, perhaps because these streams are more dependent on surface runoff than on groundwater for discharge.

The results of this study indicate that the most important factors influencing the aquatic gastropod distribution in Land Between the Lakes are the duration of water availability and calcium levels in the streams. Intermittent streams of short duration and ephemeral streams do not appear capable of supporting gastropods even though at times these streams may have adequate flow and moderately high calcium levels. In perennial streams, calcium levels, food, turbidity and flow rate become more important as possible limiting factors.

The variation in shell form between populations of *Goniobasis laqueata* within the different streams of LBL illuminates the difficulties in molluscan systematics and provides material for future studies in taxonomy and population genetics. A detailed study of this variation would be useful for the taxonomic revision needed in the genus *Goniobasis*.

ACKNOWLEDGEMENTS

Sincere thanks are extended to Billy G. Isom, Carol B. Stein, and David H. Stansbery for assistance in identification and Joe M. King, Marian J. Fuller, Thomas Timmons, Peter Whaley, and Thomas Forsythe for their helpful suggestions. The study was made possible through the cooperation of the Tennessee Valley Authority's Land Between the Lakes and the facilities of the Hancock Biological Station. Partial funding came from the Murray State University Committee on Institutional Studies and Research.

LITERATURE CITED

1. Bickel, David. 1967. Preliminary checklist of recent and Pleistocene Mollusca of Kentucky. Sterkiana 28:7-20.

2. Branson, Branley A. 1970. Checklist and distribution of Kentucky aquatic gastropods. Kentucky Fisheries Bull. No. 54. 35 pp.

3. Branson, Branley A. and Donald L. Batch. 1983. Gastropod and Sphaeriacean clam records for streams west of the Kentucky River drainage, Kentucky. Trans. KY Acad. Sci. 44:8-12.

4. Burch, J.B. 1982. Freshwater snails (Mollusca: Gastropoda) of North America. United States Environmental Protection Agency Document EPA-600/3-82-026. 294 pp.

5. Branson, Branley A., James B. Sickel, and Bruce M. Bauer. 1983. Notes on the rare and endangered or threatened Pleurocerid snails from the Cumberland River, Kentucky. Nautilus 97:58-60.

6. Krieger, K.A. and W.D. Burbanck. 1977. Morphological and electrophoretic evidence of population relationships in stream snails of the family Pleuroceridae (Prosobranchia). Doctoral Dissertation at Emory University, Georgia. 145 pp.

7. Shoup, C.S. 1943. Distribution of fresh-water gastropods in relation to total alkalinity of streams. Nautilus 56:130-134.

8. Dussart, G.B. 1974. The ecology of freshwater mollusks in northwest England in relation to water chemistry. J. Molluscan Studies 42:181-198.

9. Harman, Willard N. 1972. Benthic substrates: their effect on fresh-water Mollusca. Ecology 53 (2):271-277.

10. Houp, Katherine Hanke. 1970. Population dynamics of *Pleurocera acuta* in a central Kentucky limestone stream. Amer. Midl. Natur. 83:81-88.

11. Butcher, R.W. 1933. Studies on the Ecology of Rivers I: On the distribution of macrophytic vegetation in the rivers of Britain. J. of Ecology 21:58-91.

12. Van der Schalie, Henry and Elmer G. Berry. 1973. The effects of temperature on growth and reproduction of aquatic snails. Sterkiana 50:1-92.

13. Wurtz, Charles B. 1956. Freshwater Mollusks and stream pollution. Nautilus 69:96-100.

14. Davis, R.W., T. Wm. Lambert, and Arnold J. Hansen, Jr. 1973. Subsurface geology and groundwater resources of the Jackson Purchase region, Kentucky. Geological Survey Water Supply Paper 1987. 66 pp.

15. Stehr, William C. and J. Wendell Branson. 1938. An ecological study of an intermittent stream. Ecology 19:294-311.

16. Boss, Kenneth J. 1974. Oblomovism in the Mollusca. Trans. Amer. Micros. Soc. 93: 460-481.

17. American Public Health Association. 1981. Standard methods for the examination of water and wastewater, 15th Edition. Washington D.C., Water Pollution Control Federation. 1193 pp.

18. Tryon Jr., George W. 1873. Land and fresh-water shells of North America part IV Strepomatidae (American Melanians). Smiths. Misc. Coll. (253):1-453.

19. Blair, Lucianne. 1985. A survey of the freshwater Gastropods of selected habitats in Land Between the Lakes, Kentucky and Tennessee. Unpublished Masters Thesis at Murray State University, Murray, KY. 168 pp.

20. Clampitt, Phillip T. 1970. Comparative ecology of the snails *Physa gyrina* and *Physa integra* (Basommatophora:Physidae). Malacologia 10:113-151.

21. Baker, Frank Collins. 1911. The Lymnaeidae of North and Middle America, recent and fossil. Spec. Publ. Chicago Acad. Sci. 3:1-539.

22. Basch, Paul F. 1963. a review of the recent freshwater snails of North America. Bull. Mus. Comp. Zool., Harvard U. 129:399-461.

23. Goodrich, Calvin. 1940. Civilization and aquatic Mollusks. Nautilus 54:6-10.

24. Goodrich, Calvin. 1921. River barriers to aquatic animals. Nautilus 35:1-4.

ECOLOGICAL ASPECTS OF HELMINTH INFECTIONS IN *CHRYSEMYS SCRIPTA ELEGANS* (Wied)

RON ROSEN, Division of Natural Sciences, Union College, Barbourville, Kentucky 40906

W.C. MARQUARDT, Department of Zoology-Entomology, Colorado State University, Fort Collins, Colorado 80523

ABSTRACT

Thirteen species of helminths were recovered from 94 red-eared turtles, *Chrysemys scripta elegans*, at Lake Conway, Arkansas. Turtles had an average of 246 helminths each. The relative abundance (RA) of the acanthocephalan, *Neoechinorhynchus emyditoides* (165.74) was greater than the RA values of all the other helminth species combined. The 3 remaining species of *Neoechinorhynchus* and the 3 nematode species recovered had RA values ranging between 0.88 - 16.62 and 12.28 - 31.00, respectively, while each of the 6 trematode species had RA values less than 1.70. The mean intensity of *Spiroxys contortus* was significantly greater in female than in male turtles. The prevalence of *Heronimus mollis* and *S. contortus* was significantly greater in younger male and/or female turtles. The mean intensity of *S. contortus* increased significantly in older female turtles, but the mean intensities of *Camallanus trispinosus* and *Spironoura concinnae* were greater in the younger age class of male and/or female *C. s. elegans.* The frequency distribution of 7 enteric helminths was determined from 12 intestinal sections of *C. s. elegans. Camallanus trispinosus* was most numerous in section 1 of the small intestine adjacent to the stomach, *Neoechinorhynchus* spp. (i.e., *N. chrysemydis, N. emyditoides* and *N. pseudemydis*) in section 3, *Telorchis corti* in section 5, *Telorchis singularis* in section 6 and *S. concinnae* in section 10 which represented the first section of the large intestine. These results are discussed with regard to the ecology of the parasite and the host.

INTRODUCTION

Studies concerned with helminth parasites of the red-eared turtle, *Chrysemys scripta elegans*, and other turtle species have usually been limited to work on surveys and life cycles in North America. Host sex, size and age have been seldom considered as factors affecting parasite prevalence and intensity with the exceptions of *Chrysemys picta marginata* (1), *Chrysemys scripta scripta* (2), and *Sternothaerus minor minor* (3). In addition, reports dealing with the intestinal distribution of enteric helminths in turtles are few (4,5), and are important since they contribute to our knowledge of the physical and chemical requirements of these parasites.

The objectives of this study were to determine: 1) the effect of host sex and age on the prevalence and mean intensity of helminths found in *C. s. elegans* and 2) the frequency distribution of helminths in the intestine of *C. s. elegans.*

MATERIALS AND METHODS

Ninety four red-eared turtles were captured with a cylindrical fish basket from the Gold Creek Landing at Lake Conway, Arkansas (T5N, R13W, Sec.32), from May 20 to August 4, 1977. All turtles were necropsied within 24 hours of their capture. Host sex and plastron length were recorded, after which the turtles were killed by an injection of ether into the brain. Plastron length is used in this study to give an estimation of host age since these 2 parameters are correlated; however, the sexes were considered separately since male and female turtles of similar ages may have different plastron sizes (6). The intestine was removed immediately, placed in a dissecting pan filled with a 0.75% salt solution and its length measured. The intestine was then separated into 12 equal sections, and each section slit longitudinally and examined for helminths. Sections 1-9 represented regions of the small intestine, while sections 10-12 represented the large intestine. The stomach, urinary bladder, lungs, liver, heart and gall bladder were also examined for worms.

A listing of parasites and their location in *C. s. elegans* from this study was reported by Rosen and Marquardt (7). It should be mentioned that the identification of the 4 acanthocephalan species in the genus *Neoechinorhynchus* was based on the eggs of mature female worms (8) due to the large number of specimens recovered. This technique made it necessary to assume that the male worms of each species occur in equal proportion to the females. Therefore, all calculations dealing with species in this genus represent estimations rather than exact values.

Frequency distributions were determined for 7 helminth species in the 12 intestinal sections of *C. s. elegans*. Statistical analysis was confined to parasite species with adequate sample sizes. The terms prevalence, mean intensity and relative abundance are defined according to Margolis et al. (9). Chi-square contingency tables (2 x 2) were used to assess differences in prevalence levels of 9 helminth species due to host sex and age blocking for sex. A Student's t-test or Behrens-Fisher test assessed differences in the mean intensity of infection of 4 helminth species due to host sex and age blocking for sex using log transformed data. Homogeneity of variances were tested with the F-max test (10). In all tests, a probability of 95% ($P < 0.050$) was considered to be significant.

RESULTS

All *C. s. elegans* in the present study were infected with at least 2 species ($\bar{X} = 4.8$, range 2-10) of helminths, and a total of 13 species were recovered. Turtles had an average of 246 helminths each (range 16-1521). Relative abundance values for the 13 helminth species are given in Table 1.

Table 1. Relative abundance values for the thirteen helminth species recovered from 94 *Chrysemys scripta elegans*. * = intestinal species.

HELMINTH SPECIES	A = ACANTHOCEPHALAN N = NEMATODE T = TREMATODE	RELATIVE ABUNDANCE
Neoechinorhynchus emyditoides	A*	165.74
Camallanus trispinosus	N*	31.00
Neoechinorhynchus pseudemydis	A*	16.62
Spironoura concinnae	N*	13.02
Spiroxys contortus	N	12.28
Neoechinorhynchus chrysemydis	A*	4.30
Telorchis diminutus	T*	1.69
Telorchis singularis	T*	0.96
Neoechinorhynchus stunkardi	A*	0.88
Telorchis corti	T*	0.65
Heronimus mollis	T	0.30
Neopolystoma orbiculare	T	0.10
Dictyangium chelydrae	T*	0.04

The prevalence and mean intensity values of the parasite species segregated by host sex and age blocking for sex are given in Table 2. Female turtles, which were significantly larger than the males in this study (female plastron length - $\bar{X}$ = 15.7 cm vs. male plastron length -$\bar{X}$ = 13.3 cm, $t = 3.610$, $df = 92$), had significantly more of the stomach nematode *Spiroxys contortus* than males ($t = 3.090$, $df = 83$). No other sex-related differences in prevalence or mean intensity were present for the other parasite species evaluated. The prevalence of the lung fluke *Heronimus mollis* was significantly greater in the younger age class of male ($X^2 = 5.796$, $df = 1$) and female ($X^2 = 4.218$, $df = 1$) turtles. The prevalence of *S. contortus* was also greater in younger male turtles ($\bar{X} = 5.164$, $df = 1$), but the mean intensity of this nematode increased significantly ($t = 2.755$, $df = 42$) in the older age class of female hosts. The mean intensities of the intestinal nematodes *Camallanus trispinosus* ($t = 2.483$, $df = 43$) and *Spironoura concinnae* ($t = 2.199$, $df = 28$) were significantly greater in the younger age class of female hosts. The mean intensity of the former species was also significantly greater in the younger age class of male hosts ($t = 3.195$, $df = 47$). No other host age-related differences in prevalence or mean intensity were present among the remaining helminth species.

The frequency distributions of 7 enteric helminth species in the 12 intestional sections of C.s. elegans are summarized in Figure 1. *C. trispinosus* and the 3 species of *Neoechinorhynchus* were most numerous in sections 1 (77.8%) and 3 (37.1-41.4%), respectively. The trematodes *Telorchis corti* and *Telorchis singularis* were recovered with the greatest frequency from sections 5 (44.3%) and 6 (42.2%), respectively, while *S. concinnae* was most numerous in section 10 (69.2%).

DISCUSSION

The large number of helminth species recovered from *C s. elegans* at Lake Conway Arkansas, is probably indicative of habitat stability as discussed by Esch et al. (11) for parasites of *C.s. scripta*. Acanthocephalans and nematodes were the numerically dominant helminths indicating that large numbers of their intermediate hosts are ingested by *C.s. elegans*. The nematode and acanthocephalan species in this study (with the exception of *S. concinnae)* utilize copepods or possibly ostracods as intermediate hosts in their life cycles (12,13,14). These zooplankton may occur in tremendous numbers, promoting the infection of many second intermediate and/or definitive hosts. In contrast, snails and other macroinvertebrate intermediate hosts of digenetic trematodes recovered in this study are probably less abundant than zooplankton. This smaller reservoir of intermediate hosts may have contributed to the low relative abundance of flukes in *C. s. elegans*.

Table 2. Prevalence and mean intensity of infection of nine helminth species in male vs. female and young (Y) vs. old (O) *Chrysemys scripta elegans* blocking for host sex.

HELMINTHS	HOST SEX		HOST AGE			
	MALE (49)*	FEMALE(45)*	MALE		FEMALE	
			Y(24)§	O (25)§	Y (23)§	O (22)§
S. contortus	87.8*	95.6	95.8	72.0	100.0	95.5
	10.12 ± 1.16 π	16.72 ± 2.22	9.44 ± 2.06	10.33 ± 2.69	11.70 ± 2.08	22.71 ± 3.62
C. trispinosus	100.0	100.0	100.0	100.0	100.0	100.0
	25.33 ± 3.24	37.96 ± 5.31	33.92 ± 5.06	17.12 ± 3.44	45.91 ± 8.00	28.00 ± 6.56
S. concinnae	75.5	66.7	83.3	68.0	65.2	68.2
	20.19 ± 3.93	15.90 ± 3.05	19.90 ± 3.96	20.53 ± 7.33	21.87 ± 5.36	9.93 ± 2.16
N. emyditoides	95.7	100.0	95.8	95.7	100.0	100.0
	142.78 ± 18.62	196.77 ± 32.11	117.04 ± 14.45	169.68 ± 34.51	174.00 ± 29.18	215.32 ± 56.93
N. pseudemydis	27.7	28.9	29.2	26.1	18.2	40.9
N. chrysemydis	16.3	13.3	25.0	8.7	13.6	13.6
T. corti	12.3	22.2	20.8	4.0	26.1	18.2
T. singularis	20.0	15.6	29.2	8.0	21.7	9.1
H. mollis	10.2	8.9	20.8	0	17.4	0

* ( ) = no. hosts examined; Note Male (47) should be substituted for *Neoechinorhynchus* spp. as species identification not possible in two turtles.

§ ( ) = no. hosts examined in young male (plastron length = 9.0 - 13.2 cm) vs. old male (13.3 - 18.5) and young female (9.1 -16.2) vs. old female (16.3 - 20.9) turtles; Note O (23) should be substituted for *Neoechinorhynchus* spp. in male turtles as species identification not possible in two turtles.

* and π = *prevalence and mean intensity* ± SE, respectively.
= Sig. at P<0.050

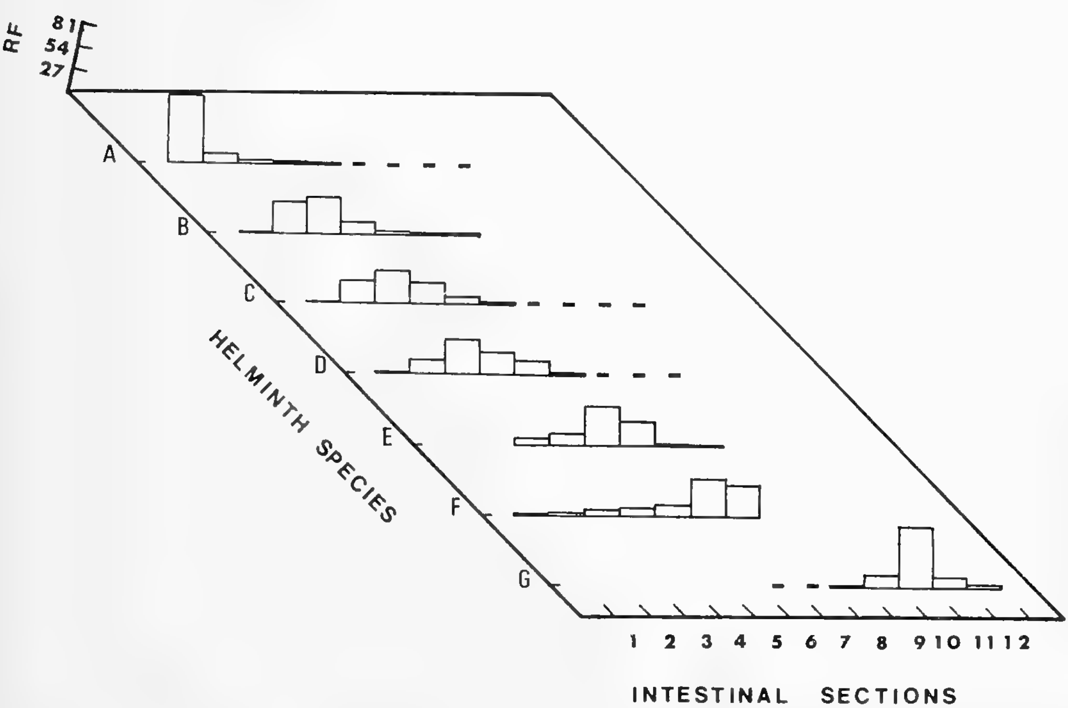


Figure 1. Relative frequency (RF) of *C. trispinosus* (A - 94, 2913)*, *N. pseudemydis* π (B - 23, 1380), *N. emyditoides* (C - 72, 13809), *N. chrysemydis* (D - 14, 404), *T. corti* (E - 16, 61), *T. singularis* (F -16, 90) and *S. concinnae* (G - 67, 1223) in twelve intestinal sections of *Chrysemys scripta elegans*. * = n. of hosts, no. of worms; π = only turtles with more than 20 mature female worms assessed for the frequency distribution of *Neoechinorhynchus* spp. in the intestine.

Esch and Gibbons (1) attributed differences in the mean intensities of some helminths in male vs. female *C. p. marginata* to intrinsic differences between the sexes. Differences in the mean intensity of *S. contortus* in *C. s. elegans* due to host sex could be related to hormonal differences between the sexes or differential food requirements between male and female turtles. The latter assumes that the larger female *C. s. elegans* routinely ingest more of the macroinvertebrate, vertebrate and copepod intermediate hosts listed by Hedrick (13) than the smaller male turtles over a given time to meet possibly greater nutrient demands.

Several studies (15,16) have indicated that the degree of parasitism in turtles increases in relation to the size or age of the host. Both significant increases and decreases in the prevalence or mean intensity of several helminths in relation to host age were observed in this study. The significant decrease in the prevalence of *H. mollis* in the older age class of male and female *C. s. elegans* has been reported for other trematode species in turtles (1,17). This trend, as stated in previous studies, is probably related to the differing food habits of juvenile and mature *Chrysemys scripta. C. scripta* juveniles are highly carnivorous and the adults are omnivorous (18), the former thus consuming more of the macroinvertebrate intermediate hosts of trematodes. The life cycle of *H. mollis* is completed by the ingestion of infected snails by turtles (19), and thus the smaller, juvenile turtles in this study would be expected to have a greater prevalence of infection with this worm. In addition, an age-related immune response cannot be ruled out as a possible factor contributing to the decreased prevalence of *H. mollis* in the lungs of older *C. s. elegans*. This reduction of trematode prevalence with an increase in turtle age does not support the general observation of Brooks and Mayes (20) that older turtles are more likely to be infected with platyhelminthes.

Esch and Gibbons (1) found that the pooled nematode population of *C. p. marginata* (i.e., *Camallanus microcephalus, S. contortus, Spironoura sp.* and *Aplectana sp.*) experienced a rise and fall in numbers in relation to host age. Separate consideration of the same or related species in this study showed that the mean intensity of *S. contortus* increased significantly in the older age class of female turtles, while the mean intensities of *S. concinnae* and *C. trispinosus* were highest in the younger age class of male and/or female *C. s. elegans*.

It is unclear why younger female turtles had a significantly greater mean intensity of *S. concinnae* than older female hosts. This nematode lives in the feces of the large intestine with no direct attachment to host tissues, and thus it is unlikely that an age-related immune response is involved. It is doubtful that documented differences in diet between young and old turtles play a significant role since *S. concinnae* has a direct life cycle (14). Perhaps other behavioral differences in female turtles associated with host age promote greater contact between young hosts and the infective larvae of *S. concinnae*. Further studies on the life cycle of *S. concinnae* and the behavior of *C. s. elegans* will be required to verify this.

Spiroxys contortus and *C. trispinosus* utilize similar intermediate and transport hosts (i.e., copepods and aquatic vertebrates—13,14) to complete their life cycles, and both nematodes live in the digestive tract of turtles where they are firmly attached to host tissues. However, the mean intensity of these 2 nematodes showed opposite trends with an increase in the age of female turtles. This may suggest that the life cycle of *C. trispinosus* has a greater dependence on vertebrate transport hosts for its completion than does *S. contortus*. This would account for the greater mean intensity of *C. trispinosus* in the younger, more carnivorous male and female turtles. Further work focusing on the relative importance of each type of intermediate or transport host in the life cycle of these 2 nematodes will be required for further insight into this problem.

The intestinal habitats occupied by helminths in the present study were determined by numerous interacting factors which served to satisfy the physiological requirements of each parasite species. The concentration of *C. trispinosus* in intestinal section 1 corroborates the findings of Uglem and Beck (5). They found that this parasite must live in the anterior part of the turtle intestine where APase activity is abundant since this nematode is unable to hydrolyze substances itself. In contrast, they found that *Neoechinorhynchus emydis* has a broad spectrum of APase activity. This may, in part, account for the more posterior concentration of *Neoechinorhynchus* spp. (i.e., most abundant in section 3) where APase activity would be less (5). It has been suggested that the location of telorchid trematodes posterior to the bile ducts (i.e., greatest frequency in sections 5 or 6 in this study) in the small intestine is related to their need to acquire essential substances from the host bile (21). The preference of *S. concinnae* for the large intestine, where it lives in the lumen, supports Mackin's (22) contention that the genus represents recent parasites which are similar to free-living species living in dung.

The frequency distribution of enteric helminths should be specific for each host species, and therefore considered to be a stable biological characteristic, as demonstrated for the nematode *Trichinella spiralis* (23). Recently, Ernst and Ernst (24) attempted to clarify the status of the turtle genus, *Chrysemys*, by using Sorenson's Index of Similarity to compare endoparasitic helminths found in the species of this genus. They assumed that the parasites were biological characteristics of the host. In addition to this use of host specificity, comparison of frequency distributions of shared species of enteric helminths in the *Chrysemys* complex may provide an additional biological characteristic for determining taxonomic relationships of turtles in this genus.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Dr. Arthur Johnson, Hendrix College, for providing housing and laboratory facilities for the field phase of this research. We thank Dr. Gerald Schmidt, University of Northern Colorado, for his assistance with helminth identification and general comments on the research. Dr. Terry Dick and Allan Shostak, University of Manitoba, provided valuable comments on the manuscript. This work represents a portion of an M.S. thesis completed by the senior author at Colorado State University in 1978.

LITERATURE CITED

1. Esch, G.W. and J.W. Gibbons. 1967. Seasonal incidence of parasitism in the painted turtle, *Chrysemys picta marginata* Agassiz. J. Parasitol. 53:818-821.

2. Esch, G.W., J.W. Gibbons and J.E. Bourque. 1979. The distribution and abundance of enteric helminths in *Chrysemys s. scripta* from various habitats on the Savannah River Plant in South Carolina. J. Parasitol. 65:624-632.

3. Gibbons, J.W. and G.W. Esch. 1970. Some intestinal parasites of the loggerhead musk turtle (*Sternothaerus m. minor*). J. Herpetology 4:79-80.

4. Schad, G.A. 1963. Niche diversification in a parasite species flock. Nature 198:404-406.

5. Uglem, G.L. and S.M. Beck. 1972. Habitat specificity and correlated aminopeptidase activity in the acanthocephalans *Neoechinorhynchus cristatus* and *N. crassus*. J. Parasitol. 58: 911-920.

6. Webb, R.G. 1961. Observations on the life histories of turtles (genus *Pseudemys* and *Graptemys*) in Lake Texoma, Oklahoma. Amer. Midl. Nat. 65:193-214.

7. Rosen, R. and W.C. Marquardt. 1978. Helminth parasites of the red-eared turtle (*Pseudemys scripta elegans*) in central Arkansas. J. Parasitol. 64:1148-1149.

8. Little, J.W. and S.H. Hopkins. 1968. *Neoechinorhynchus constrictus* sp. n., an acanthocephalan from Texas turtles. HELMSOC. 35: 46-49.

9. Margolis, L., G.W. Esch, J.C. Holmes, A.M. Kuris and G.A. Schad. 1982. The use of ecological terms in parasitology (Report of an ad hoc commitee of the American Society of Parasitologists). J. Parasitol. 68:131-133.

10. Sokal, R.R. and F.J. Rohlf. 1969. Biometry. W.H. Freeman and Co., San Francisco.

11. Esch, G.W., J.W. Gibbons and J.E. Bourque. 1979. Species diversity of helminth parasites in *Chrysemys s. scripta* from a variety of habitats in South Carolina. J. Parasitol. 65:633-638.

12. Hopp, W.B. 1954. Studies on the morphology and life cycle of *Neoechinorhynchus emydis* (Leidy), an acanthocephalan parasite of the map turtle, *Graptemys geographica* (Le Sueur). J. Parasitol. 40:284-299.

13. Hedrick, L.R. 1935. The life history and morphology of *Spiroxys contortus* (Rudolphi); Nemotoda: Spiruridae. Trans. Am. Microsc. Soc. 54:307-335.

14. Cheng, T.C. 1964. The Biology of Animal Parasites. W.B. Saunders Co., Philadelphia.

15. Rausch, R. 1947. Observations on some helminths parasitic in Ohio turtles. Amer. Midl. Nat. 38:434-442.

16. Johnson, C.A. 1967. Helminth parasites in turtles collected from farm ponds in Lee County, Alabama. J. Alabama Acad. Sci. 38:325.

17. Thatcher, V.E. 1954. Some helminths parasitic in *Clemmys marmorata*. J. Parasitol. 40:481-482.

18. Ernst. C.H. and R.W. Barbour. 1972. Turtles of the United States. The University of Kentucky Press, Lexington.

19. Crandall, R.B. 1960. The life history and affinities of the turtle lung fluke, *Heronimus chelydrae* MacCallum, 1902. J. Parasitol. 46: 289-307.

20. Brooks, D.R. and M.A. Mayes. 1975. Platyhelminthes of Nebraska turtles with descriptions of two new species of Spirorchiids (Trematoda: Spirorchiidae). J. Parasitol. 61: 403-406.

21. Wharton, G.W. 1941. The function of respiratory pigments of certain turtle parasites. J. Parasitol. 27:81-87.

22. Mackin, J.G. 1936. Studies on the morphology and life history of nematodes in the Genus *Spironoura*. Illinois Biol. Monogr. 52:1-64.

23. Dick, T.A. 1983. Species and infraspecific variation, pp. 31-73. In *Trichinella And Trichinosis*, ed. W.C. Campbell, Plenum Pub. Corp.

24. Ernst, C.H. and E.M. Ernst. 1980. Relationships between North American turtles of the *Chrysemys* complex as indicated by their endoparasitic helminths. Proc. Biol. Soc. Wash. 93:339-345.

VARIATION IN SEASONAL, SPATIAL, AND SPECIES COMPOSITION OF MAIN CHANNEL ICHTHYOPLANKTON ABUNDANCE, OHIO RIVER MILES 569 to 572

THOMAS P. SIMON
Large Rivers Larval,
Research Station
P.O. Box 727
Grayslake, Illinois 60030

ABSTRACT

Seasonal, spatial, and species composition of ichthyoplankton was investigated in 1983 in 3 main-channel stations on the Ohio River (River Mile 569 to 572). Specific objectives of this study were to determine the species composition of ichthyoplankton drift, to assess vertical distribution of taxa at 3 main-channel locations, and to consider temporal variations in abundance of fish eggs and larvae of main-channel species.

Ichthyoplankton drift was composed of 19 distinguishable taxa distributed among 8 families. Dominant taxa included the Clupeidae, Cyprinidae, and Catostomidae. The majority of ichthyoplankton collected in the Ohio River was distributed near the surface, with a small percentage found in mid-depth and bottom samples. The average density of larvae obtained from 12 sampling dates, from 30 April to 24 August, was 2.42 larvae/m^3 for the locations combined. Two peaks were observed during 1983, with the maximum density of 16.06 larvae/m^3 present on 25 June.

INTRODUCTION

The Ohio River has channeled waters of the midwest to the Mississippi River for over 200 million years. The present channel of the Ohio lies roughly at the edge of the southernmost extension of the last glacial invasion of North America.

The Ohio River valley has been drastically altered by man's activities in the watershed (1, 2). The initial clearing of large sections of forests for agriculture and the increase in the human population has changed the physical, chemical, and biological constituents of the Ohio River. The Ohio River valley contains one of the worlds greatest coal-producing regions, 3 major metropolitan areas, over 40 power plants, and numerous other large industries. The Ohio River basin incorporates 8 states and 14 major river systems draining approximately 528,000 km^2. The river carries over 150 million tons of waterborne cargo per year.

During the 1970's comprehensive studies designed to assess the impacts to early life-history stages of fishes from the operation of power plants and large industries were undertaken (3, 4) on the Ohio River. This paper presents data on patterns of larval fish abundance in 3 study locations within McAlpine Pool, a section of the Middle Ohio River. Such a study is basic to the understanding of main-channel utilization by larval fishes with regard to seasonal, spatial, and species variation trends.

STUDY AREA AND METHODS

The Ohio River has been converted from a free-flowing river with annual and seasonal variations in flow, depth, and width, to a river of relatively constant width and a minimum channel depth of 9 feet by the installation of a series of navigation dams. The basin-wide system of flood control reservoirs store flood water, and releases them slowly during the dry seasons, resulting in much lower flood crests, and much higher flows in late summer. The amount of rock, gravel, and coarse sand substrates have decreased, while increases have been observed in the amount of silt, fine sand and organic detritus. The construction of the navigation dams also inundated all of the original rapids and riffles of the river.

The present study area, situated in northcentral Kentucky, encompasses Ohio River Miles (ORM) 569 through 572, part of McAlpine Pool (Fig. 1). Ichthyoplankton sampling was conducted at three study locations in the main channel of the Ohio River on 12 dates from April through August 1983. The study site was selected because of the species diversity, and previous ichthyoplankton sampling was conducted in the vicinity (5, 6). The 3 sites were selected based on observed differences in depth, river width, and substrate composition. Station 1, located 183 m upstream of Big Saluda Creek, represented the furthest upstream location (ORM 569). The substrate consisted of hard clay during April and May, and during August was composed of rock gravel, silt, fine-sand, and clay. Station 1 had depths ranging from 4 m to 5.5 m, and a shoreline that was primarily cutbank. Station 2 was located 876.7 m below Little Saluda Creek near ORM 570.5, and was a wider section of the river forming a pool habitat.

A permanent base of large cobble and boulders was present, while April substrates were mostly composed of fine sand, silt, gravel, and to a limited extent clay; May and August substrates were composed of silt and accumulated detritus. Station 2 was the deepest location with depths ranging from 6.8m to 8.0 m and had a shoreline composed of rock rip-rap and decidous forest. Station 3, located near ORM 572, represented the farthest downstream location. Substrates included a permanent base of large cobble and boulders, with fluvial substrates in April composed of hard clay; in May accumulated silt and detritus formed over the hard clay, while in August the substrate composition included gravel, clay, and fine sand. Depths at station 3 ranged from 5 m to 6 m, and bluffs lined the shoreline. Current velocities were equivalent at stations 1 and 3, with station 2 having the slowest current of the 3 areas.

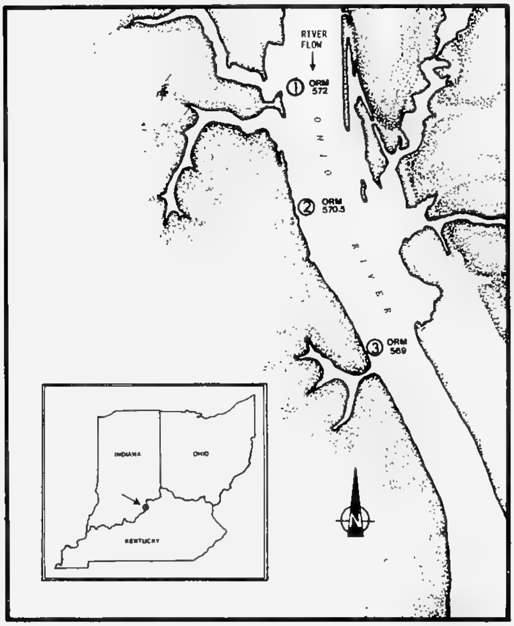


Figure 1. McAlpine Pool of the Ohio River Indicating Three Main-Channel Sampling Stations.

Biweekly samples were collected from each station during late afternoon from the 12 collection sites. Samples were collected at main-channel locations at the surface, mid-depth, and 1 m off the river bottom at each of 3 stations using paired 0.5 m diameter, conical nets with 560 micron mesh. Near-bottom sampling was facilitated by a weighted anchor to prevent accumulation of bottom sediments. Each tow was made 30 m off the Indiana shore in a upstream direction for a minimum of 5 minutes. A digital flowmeter was positioned in the mouth of the net to quantify the volume of water filtered. The volume ranged from 50 to 100 m^3. Appropriate collection information was recorded, physical features (Fig. 2), and the sample preserved with 10% formalin. Data were analyzed by standard analysis of variance.

RESULTS

Taxonomic Composition

Of the 9 distinguishable families in samples, members of the Clupeidae, Cyprinidae, and Catostomidae constituted 96% of the total catch (Table 1). Sciaenidae, Centrarchidae, Hiodontidae, Percidae, and Percichthyidae were sometimes common, but composed only 4% of the total catch. Lepisosteidae was represented by a single individual. Adult or

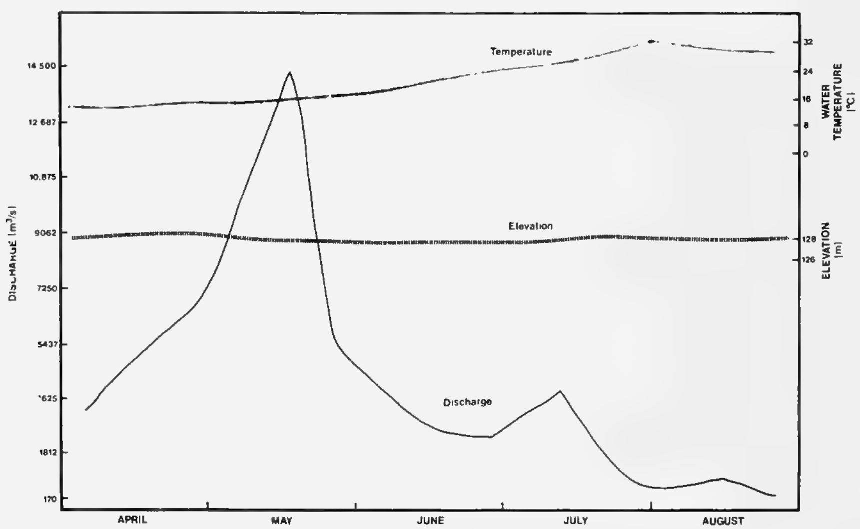


Figure 2. Discharge, River Stage, and Water Temperature at McAlpine Dam, Ohio River, during 1983.

juvenile blackbasses, *Micropterus* sp., catfishes *Ictalurus/Pylodictis* sp., topminnows, *Fundulus* spp., commonly occurred in the area, but larvae were not collected.

Table 1: Per cent Composition by Location of the Ichthyoplankton Fauna at Stations 1, 2, and 3 in Ohio River Miles 569 to 572.

	Per Cent Composition		
Taxa	*Station 1*	*Station 2*	*Station 3*
Longnose gar	—	—	< 0.1
Mooneye	0.2	0.2	0.1
Gizzard shad	72.8	78.6	64.1
Skipjack herring	0.1	0.4	0.9
Catostomus / Moxostoma spp.	< 0.1	< 0.1	—
Ictiobus / Carpiodes spp.	7.0	4.4	10.0
Carp	0.9	0.5	1.4
Emerald shiner	15.7	13.3	17.2
Cyprinid spp	0.8	0.3	0.8
White bass	0.3	0.1	0.2
Striped bass	—	< 0.1	0.2
Lepomis spp.	< 0.1	< 0.1	< 0.1
Pomoxis spp.	0.1	0.1	0.1
Stizostedion spp.	0.4	0.4	0.5
Orangethroat darter	< 0.1	< 0.1	< 0.1
Johnny darter	—	—	0.1
Logperch	< 0.1	< 0.1	< 0.1
River darter	—	0.1	—
Freshwater drum	1.6	1.5	4.1

Identification of the larvae of several families was facilitated because each family was represented by only a few species in McAlpine Pool: Sciaenidae (freshwater drum, *Aplodinotus grunniens*); Hiodontidae (mooneye, *Hiodon tergisus*, and goldeye, *Hiodon alosoides*; Clupeidae (gizzard shad, *Dorosoma cepedianum*, and skipjack herring *Alosa chrysochloris*); and Percichthyidae (white bass, *Morone chrysops*, yellow bass, *M. mississippiensis*, and striped bass, *M. saxatilis).* Although mooneye and goldeye have been reported from the pool (4), goldeye larva were not collected, identification was based on characteristics presented by Snyder and Douglas (7), Battle and Sprules (8), and Wallus (9). Hiodontids accounted for less than 0.2% of the total catch. Gizzard shad were much more numerous than skipjack herring and were separated based on the position of the yolk sac, the length at which fin rays developed while yolk was still present, and the number of preanal myomeres (10). Clupeids dominated the total catch, comprising 73.9% with gizzard shad accounting for 99.2% of the family. A three-species assemblage of percichthyids occured in McAlpine pool. Yellow bass were reported as occasionally occurring as far north as McAlpine pool (4) but were never collected, while white bass and striped bass were identified based on pigmentation, and differential postanal myomere counts. Specimens were verified by the Larval Fish Laboratory at Colorado State University, Fort Collins, Colorado. The percichthyids comprised 0.3% of the total catch.

Of the 18 species of cyprinids known to occur near McAlpine pool (4), common carp, *Cyprinus carpio*, emerald shiner, *Notropis atherinoides*, spotfin shiner, *N. spilopterus*, sand shiner, *N. stramineus*, mimic shiner, *N. volucellous*, spottail shiner, *N. hudsonius*, rosefin shiner, *N. ardens*, silver chub, *Hybopsis storeriana*, suckermouth minnow, *Phenocobius mirabilus*, bluntnose minnow, *Pimephales notatus*, creek chub, *Semotilus atromaculatus*, and blacknose dace, *Rhinichthyes atratulus* were identified in larva collections. However, consistent identification of cyprinid larvae, except those of common carp and emerald shiners, was not possible; consequently these other species were analyzed only at a family level. The cyprinidae accounted for 16% of the total catch with emerald shiners and carp accounting for 96% of the family.

Catostomid larvae collected in McAlpine pool included buffaloes, *Ictiobus bubalus* and *I. cyprinellus*; carpsuckers, *Carpiodes carpio*, and *C. cyprinus*; redhorses, *Moxostoma anisurum*, and *M. erythrurum*; and white sucker, *Catostomus commersoni*. The consistency of identification for these species was limited to the genera levels of *Ictiobus/Carpiodes* and *Catostomus/Moxostoma*. The family catostomidae accounted for 6.5% of the total catch, while the *Ictiobus/Carpiodes* spp. subgrouping comprised 99.9% of the family collected.

Centrarchids accounted for only a small portion of the total catch (0.1%). Adults of 3 genera, *Micropterus, Lepomis,* and *Pomoxis*, were common in the pool. Larvae of the genus *Lepomis* were a mixture of bluegill *L. macrochirus*, longear sunfish, *L. megalotis*, green sunfish, *L. cyanellus*, warmouth, *L. gulosus*, and orangespotted sunfish, *L. humilis*; bluegill larvae were most abundant in my collection. Both white crappie, *Pomoxis annularis* and black crappie, *P. nigromaculatus* were present, but most larvae were identified as white crappie. No black bass larvae were collected.

The larval percids collected included walleye and sauger, *Stizostedion* spp.; logperch, *Percina caprodes*; river darter, *P. shumardi*; johnny darter, *Etheostoma nigrum*; and orangethroat darter, *E. spectabile*. The family percidae comprised only 0.5% of the total catch, while *Stizostedion* spp. accounted for 78% of the family.

Seasonal and Spatial Distribution

Fish eggs and larvae were initially collected in late April although previous collection attempts were made. Eggs were collected regularly from 24 May until 24 August, while larvae were collected throughout the sampling period until 24 August (Table 2). Ichthyoplankton was most abundant in June. Five larval fish taxa were collected in April: the percids *Stizostedion* sp., logperch, river darter, and orangethroat darter and a single creek chub larva (water temperature 12.7°C). Numbers of taxa and numerical abundance increased with increases in temperature. Mooneye, *Ictiobus/Carpiodes* spp, carp, and white bass (14.4°C), gizzard shad and a johnny darter larva (17.2°C) were collected during May. The greatest abundance of larvae and a noticeable shift in species composition occurred in June. Freshwater drum, *Pomoxis* spp. and emerald shiner (17.2°C), skipjack herring (21.5°C), striped bass and *Lepomis* spp. (23.5°C), and longnose gar (25.9°C) first appeared during ichthyoplankton sampling in June. Egg and larval gizzard shad were collected from mid-May until late July (17.2°C to 30.2°C); freshwater drum were collected from early June until late July (19.1°C to 30.2°C); *Ictiobus/Carpiodes* spp. were collected from mid-May until late June (14.4°C to 25.9°C); while the cyprinids—emerald shiner occurred from early June until early July (19.1°C to 25.5°C), carp from mid-May until early July (14.4°C to 25.5°C), and cyprinid spp.—had the longest collection period, occurring from late April until mid-August (12.7°C to 29.5°C).

Of the main channel locations sampled during the present study, station 2 yielded the greatest average number of larvae (3.5/m³). Average densities at stations 1 and 3 were equivalent with 1.9/m³ and 1.8/m³, respectively. Station 2 accounted for 49% of the larvae collected, while stations 1 and 3 comprised 26% and 25%, respectively.

Spatial variations in larva abundance showed significant interactions ($P = 0.05$) with time of year. Larvae were first collected at upstream stations, which were discharged into by Big Saluda and Little Saluda Creeks. Larval orangethroat darters and creek chub larva were strays from the tributaries. Substrates preferred by river darters for spawning were present only at station 2, which included large cobble, boulders, moderate current, and gravel. As the season progressed, typical main channel species were collected at upstream locations, and utilized station 2 as a nursery habitat before being collected downstream at station 3. This was evident by the larger lengths and advanced development of larvae collected at stations 2 and 3 on similar collection dates. By mid-June, larvae were present in collections from all stations.

Two peaks were observed in ichthyoplankton sampling in the Ohio River (Fig. 3). On 24 May, larval fish densities were 1.4/m³, primarily because of the peak drift of *Ictiobus/Carpiodes* spp. (1.21/m³), and mooneye (0.06/m³). The second peak occurred on 25 June, which corresponded to the maximum average density observed, with 16.1/m³. This peak incorporated peak densities for skipjack herring (0.113/m³), carp (0.103/m³), emerald shiner (3.903/m³), striped bass (0.13/m³), and a large number of gizzard shad (13,431 larvae), which composed 74% of the drift on that date. Peak densities for gizzard shad drift was observed on 19 June (7.297/m³), as was fresh-

Table 2: Seasonal Distribution of Ichthyoplankton (number /m³) at Three Main Channel Stations, Ohio River Miles 569 to 572, from April to August during 1983.

	April			May			June			July			August		
	Station			Station			Station			Station			Station		
Species/Taxon	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Longnose gar	—	—	—	—	—	—	—	—	0.008	—	—	—	—	—	—
Mooneye	—	—	—	0.105	0.281	0.110	0.033	0.009	—	—	—	—	—	—	—
Gizzard shad	—	—	—	0.009	0.009	0.081	48.951	95.804	39.980	0.122	0.630	1.304	—	—	—
Skipjack herring	—	—	—	—	—	—	0.155	0.411	0.792	—	—	—	—	—	—
Catostomus/Moxostoma spp.	—	—	—	—	—	—	0.016	0.006	—	—	—	—	—	—	—
Ictiobus/Carpiodes spp.	—	—	—	5.664	8.228	7.236	0.291	0.271	0.541	—	—	—	—	—	—
Carp	—	—	—	0.286	0.378	0.392	0.358	0.372	0.666	—	—	0.009	—	—	—
Emerald shiner	—	—	—	—	—	—	9.716	16.319	11.457	—	0.040	—	—	—	—
Cyprinid spp.	0.010	—	—	—	0.009	0.036	0.621	0.311	0.427	0.026	0.032	0.093	—	0.010	0.010
White bass	—	—	—	—	0.011	0.009	0.066	0.104	—	—	—	—	—	—	—
Striped bass	—	—	—	—	—	—	—	0.161	0.164	—	—	—	—	—	—
Lepomis spp.	—	—	—	—	—	—	0.051	0.039	0.008	0.008	0.018	—	—	—	0.010
Pomoxis spp.	—	—	—	—	—	—	0.017	0.010	—	0.009	0.032	0.034	—	—	—
Stizostedion spp.	0.010	0.081	0.056	0.283	0.246	0.339	—	—	—	—	—	—	—	—	—
Orangethroat darter	—	0.023	0.011	0.010	0.028	—	—	0.010	0.011	—	—	—	—	—	—
Johnny darter	—	—	—	—	—	0.009	—	—	—	—	—	—	—	—	—
Logperch	0.010	0.078	0.053	0.012	0.053	—	0.020	—	—	—	—	—	—	—	—
River darter	—	0.011	—	—	0.023	—	—	—	—	—	—	—	—	—	—
Freshwater drum	—	—	—	—	—	—	1.081	1.619	2.726	0.035	0.028	—	—	—	—

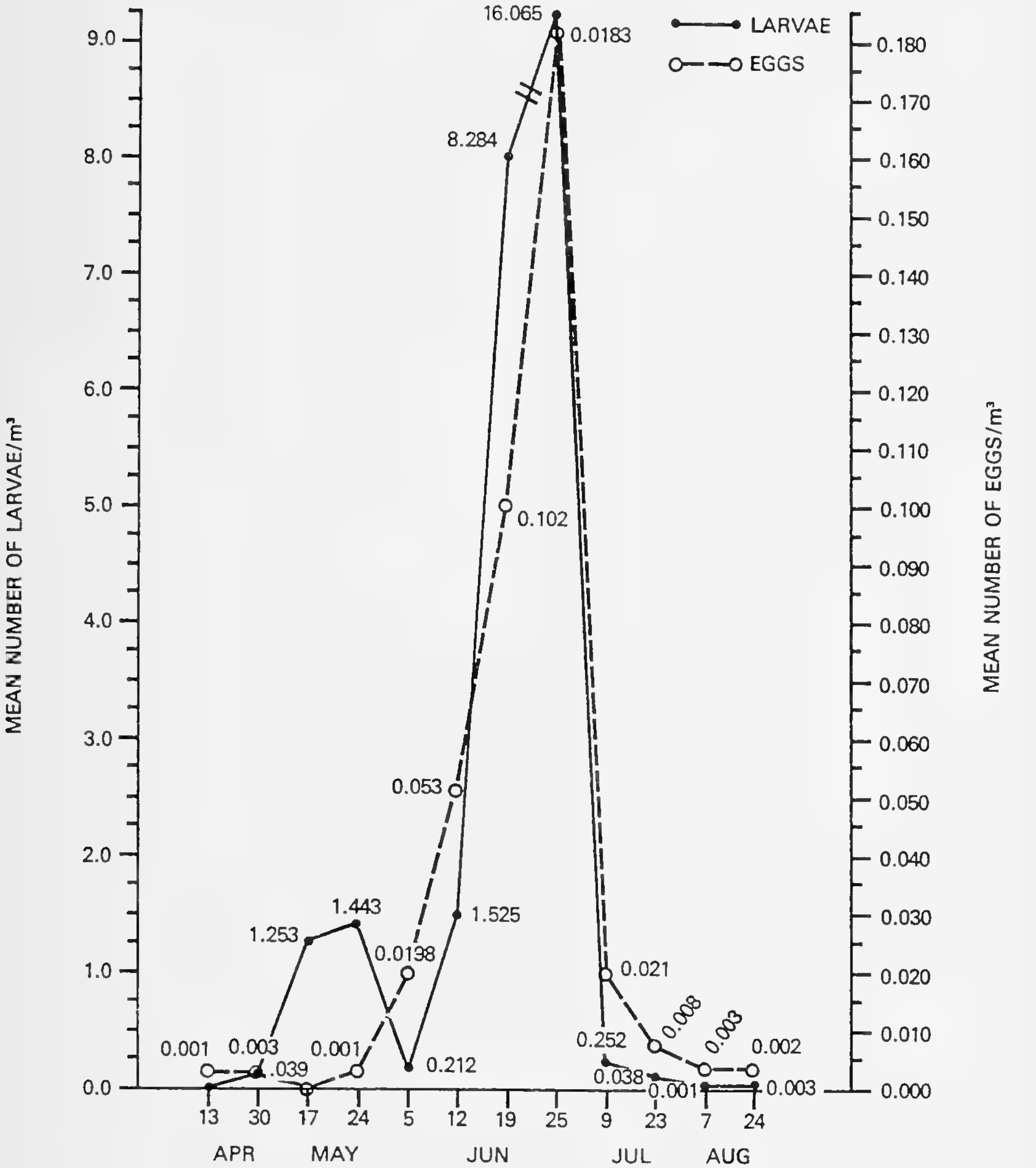


Figure 3. Mean Density of Ichthyoplankton Collected in McAlpine Pool, Ohio River, April through August 1983.

water drum ($0.50/m^3$), and white bass ($0.02/m^3$). Densities of larval fish on the Ohio River during 1983 averaged $2.42/m^3$ during ichthyoplankton collections in McAlpine Pool.

Vertical distribution of larval fishes was significantly greater ($P < 0.05$) in surface collections. The majority of larvae were collected near the surface, followed by mid-depth, and bottom (Table 3). Surface drift was observed for mooneye (69%), gizzard shad (90%), skipjack herring (74%), emerald shiner (87%), white bass (59%), *Pomoxis* spp. (55%), *Stizostedion* spp. (72%), logperch (57%), and orangethroat darter (66%). Carp and *Lepomis* spp. were most abundant at mid-depths. *Ictiobus/Carpiodes* spp. were equally distributed throughout the water column, while striped bass were collected mostly at the surface and near-bottom. Freshwater drum were found at mid- to near bottom depths. Significant surface differences ($P < 0.05$) were observed in vertical distribution trends for gizzard shad, skipjack herring, mooneye, and *Stizostedion* spp. (Fig. 4).

Table 3: Density of Larval Fishes (number/m³) at Surface, Mid-, and Bottom Depths at Three Main Channel Stations, Ohio River Miles 569 to 572, during 1983.

Species/Taxon	Station 1 - ORM 569			Station 2 - ORM 570.5			Station 3 - ORM 572		
	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom
Longnose gar	—	—	—	—	—	—	0.008	—	—
Mooneye	0.083	0.161	0.053	0.032	0.073	—	0.023	0.012	0.038
Gizzard shad	38.714	8.567	2.168	91.788	3.246	1.257	36.684	3.684	0.777
Skipjack herring	0.049	0.064	0.041	0.330	0.051	0.031	0.448	0.077	0.051
Catostomus/Moxostoma spp.	0.008	—	0.008	—	—	0.006	—	—	—
Ictiobus/Carpiodes spp.	1.852	1.933	2.178	2.717	3.225	2.599	2.782	2.776	2.366
Carp	0.130	0.291	0.223	0.238	0.223	0.290	0.242	0.425	0.332
Emerald shiner	8.899	0.943	0.892	14.630	0.775	0.974	9.941	0.643	0.874
Cyprinid spp.	0.070	0.370	0.216	0.271	0.107	0.076	0.253	0.240	0.088
White bass	0.096	0.063	0.008	0.099	0.016	—	0.065	0.084	—
Striped bass	—	0.008	—	0.141	0.014	—	—	—	0.156
Lepomis spp.	—	0.050	0.009	0.048	0.009	0.006	0.008	0.024	0.025
Pomoxis spp.	—	0.009	0.018	0.042	—	—	0.016	0.009	0.009
Stizostedion spp.	0.263	0.010	0.061	0.445	0.171	0.025	0.261	0.102	0.045
Orangethroat darter	0.010	—	—	0.061	—	—	—	0.022	0.013
Johnny darter	—	—	—	—	—	—	—	—	0.009
Logperch	0.020	0.022	—	0.076	0.012	0.053	0.044	0.032	—
River darter	—	—	—	0.022	0.012	—	—	—	—
Freshwater drum	0.046	0.432	0.639	0.155	0.848	0.644	0.058	1.528	1.141

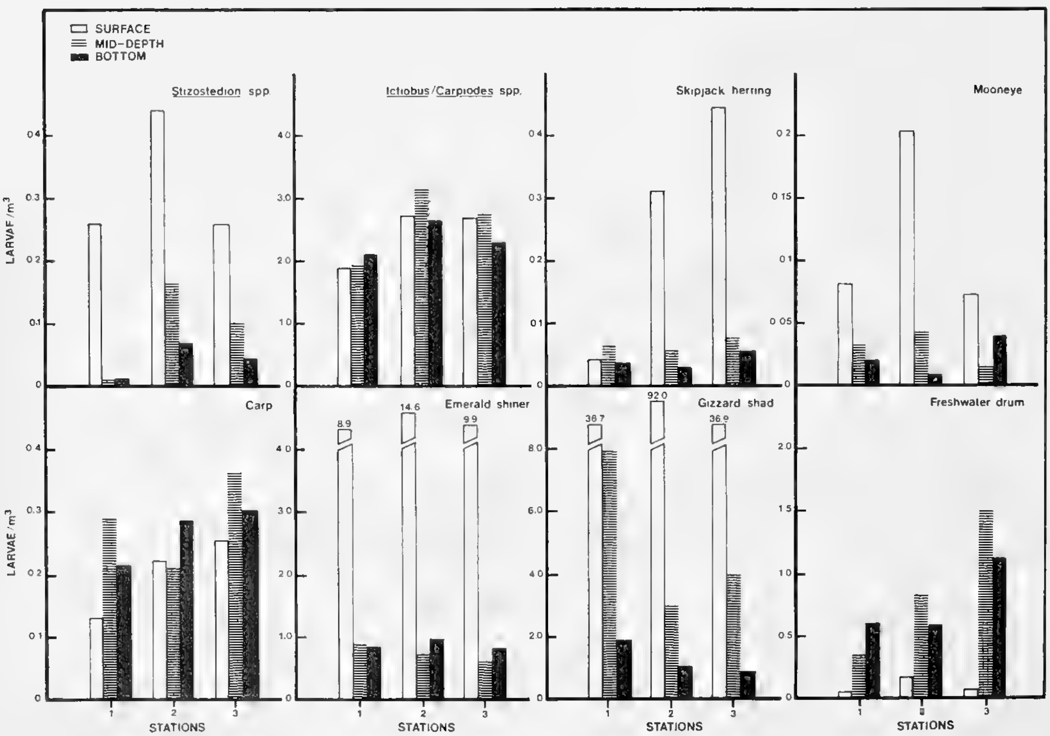


Figure 4. **Relative Abundance (number/m³) of Selected Species of Ichthyoplankton During Vertical Distribution Sampling at Three Stations in McAlpine Pool, Ohio River, 1983.**

DISCUSSION

The abundance of larval fishes of McAlpine pool were examined to detect significant seasonal, spatial, and taxon-specific variations. Previous studies conducted in McAlpine pool found similar dominance in taxon composition (4, 5); however, fluctuations were evident in per cent composition. The density of larvae is determined by a variety of factors: species reproductive capacities (11, 12); time of day or month sampled (6, 13); water temperature (14); and effort and gear efficiency (15, 16, 17). The distribution, species variation, and seasonal trends observed in the present study were similar to those reported by Clark (5), Gale and Mohr (15), Burch et al. (3), and Holland and Sylvester (13) in lotic systems, but different from Tuberville (18). Species chronology of appearance was earlier in Clarks' (5) study; however, correlations were equivalent if examining appearance based on water temperature.

Most of the species-specific data agree with published accounts (19, 20, 21). The present study disagreed with Kindschi et al. (22) and Cada and Hergenrader (23) on the vertical distribution of freshwater drum. They reported surface drift for freshwater drum. It was evident that the high percentage of prolarvae found by Kindschi et al. (96%) and the difficulty in collecting larger length intervals (23) was due to the neustonic newly hatched larvae of the freshwater drum not yet dispersing into the "normal" vertical drift pattern. Tuberville (18), Holland and Sylvester (13), and Matthews (24) found freshwater drum larvae primarily at depths below 3-6 m during daylight collections indicating a phototropic response. White bass larvae appeared later in Ohio River drift than in lacustrine studies (22). Kindschi et al. (22) reported 2 spawnings for white bass with the second reported spawning occurring at the observed time in the Ohio River. Riverine populations may be limited to a single spawn later in the season or an earlier spawning attempt was unsuccessful due to high discharges. Kindschi et al. (22) found white bass mostly near the bottom while the present study found white bass in surface collections.

Striped bass were previously unreported in larval collections from McAlpine pool. A total of 39 larvae were collected during 1983 indicating natural reproduction is occurring. Introduction of striped bass through an egg and larvae stocking program was initiated in 1968 by the Ohio Division of Wildlife, and the West Virginia Conservation Department (2). Spawning occurred later in the Ohio River than reported from the Potomac Estuary. Mihursky et al. (25) reported striped bass spawning at 14° C to 19° C. Larvae were collected in mid-to late June (23.5° C to 25.9° C), with peak drift observed on 25 June.

The large densities of ichthyoplankton observed at station 2 were twice that observed at stations 1 or 3. The river at station 2 does widen, has decreased current velocities, a variety of substrates providing numerous microhabitats, and serves as a spawning and nursery area for many large-river species. Increased densities were not apparent because of the rock rip-rap shoreline. Rock substrates should have provided increased spawning substrates for *Lepomis* spp, or *Pomoxis* spp., however, equivalent densities were observed at all stations. Inputs from Big Saluda and Little Saluda Creek populations were negligible since the major constituents of the catch were main-channel species (99%). Higher density values were the result of a successful spawning year and the utilization of the station as a nursery.

Diel variation was studied by Clark and Pearson (6), at RM 571 during a single date in May. They found no significant difference between surface: bottom distribution, but found significant differences in night densities for all larvae collected. They observed higher bottom densities than surface densities in most sampling periods. The diel sampling period in the current study did agree with Clark and Pearsons (6); however, observed tendencies in the present study were toward surface drift rather than bottom drift over season.

ACKNOWLEDGEMENTS

Appreciation is extended to Greg Seegert, Regional Director; and Randy Lewis, Senior Aquatic Biologist, EA Science and Technology for preliminary review of the manuscript, and to 2 anonymous reviewers for improvements of the revised draft. I would like to thank Beth Simon for preparation of Figs. 1, 2 and 4. Representative specimens from the current study were deposited with Robert Wallus at the Larval Fish Information and Identification Collection (LFIIC), Tennessee Valley Authority, Norris, Tennessee.

LITERATURE CITED

1. Gammon, J. R. 1977. The status of Indiana streams and fishes from 1800 to 1900. Proc. Ind. Acad. Sci. 86:209-216.

2. Trautman, M. B. 1981. The fishes of Ohio. Ohio State University Press, Columbus, Ohio.

3. Burch, O. S., D. Marguiles, B. F. Clark, G. R. Finni, and B. L. Huff. 1981. Temporal and spatial distribution patterns of ichthyoplankton: Ohio River Ecological Program 1976-1978.

Rapp. P.-v. Reun. Cons. int. Explor. Mer. 178: 163-164.

4. Pearson, W. D. and L. A. Krumholz. 1984. Distribution and status of Ohio River fishes. Water Resources Laboratory: Louisville, KY. ORNL/Sub/79-7831/1.

5. Clark, A. L. 1979. Temporal and spatial distribution of ichthyoplankton at Ohio River Mile 571. Masters thesis, Univ. Louisville, Louisville, KY.

6. Clark, A. L., and W. D. Pearson. 1980. Diurnal variations in ichthyoplankton densities at Ohio River Mile 571. Trans. Ky. Acad. Sci. 41: 116-121.

7. Snyder, D. E. and S. C. Douglas. 1978. Description and Identification of Mooney, *Hiodon tergisus*, protolarvae. Trans. Am. Fish. Soc. 107:590-594.

8. Battle, H. I. and W. M. Sprules. 1960. A description of the semibuoyant eggs and early developmental stages of the goldeye, *Hiodon alosoides* (Rafinesque). J. Fish. Res. Bd. Can. 17:245-266.

9. Wallus, R. (unpublished). Larval development of *Hiodon tergisus* LeSueur with comparisons to *Hiodon alosoides* (Rafinesque). Tenn. Acad. Sci.

10. Hogue, J. J., Jr., R. Wallus, and L. K. Kay. 1976. Preliminary guide to the identification of larval fishes in the Tennessee River. Tenn. Valley Authority, Norris, Tenn. Tech. Note B19. 1-66.

11. Lewis, S. L. 1969. Physical factors affecting fish populations in pools of a trout stream. Trans. Am. Fish. Soc. 98:14-19.

12. Bidgood, B. F. 1974. Reproductive potential of two lake white fish *(Coregonus clupeaformis)* populations. J. Fish. Res. Bd. Can. 31: 1631-1639.

13. Holland, L. E. and J. R. Sylvester. 1983. Distribution of larval fishes related to potential navigation impacts on the Upper Mississippi River, Pool 7. Trans. Am. Fish. Soc. 112(2B): 280-285.

14. Graser, L. F. 1979. Spatio-temporal distributions of clupeid larvae in Barkley Reservoir Pages 120-138. *In* R. D. Hoyt (ed) Proc. Third Symp. Larval Fish. Western Ky. Univ., Bowling Green, KY.

15. Gale, W. and H. Mohr, Jr. 1978. Larval fish drift in a large river with comparisons of sampling methods. Trans. Am. Fish. Soc. 107:46-55.

16. Thayer, G. W., D. R. Colby, M. A. Kjelson, and M. P. Weinstein. 1983. Estimates of larval-fish abundance: diurnal variation and influences of sampling gear and towing speed. Trans. Am. Fish. Soc. 112:2B72-279.

17. Gallagher, R. P. and J. V. Conner. 1983. Comparisons of two ichthyoplankton sampling gears with notes on microdistribution of fish larvae in a large river. Trans. Am. Fish. Soc. 112:272-279.

18. Tuberville, J. D. 1979. Vertical distribution of ichthyoplankton in Upper Nickajack Reservoir, Tennessee. Pages 185-203. *In* R.D. Hoyt (ed). Proc. Third Symp. Larval Fish. Western Kentucky University, Bowling Green, Ky.

19. Netsch, N. G., G. M. Kensh, Jr., A. Houser, and R.V. Kilambi. 1971. Distribution of young gizzard shad and threadfin shad in Beaver Reservoir. Am. Fish. Soc. Spec. Pub. 8:95-105.

20 Edwards, T. J., W. H. Hunt, and L. L. Olmsted. 1977. Density and distribution of larval shad *(Dorosoma* spp) in Lake Norman, North Carolina, entrainment at McGuire Nuclear Station. Pages 143-158. *In* L. L. Olmstead (ed.) Proc. First Symp. Freshwater Larval Fish. Duke Power Company, Huntersville, NC.

21. Krause, R. A. and M. J. Van Den Avyle. 1979. Temporal and spatial variations in abundance and species composition of larval fishes in Center Hill Reservoir, Tennessee. Pages 185-203. *In* R. D. Hoyt (ed) Proc. Third Symp. Larval Fish. Western Kentucky University, Bowling Green, KY.

22. Kindschi, G. A., R. D. Hoyt, and G. J. Overman. 1979. Notes on the life history of fishes in a small flood control lake in Kentucky. Pages 139-166. *In* R. D. Hoyt (ed) Proc. Third Symp. Larval Fish. Western Kentucky University, Bowling Green, KY.

23. Cada, G. F. and G. L. Hergenrader. 1980. Natural mortality rates of freshwater drum larvae in the Missouri River. Trans. Am. Fish. Soc. 109:479-483.

24. Matthews, W. J. 1984. Influence of turbid inflows on vertical distribution of larval shad and freshwater drum. Trans. Am. Fish. Soc. 113: 192-198.

25. Mihursky, J. A., E. M. Setzler-Hamilton, F. D. Martin, and K. V. Wood. 1982. Spatial and temporal patterns of springtime utilization of the Potomac Estuary by fish larvae. Pages 20-27. *In* C. F. Bryan et al. (eds) Fifth Annual Larval Fish Conf., Baton Rouge, LA.

RESOLVING LOCATIONAL CONFLICT IN PUBLIC TRANSPORT BY VOTER REFERENDUM: A STUDY OF THE LEXTRAN ISSUE

by

Stanley Jaworowski

Department of Geography
University of Kentucky
Lexington, Kentucky 40506

Robert G. Cromley

Department of Geography
University of Connecticut
Storrs, Connecticut 06268

and

Thomas R. Leinbach

Department of Geography
University of Kentucky
Lexington, Kentucky 40506

ABSTRACT

Public transportation policy has become a source of community conflict because spatially distributed social groups perceive differential utility in alternative modes of transport services. This paper examines the resolution of this conflict in Lexington, Kentucky in terms of support for the Lextran referendum, in which voters were asked to approve a payroll tax deduction to maintain the local transit authority. Results indicate that pro-Lextran support was a function of socioeconomic status and demographic factors. Areas with a higher concentration of elderly and lower socioeconomic groups gave greater support to the referendum. The correlations between support and neighborhood characteristics pose problems for the future of providing public transit by electoral consensus as those who are most adversely affected by service cuts are least likely to voice public opinion on the issue.

INTRODUCTION

One of the major problems facing American metropolitan areas today is providing adequate circulation of people and resources within the urban environment. The improvement of transportation facilities are often accomplished by allocating public monies according to transportation policies that exist within municipalities. Public transportation policy becomes a source of community conflict because resources available for construction and maintenance of facilities are limited. The allocation of these funds is in part dependent on how forecasted improvements will generate benefits to the population as a whole. Any predicted benefits will differ by the importance attached to specific aspects of transportation provision. Because the selection of community goals is reflected in transportation policy, the decision making process is a political one.

Conflict occurs as spatially distributed social groups perceive differences in utility obtained by alternative types of service. Travel needs are spatially variable and reflect residential patterns that exist in the city. The perceived utility of alternative modes is consistent with the shared situational characteristics of residents in these social areas. These characteristics help define the probability of auto use and ownership, and the degree of dependence on mass transit. Attitudes regarding the distribution of transport service expenditures differ among spatially distinct social groups that view the allocation of transport monies as either promoting or reducing their mobility and accessibility to points within the city.

The objective here was to examine the basis of this conflict in Lexington, Kentucky and to measure aggregate perceptions of utility in terms of support for the Lextran referendum, in which voters were asked to approve a payroll tax deduction to maintain the local transit authority. The rational voter model, that states that citizens will vote in favor of proposals that provide greater perceived benefits than personal liabilities, is used to gain insight into the areal distribution of voter response to mass transit issues. The benefits of an improved mass transit system are weighed against the increased tax burden by the citizen-consumer. Actual results of the referendum are compared against expected support, given the socioeconomic characteristics and proportion of transit dependents among different voter precincts.

SPATIAL VOTER RESPONSE AND PUBLIC EXPENDITURE

The distribution of transportation, like all municipal services, can be viewed as "a package of goods and services allocated to sociospatial groups within the city (2)." The internal spatial organization of the urban environment assures differences in mode and destination demand. These differences are potentially manifested in 2 respects as the voter reveals preferences for collective goods. First, the consumer can realize preferred political expenditure patterns by selecting a community of residence where taxation and spending allocations are consistent with his own. According to Tiebout (3), community differences are based upon several factors. Voters recognize differences in service provision among communities; communities also recognize optimal conditions for providing established service priorities and attempt to limit or increase population within the community to provide them in the most efficient manner. Additionally, given a choice of communities, the consumer will choose the one with the closest approximation of his preference. In selecting a residential location, the consumer maximizes his well-being through spatial mobility within the constraints of the market.

Secondly, a voter within a community expresses a preference for certain types of expenditures by voting for those proposals that promote his own economic self-interest. The decisionmaking process is based upon those inputs that affect perceived utility. Deacon and Shapiro (4) concluded that voter acceptance of transit systems are based on perceived individual economic self-interest. Voter decisionmaking on transit referenda was consistent with attitudes exhibited in other situations, and "results obtained cast doubt upon the notion that individuals somehow alter their preference (or behavior) away from selfishness and toward the social good as they leave the market and enter the polling booth (4)."

TRANSPORTATION AND THE URBAN ENVIRONMENT

Transportation is an integral force in establishing patterns of residential differentiation; the physical separation of varying socioeconomic groups is a product of perceived residential opportunity. The utility of any location is assessed by a potential resident not only in terms of the attributes of an individual location but on others adjacent to it (5). A desire exists to achieve the greatest possible physical distance from socially undesirable facilities or neighbors within the budget available for housing (6). Use of the automobile has increased the availability of residential land that is feasible for travel between the home and places of employment, shopping and other needs. As such, middle and upper socioeconomic groups can afford to live at greater distances in lower density levels given an adequate highway system (7,8). Past policy at various government levels emphasizing auto travel reinforces residential segregation, while simultaneously acting as an agent of urban dispersal. Auto use is essential to the existence of low-density residential areas and it is the primary mode of transport in these areas (9).

The auto-based transport system has produced the morphological foundation for contemporary urban America. However, as the middle and upper classes have moved from the original city core, the minorities, the poor, and the elderly have grown increasingly isolated in inner-city neighborhoods. The transport needs of these residents are usually measured in terms of auto availability which depends primarily on income and the ability to drive. By providing these citizens with some degree of mobility, public mass transit produces positive externalities, such as accessibility to manufacturing sites that can reduce unemployment levels (10).

A distinct difference in travel demand by mode exists throughout the urban areas; the dispersal of commercial facilities and the concentration of transit dependents creates locational conflict in providing adequate transport facilities to all residents of the metropolitan region. Any acceptance of the notion that all citizens are entitled to a minimum level of mobility is complicated by the reality of limited transport expenditures. While the utility of public transit is largely dependent on the ability to procure alternative means of travel, the assessment of that utility is likely to vary among the spatially segregated residential groups. The distribution of limited transit funds produces competition between transit dependent populations who perceive a loss of the mobility provided by publicly supported mass transit and suburban residents who have have little need for public transit and prefer a proportional increase in roadway construction.

Until recently, public policy has addressed the situation as maintaining reasonable levels of traffic flow. Since the automobile became the preferred mode of intraurban travel, mobility has been expressed in terms of traffic volumes and road capacities (7). Social costs involved in providing transportation, such as the auto's effect on urban form, land consumption, increased air and noise pollution, and the destruction of residential neighborhoods for road construction were rarely recognized or considered (11). As a result, auto use was supported and encouraged by all citizens through public policy, and the costs in terms of both social costs and physical construction were borne by all taxpayers, not just the individual car user. Recognition of past policy inadequacies suggests reassessing all costs as the basis for determining the utility of alternative modes of travel. Ideally, this requires measuring the level of mobility provided by differing modes, and matching available supply with a socially acceptable level of mobility for all area residents. However, this requires a public consensus that inadequacies do exist and that certain solutions are more socially acceptable. If conflict exists among various portions of the population, it must be resolved through the political process. Increasingly at the local level, that means the passage or defeat of initiatives supporting the allocation of public funds for transportation projects. As an analysis of the Lextran issue demonstrates, public support of mass transit is highly segmented and highly resistant to increased taxes.

THE LEXTRAN ISSUE

Transit service in Lexington, Kentucky dates back to the streetcar era when it was the first system in the country to completely electrify its lines. In 1937, streetcars were replaced by motor coaches, and since then bus service has been the only form of mass transit available in Lexington. Routes have consistently formed a radial pattern focused on the central business district (CBD), and route-mileage extensions were accomplished by merely adding service to more distant points along major arterials.

Since public takeover in 1973, bus service has operated through a combination of rider fares and government subsidies. Although ridership stablized and improved during the 1970s, increases in revenue were countered by higher operating costs. In 1968, the system cost $991,000 to operate; by 1978, this expenditure has increased to $2.1 million. Local municipal contributions increased somewhat but did not begin to meet the local subsidy necessary to obtain federal funds. By September, 1980, it became apparent to Lextran officials that local revenues would be 8.0% short of the amount necessary for the matching federal funds needed to balance the budget. Despite a fare increase to 50¢ in that month, a $107,000 shortfall in revenues was anticipated. Expectation of the deficit prompted Lextran officials to submit a 0.142% payroll tax proposal to county residents on the fall ballot.

The Lextran payroll tax and a property tax proposal to support the Lexington Public Libraries were the first referenda on the ballot in 23 years. This method was prompted in part by an inability to secure further funding from any other source. Lextran officials preferred the payroll tax to other tax schemes because it was perceived to be less regressive than property taxes. In public opinion polls, payroll taxes are generally preferred to sales taxes but are less popular than property taxes (12).

The fiscal crisis was publicized by the local papers and reports on Lextran meetings with local citizen groups received favorable coverage, despite consistently low attendance. Editorial support was given by both local newspapers; this support was in contrast to the editorial opposition to the proposed library tax by both papers. Lextran's annual advertising budget of $1000 was spent prior to the vote in an attempt to promote a positive image. A "Lextran Fact Sheet" brochure and slide show were prepared for the modest campaign. Advertising posters were obtained for free and posted on the sides of buses. On the posters, a silhouette of a bus was pictured with a red 'X' marking its extinction if the tax failed.

Although no organized political opposition existed, support for the tax was sparse. The mayor remained uncommitted on the issue, and the urban county council support was split. A pre-election poll conducted by one paper predicted defeat of the tax. (13). This prediction was fulfilled in the November election when the transit payroll tax was defeated by a significant majority. Citywide, a total of only 37% of the voters supported the levy. In only 30 of the 158 precincts did a majority of residents vote for transit subsidy.

A SPATIAL ANALYSIS OF THE LEXTRAN VOTE

Many studies have attempted to explain voter attitude by weighing accrued advantages of the proposed legislation against liabilities or taxes borne by the voter (14). For a "rational voter," the decision making process is based on those inputs that affect his perceived utility (1).

The identification of these inputs provides a basis for determining the propensity to support a public good.

If the voter attitudes vary spatially, an areal analysis of support for a transit referendum should correlate with the characteristics of an area's population. A general assumption of pro-Lextran support is that it will come from those areas that contain transit dependent populations. Housing and population characteristics provide an indication of social status within tract boundaries. It is expected that as status increases, the propensity of that area to support transit will decrease, due to less use and dependence on the system. Another factor that may motivate population groups to subsidize the Lextran system is the distance to the city center or the university area. Residents of more distant suburbs are expected to obtain goods and services in suburban locations, and are less likely to travel to the CBD. An inverse relationship between distance from the city center and Lextran support is expected. Lastly, economic status determines tax liability: studies cited have indicated that advantages derived by residents are weighed against tax burden in the voter decision making process. As income increases, there is a decreasing probability that residents will use the transit system, yet they will be paying more to support it. Therefore, it is expected that economic status and support will be negatively correlated.

To test the impact of geographically distributed socioeconomic factors on the results of the Lextran referendum, social areas were first identified using factor analysis. Data were collected for the 42 census tracts in Lexington, as compiled in 1970 (Fig. 1): a total of 25 variables were chosen to measure socioeconomic characteristics as represented by demographic factors and features of housing units (Table 1).

Figure 1. Census tract map of Lexington, Kentucky.

Table 1

	Socio-economic and Housing Variables
1	Total Population
2	Total Employment
3	Median Value Owner Occupied Homes
4	Median School Years
5	Percent Black
6	Median Family Income
7	Percent Owner Occupied Dwellings
8	Percent Employed Professional
9	Percent White Collar
10	Percent Clerical
11	Percent Sales
12	Percent Craftsmen
13	Percent Laborers
14	Percent Service Workers
15	Percent Population over 65 Years Old
16	Percent Population under 5 Years Old
17	Housing Built before 1950
18	Housing Built after 1950
19	Percent Women over 16 Employed
20	Percent Below the Poverty Level
21	Percent Population under 18 Years Old
22	Women as Heads of Household
23	Percent of Females in Workforce
24	Percent Unemployment
25	Median Persons per Unit, All Occupied Units

A Varimax rotation was employed to produce the best orthogonal group representation for the most important factors. Three interpretable factors were produced. Although the fourth factor had an eigenvalue of 1.7, the distribution of significant loadings were not consistent and could not be summarized. The factors, loadings, and communalities are given in Table 2.

The first factor is an indicator of socioeconomic status; strong positive correlations are shown with median family income (0.938); median school years (0.868); white collar (0.831), sales (0.774) and professional (0.725) occupations. Higher income and status correspond with higher rates of home ownership (0.696), less ownership of older homes (-0.709) and homes built after 1950 (0.581).

Low-income occupations, laborers and service workers, scored high negative correlations. Per cent of the population below the poverty level, -0.897, also loaded very negatively on factor 1, as did unemployment (-0.864). Per cent black (-0.719) is a socioeconomic indicator as it indicates a lower status.

Demographic variables are less outstanding, yet reinforce notions of socioeconomic status. The tendency of persons over 65 to score low (-0.534) reflects lower income; the negative correlations of per cent women employed (-0.394) and women as household heads (-0.645) indicates lower economic status. Percentage of women as part of the workforce, however, correlates positively (0.328).

Table 2

Summary of the Lexington Factor Analysis (Rotated Loadings)

	Factor 1	Factor 2	Factor 3	Communalities
1. Population		0.491	0.628	0.662
2. Employment		0.529	0.672	0.767
3. Median Value Unit	0.816			0.894
4. Median School Years	0.868	0.317		0.929
5. Percent Black	-0.719		0.406	0.737
6. Median Family Income	0.938			0.938
7. Percent Owner Occupied	0.696	-0.352		0.617
8. Percent Professional	0.725	0.377		0.787
9. Percent White Collar	0.831			0.721
10. Percent Clerical	0.570	0.309		0.526
11. Percent Sales	0.774		0.649	
12. Percent Craftsmen		-0.506		0.625
13. Percent Laborers	-0.883			0.879
14. Percent Service Workers	-0.951			0.913
15. Percent Population Over 65 Years	-0.534	0.453	-0.340	0.608
16. Percent Population Under 5 Years		-0.697	0.443	0.685
17. Homes Built Before 1950	-0.709	0.434		0.705
18. Homes Built After 1950	0.581		0.453	0.532
19. Percent Women Employed	0.394	0.601		0.665
20. Percent Living Under Poverty Level	-0.897			0.942
21. Percent Population Under 18		-0.882	0.395	0.925
22. Percent Female Heads of Household	-0.645		0.536	0.792
23. Percent Women in the Workforce	0.328		0.527	0.743
24. Percent Unemployment	-0.864		0.527	0.882
25. Median Value Per Unit				

Interpreted spatially (Fig.2), the most extreme factor scores occur in tract four (3.20) and tract ten (2.12), both areas of public housing projects, as well as areas of general decay. Low socioeconomic status, measured in high factor scores, is basically centered around the downtown area, especially to the north and east. Middle levels are indicated in the university area, tracts adjacent to downtown on the south side, and outlying areas to the northwest and east. Upper socioeconomic encompasses most of the southern one-third of the city as well as outlying areas to the north. Extremely high status areas are along Richmond Road, in tract 17, along Leestown Pike in tract 22, and in southern fringe developments in tract 41. Incomplete data in tract 21 is probably due to few residential developments and heavy industrial location; in tract 12, the Eastern State Hospital and associated facilities seem to dominate the area. These tracts are excluded in all factors.

The second factor is a measure of family life cycle or family status. High loadings on the factor indicate high numbers of elderly (0.453); high negative loadings denote high numbers of children; population under 18 (-0.822) and under 5 (-0.679) illustrate the number for this factor. Houses built before 1950 have a loading of 0.433; there is also a tendency for fewer persons per dwelling (-0.795).

Total employment (0.529), and types of employment that receive positive loadings on factor 2 reflect the types of employment one

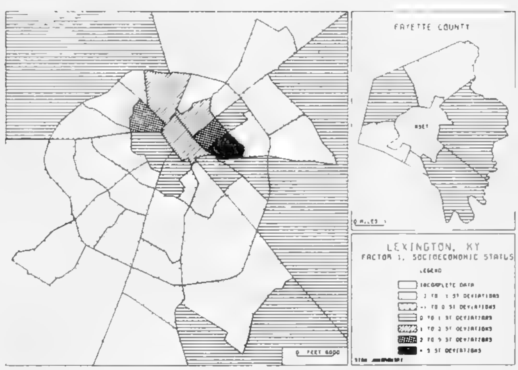


Figure 2. Spatial Distribution of factor one.

might expect of a more mature population to hold, albeit a successful mature population. Per cent women employed shows a relatively high degree of correlation (0.601), again demonstrating a lack of child related activities.

This demographic factor demonstrates the lack of family oriented activities in the university area, as well as older neighborhoods in the north and south of downtown (Fig.3). Highest family status correlation lies in newer subdivisions around the city periphery, and census tract 4, an area of public housing projects.

The third factor is less readily interpretable, but appears to be an indicator of race and

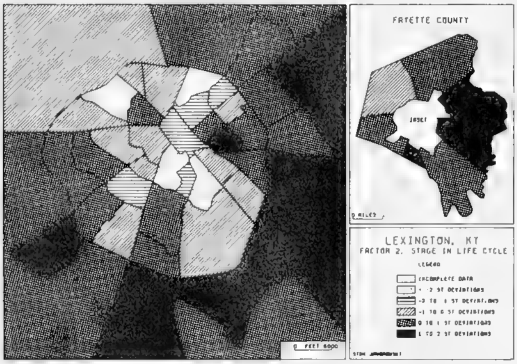


Figure 3. Spatial factor of two.

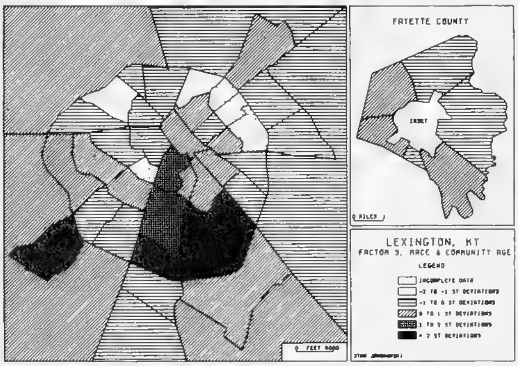


Figure 4. Spatial Distribution of factor three.

population characteristics. Communities that score low on factor 3 (Fig. 4) tend to have a higher percentage of residents that are black (0.406), and that have women household heads (0.536), and have a large per cent of women in the workforce (0.527). Children, both under 5 (0.443) and under 18 (0.395) load positively, while the elderly (-0.340) do not. Employment and population also have considerable impact on the factor, suggesting that even though absolute numbers were used in these categories, higher numbers reflect higher densities.

To determine the relationships between Lextran support and areal social characteristics, voting patterns were regressed against the factor scores. Support for the referendum is measured by the proportion of voters that favored the subsidy. Socioeconomic status, life-cycle stage, and ethnicity-population are used to explain variation in the electoral results. Examination of patterns of favorable Lextran votes and of large residuals of support are used to test the hypothesis of spatial conflict in transit support.

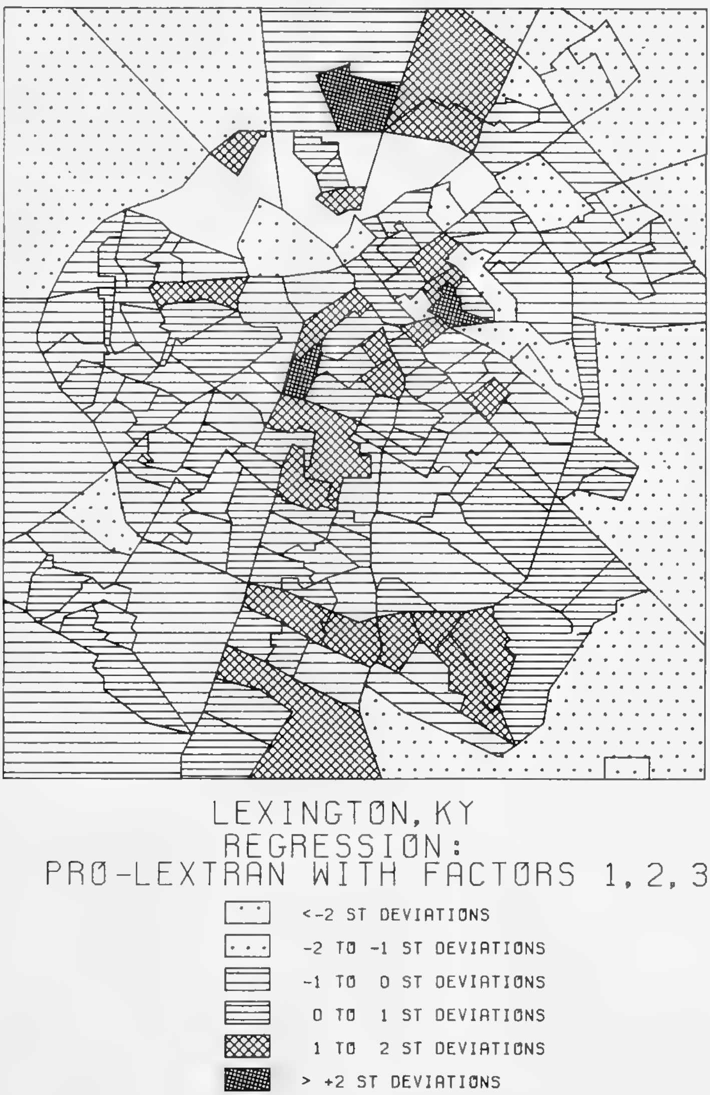
Socioeconomic status provides a negative relationship with pro-levy votes in the Lextran referendum. The standardized beta value is positive because high factor scores indicate low status. It is consistent with the hypothesis that increased SES translates into less transit support, yet the potential effect of SES is difficult to predict. It can be argued that tax liability discourages upper socioeconomic class members from voting for subsidy or that their group is far less likely to use transit. Conversely, higher education and greater access to information sources could enlighten the more affluent to advantages stemming from a healthy mass transportation service in their community. Intuitive notions of poorer areas supporting transit in greater proportions than the rich are substantiated to some degree.

Position in family life-cycle was inversely related to a pro-Lextran referendum vote. Areas of high family status reflected negative opinion on the proposed levy. This relationship substantiates the presumption that single and elderly persons, often living in central city and university locations, perceive self-benefit emerging from an improved transit system. Suburban areas with high family status have, for the most part, less need for Lextran services than central city residents. Auto availability is more likely, and the system's radially oriented route pattern centered on the downtown area does not serve the majority of transportation needs in suburban areas.

The weaker direct association between scores for the factor that represents ethnicity and population with pro-Lextran votes was unexpected; the beta coefficient of 0.129 is relatively unimportant. Higher factor scores indicate fewer minority residents. Thus, the expected relationship is not substantiated.

Since only 49% of the variation in Lextran support was explained by the 3 explanatory variables, the pattern of residuals was examined (Fig. 5). Areas of high positive and negative residuals represent locations of unusual variation from the predicted level of support; such patterns can of course reveal possible spatial and systematic influences that affect voter response (Fig. 5). Generally, the dichotomy of opinion between inner city voters and suburban ones is reflected in these areas of high residuals. Although inner city areas with high minority concentrations were expected to support the referendum in greater proportion than others, precincts had considerably higher observed values than predicted. Areas in the north end of town with a high proportion of minority residents also voted in higher numbers than expected.The Oakwood and Green Acres precincts, outside of New Circle Road also contain many multiple dwelling units, indicating a generally lower status; Terrace View precinct, on Versailles Road, also contains many apartment buildings. The university area is bounded by areas of unexpectedly high support. The spatial influence of that institution on voter response is felt not only in student residential neighborhoods, but in suburban areas directly to the south, suggesting that university staff and commuters could value transit as a viable transportation means. Distance to these sites is relatively short, and differences in travel time between home and office is compounded less by transit use. On the south end of town, areas bordering New Circle Road with more recent, higher density development again support the tax in higher numbers than expected, as did the Gainesway area. The overall pattern of high positive residuals follows a very general north-south axis, passing through the downtown area. North of the CBD, areas of high density development, low socioeconomic status, and high minority residents voted in greater proportion in favor of the tax than expected. The university effect and areas containing apartment complexes exerted a similar but lesser effect on the south side of town.

Areas of high negative residuals were more geographically dispersed. Generally, the probability of observed support being less than predicted increased with distance from the CBD. The Walnut Hill precinct, in the distant southwest portion of the county near Athens, displayed one of the greatest residual values. Loudon precinct, on the near north side adjacent to many of the areas of highest support produced the other large residual. Residents of this working class area may have been particularly wary of the proposed tax.



The pre-election poll indicating greatest opposition in the $10,000 to $15,000 income bracket, especially by those with a limited education, seems applicable in these areas of lower income working class residents.

SUMMARY

The description and analysis of voter behavior on the Lextran referendum has examined the spatial distribution of political attitudes. Behavior is a function of shared characteristics that are spatially patterned in the urban environment, and the correlations between areal characteristics and voting patterns demonstrate some consistency between them. In the Lextran referendum, the differences in transportation demand are affected by the socioeconomic and demographic factors indicated in social areas by the analysis. Areas that are most likely to contain transit dependents were also areas that supported the Referendum. It is difficult to separate the effects of distance from the CBD as a potential influence from the characteristics that indicate transit dependence because concentrations of people likely to use transit occur in communities near the city center. A definite dichotomy in suburban and inner city voting patterns does exist, and residential characteristics like lower percentage of home ownership and the presence of multi-family housing units do correspond with increased transit support.

These correlations pose problems for the provision of public transit by electoral consensus. The use of the referendum process to decide an issue like transit support can be questioned when the service is of value to a minority within the community. In the Lextran referendum the inequity of the electoral system in this decision making process is particularly biased. Lextran ridership surveys show that 80% of its riders are transit dependent, in terms of employment or other ride purposes; 37% own no automobiles; 66% of all riders are women, and 12% are elderly and handicapped. Presumably, these segments of the population will feel service cuts most of all; but because these persons are least likely to voice public opinion on the transit issue, they exert the least amount of control over the facility that they use most. As the federal government turns more transit programs over to states and localities, the interests of many minority groups will likely be ignored by the electoral process.

LITERATURE CITED

1. Downs, A. 1957. An Economic Theory of Democracy. Harper and Row, New York.

2. Lineberry, R.L. 1974. Equality and Urban Policy: The Distribution of Municipal Public Services. Sage Publications, Beverly Hills, California.

3. Tiebout, C. 1956. "A Pure Theory of Local Expenditures. Journal of Political Economy 64: 416-424.

4. Deacon, R. and P. Shapiro. 1975. Private Preference for Collective Goods Revealed Through Voting on Referenda. Amer. Econ. Rev. 65:943-954.

5. Cox, K. 1973. Conflict, Power, and Politics in the City. John Wiley, New York.

6. Herbert, D. and R.J. Johnston, Eds. 1978. Social Areas in Cities: Processes, Patterns, and Problems. John Wiley, New York.

7. Kemp, M. and M. Cheslow. 1976. Transportation in The Urban Predicament, W. Gorham and N. Glazer, Eds. The Urban Institute, Washington, D.C., 288-289.

8. Timms, D. 1971. The Urban Mosaic: Towards a Theory of Residential Differentiation. Cambridge University Press, Cambridge, 118-119.

9. Pushkarev, B. and J. Zupan. 1977. Public Transportation and Land Use Policy. Indiana University Press, Bloomington, Indiana, 32-33.

10. Davies, C. and M. Albaum. 1975. The Mobility Problems of the Poor in Indianapolis, in The Manipulated City, S. Gale and E.G. Moore, Eds. Maaroufa Press, Chicago.

11. Downs, A. 1970. Uncompensated Nonconstruction Costs Which Urban Highways and Urban Renewal Impose Upon Residential Households, in Analysis of Public Output, J. Margolis, Ed. Columbus University Press, New York, 69-106.

12. Institute of Public Administration. 1979. Financing Transit: Alternatives for Local Government. Washington, D.C.

13. Lexington Leader. October 31, 1980.

14. Brunn, S.D., W. Hoffman and G. Romsa. 1970. The Youngstown School Levies: A Geographical Analysis in Voting Behavior. Urban Education, April, 21-51.

15. Hetrick, V. and H. Calkins. 1972. Urban Mass Transportation in Seattle: A Behavioral Analysis of Special Election Results. Proc. Assoc. of Amer. Geog. 4:41-44.

DISCRIMINATIVE COURTSHIP BETWEEN TWO DOMESTIC COLOR MORPHS OF *XIPHOPHORUS HELLERII* HECKEL (PISCES:POECILIIDAE)

RAYMOND E. HAMPTON

Laboratory of Animal Behavior and Behavioral Ecology,
Department of Biology,
Central Michigan University,
Mt. Pleasant, Michigan 48859

ABSTRACT

Males of the live-bearing poeciliid, *Xiphophorus hellerii,* preferentially court females of their own color morph when given a choice of females of their own or a different color morph. This discrimination is exhibited by males raised in single-morph groups as well as by males raised in mixed-morph groups, indicating that males do not learn this behavior by association with cohorts.

INTRODUCTION

Mating between different phenotypes of the same species is said to be assortative when it occurs between like phenotypes more often than would be expected if mating between phenotypes was random (1). This phenomenon is well documented in birds and seems to be a result of the young birds sexual imprinting on the parents (1,2). Assortative mating in nature may be advantageous in that it would tend to preserve local adaptations in populations.

Fishes are not known to mate assortatively, even though many species of fishes are polychromatic. However, Kosswig (3) suggested that selective (assortative) mating might be an important factor in the apparent rapid speciation of the cichlid fishes of Africa, although there is no experimental evidence to support or reject this hypothesis.

The experiments reported here were undertaken to determine if color strains of *Xiphophorus hellerii,* produced through selective breeding, preferentially court members of their own color morph. *X. hellerii,* known among aquarium hobbyists as the "swordtail", is a sexually dimorphic, ovoviviparous poeciliid which is indigenous to Mexico and Central America. Both sexes are promiscuous and mating is almost constant. As in other poeciliids, males assume very active roles in courtship while the role of the female appears to be quite passive. There is no parental care by either sex after the female delivers the young.

MATERIALS AND METHODS

Species of *X. hellerii* of the "green" strain, which resembles the wild type in coloration, and of the "red velvet" strain, which is a uniform red color without the prominent lateral stripes of the wild type, were obtained from a local pet store. The fish were quartered in single-morph groups in 100 L aquaria at a temperature of 25 to 27 C with constant circulation and filteration of the water. They were fed once daily with commercial tropical fish food. Individuals of the green strain which were raised in a mixed-morph group were obtained by placing newly delivered green fry into an aquarium containing 2-day old red velvet fry. (Since the red fry were already two days old when the green fry were introduced, red fry were not used in experiments to determine the mating preference of males raised in mixed groups).

Courtship preference of males was determined by placing 2 green females and 2 red females into a 380 L aquarium and introducing test males one at a time. Each male was allowed to remain with the 4 females for 24 hours before observations were made. Following this acclimation period, the frequency of "backing displays" made by the male to either green females or red females in a period of 1 hour was recorded. The "backing display" is a species-specific courtship display in which the male darts rapidly about the female with his fins fully extended and often attempts to touch the female with the long extension of his caudal fin (the "sword") while swimming backward toward her. The paired t-test (4) was used to test for significance in differences between the frequency of courtship displays directed by males to females of like and unlike morphs. Six males of each group (green and red males raised in single-morph groups and green males raised in mixed-morph groups) were used.

RESULTS AND DISCUSSION

Green males raised in single-morph groups, red males raised in single-morph groups, and green males raised in mixed-morph groups all directed significantly more courtship displays to females of their own morph than to females of the opposite morph (Table 1). Sexual imprinting on the parents seems unlikely in this species, since there is no parental care period and, in fact, parents represent a threat to fry and are avoided. Imprinting on cohorts as a mechanism for later sexual identification also seems unlikely, since green males raised in mixed-morph groups were exposed from birth to both green and red females of their own age group.

The possible relationship of discriminative courtship based on phenotype to assortative mating is obvious and needs no elaboration. Genetic experiments are now being conducted to determine the extent to which such discrimination in courtship leads to assortative mating among color morphs of *X. hellerii*.

SUMMARY

Males of the "green" and "red velvet" varieties of the swordtail, *Xiphophorus hellerii*, preferentially court females of their own morph when given a choice of females of both morphs. Males discriminate regardless of whether they were raised in single-morph groups or in mixed-morph groups. Such discrimination is expected to result in assortative mating.

ACKNOWLEDGMENTS

This investigation was supported in part by a grant from the Faculty Research and Creative Endeavours Committee of Central Michigan University.

LITERATURE CITED

1. Partridge, L. 1983. Non-random Mating and Offspring Fitness. In, P. Bateson (ed.) Mate Choice. Cambridge University Press, Cambridge.
2. Cooke, F., and J. C. Davies. 1983. Assortative Mating, Mate Choice, and Reproductive Fitness in Snow Geese. In, P. Bateson (ed.) Mate Choice. Cambridge University Press, Cambridge.
3. Kosswig, C. 1947. Selective Mating as a Factor for Speciation in Cichlid Fish of East African Lakes. Nature 159: 604-605.
4. Netter, J., W. Wasserman and G. A. Whitmore. 1982. Applied Statistics. Allyn and Bacon, Inc., Boston.

Table 1: Courtship Behavior of Green and Red Velvet Swordtail Males with Green and Red Velvet Females.

Males (n = 6)	Mean frequency of "backing" displays per hour directed to:		
	Green Females	Red Females	P*
Green raised in single morph group	44.2 ± 4.76 (27-59)	2.3 ± 2.14 (0-13)	0.001
Red raised in single morph group	4.5 ± 2.70 (0.-17)	30.4 ± 5.64 (16-46)	0.05
Green raised in mixed morph group	37.3 ± 4.55 (26-56)	9.7 ± 4.58 (0-30)	0.05

Figures in parentheses below the means are the ranges of the observations. Figures following the (±) are the standard errors of the means.
*The probability that the difference between groups was not significant.

FISHES OF THE GREEN RIVER DRAINAGE IN TAYLOR COUNTY, KENTUCKY

by
GORDON K. WEDDLE
Department of Biology
Campbellsville College
Campbellsville, Kentucky 42718

ABSTRACT

A systematic survey of streams in the Green River drainage, Taylor County, Kentucky was conducted to determine the current ichthyofauna and to examine the influence of physiography on the distribution of fishes. Forty three species and 3 sunfish hybrids were collected from 41 sites. Combination of these data with data from previous studies indicates a current Taylor County Green River ichthyofauna of 69 species. Distributional records for 5 species of fishes are reported. *Ericymba buccata*, the silverjaw minnow was collected for the first time in the upper Green River. Presence of this species is likely due to a stream capture exchange with the Rolling Fork drainage in Casey County. Nine species exhibited localized distributions within the survey area ($P<0.02$). Two distinctive fish faunal assemblages occur in Taylor County: the first inhabits the Eastern Pennyroyal Province; the second inhabits the Knobs Province and is isolated from the remainder of the Green River drainage by Green River Reservoir. It is probable that these faunal differences reflect the impact of Green River Reservoir on Knobs communities of fishes but possible that distributions may be influenced by physiography.

INTRODUCTION

Taylor County is located near the geographic center of Kentucky and contributes significantly to the watershed of the Upper Green River. The only distinctive physiographic boundary of the country is the Muldraugh Escarpment, which forms the southwestern rim of the outer Bluegrass Region and the divide between the Green and Salt river drainages. The county is approximately 736 km^2 in area and is characterized by rolling uplands dissected by relatively flat stream valleys typically aligned in a southwesterly direction.

Two distinct physiographic regions are present in Taylor County. Most of the central and western portions of the county are included in the Eastern Pennyroyal, characterized by Mississippian strata of the Salem-Warsaw and Fort Payne limestone formations. In contrast to the Pennyroyal, the Knobs Province, which cuts across the northeastern corner of the county, is underlain by shales of the New Province and New Albany formations that are of Lower Mississippian and Devonian ages, respectively (1).

In 1969, a flood control dam was constructed on the Green River in Taylor County, forming Green River Reservoir, a 12,950 ha lake. Approximately one-half of the lake falls within the boundaries of Taylor County. The remainder is located in adjoining Adair County to the southeast. Most of the streams that flow through the northeastern Knobs Province of Taylor County are tributaries of Robinson Creek which now merges with the reservoir several km upstream from its pre-impoundment confluence with Green River. This river flows from the reservoir and across the southern tip of Taylor County, then southwesterly through Green County. The principal stream system within the Eastern Pennyroyal is the Big Pitman Creek drainage. This stream is tributary to Green River in Green County.

The fishes of the Upper Green River have been the subject of many studies, including the historically important early works of Rafinesque (2) and Woolman (3). More recently, biologists have examined the effect of point-source pollution of the Pitman system (4,5,6), the effect of impoundment on the fishes of the Green River (7), the sport fishery potential of a number of sites (8 and B. D. Laflin, pers. com.) and the water quality and aquatic biota of the oil shale region in the Knobs Province (9). However, no systematic survey of the stream ichthyofauna of Taylor County has been completed.

Accordingly, this study was undertaken to document the occurrence and distribution of stream fishes in Taylor County and to examine the possibility that fish distributions within the county might be influenced by the presence of two distinct physiographic regions.

MATERIALS AND METHODS

Fishes were sampled from 27 August 1982 through 27 August 1983. One additional site was sampled in March of 1985. No samples were taken during January or February of 1983. A total of 43 samples were collected from 41 locations. Fourteen sites were sampled in the Knobs Province and 27 sites were sampled in the Eastern Pennyroyal Province (Fig. 1). No attempt was made to sample either the Green River Reservoir or its tailwaters.

Initially, fishes were collected with minnow seines of 5 mm² mesh. However, all later collections were made using a backpack electroshocker (10). Representative specimens of each species were fixed in 10% formalin in the field and returned to the laboratory for final storage in 35% isopropanol. Identifications were performed using both published and unpublished keys of several authors (11-16). A tinct assemblages of fishes occur within the county. Fisher's Exact Test was used to calculate probabilities (two-tailed) that individual species of fishes were equally distributed between the Robinson and Pitman drainages. Data for all species occurring at two or more sites were examined using a FORTRAN program (17:731) and an IBM PC computer.

Data from this work have been recorded on permanent computer files that also contain fish, macroinvertebrate and physicochemical data from other sites within the Upper Green River basin. These efforts may, in time, provide a significant data base for the aquatic biota of central Kentucky.

RESULTS

A total of 43 species and 3 sunfish hybrids in 12 families was identified during this survey. Table 1 lists species and collection localities. New distributional records are reported for 5 species.

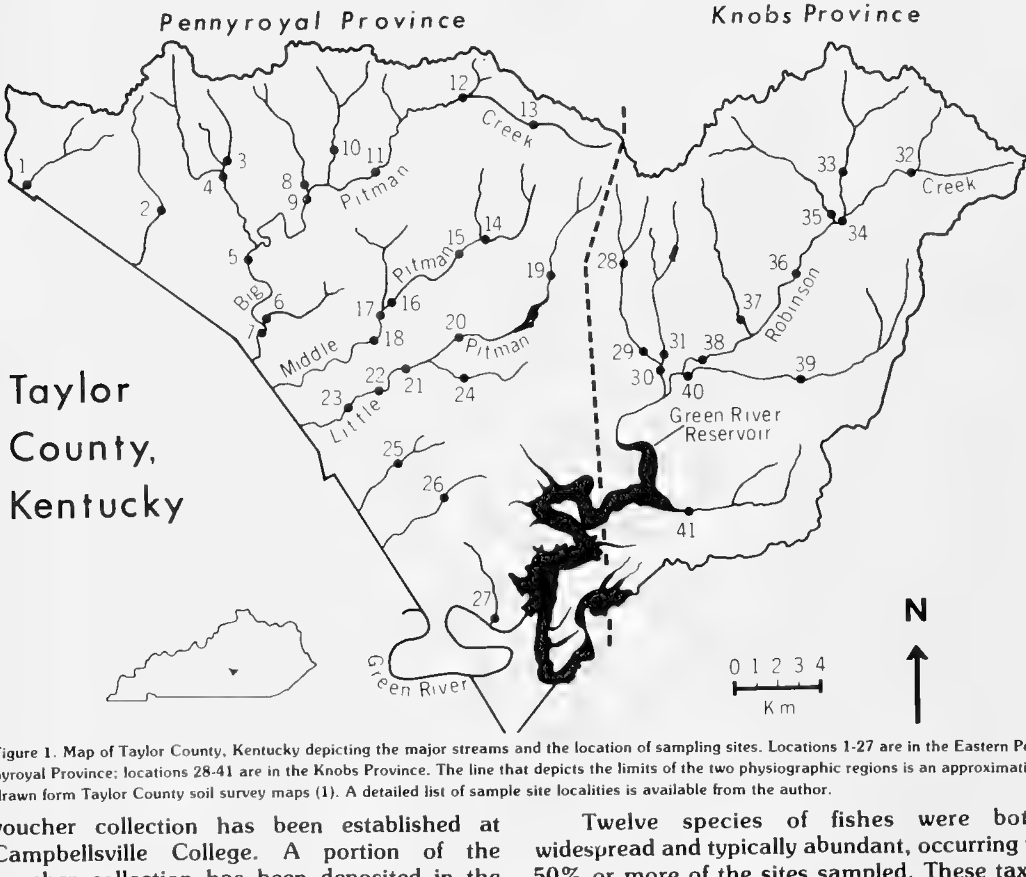


Figure 1. Map of Taylor County, Kentucky depicting the major streams and the location of sampling sites. Locations 1-27 are in the Eastern Pennyroyal Province; locations 28-41 are in the Knobs Province. The line that depicts the limits of the two physiographic regions is an approximation drawn form Taylor County soil survey maps (1). A detailed list of sample site localities is available from the author.

voucher collection has been established at Campbellsville College. A portion of the voucher collection has been deposited in the ichthyological collection of Southern Illinois University at Carbondale.

Distributional data were examined statistically to test the hypothesis that two dis-

Twelve species of fishes were both widespread and typically abundant, occurring in 50% or more of the sites sampled. These taxa were equally distributed between the 2 physiographic regions. *Campostoma oligolepis*, *Pimephales notatus*, *Lepomis megalotis* and *Semotilis atromaculatus* were the most frequently encountered stream fishes in Taylor County. *Fundulus catenatus, Etheostoma caeruleum, E. flabellare, L. macrochirus* and *Notropis chrysocephalus* were nearly as common.

Table 1. List of the stream fishes of Taylor Co., Kentucky with collection localities. (Fig. 1) Sample sites marked with an asterisk are new distributional records (B.M. Burr, pers. com.).

Species	Collection Localities
Ammocoetes larvae	1
Lepisosteus osseus	27
Dorosoma cepedianum	27, 32, 33, 35
Esox americanus	36-38
Campostoma oligolepis	1, 3-20, 23-41
Cyprinus carpio	27, 35, 36
Ericymba buccata	28*, 29*, 30*, 32*, 33*, 35*, 39*, 40*
Notropis ardens	3-6, 8, 11, 14-19, 29, 33, 35, 36, 39, 40
N. chrysocephalus	1-6, 8, 9, 11, 12, 15-19, 23, 26, 27, 29-31, 33-37, 39-41
N. spilopterus	4-6, 28, 29, 33-36, 38-41
Pimephales notatus	1-3, 4-6, 8-20, 23, 25, 27, 29, 30-41
P. promelas	24
Phoxinus erythrogaster	1, 2, 5, 10, 14, 15, 18, 19, 24-27, 28*, 40*
Semotilus atromaculatus	1-6, 8-16, 18-20, 23-27, 32-37, 39-41
Catostomus commersoni	2, 3, 4, 11, 12, 14, 15, 18-20, 27
Hypentelium nigricans	1, 3-5, 9-12, 15-20, 28-33, 35, 36-41
Moxostoma duquesnei	5, 7, 9, 17, 18, 30, 36, 40
M. erythrurum	6, 35
Ictalurus melas	11*, 35*, 36*, 37*
I. natalis	6, 9, 11, 12, 18-20, 30, 32-37, 40
Noturus elegans	5*, 6*, 9*, 18*, 35, 39
Fundulus catenatus	3, 4, 8-20, 25, 26, 28-41
Labidesthes sicculus	20, 29, 31, 41
Cottus carolinae	1, 3-10, 15, 18, 20, 25, 26, 27
Ambloplites rupestris	3-6, 9, 11, 17, 18, 27, 40
Lepomis cyanellus	2, 5, 8-14, 18, 19, 22, 24-27, 32-40
L. gulosus	38, 41
L. macrochirus	2, 6-9, 11-15, 17-20, 22, 23, 25-27, 29, 30, 32-38, 41
L. megalotis	2, 4-20, 23, 26, 27, 30-41
Lepomis x Lepomis hybrid	10, 18, 35, 36, 38
Micropterus dolomieui	4, 6, 11, 12, 18, 35
M. punctulatus	5, 6, 18, 30, 32, 34-37, 40
M. salmoides	7, 9, 11, 19, 23, 29, 37, 40, 41
Pomoxis annularis	30, 37
Etheostoma barbouri	32-36, 40
E. blennioides	1, 3-7, 9-13, 18, 20, 25, 32, 34, 36, 37, 40
E. caeruleum	1-7, 9-12, 15, 18-20, 25, 27-30, 32-41
E. flabellare	1, 3-6, 8-13, 15, 18, 19, 25, 27, 28, 30-41
E. rafinesquei	1-7, 9, 10, 12, 15, 16, 18, 20, 26
E. spectabile	9, 10, 12-16, 18, 20, 23, 26-29, 31-33, 35-37, 39-41
E. squamiceps	20, 26
E. stigmaeum	7
E. zonale	5, 7
Percina caprodes	6*, 29, 30, 32, 35-37, 39-41

In contrast, one-third of the fauna was rare, occurring in fewer than 10% of the sites. *Pimephales promelas, E. stigmaeum* and *E. zonale* were characteristic rare taxa. Several of the remaining taxa, which occurred at frequencies of 10-50%, demonstrated localized distributions within the county, being much more prevalent in one or another of the 2 major physiographic regions (Table 2).

Results of statistical analyses of distributional data are included in Table 2. The null hypothesis was that species of fishes were distributed equally between the Western Pennyroyal and Knobs provinces. Nine species (21% of the fauna) exhibited unequal distributions ($P < 0.02$; Table 2). Calculated probabilities for several other species, including *Esox americanus* ($P = 0.0683$), *Etheostoma caeruleum* ($P = 0.0830$), *E. flabellare* ($P = 0.0506$) and *E. spectabile* ($P = 0.0756$), may represent real differences in distribution, but additional collections would be necessary to verify this. Although many species were randomly distributed within the county, fish assemblages inhabiting the 2 physiographic provinces are distinctly different. *Ericymba buccata, Notropis spilopterus, Etheostoma barbouri* and *Percina caprodes* characterize the fauna of the Robinson drainage in the Knobs Province; *Catostomus commersoni, Cottus carolinae* and *Etheostoma rafinesquei* characterize the fauna of the Pitman drainage in the Eastern Pennyroyal Province. Because the potential effect of fish migration was not assessed, additional sampling might alter these conclusions.

Table 2: Frequency of occurrence of fishes with localized distribution in Taylor County. Occurrence values are expressed as percentage. Two-tailed probabilities were calculated with Fisher's exact test. Significant probabilities (*) indicate statistical differences in distribution.

	Frequency of occurrence		
Taxon	Pennyroyal	Knobs	p
Esox americanus	0	21	0.0683
Ericymba buccata	0	57	0.0001*
Notropis spilopterus	12	71	0.0003*
Hypentelium nigricans	52	93	0.0171*
Micropterus punctulatus	13	50	0.0199*
Etheostoma barbouri	0	36	0.0013*
E. flabellare	59	93	0.0506
Percina caprodes	4	57	0.0001*
Catostomus commersoni	38	0	0.0083*
Cottus carolinae	58	0	0.0005*
Etheostoma rafinesquei	58	0	0.0005*

DISCUSSION

The stream fish fauna of Taylor County is similar to that reported by Murphy (18) in his studies of Lincoln and Casey counties and typifies tributary habitats of the Upper Green River. Charles (4) and Hoyt and Robinson (7) made the most extensive collections of Taylor County fishes prior to this study. Charles reported 57 species from Green River and 48 species from Big Pitman Creek during 1960-63. Hoyt and Robinson collected 45 species in the Green River tailwater in 1978-79. Most of the species that were collected by these authors yet absent from my samples were riverine cyprinids and percids. This was expected because large-river habitats were not sampled.

Combination of data from this paper with earlier surveys indicates that the current Taylor County fish fauna consists of 69 species. Eight additional species, collected by Charles (4), have not been reported since the impoundment of Green River. Four of these may still inhabit Big Pitman Creek, but the remainder, which were originally found only in the tailwater reach of Green River, have likely been extirpated (7).

New collection localities for 5 species of fishes are reported here (Table 1). Most notably, *Ictalurus melas* and *Ericymba buccata* had not been previously reported from Taylor County, although *I. melas* has been collected in both Big Pitman Creek and Green River in adjoining Green County (4).

Ericymba buccata, the silverjaw minnow, occurred in 57% of the sampling sites in the Robinson Creek drainage and was commonly the most abundant cyprinid. Previously, this minnow was known in the Green River only from its extreme lower reaches in western Kentucky (19, 20). Subsequent collections by Kentucky Nature Preserves Commission biologists have substantiated the presence of this fish in Robinson Creek (9).

The occurrence of *E. buccata* in the Upper Green River is enigmatic. Wallace (21), in an attempt to explain the overall distributional pattern of this species, hypothesized that either it never occupied the Green River or that populations formerly inhabiting the drainage had undergone recent extinction. The discovery of the silverjaw in the Upper Green River could be construed as supportive of the latter. However, it is equally possible that the Taylor County population is the result of recent introduction from a stream capture exchange with the Rolling Fork River (Salt River drainage) or from a bait release. Faunal exchanges have been suggested between the headwaters of the Dix and Rolling Fork rivers in Boyle County (22). Headwaters of Green River occur near the same area. Although Harrison Garman collected fishes from Robinson Creek in the late 1800's, his samples (Mus. Comp. Zool., Harvard) were incomplete and did not include *E. buccata*. Unfortunately, other samples of historical value, that predate the impoundment of Green River, do not exist for Robinson Creek, and conclusions regarding the disjunct distribution of *E. buccata* in Kentucky are speculative. Comparative morphometric and electrophoretic studies of Kentucky populations of the species would possibly clarify distributional history.

The Knobs Province assemblage of fishes, of which *E. buccata* is a member, is a distinctive fauna. Five species occurred in more than 10% of the samples in the Robinson drainage but were absent from Big Pitman samples. Conversely, excepting rare taxa, only 3 species were unique to the Big Pitman drainage (Tables 1 and 2). One site, Black Lick Creek, in the Knobs Province supported the most diverse community of the study (26 species).

Fishes occurring within streams of the Robinson Creek drainage are isolated by the reservoir from those in the Pitman Creek drainage of the Eastern Pennyroyal. The reservoir might also act selectively to filter the dispersal of fishes from the Knobs Region to the upstream reaches of Green River. This, coupled with differences in bedrock geology and water chemistry between the Pitman and Robinson drainages (9 and unpublished data) and the potential effect of the impoundment on the Robinson drainage, suggests plausible explanations for the localized distributions of Taylor County fishes.

Studies of the impact of impoundments on fish community composition have concentrated principally on alteration of the tailwater environment to explain faunal differences upstream and downstream (7, 23). However, it is possible that restrictions on fish migratory movements and certain physical changes in the habitat, such as increased siltation, channel encroachment (24) and instability of flow, mediated by fluctuating reservoir levels, probably alter the composition of upstream fish communities as well. An increase in number of fishes that can tolerate lentic environments in streams above impoundments is expected (25). The increased frequency of *Micropterus punctulatus* ($P = 0.0199$), *Etheostoma barbouri* ($P = 0.0013$) and *Percina caprodes* ($P = < 0.0001$) in Knobs Province streams, relative to Eastern Pennyroyal streams, is supportive of this idea.

Lotic habitats upstream from impoundments are essentially insular in character and the importance of various limiting factors is, by and large, dependent on the amount of usable habitat in the isolated watershed. During periods of stress, such as prolonged drought, the amount of usable habitat could become limiting as species aggregate in pools. Under such conditions selection would favor eurythermal species that are also tolerant of reduced oxygen concentration. Inbred gene pools in isolated populations of fishes may predispose certain habitat restricted species to extinction (26).

Current data are insufficient to allow a conclusive explanation of the origins of the distinctive fish assemblage inhabiting the Knobs Province of Taylor County. It is likely that the fauna reflects alteration of habitat caused by the impoundment of Green River, but it is also possible that the Knobs assemblage is, in part, a relict assemblage adapted to a unique geologic and physicochemical environment.

Comparative ecological studies of shale and limestone streams in the Green River drainage in Casey County are ongoing and should add to our understanding of the differences in these habitats. The results of this project indicate that future pre-impoundment studies should include examinations of low-order streams that will be isolated by the impoundment.

ACKNOWLEDGMENTS

I would like to express my sincerest appreciation to the many students who assisted in field work. Jeff Crask and Robert Netherland made significant contributions. Dr. Brooks M. Burr confirmed many of my identifications, provided distributional data and editorial comments. Dr. Thomas L. Wenke provided invaluable recomendations for the statistical analyses and editorial comments. Drs. Robert L. Doty and Tom Kozel read an earlier version of the paper and provided useful recommendations. Dr. R. L. Doty assisted with photography. Financial support for field and laboratory work was provided by the Division of Natural Sciences and Mathematics at Campbellsville College.

LITERATURE CITED

1. Ross, J. C. and T. R. Leathers. 1982. Soil survey of Green and Taylor counties, Kentucky. U. S. Dept. Agri., Soil Cons. Ser., and Nat.Res. and Environ. Prot. and Ky. Agri. Exp. Sta., U. S. Gov. Print. Off., Washington, D. C.
2. Rafinesque, C. S. 1820. Ichthyologia ohiensis. W. G. Hunt, Lexington, Ky.
3. 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.
4. Charles, J. R. 1964. Effects of oilfield brines. Proc. Ann. Conf. S. E. Game and Fish Comm. 18:371-403.
5. Division of Environmental Services. 1984. Little Pitman Creek drainage biological and water quality investigation. Dept. Environ. Prot., DES, Bio. Branch, Tech. Rept. No. 16, Frankfort, Ky. 27 pp.
6. Division of Environmental Services. 1984. Big Pitman Creek drainage biological and water quality investigation. Dept. Environ. Prot., DES, Bio. Branch, Tech. Rept. No. 21, Frankfort, Ky., 97 pp..
7. Hoyt, R. D. and W. A. Robinson. 1980. Effects of impoundment on the fishes in two Kentucky tailwaters. Proc. Ann. Conf. S. E. Assoc. Fish and Wildl. Agencies 34:307-317.
8. Axon, J. R., W. N. McLemore, D. E. Bell, B. D. Laflin, J. P. Henley, L. E. Kornman, A. R. Jones and K. W. Prather. 1981. Annual performance report for statewide fisheries management project. Streams research and management . Ky. Dept. Fish. Wildl. Res., Project No. F-50, Segment 3, Frankfort, Ky. 165 pp.
9. Hannan, R. R., R. R. Cicerello, E. D. Keithan, M. L. Giovannini, and L. J. Andrews. 1984. Aquatic biota and water quality and quantity survey of the Kentucky oilshale region. Dept. Sur. Mining Reclamation and Enforcement, Ky. Nat. Res. and Environ. Prot. Cab., Tech. Rept., Frankfort, Ky. 557 pp.
10. Knudsen, J. W. 1966. Biological techniques: collecting, preserving, and illustrating plants and animals. Harper and Row, New York.
11. Clay, W. M. 1975. The fishes of Kentucky. Ky. Dept. Fish and Wildl. Res., Frankfort, Ky.
12. Etnier, D. A. 1982. The Tennessee species of the Family Percidae. Unpub. Ms.
13. Kuehne, R. A. and R. W. Barbour. 1983. The American darters. Univ. Press of Kentucky, Lexington, Ky.
14. Page, L. M. 1983. Handbook of darters. TFH Publications, Neptune City, NJ.
15. Pflieger, W. L. 1975. The fishes of Missouri. Mo. Dept. Cons., Jefferson City, Mo.
16. Trautman, M. A. 1981. The fishes of Ohio. Ohio State Univ. Press, Columbus, Oh.
17. Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman, San Francisco.
18. Murphy, G. W. 1964. Fishes of the Green River Basin in Casey and Lincoln counties, Kentucky. Trans. Ky. Acad. Sci. 25:65-74.
19. Burr, B. M., M. E. Retzer, and R. L. Mayden. 1980. A reassessment of the distributional status of five Kentucky cyprinids. Trans. Ky. Acad. Sci. 41:48-54.
20. Retzer, M. E., B. M. Burr and M. L. Warren, Jr. 1983. Fishes of the lower Green River drainage Kentucky. Ky. Nature Preserves Comm., Sci. Tech. Series No. 3:1-48.
21. Wallace, D. C. 1973. The distribution and dispersal of the silverjaw minnow, *Ericymba buccata* Cope. Amer. Midl. Nat. 89:145-155.
22. Branson, B. A. and D. L. Batch. 1971. Stream capture in Kentucky indicated by distributional records of *Fundulus catenatus* and *Etheostoma spectabile*. Amer. Midl. Nat. 86:496-500.
23. Spence, J. A. and H. B. Hynes. 1971. Differences in fish populations upstream and downstream of a mainstream impoundment. J. Fish. Res. Bd. Canada 28:45-46.
24. Brenner, F. J. 1981. Impacts of impoundments on six small watersheds in Pennsylvania. *In*

Warmwater Streams Symposium. (L. A. Krumholz, ed.). Amer. Fish. Soc., pp. 291-302.

25. Mundy, P. R. and H. T. Boschung. 1981. An analysis of the distribution of lotic fishes with application to fisheries management. *In* Warmwater streams symposium. (L. A. Krumholz, ed.). Amer. Fish. Soc., pp. 266-275.

26. Harris, L. D. 1984. The fragmented forest: island biogeography theory and the preservation of biotic diversity. Univ. Chicago Press, Chicago.

PETROGRAPHIC STUDY OF THE VALLEY VIEW AND CLAY'S FERRY SANDSTONE DIKES IN EAST—CENTRAL, KENTUCKY

by

J. MACKLIN COX
Ohio-Kentucky Oil Corporation
3060 Harrodsburg Road
Lexington, Kentucky 40503

ROY B. VANARSDALE
Department of Geology
University of Arkansas
Fayetteville, Arkansas 72701

ABSTRACT

Studies of thin-sections and slabs of the Clay's Ferry and Valley View sandstone dikes in east-central Kentucky were undertaken in order to determine their petrology and emplacement mechanism. In addition, grain-mounts of the Irvine Formation sands of Pliocene-Pleistocene age were analyzed to determine if they were a possible sediment source for the dikes.

The sandstone dikes consist of well-sorted, angular to well-rounded, calcareous quartz arenite apparently derived from the same sediment source. Petrographic analysis of the two sandstone dikes and the Irvine Formation suggest that the dike sands were not derived from the Irvine Formation.

Flow structures in the Valley View dike indicate that emplacement occurred through forceful injection of sediment in a hydroplastic state. The sand in the Clay's Ferry dike appears to have been emplaced by forceful injection from above the dike's roadcut exposure. Therefore, sands of Mississippian and Pennsylvanian age are considered most favorable as a sediment source for the two dikes but an underlying Ordovician sand source can not be discounted.

Minor reactivation of the Kentucky River fault appears to have occurred after the emplacement and cementation of the Valley View dike. Cross-cutting relationships within the Valley View dike reveal that south-dipping normal faults have been displaced by north-dipping reverse faults.

INTRODUCTION

Two sandstone dikes were studied along the Kentucky River fault zone in east-central Kentucky (Fig 1). One dike is located in northern Madison County at Clay's Ferry and the other extends from southwestern Fayette County into southeastern Jessamine County near Valley View. The Clay's Ferry dike is exposed in a roadcut along U.S. 25 (Fig.2) and the Valley View dike is exposed in a roadcut along Kentucky 169 (Fig. 3).

McFarlan (1,2) concluded that the Clay's Ferry and Valley View dikes consist of fluvial sands of either Pennsylvanian or Pliocene-Pleistocene age that washed into earthquake fissures resulting from late Paleozoic or Tertiary movement along the Kentucky River fault zone. McFarland (1,2) favored the interpretation that the sand was derived from the Pliocene-Pleistocene Irvine Formation which was washed into Pliocene-Pleistocene earthquake fissures. Rieke and King (3) postulated that the dikes are solution-widened joints filled with sediments washed in by the Pliocene-Pleistocene Kentucky River. More recently, Tillman (4) described a sandstone dike exposed in a trench 2 km east of Valley View which appears to be related to reactivation of the Kentucky River fault. The dike mapped by Tillman appears to have been injected from below (4).

If these dikes are indeed earthquake fissure fillings, as proposed by McFarlan (1,2), or have been emplaced coincident with fault reactivation, as proposed by Tillman (4), then they may reflect Pliocene-Pleistocene reactivation of the Kentucky River fault zone. The purpose for this study was, therefore, two fold: (1) to determine if

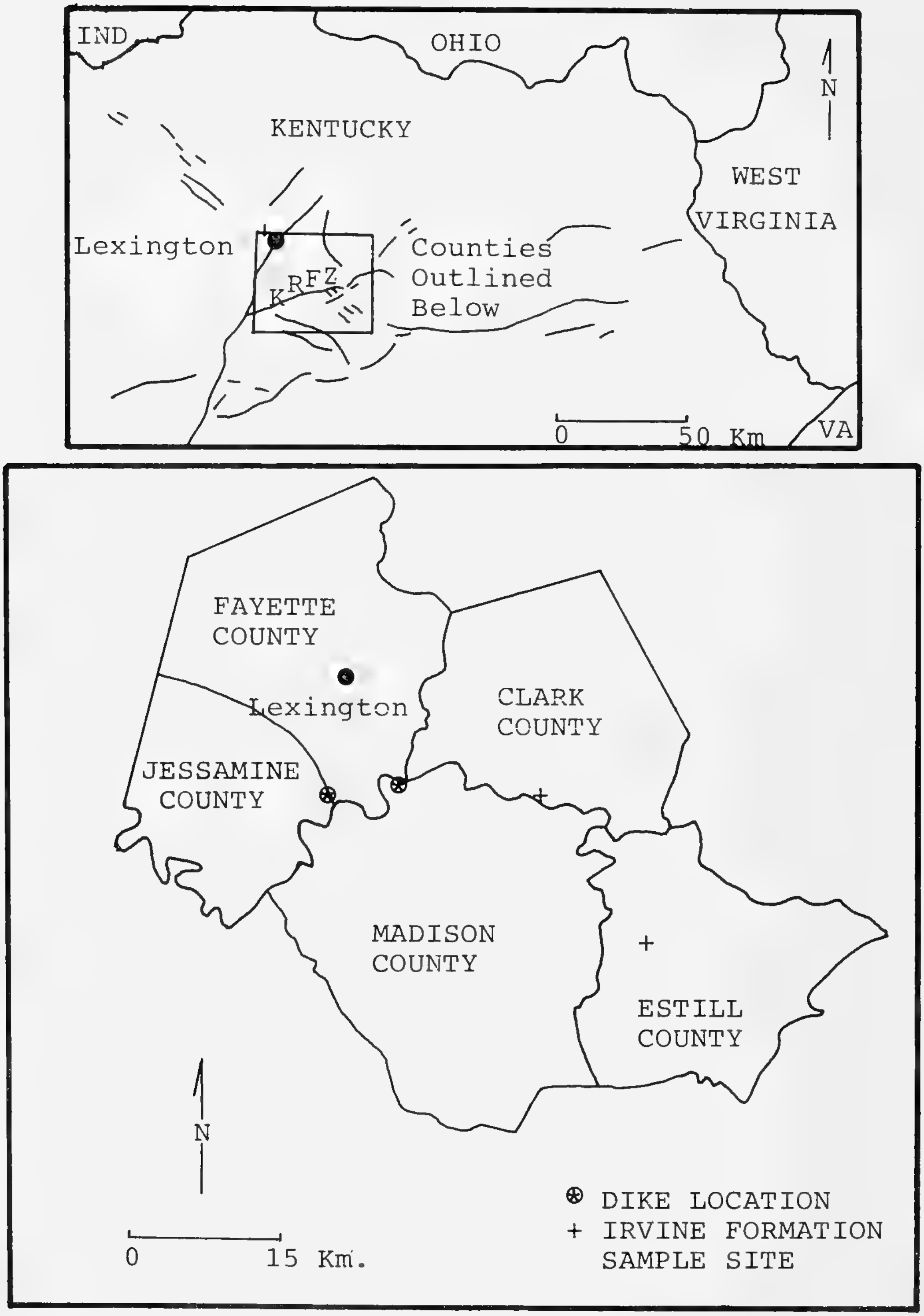


Figure 1. Map showing the Kentucky River fault zone (KRFZ), sandstone dike locations, and the Irvine Formation sample sites.

the Irvine Formation was the source of the sand in the two dikes, and (2) to determine how the dike sands were emplaced.

THE KENTUCKY RIVER FAULT ZONE

The Kentucky River fault zone is a portion of a discontinuous east-west fault system which extends from southern Illinois (Shawneetown fault) through western Kentucky (Rough Creek fault), then across eastern Kentucky (Kentucky River fault zone) into West Virginia (Woodward fault) (Fig. 1) (5,6). The Kentucky River fault zone cuts across the east limb of the Cincinnati Arch and is the northern boundary fault of the Rome Trough (7). The Rome Trough has, in turn, been interpreted to be part of an east-trending aulacogen of Late Precambrian and Palezoic age (7,8).

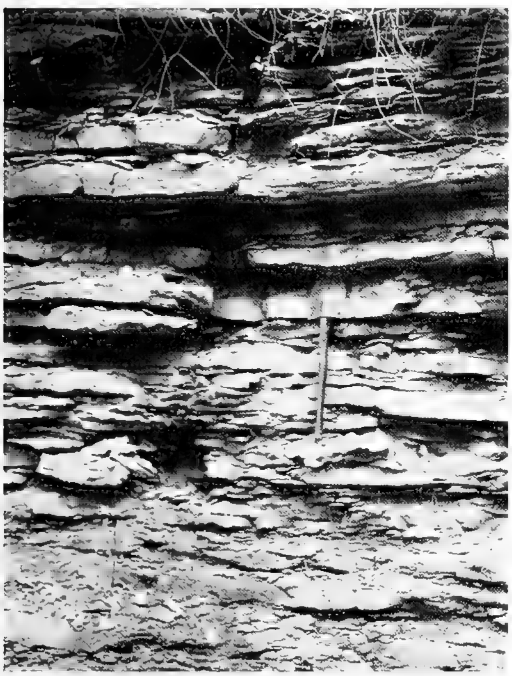


Figure 2. The sandstone dike at Clay's Ferry. North is to the left.

The surface expression of the Kentucky River fault zone varies along its trace in the study area near Lexington, Kentucky (Fig 1.). The fault zone is a maze of faults within a major linear graben in the Ford quadrangle (9). Farther west, in the Valley View quadrangle, the fault zone is an asymmetric graben with the major displacement on the north fault.(10).

The sense of movement along the Kentucky River fault zone has been cited as right lateral, left lateral, reverse, and normal. The diversity of sense of displacement is the consequence of recurrent movement from Precambrian through Pennsylvanian time (5,6,11,12,13). Late Precambrian, right lateral offset and early Cambrian normal displacement have been reported (14,7,5). Maximum normal displacement occurred during mid-Cambrian time (7). Minor activity continued in the Ordovician, Silurian, and Devonian periods with larger normal displacements in the Upper Mississippian and Pennsylvanian periods (15,12,7). The total down-to-the-south displacement at the top of the Precambrian is approximately 457 m in the area of figure one (7); however, the Ordovician-to Mississippian-age rocks are vertically displaced down-to-the-south an average of 61 m with a maximum of 183 m at Burdette Knob (13).

Due to the absence of Mesozoic and Lower Tertiary stratigraphy in eastern Kentucky, it has not been possible to determine if there has been

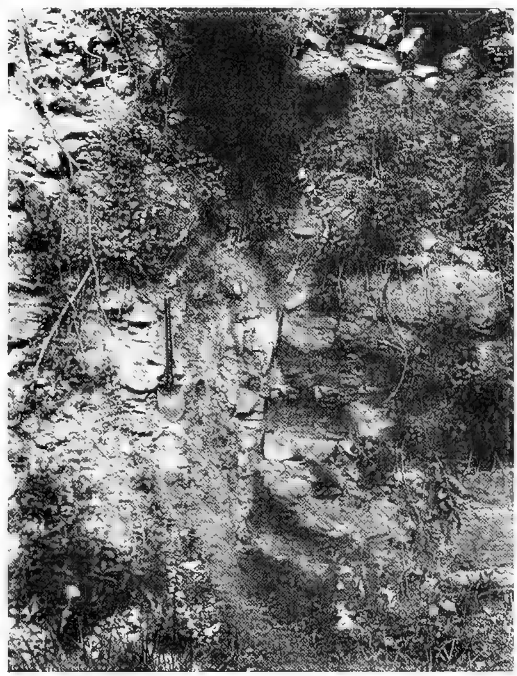


Figure 3. The sandstone dike at Valley View. North is to the left.

recurrent fault movement during Mesozoic and Early Tertiary time. However, Tertiary movement has been suggested based on geomorphic evidence (2,16). Jillson (16) proposed that the anomalous southwest bend in the Kentucky river near Winchester, Kentucky, is due to diversion during Early Tertiary reactivation of the Kentucky River fault zone. McFarlan (2) proposed that sandstone dikes at Clay's Ferry and Valley View (Fig 1) consist of sand derived from high-level Kentucky river terraces of Late Tertiary age. As discussed above, the dikes were proposed by McFarlan to be the filling of earthquake fissures formed by Late Tertiary reactivation of the Kentucky River fault zone. More recent studies by VanArsdale and Sergeant (17) have revealed folded and faulted Pliocene-Pleistocene Kentucky River terraces (Irvine Formation) which suggest Pliocene-Pleistocene reactivation of the Kentucky River fault zone.

ORIGIN OF CLASTIC DIKES

Clastic dikes (of which sandstone dikes are one type) are cross-cutting, tabular-shaped bodies of clastic sediment created by the filling or injection of sediment into fissures (18). Clastic dikes do not create the fissures in which they are contained; therefore, fissures are created by another, perhaps related, mechanism before clastic dikes may be emplaced 19,20). The fissures may be filled with clastic sediment through two mechanisms: (1) from above by wind, water, or gravity; or (2) from above or below by forceful injection (21,22).

The structures developed within a dike depend upon the emplacement mechanism and/or the properties of the sediment during emplacement. Dikes emplaced through infilling from above by wind, water, or gravity generally show some degree of horizontal stratification (21,23) and a considerable range in composition and texture (21,24). When a dike is emplaced through forceful injection, the resulting structures depend upon the properties of the sediment during injection. Sediment injected in a hydroplastic state is thought to occur under laminar flow conditions (25). Flow structures within the dike form as a consequence of these laminar flow conditions (18,25,26,27). These structures include oriented grains, banding, scour marks, rod structures, and crushed and split-mica folia. Dikes emplaced through forceful injection of sediment in a liquefied state are generally massive and well sorted, and then become finer grained with increasing distance from their source (28).

METHODS

Both dikes were sampled at their roadcut exposures on Kentucky 169 and U.S. 25. Five thin sections were prepared for petrographic study, two from the Valley View dike and three from the Clay's Ferry dike. Two slabs were cut from the Clay's Ferry dike and 3 were cut from the Valley View dike. All slabs were cut perpendicular to the strike of the dike.

Three samples of the Irvine Formation (Kentucky River terrace sediments of Pliocene-Pleistocene age) were obtained from 2 locations (Fig 1). One sample was collected at Sand Hill, Kentucky, from a foundation excavation. The other 2 samples were collected in southern Clark County by TenHarmsel (30) using a truck-mounted auger rig. The auger samples were collected from 4 to 6 meters below the surface. Clay layers above the sample depths assured relatively fresh samples. A grain mount was prepared from each Irvine sand sample for petrographic analysis.

RESULTS

CLAY'S FERRY DIKE

The dike at Clay's Ferry (Figs. 1 and 2) is approximately 5 cm thick, strikes north 75° east, and dips approximately 85° to the northwest. The dike is contained within the Lexington Limestone and is approximately parallel to, and 61 m south of a major eastward trending fault of the Kentucky River fault zone. The fault at Clay's Ferry has 76 m of down-to-the-south displacement (9).

PETROGRAPHY OF THE CLAY'S FERRY DIKE

The Clay's Ferry dike is a well-sorted, angular to well-rounded, calcareous quartz arenite. The framework elements consist of 94% monocrystalline quartz, 2% polycrystalline quartz, 1% microcline, 2% rock fragments, and trace amounts of plagioclase, muscovite, biotite, zircon, glauconite, and opaques. Clay matrix occurs only in trace amounts and the dike is cemented with sparry calcite (17%).

The monocrystalline quartz was initially subrounded to rounded, although replacement by calcite has produced irregular grain boundaries. Some quartz grains contain vacuoles, bubble trains, microlite inclusions, and negative crystals. Much of the polycrystalline quartz is also partially replaced with calcite. Grains of this quartz variety are subrounded to rounded, and many have crenulated internal boundaries. A majority of the microcline grains are generally fresh, although some display a high degree of alteration to clay minerals. Most microcline grain boundaries are replaced with calcite. In addition, highly weathered plagioclase grains were found in one sample.

Biotite and muscovite are present in all samples. The biotite ranges from relatively fresh flakes to flakes almost completely altered to chlorite. Glauconite occurs as green microcrystalline, elliptical pellets. Rock fragments include chert, shale, and possibly schist. The chert grains are rounded and partially replaced with calcite.

The dike consists of well-sorted, angular to well-rounded grains. The finer grains appear to concentrate along the walls of the dike and there is a tendency for the long axis of grains to be oriented vertically throughout the dike.

SLAB DESCRIPTIONS OF THE CLAY'S FERRY DIKE

Slab 1 from the Clay's Ferry Dike, was cut from a sample collected at the basal exposure of the dike and revealed that the dike is separated into one main body and two subsidiary bodies (Fig. 4). The 3 bodies are oriented vertically and display no apparent structures within the dike rock. The dike walls consist of a skeletal grainstone in the upper portion of the slab and skeletal packstone in the lower portion of the slab. Tabular-shaped wall fragments occur within the dike rock. One fragment, a skeletal grainstone, appears to have originated from the upper portion of the slab and was moved downward within the dike to the lower portion of the slab (Fig. 4).

Slab 2 from the Clay's Ferry Dike was cut from a sample collected 1 m above the first slab. Here, the dike rock lies between 2 roughly, parallel walls of skeletal wackestone (Fig 5). The wall rock is split and a thin layer of sand penetrates approximately 4 cm into the enclosing limestone (Fig 5). Concave-upward, trough-shaped structures occur within the main body of the dike.

VALLEY VIEW DIKE

The Valley View dike (Figs. 1 and 3) varies from 15 to 23 cm in thickness, strikes north 70° east and dips 85° to the northwest. The dike lies along the plane of the Kentucky River fault with the Tyrone Limestone on the north and the down-thrown (30 m) Lexington Limestone on the south (10,31). The dike rock weathers to produce smooth, wavey, vertical surfaces which are generally parallel to the dike walls (Fig. 6).

PETROGRAPHY OF THE VALLEY VIEW DIKE

The Valley View dike is a well-sorted, angular to well-rounded calcareous quartz

Figure 4. Slab 1 from the Clay's Ferry dike (cut perpendicular to dike walls) showing the apparent downward movement af a biogenic grainstone wall fragment at A. North is to the left.

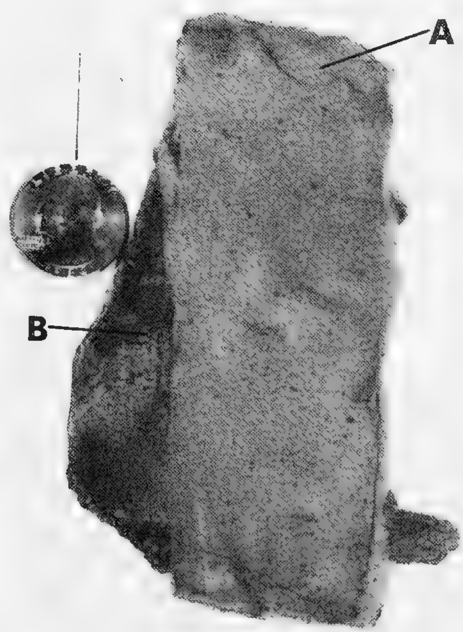


Figure 5. Slab 2 from the Clay's Ferry dike (cut perpendicular to dike walls) showing concave upward trough-shaped structures at A. A thin layer of sand penetrates the enclosing limestone at B. North is to the left.

arenite. The framework elements consist of 94% monocrystalline quartz, 2% polycrystalline quartz, 2% chert, 1% microcline, and trace amounts of muscovite, zircon, glauconite, and opaques. Clay matrix is present only in trace amounts and the dike is cemented with sparry calcite (15%).

The monocrystalline quartz grains were apparently subrounded to rounded, but replacement by calcite has produced irregular grain boundaries. Some of the quartz contains vacuoles, bubble trains, and microlite inclusions. A minor amount of the quartz is fractured with the factures displaying no apparent preferred orientation. The fractures are filled with calcite. The polycrystalline quartz is subrounded to rounded and many exhibit crenulated internal boundaries. The microcline, which is relatively unweathered, is almost completely replaced at the grain boundaries by calcite. Zircon occurs as round to elliptical grains and glauconite occurs as green microcrystalline elliptical pellets. Many of the chert grains, which were originally rounded, are almost completely replaced by calcite. There is a tendency for finer grains to concentrate at indentations in the wall rock. Many of the elongated grains are oriented vertically and parallel to the dike walls.

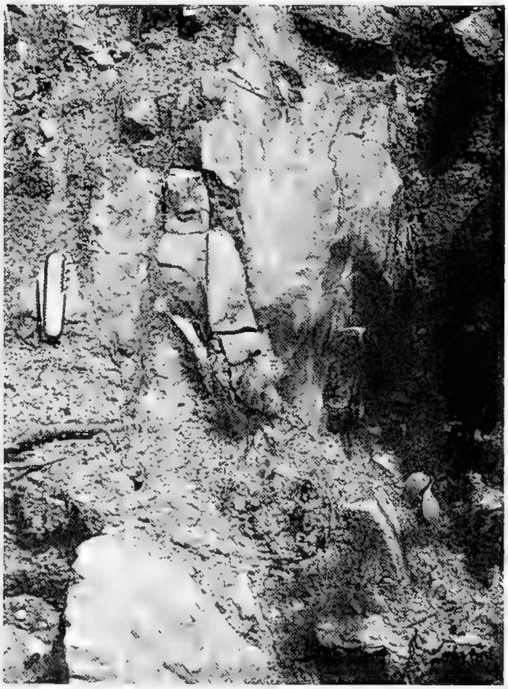


Figure 6. Apparent flow structures within the Valley View dike at its roadcut exposure. North is to the left.

SLAB DESCRIPTIONS OF THE VALLEY VIEW DIKE

Slab 1 from the Valley View dike has irregular surfaces that are roughly parallel to the walls of the dike (Fig. 7). Many of these surfaces join thus forming sediment enclosures. The sediment varies in color and/or concentration of wall fragments across several surfaces.

Slab 1 is also crossed by two sets of fractures both of which contain calcite veins. One set dips southward approximately 60° and the other set dips northward approximately 65°. Reverse fault movement is indicated along the northward-dipping fractures by the 2.5 mm displacement of the southward-dipping veins (Fig. 7).

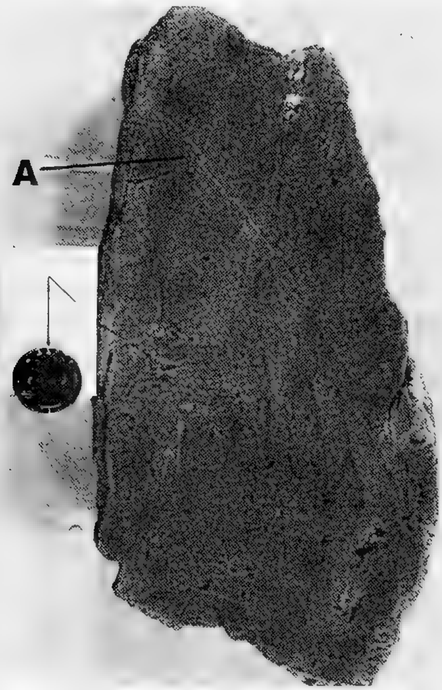


Figure 7. Slab 1 from the Valley View dike (cut perpendicular to dike walls) showing irregular sediment enclosures and calcite-filled fractures. The calite vein at A is displaced 0.25 millimeters. North is to the left.

Slab 2 contains thin layers which parallel the dike walls (Fig. 8). These structures are more planar and continuous than those found in slab 1. The layers have formed from the parallel alignment and sorting of grains. This is indicated by an obvious alignment of muscovite folia and a smooth, wavey parting of the dike rock parallel to the layering (Fig. 6). Two sets of calcite-filled fractures, which have southward and northward dips of approximately 15° and 35°, respectively, cut sample two. Although not readily visible in Figure 8, normal fault movement has occurred along the southward-dipping fractures, as indicated by an apparent 1.2 mm displacement of the vertical flow layers. The northward-dipping fractures show reverse fault movement and have displaced both the vertical flow layers and the southward-dipping fractures approximately 3.8 mm.

Slab 3 exhibits well-developed vertical layering along the northern edge of the dike (Fig. 9). The layers are nearly parallel to the dike walls and reflect parallel alignment and sorting of grains. One layer contains numerous elongated carbonaceous fragments that are generally aligned parallel to the dike walls. The interior portion of the dike appears massive; however, close inspection reveals muscovite folia aligned parallel to the dike walls. The dike rock parts along smooth, wavey surfaces which apparently result from the general alignment of elongated and platy grains parallel to the parting. In the upper portion of the slab the dike rock is fractured into blocks which are enclosed in a matrix of limestone breccia. The minimum vertical displacement between the blocks and the undisturbed dike is 2.5 cm. The fracturing and vertical movement of the dike rock occurred after the dike's emplacement and cementation.

Figure 8. Slab 2 from the Valley View dike (cut perpendicular to dike walls) showing layered structures parallel to the dike walls and calcite-filled fractures at A and B which have been displaced by faulting. North is to the left.

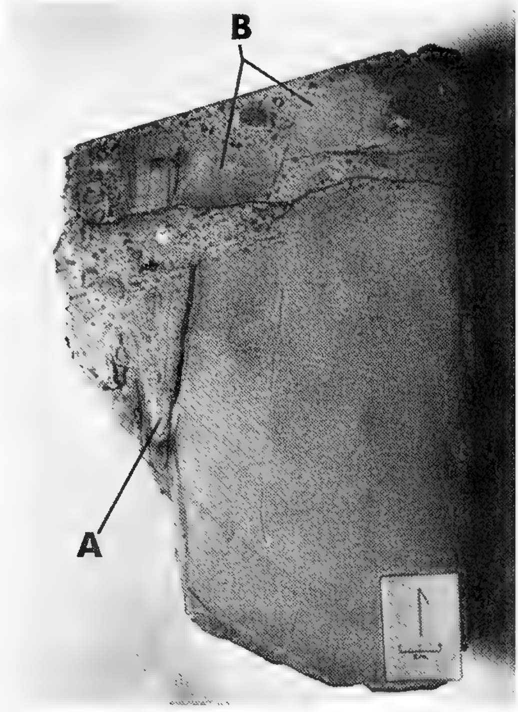


Figure 9. Slab 3 from the Valley View dike (cut perpendicular to the dike walls) showing well-developed layered parallel to the dike walls at A, and fractured blocks of dike rock floating in a matrix of limestone breccia at B. North is to the left.

PETROGRAPHY OF THE PLIOCENE-PLEISTOCENE IRVINE SANDS

Petrographic study of the Pliocene-Pleistocene Irvine sands revealed a super mature, ferruginuous, quartz arenite (32). The framework elements consist almost entirely of well-sorted, subangular to subrounded monocrystalline quartz. Muscovite, zircon, tourmaline, and shale fragments are present in trace amounts. Iron oxide occurs as a thin coating on most grains.

DISCUSSION

The framework elements of the Clay's Ferry and Valley View dike sediments are very similar, which suggest that they were derived from the same sediment source. Monocrystalline quartz, polycrystalline quartz, microcline, chert, zircon, muscovite, and glauconite occur in the same concentrations in each dike and represent greater than 99% of the framework elements. The only framework components of the 2 dikes that do not directly correlate are trace amounts of plagioclase, biotite, and rock fragments present only in the Clay's Ferry dike. However, biotite and plagioclase may be absent in the Valley View dike because they have been completely altered to clay. The shale fragments, which are not present in every thin section of the Clay's Ferry dike, may be derived from the wall rock. If this is true, then the shale fragments would have an uneven distribution and may be limited entirely to the Clay's Ferry dike.

The Irvine Formation sands are significantly more mature than the sand of the dikes. The Irvine Formation samples consist entirely of highly resistant minerals, namely monocrystalline quartz, zircon, tourmaline and muscovite. Exposure of the Irvine Formation to chemical weathering since deposition is undoubtedly a contributing factor in producing these super mature sands. If the sand of the dikes represents relatively unweathered Irvine age sands, then the Irvine Formation would represent a weathered residue of these dike sands. Therefore, the chemically stable minerals present in the dikes should also be present in the Irvine Formation. The dikes contain an average of 2% polycrystalline quartz and 2% chert fragments. It is unlikely that these highly resistant minerals would be removed from the Irvine Formation through chemical weathering. These quartz varieties were not found in the Irvine Formation sands studied during this investigation. Cantrell (32) also noted an absence of polycrystalline quartz and chert in the Irvine Formation. Consequently, it appears unlikely that the dikes consist of Irvine Formation (Pliocene-Pleistocene) sand.

If the Irvine Formation is not the sediment source of the dikes, then other sand bodies must be considered as possible sediment sources. The Saint Peter Sandstone and the Rose Run Formation, both of Ordovician age, lie approximately 304 m and 422 m, respectively, below the Lexington Limestone (33). These Ordovician units are possible sediment sources. Mississippian and Pennsylvanian sands, which would overlie the study area but are eroded, may also be the source of the sand. Further petrographic studies of these alternative sand sources may help resolve this problem.

The data concerning the emplacement mechanism of the Clay's Ferry dike are inconclusive. The trough-shaped structures in slab 2 from the Clay's Ferry dike, appear to be bedforms which result from sediment being washed into open fissures; however, they may also represent flow structures produced during downward injection of sediment. The slight vertical orientation of elongated grains and the tendency for finer grains to occur in wall indentations suggest that the dike sediment was emplaced through injection. Although the data are inconclusive, the present investigators propose that the Clay's Ferry dike was emplaced from above through forceful injection.

The dike at Valley View was emplaced along the fault apparently through forceful injection of sediment in a hydroplastic state from either above or below the present exposure level. Evidence for this emplacement mechanism includes: (1) apparent flow structures at the dike exposure and in the slabs prepared from the Valley View dike; (2) vertical aligment of muscovite folia in slabs 2 and 3 and along parting surfaces; (3) vertical alignment of carbonaceous fragments in slab 3; (4) layering parallel to the walls of the dike in slabs two and three; and (5) the tendency for finer grains to concentrate at indentations in the wall rock and the apparent vertical alignment of elongated grains.

The Valley View dike also contains evidence for minor fault movement subsequent to its emplacement and cementation. This evidence includes: (1) displaced fractures in slabs 1 and 2; (2) calcite veins that suggest vertical extension in slabs 1 and 2; and (3) a minimum 2.5 cm vertical displacement of the dike rock and infilling of limestone breccia in slab 3. Furthermore, the cross-cutting relationships revealed in slab 2 of the Valley View dike (Fig. 8) indicate that normal displacement along south-dipping faults was followed by reverse displacement on north-dipping faults.

SUMMARY

The sandstone dikes at Clay's Ferry and Valley View are apparently derived from the same sediment source. The Irvine Formation sands are probably not the sediment source, as suggested by previous investigators (1,2,3). It is, therefore, proposed that sands of Mississippian, Pennsylvanian, or Ordovician age may have been the sand source for the dikes.

Structures within the dikes suggest that the Valley View dike was forcibly intruded from above its exposure. We therefore prefer a Mississippian or Pennsylvanian age sand source for the dikes; however, more petrographic analysis is needed.

Minor movement on the Kentucky River fault, subsequent to dike emplacement and cementation, is indicated by the presence of faults within the Valley View dike. Cross-cutting relationships of calcite veins and faults reveal that south-dipping normal faults have been subsequently displaced by north-dipping reverse faults.

ACKNOWLEDGEMENTS

The authors wish to thank the Nuclear Regulatory Commission (contract number NRC-6-04-81-018) and the National Science Foundation (grant number EAR-8025893) for funding this project.

LITERATURE CITED

1. McFarlan, A.C. 1936. A sandstone dike in the Kentucky River fault zone of central Kentucky: Trans. Ky. Acad. Sci. 7:71.
2. ———.1943. Geology of Kentucky. U. Ky. Press.
3. Rieke, H.H., and F.K. King, 1961. Preliminary report on the sandstone dikes in central Kentucky. Compass Sigma Gamma Epsilon 31: 13-19.
4. Tillman, J. 1985 Post Pliocene displacement history of the Kentucky River Fault in northwest Madison and southeast Jessamine counties, Kentucky. Unpub. MS thesis, Eastern Ky. Univ., Richmond, Ky.
5. Heyl, A.V. 1972. The 38th parallel lineament and its relationship to ore deposits. Econ. Geol. 67:879-894.
6. Haney, D.C. 1974. Recurrent movement along the Kentucky River fault system. Geol. Soc. Amer. (Abstract) 6:359.
7. Webb, E.J. 1980. Cambrian sedimentation and structural evolution of the Rome trough in Kentucky. Unpub. Ph. D. Diss., U. Cinn., Ohio.
8. Harris, L.D. 1978. The Eastern Interior aulacogen and its relation to the Devonian shale-gas production. Dept. Energy Second Eastern Gas - Shale Symp. 2:55-72.
9. Black, D.F.B. 1968. Geologic map of the Ford quadrangle, central Kentucky. U.S. Geol. Surv. Quad. Map GQ-764.
10. Greene, R.C. 1966. Geologic map of the Valley View gradrangle, central Kentucky. U.S. Geol. Surv. Quad. Map GQ-470.
11. Black, D.F.B., and D.C. Haney 1975. Selected structural features and associated dolostone occurrences in the vicinity of the Kentucky River fault system. Ann. Field Conf. Geol. Soc. Ky., Ky. Geol. Surv. Pub.
12. Horne, J.C., F.C. Ferm and B.P. Baganz 1976. Sedimentary response to penecontemporaneous tectonics in the Carboniferous of eastern Kentucky. Geol. Soc. Am. (Abstract), 8:198.
13. Phillips, D.T. 1976. Deformational history of the Kentucky River fault system. Unpub. MS thesis, Eastern Ky. U., Richmond, Ky.
14. Woodward, H.P. 1961. Preliminary subsurface study of southeastern Appalachian Interior Plateau. Amer. Assoc. Petr. Geol. Bull. 45: 1634-1655.
15. Haney, D.C. 1976. Structural control on Paleozoic sedimentation in eastern Kentucky (Abstract). Amer. Assoc. Petr. Geol. Bull. 60: 1620.
16. Jillson, W.R. 1945. The Kentucky River. State J. Frankfort, Kentucky.
17. VanArsdale, R.B., and Sergeant, R. 1985. Post-Pliocene displacement on faults within the Kentucky River fault zone of east-central Kentucky. Geol. Soc. Amer. (Abstract) 17:7.
18. Peterson, G.L. 1968. Flow structures in sandstone dikes. Sed. Geol. 2:177-190.
19. Smith, A.J., and Rast, N. 1958. Sedimentary dykes in the Dalradian of Scotland. Geol. Mag. 95:234-240.
20. Pettijohn, F.J., P.E. Potter and R. Seiver 1972. Sand and sandstones. New York, Springer-Verlag.
21. Shrock, R.R. 1948. Sequence in layered rocks. New York, McGraw-Hill.
22. Potter, P.E., and F.J. Pettijohn 1963. Paleocurrents and basin analysis. New York, Academic Press.
23. Lupher, R.L. 1944. Clastic dikes in the Columbia Basin region, Washington and Idaho. Geol. Soc. Amer. Bull. 55:1431-1462.
24. Reineck, J.E., and I.B. Singh 1975. Depositional sedimentary environments. New York, Springer-Verlag.
25. Dott, R.H. 1966. Cohesion and flow phenomena in clastic intrusions. Amer. Assoc. Petr. Geol. Bull. (Abstract). 50:610.
26. Vintage, P.W. 1954. Sandstone dikes in the South Platte area, Colorado. J. Geol. 62: 493-500.
27. Harms. J.C. 1965. Sandstone dikes in relation to Laramide faults and stress distribution in the southern Front Range, Colorado. Geol. Soc. Amer. Bull. 76:981-1002.
28. Swarbrick, E.E. 1968. Physical diagenesis: intrusive sediment and connate water. Sed. Geol. 2:161-175.
29. Cox, J.M. 1983. Investigation of late Tertiary to recent movement along the Kentucky River fault system in northwest Madison and southeast Jessamine Counties, Kentucky. Unpub. MS thesis, Eastern Ky. U., Richmond, Ky.
30. TenHarmsel, R.L. 1982. Investigation of Late Tertiary to Recent movement along the bounding faults of the Shearer graben within the Kentucky River fault system in southern Clark County, Kentucky. Unpub. MS thesis, Eastern Ky. U., Richmond, Ky.
31. Nosow, E., and McFarlan, A.C. 1960. Geology of the central Bluegrass area. Geol. Soc. Amer., southeastern section guidebook for field trip, March 23-26, 1960. Kentucky Geol. Surv.
32. Cantrell, C.L. 1973. The geology of the Irvine Formation, Irvine, Kentucky. Unpub. MS thesis, Eastern Ky. U., Richmond, Ky.
33. Wilson, E.N., and Sutton, D.G. 1973. Oil and gas map of Kentucky, sheet 3, east-central part. Ky. Geol. Surv., series x.

NOTES

MISSISSIPPI RIVER STURGEONS: NEW KENTUCKY RECORDS AND COMMENTS ON STATUS.—The three species of sturgeons (*Acipenser fulvescens*, *Scaphirhynchus albus*, and *S. platorynchus*) inhabiting the Mississippi River adjacent to Kentucky are among the poorest known members of the state ichthyofauna. Inefficiency of conventional collecting gear and probable historical decline and rarity of some of these species (Kallemeyn, Fisheries 8:3-9,1983; Forbes and Richardson, *The Fishes of Illinois*, 2nd ed., Nat. Hist. Surv. Div., 1920) has limited the literature on Kentucky populations primarily to anecdotal accounts. Records are usually based on occasional reports by fisheries biologists and sport and commercial fishermen of large individuals (Barnickol and Starrett, Ill. Nat. Hist. Surv. Bull. 25:267-350, 1951; Clay, *The Fishes of Kentucky*, Ky. Dept. Fish Wildl. Resour., Frankfort, 1975; Burr, Brimleyana 3:53-84, 1980; Cicerello, Trans. Ky. Acad. Sci. 42:132-133, 1981) and on commercial fishery assessments in which the species were not discriminated (Renaker and Carter, Ky. Dept. Fish Wildl. Publ., 1968). Few vouchered collections are known from the state of any sturgeon species (Bailey and Cross, Pap. Mich. Acad. Sci. Arts Lett. 34:169-208, 1954; Burr, loc. cit.; Cicerello, loc. cit.; Clay, loc. cit.), and the paucity of information precludes accurate assessments of distribution, abundance, and conservation status. We report the first vouchered record in Kentucky of *S. albus* and the first confirmed records of *A. fulvescens* from the Mississippi River of Kentucky. We also comment on the conservation status of each species, including *S.platorynchus*, in the Kentucky portion of the Mississippi River as judged from acquisition of specimens, compilation of recent records, and interviews with commercial fishermen.

Vouchered records of *S. albus* were previously unavailable in Kentucky; however, Burr (loc. cit.) regarded it as part of the state ichthyofauna, citing its presence in the Mississippi River, both north and south of Kentucky. On 5 November 1985, we collected a 685 mm SL, 1.8 kg female *S. albus* (SIUC 12549) from the Mississippi River adjacent to Middle Bar (approximately 9 km S of Columbus), Hickman County. The specimen was 1 of 7 sturgeons taken (the others being *S. platorynchus*) by trotline (10 lines with 40 hooks each, baited with worms and fished overnight). We were previously provided with a head and partial skin of a *Scaphirhynchus* sp. (SIUC 10563) by Mr. Ronald R. Cicerello taken on 2 August 1984, in the Mississippi River (approximate river mile 921), near Hickman, Fulton County, by Mr. Roy Wiseman, a commercial fisherman. The former specimen conformed in morphological, meristic, and morphometric features to *S. albus* as presented by Bailey and Cross (loc. cit.); however, the latter specimen possessed features of both *S. albus* and *S. platorynchus*. The incompleteness of the specimen somewhat precluded our identification, but we regard it as a possible *S. albus* x *S. platorynchus* hybrid, a combination suspected in other Mississippi River drainage populations (Phelps and Allendorf, Copeia 1983: 696-700, 1983). Assessment of the conservation status of *S. albus* in Kentucky is problematic given the limited distributional data available; however, discussions with commercial fishermen indicate that the species is less commonly taken than *S.platorynchus*. Deacon et al. (Fisheries 4:29-44, 1979) classified the species as threatened throughout its range. We recommend that the species be placed in the endangered category of the Kentucky Academy of Science-Kentucky Nature Preserves Commission Endangered, Threatened, and Rare Animal list because of its apparent rarity and the lack of information on relative abundance.

Twentieth century records of *A. fulvescens* in the Mississippi River of Kentucky were lacking except for anecdotal accounts from commercial fishermen (Burr, loc. cit.), although Forbes and Richardson (loc. cit.) noted that the species was formerly abundant throughout the Mississippi River. We examined photographs (now at SIUC) of this species caught in the Mississippi River in 1977 above Smith Island Chute, Ballard County, by Mr. Glenn M. Burnett, a sport fisherman, and in 1968 near Columbus, Hickman County, by Mr. Lynn L. Bencini, a commercial fisherman. The fish captured by Mr. Bencini was featured in the 8 February 1968 issue of the Carlisle County News. Additionally, Mr. Wiseman indicated he had taken a specimen near Hickman, Fulton County, in the late 1960's (Ronald R. Cicerello, pers. comm.). The former 2 records are the only ones verified for the Mississippi River of Kentucky, and based on the description provided by Mr. Wiseman, we accept the latter as valid. Branson et al. (Trans. Ky. Acad. Sci. 42:77-89, 1981) listed this species as threatened in Kentucky. As judged from the sporadic occurrence of this species in the Mississippi River and its virtual disappearance from the commercial catch, we consider the population in the Mississippi River as endangered.

Only 2 vouchered records (SU 17109, Clinton, Hickman County and UMMZ 111542, Cairo Alexander County, Illinois), reported by Bailey and Cross (loc. cit.), were known previously for *S. platorynchus*in the Mississippi River of Kentucky. They also included a verbal report (Barnickol and Starrett, loc. cit.), on their map of the species range in the Kentucky portion of the Mississippi River from Hickman, Fulton County. We have collected or obtained from commercial fishermen 43 specimens of this species from 1979 to 1985, most of which have come from the Mississippi River near Columbus, Hickman County (all SIUC). Interviews with commercial fishermen from Hickman, Columbus, and Cairo indicate the species is taken year-round with greatest numbers occurring in late fall to spring. Branson et al. (loc. cit.) listed this species as threatened in Kentucky. Our observations and interviews with commercial fishermen suggest the Mississippi River populations of this species do not warrant a conservation status; however, further data on abundance, recruitment, and exploitation rate are needed to formulate management policies to insure that the species continues to provide a commercial fishery.

We gratefully acknowledge the cooperation, logistical support, or photographs of specimens provided by Mr. Lynn L. Bencini of Columbus, Mr. Glenn M. Burnett of Barlow, and Mr. Roy Wiseman of Hickman. Mr. Ronald R. Cicerello of the Kentucky Nature Preserves Commission graciously provided a specimen and results of interviews with commercial fishermen.—**MELVIN L. WARREN, JR., BROOKS M. BURR, and BERNARD R. KUHAJDA**, Department of Zoology, Southern Illinois University at Carbondale, Carbondale, Illinois 62901.

ACADEMY AFFAIRS

KENTUCKY ACADEMY OF SCIENCE
The Seventy First Annual Meeting
at
Morehead State University
November 8 - 9, 1985

Arrangements: Dr. John C. Philley

OFFICERS OF THE ACADEMY

President	Joe Winstead Western Kentucky University
President-Elect	Charles V. Covell, Jr. University of Louisville
Vice-President	Larry Giesmann Northern Kentucky University
Past President	Gary Boggess Murray State University
Secretary	Robert Creek Eastern Kentucky University
Treasurer	Morris Taylor Eastern Kentucky University
Director of Junior Academy	Herbert Leopold Western Kentucky University
Editor of Transactions	Branley Branson Eastern Kentucky University
Representative to A.A.A.S	Joe King Murray State University

BOARD OF DIRECTORS

Paul Freytag	1985
William Baker	1985
Gerrit Kloek	1986
Manuel Schwartz (Chp)	1986
Lawrence Boucher	1987
Bill Hettinger	1987
William Bryant	1988
William Beasley,Jr.	1988

THE SEVENTY FIRST ANNUAL BUSINESS MEETING OF THE KENTUCKY ACADEMY OF SCIENCE

MOREHEAD STATE UNIVERSITY MOREHEAD, KENTUCKY

8-9 November 1985

Host: Dr John Philley

Minutes of the Annual Meeting

The meeting was called to order by President Winstead at 9:15 , 9 November, in the auditorium of the Claypool-Young Art Building with approximately 115 members in attendance.

After a motion by Secretary Creek, and a second from the floor, the minutes of the 1984 annual business meeting at Kentucky State University, as recorded in the *Transactions* Vol. 46(1-2), were approved. Secretary Creek moved that all new members for 1985 be accepted by the Academy. Following a second from the floor, the motion passed. Dr. Creek reported that the 1986 meeting will be a joint meeting with the School Science and Mathematic Association (SSMA), Kentucky Association for Progress in Science (KAPS) and the Kentucky Council of Teachers of Mathematics (KCTM) on November 20-22 at the Radisson Plaza Hotel and Lexington Convention Center. The deadline for submitting papers for this meeting will be May 16, 1986. The sectional officers will be sending out more information in the near future. The secretary states that 50 members had indicated they would participate in the proposed speaker's bureau. He suggested a committee be set up to begin putting together the booklet. It was recommended that the speakers be contacted to determine their continued interest in participating. Dr. Creek indicated the speakers would be contacted.

The Treasurers report was made by Dr. Taylor.

TREASURER'S REPORT
TO THE
KENTUCKY ACADEMY OF SCIENCE
NOVEMBER 1, 1984-NOVEMBER 1, 1985

Cash in Madison National Bank (Nov 1, 1984)	$ 7902.00
RECEIPTS:	
Registration 1984 (Total deposits)	$3820.94
Membership	$7400.00
Library Subscription	$2159.00
Institutional Affiliations (1984-1985)	$6650.00
Page Charges	$2191.69
Subtotal	$21,711.69
DISBURSEMENTS:	
Junior Academy of Science (1984-1985)	$1500.00
Operating Expenses	$1081.56
Transactions (Vol 45, 3-4 & Vol 46, 1-2)	$5620.94
Kentucky Tomorrow	$500.00
Subtotal	8702.50
BALANCE:	
Total Cash and Receipts	$21,722.69
Total Disbursements	$ 8702.50
Cash on Hand Nov 2, 1985	$13020.19
KENTUCKY ACADEMY OF SCIENCE FOUNDATION:	
Botany Foundation Interest 1985	$ 916.24
Botany Foundation residual from 1984	$ 340.04
Subtotal	$1259.28

Marcia Athey Fund interest 1985	$5413.70
Residual 1984	$2838.40
Subtotal	$8252.10
Grants 1985	$1374.00
Marcia Athey Fund Total	$6878.10

Dr. Taylor indicated the amount received from the Institutional Affiliations and also included those that had been received for 1986. He said the $1500 dispersement to the KJAS reflected two years (1985-$500 and 1986-$1,000).

Dr. Taylor then presented the following summary of interest earned on investments by the KAS Foundation.

Date	1982	1983	1984	1985	Totals
Marcia Athey Fund	$1627.53	$1632.76	$1819.87	$2213.34	$7293.50
		1598.33	1892.66	1696.91	5187.90
(16188.78 CD)					
	1188.78	704.70	787.04	827.41	3507.93
	1062.71	703.09	736.99	676.04	3178.83
($16188.78 CD)					
Totals	$3879.02	$4638.88	$5236.36	$5413.70	$19168.16
Botany Foundation	657.51	659.62	487.66	517.33	23322.12
		419.50	467.46	398.91	1285.87
($10000 CD)					
Totals	$657.51	1079.12	955.12	916.24	3607.99

Note: The original funds came to us in the following amounts:

Botany Foundation	$10000
Marcia Athey Fund	10000
	25000
	15000

The Botany Foundation monies were invested in a CD at the Madison National Bank and the interest generally was used for grants. The CD remained unchanged until this Fall with the exception of the falling interest rates.

The Marcia Athey Fund monies were received in the amounts shown above but spread over several months. So CD s were purchased at different times with different investment modes. Since the interest was not used completely, some of it was reinvested as CD s. This is the reason the CD s are not in the amount of the original gifts. However, the money was invested at all times to keep it working. Since the interest rates are not as high as we would like, the monies are being invested in a different mode.

Following a motion and a second from the floor, the report was approved.

The Audit Committee made the following report on the Botany and Marcia Athey Funds.

BOTANY FUND

The Botany Fund Endowment has significantly enhanced student research on various aspects of botany in Kentucky. During the eight year period since establishment of the Botany Fund, interest earned from the principal sum has been accumulated in a separate account. Funds for research grants have been accumulated in a separate account. The principal has grown at an average annual rate of $195.70, while an average of $434.38 in awards have been made annually.

Recipients follow:

Deborah Otte	Univ N. Carolina	Red River Gorge Flora
Sally Arnold	W. K. U.	Aquatic Vascular plants
John Roth	Indiana University	Paleobotany
R. Oddo & G. Houser	Murray State Univ.	Murphy's Pond Flora
Jay Jones	Indiana University	Paleobotany
Charles Tarrants	Syracuse University	Sumac ecology
Kelly Carter	Pikeville College	*Solidago* biology
Donna Godbey	E. K. U.	Flora of Maywoods
Harry Woodward	Univ. Louisville	Liriodendron anatomy
Max Medley	Univ. Louisville	Kentucky flora
George Buddell	N. K. U.	Lewis County flora

Paul Grote	Indiana University	Paleobotany
Jennifer Sharp	W. K. U.	Dendrochronology

The recent reinvestment of the Botany Fund principal ($11,529.01) in a GNMA (10.55%) should insure that the current level of funding can be continued.

MARCIA ATHEY FUND

Growth of this fund has been substantial. Interest earned on these accounts during 1983-85 totaled $17,340.50. Fifty-six% of these earnings was retained while the remainder ($7,624.00) was awarded in five grants. Topics supported by these grants follow:

Survey of the Kentucky Lepidoptera.
The genus ***Rubus*** (Rosaceae) in Kentucky.
An undescribed species of rosin weed (*Silphium*, Asteraceae) in Kentucky.
Inner Bluegrass flora.
Vascular Flora of Rock Creek Natural Area.

Marcia Athey Funds are also being reinvested in GNMA's with interest accumulation in Money Market Accounts. This will provide monthly statements of earned interest and should enhance stewardship of these funds.

In summary, the Botany and Marcia Athey funds have positively influenced the study of science in Kentucky. This is evidenced by the fact that two of the papers being presented in the Botany Section are the result of research supported by Botany Fund grants.

Dr. Winstead reported that there were 17 Educational Affiliates which represented an all-time high. He presented the following list of Educational Affiliates:

Sustaining Member

University of Kentucky

Member

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

Associate Member

Alice Lloyd College
Bellarmine College
Berea College
Campbellsville College
Centre College
Georgetown College
Kentucky State University
Lindsey Wilson College
Spalding College
Thomas More College

1. COMMITTEE ON PUBLICATION. Dr. Branson made the following report.

In several ways, 1985 has been frustrating for the editor, principally because of the printer's inability to meet publication deadlines, as witnessed by the tardiness of the last two issues. Volume 46(3-4) is still not out, although all materials are in the hands of the printer. Hopefully, this last issue of 1985 will appear while there is still a 1985 in which to appear.

Otherwise, the business of publishing the journal has flowed along rather smoothly. Volume 46(1-2) consisted of 80 pages that included 10 feature-length articles, 3 notes, Academy Affairs, the annual program, News and Comments, and abstracts of some papers presented at the annual meeting. Volume 46(3-4) — when it appears — will consist of 75 pages (excluding the index, not yet paginated) that will include 11 features, 3 notes, and Robert Keuhne's obituary, News and Comments, Academy business, and the index. The cost of printing 46(1-2) was $3,583.72. Although we have not been billed for 46(3-4), it's length indicates that it will cost approximately the same as 46(1-2), for a total cost for 1985 of approximately $7,200.

The subjects of the 21 articles and 7 notes in Vol. 46 were: Zoology and Entomology, 13; Botany and Microbiology, 8; Geology and Geography, 6; Obituaries, 1. Not a bad mix of subject matter, but it would be nice to have a few articles dealing with mathematics, anthropology, chemistry and related fields.

Volume 47 is now being compiled, although manuscript flow is on the sluggish side. Unless it picks up *tout de suite,* 47(1-2) may be on the thin side. but, then, as circles are not known by greatness of size but by the perfectly formed, thus, go publications of this sort.

2. KENTUCKY JUNIOR ACADEMY OF SCIENCE. Mr. Leopold made the following report.

Last years operations culminated with the annual symposium held at Eastern Kentucky University. Forty four titles were scheduled of which forty were read. Our other activities included the Lab-Skills Science-Bowl competitions and refreshments at the conclusion of our organized activities.

The symposium was visited by the K.A.S. Executive Committee which gave us an opportunity to show the "live-side" of K.J.A.S. which is far more animated and interesting than our annual reports. We appreciated the fact that this visitation was the first such "review of the troops" in recent years.

Our "Outstanding Science Graduates" program was joined by Cumberland College which made two scholarships available. This was in addition to the Ogden Foundation scholarships.

Mr. Patrick Stewart of Warren East High School was appointed to serve as Co-Director until the end of the 85-86 school year at which time he will become director of K.J.A.S. This was to provide a smooth transition in the directorate.

A serious problem has arisen which makes this year's outlook very uncertain. Our established symposium day, along with two other possible dates, is being pre-empted by the Kentucky Academic Association. Under ordinary circumstances this would not present an insurmountable problem. But, in this situation we find ourselves pitted against many of the people whose support has been essential for our success. This year we are having to ask our members to make a hard choice of participating in our symposium or in a new State-wide Governor's Cup competition, operated and governed by the Kentucky Association of School Administration with the active support of the State Board of Education and the Governor's office. If we actively oppose this new competition we endanger the administrative support we have enjoyed for years. And if we use our only possible date we stand to lose participation.

In conclusion, I would like to take this opportunity to thank the Academy for the help and cooperation it has given me through the years of my tenure as director.

The following Treasurer's report was presented for the KJAS.

Balance on Hand, April 27, 1985		1342.70
Disbursements		479.96
Spring Meeting, 1985 (Eastern Kentucky University)		
Awards	313.36	
Coca-Cola	60.00	
Sandwiches/Cakes	95.00	
Doughnuts (Judges/Sponsors)	9.60	
Total	479.96	
Receipts		1010.00
Academy of Science Contribution	1000.00	
Club Dues (1985-86)		
Calloway County	5.00	
Grant County	5.00	
Total	1010.00	
Balance on Hand, November 7, 1985		1854.74

3. KAS FOUNDATION. Dr. Schwartz reported that many nominations had been received for the Distinguished Scientist as well as for the Outstanding Teacher awards. He said it was difficult to make the selections because of the many excellent nominees. He thanked Dr. Larry Boucher for the work he contributed in obtaining nominations.

Dr. Ralph Thompson presented the following report for the KAS Foundation Botany Fund Committee.

During this year (1985) no grant proposals were submitted to the committee for review, thus, no monies were awarded. This assures us that more money will be available during 1986 to fund botanical research in the state.

The committee is now accepting grant proposals for research to be conducted during 1986. Proposals may be submitted at any time for evaluation. The number of grants awarded depends on the money available in the fund and the amounts requested. Proposals are evaluated on a first-come basis. Not all grant requests are funded, however, all interested students are encouraged to apply.

Dr. Joe Winstead presented the following report for the KAS Foundation Marcia Athey Fund Committee. Dr. Winstead said that in 1984 four grants were funded and one was funded in 1985. The proposals that were funded are as follows:

1984

1. *Charles Covell, Jr., Univ. of Louisville "Survey of Kentucky Lepidoptera". $3,350.00.*
2. *Julian Campbell and Millem Meijer, Univ. of Kentucky "Inner Bluegrass flora". $1,500.00.*
3. *Max Medley, Univ. of Louisville "The Genus Rubus* (Rosaceae) in Kentucky". $700.00.
4. Max Medley, Univ. of Louisville "An Undescribed Species of Rosin Weed (*Silphium*, Asteraceae) in Kentucky". $700.00.

1985

1. Ralph Thompson, Berea College and Ronald Jones, Eastern Kentucky Univ. "The Vascular Flora of Rock Creek Research Natural Area and Environs, Laurel Co., Kentucky". $1,374.00.

4. COMMITTEE ON LEGISLATION. Dr. Charles Kupchella presented the following report.

Dr. Kupchella said he had been involved in the Kentucky EPSCOR Program as a member of the Planning Committee along with Dr. Hettinger. He is also a member of the Science and Technology Committee of the Kentucky Tomorrow program. This committee has been working on an assessment of science and technology in Kentucky. He presented the following as the final draft of the Committee Assessment.

The ability of science and technology to expand human capabilities, improve health and extend life, shrink the world and wage ever more destructive war is well understood, and their impact on the social and economic structure of the world is an established historic fact. Why then are science and technology any more important now than they have been in the past—and why are they of special importance to the citizens of Kentucky at this time?

This question has no simpler answer. Because of the accelerating rate at which important breakthroughs in science and technology are currently being created, we find ourselves, along with the nation and every other state, in a new social and economic environment that presents both substantial threats and enormous opportunities. The range of possible futures is greater than it has ever been, and which of these futures Kentucky realizes seems likely to be influenced by: (1) How well the underpinnings and implications of this new era are understood, and (2) How well we plan and act to take advantage of and/or cope with them.

Over the past century we have seen developments in science and technology reshape almost every aspect of our lives. While many of us grew up seeing space travel as science fiction, our children now know it as history. Scientific discoveries are being made and applied to all facets of our lives at a staggering pace. The application of microelectronics technology has revolutionized business, industry, agriculture, education and research. The world of true robotics on a grand scale is now within sight.

Equally revolutionary developments are happening in many other fields of research and technology. Advances in biochemical research have provided the tools to diagnose and treat many of the most dreaded diseases of humanity, leading to longer, more productive and enjoyable lives. The explosion of our knowledge in this and related areas in the last 20 years has led to the next major phase in new technology—biotechnology and genetic engineering—which will have impact not only on health care but also will revolutionize agriculture, materials and energy production and many other facets of our lives. Indeed, the marriage of biotechnology and microelectronics in the next century will give us the ability to rationally alter the very nature of living organisms on this planet.

In its deliberations thus far, the committee has reviewed considerable data and engaged in lengthy discussions on the state of affairs relative to technology and scientific research within the Commonwealth. This particular assessment reflects the thinking of the Committee at this point in its deliberations. What we have learned thus far gives us cause for concern and stresses to us the importance of developing a workable, imaginative agenda for Kentucky in this area. The question before us is not whether to choose to participate in the science and technology revolution but whether we choose to sit on the sidelines and watch as the game is played without us.

WHERE HAVE WE BEEN?

Throughout its history, Kentucky has lagged far behind most other states in science and technology, unfortunately finding itself near or at the bottom of far too many lists. Kentucky has been the home of relatively few corporate headquarters with associated research operations and has never had a federal research installation (such as Oakridge National Laboratory). Rather than encourage university research, the state has been continually distracted by the politics of inter-university competition for resources. Kentucky's leadership has been dominated by people who have been rather narrowly focused on regional/political interests, oftentimes at the expense of emerging opportunities. Our colleges and universities have suffered from a lack of attention to their research and development activities—activities that are critical to the attraction and development of new industries. Contributing to this lack of attention is a perception shared by many Kentuckians that higher education in Kentucky is more than adequate. Together these factors have conspired to keep the Commonwealth out of the running, even though a number of our colleges and universities possess some very qualified and highly capable individuals. Throughout the country, Kentucky is perceived as an insignificant player in the science and technology game.

A brief review of some of the available data illustrates our historical plight. In the early 1970's a study funded by the Kentucky Department of Commerce, conducted under the joint auspices of the Kentucky Academy of Science and the Task Force on Public Science and Technology, concluded that Kentucky fared poorly in comparison with the rest of the United States in terms of federal support for research and development activities, with Kentucky ranking 50th among the 50 states in a number of areas.

A comparative quality of life study conducted by the Midwest Research Institute in 1973, revealed that Kentucky received less than half of the national per capita average per college in federal grants for research and development. Kentuckians received about 13 fellowship and traineeship awards per 100,000 people compared to a national average of 46. The study also showed that Kentucky employed 77 scientists per 100,000 people versus a national average of 103.

In 1978, a study of federal funding of research and development in Kentucky was undertaken by the Council on Higher Education, the legislative Research Commission and the Kentucky Academy of Science. Their findings included the fact that in 1977 Kentucky ranked 8th in a group of 11 benchmark states and next to the last among its contiguous states in total federal obligations for research and development. While it ranked 23rd in population, it ranked 47th in research and development dollars per capita. While ranked 25th in federal tax dollars paid in 1976, it ranked only 40th in federal research and development obligations per tax dollar contributed.

In more recent years, while perhaps showing some improvement, the basic situation has remained very problematic. Kentucky was identified in 1985 by the National Science Foundation as one of 13 states in need of help in developing its research potential. Again, due to the fact that it finds itself on the low end of the continuum in a number of key areas. What does all of this mean? It means that Kentucky has lacked an historical commitment relative to the development of science and technology and consequently must take aggressive steps to alter the dangerous course on which it now finds itself.

WHERE ARE WE NOW?

As it enters the new era, Kentucky finds itself in the following situation. Kentucky's high tech industrial sector is relatively small and is not growing as rapidly as the nation as a whole. Unlike several of the states with similar geographical characteristics, Kentucky does not have an established major center of advanced technology industry development and has not participated significantly in the rapid growth in this sector of the economy. At the same time, Kentucky does have a substantial industrial and related research and development base, both at its universities and in several industries of medium technology industry—notably chemicals, electrical equipment (especially household appliances) and motor vehicles. These industries as a group appear to have limited growth potential and also significant long-term potential for substantial technology-induced job losses. There is a significant need for increased research in automation and information technologies to help these companies remain competitive.

Most of Kentucky's small, but important, high technology and medium technology-intensive industries are concentrated in the Louisville and Lexington areas, with, however, significant technology-based industry clusters also at Ashland in Northeastern Kentucky, and at Paducah, Owensboro and Bowling Green in Western Kentucky. Kentucky's academic science and engineering resources and advanced research are concentrated at the University of Kentucky and the University of Louisville, although educational opportunities at the undergraduate and in some cases the master's level in scientific and technological fields are available statewide. Research activities at the two research institutions cover a very wide range with certain areas of special focus, including biotechnology, medical sciences (i.e., cancer, aging, pharmaceutical science, cardiovascular research), energy-related science and technology and ecology/environment.

Considering this pattern, and Kentucky equivalent of the "Silicon Valley" seems certain to be centered in Louisville and Lexington, and/or along I-64 between them. There may also be the potential for significant technology-based economic development in the Covington-Newport area, drawing upon the location of the Greater Cincinnati International Airport and the substantial scientific and technological critical mass of the Cincinnati Metropolitan Area.

A major aspect of the technological revolution is the requirement for strong programs of higher education with emphasis on applied and basic research. The economy of the present and future will depend increasingly on access to such institutions for the ideas and the people absolutely essential for the high technology industries. The University of Kentucky at Lexington and the University of Louisville are our only research universities. Both are in need of increased financial support to develop and maintain the faculties and the research facilities which will make them competitive, first rate institutions!

The lack of an aggressive commitment or resources to training and leadership has had a devastating impact on our ability to mount technology-based industry. We rank far below most of our sister states in the region in percentages of the population who are engineers, scientists and technicians. Texas, Florida and North Carolina have from three to ten times greater percentages of their population in these trades than Kentucky. We are at the bottom of the list together with Arkansas and Mississippi, both of whom are already making massive efforts at the state level to upgrade their economic and research base in science and technology.

Education in the important areas of science and mathematics are critical factors in the development of an adequate foundation on which to build effective science and technology initiatives. And yet again, Kentucky lags behind many states in science education. Science is not even considered an essential skill in Kentucky. Perhaps this is one reason why it is often neglected in the elementary grades when student interest is high. Unfortunately, many teachers, because they do not have adequate science training, feel uncomfortable in trying to teach this subject. Not only has science been neglected at the lower grade levels, but many secondary school students have not had adequate training in science.

This is particularly troublesome. The public must be sufficiently knowledgeable to be able to apply the tools of technology in their everyday lives and job environments. They must also be able to make informed decisions about the course of change and its implementation, particularly those political decisions which involve the allocation of limited monetary resources. In addition, we must train a sufficiently skilled work force to make the state competitive for the increasingly technical industry of the future. Yet by most criteria the products of our primary and secondary education system are woefully lacking in even the basic skills. There is little wonder that the Commonwealth has been all but bypassed in the recent revitalization of the economy in the South.

In addition, Kentucky presently does not possess an adequate supportive environment on which to promote and develop technology-based industries. Certain bureaucratic hurdles at our universities that are regulatory rather than facilatory as well as a lack of the necessary venture capital are two factors that limit the "incubation" of new ideas and enterprises. While some initiatives have been made, there has been little impact.

The bottom line is that Kentucky is presently not meeting the challenges created by the demands of the "new economy." According to one study, employment growth in high technology industries between 1975 and 1982 grew in Alabama 83.5%; Arkansas, 31.1%; Florida, 97.1%; Georgia, 92.3%; Tennessee, 42.9%; Virginia, 30.3%; while in Kentucky it grew at a scant 0.4%.

One report made available to Kentucky Tomorrow concluded after reviewing a number of key factors that

- Kentucky does not presently have a significantly high technology industry sector, and does not appear to be building one at a time when this sector is growing rapidly nationwide; and
- The great majority of Kentucky's manufacturing industry is of medium to low technological intensity as measured by the number of engineers and scientists per 100 employees generally employed by industries of different types.

QUESTIONS AND IMPLICATIONS

We are living in an era of rapidly expending technology unlike any ever experienced by humanity. Ninety percent of all scientists and engineers who ever existed are alive today. We are indeed in the midst of a scientific "revolution" perhaps unprecedented in our history.

The Commonwealth of Kentucky and its citizens must be prepared to meet the challenges created by this "future technocracy" and make the very difficult economic, social and ethical decisions which these changes will surely bring. How well equipped are we in 1985 to make this transition? The answer, we're afraid, is very poorly. But our future can be one of *opportunity*. However, the proper base for growth and development is research, both academic and industrial. From an historic point of view, the time is fight for a bold, new initiative.

The state of Kentucky is positioned in a fortuitous environmental locale and historic moment. Research in this state could have a major focus in a tripartite program concerned with energy/ecology/environment. Our coal and mining resources are a potential source of greater economic growth and development.

Given the importance of science and technology to Kentucky's future, we must begin *now* to develop an aggressive, imaginative program in this area. Over the next 25 years, many experts predict that expansion and technology-driven industries will result from "spin-offs" from existing businesses rather than from industrial relocation. The conspicuous absence of a solid research and technology base in Kentucky is a clear warning that we cannot ignore.

5. SCIENCE EDUCATION COMMITTEE. Dr. Ted George presented the following report.

A. *Honoring Science Fair Winners and Sponsoring Teachers:* At the suggestion of President Winstead and with approval of the Executive Committee, at last night's banquet the Academy began what we hope will become a tradition. We honored the student winners of the five Regional Science Fairs, and the winners of the Symposium of the Junior Academy and their sponsoring teachers. We feel that this is a very worthwhile project and should help to promote science in Kentucky and should also promote interest in the Academy. Each student winner and sponsoring teacher was invited to the meeting and was offered a banquet ticket at Academy expense and presented with a plaque noting their achievements. There was no charge for their registration and each was given a free one-year membership in the Academy. Four hundred dollars was budgeted to pay for the plaques and banquet tickets.

B. *Three-Level Certification:* Three-level certification is now in place for freshmen teacher candidates for this fall. They are Elementary (K-5), Middle School/Junior High (5-8) and Secondary (9-12). The old certification will be valid for graduated teachers and also teacher candidates who graduate before fall, 1989.

The regulations for elementary and secondary certification remain essentially the same. Briefly, the new requirements for Middle School require forty-eight semester hours in the specialty component, which must be divided between two teaching fields of twenty-four hours each. The fields are: (1) English and Communications, (2) Mathematics, (3) Science and (4) Social Studies.

The certification for the science fields is as follows; Science: Preparation shall include biology—9 semester hours; a selection from either earth science—9 semester hours, chemistry—9 semester hours, or physics—9 semester hours; and the remaining 6 semester hours to be divided equally among the two remaining disciplines. All four areas must include laboratory experiences.

We have concerns about the adequacy of the preparation to teach science in middle school, and we cannot help but contrast that with requirements of the mathematics field: Mathematics Option I: Preparation to include mathematics for the elementary school teacher—6 semester hours; fundamental computer techniques and programming—3 semester hours; probability/statics—3 semester hours; geometry—3 semester hours; and the remainder in electives to provide additional breadth and depth in mathematics.

Mathematics Option II: A secondary level teaching major or minor in mathematics plus a two course sequence in mathematics for the elementary school teacher.

Thus, the mathematics teacher would most likely have some calculus (to teach eighth grade) while the science teacher will have only a three-hour course in two of the Physical Sciences. But these regulations are now in place and the present administration is in no mood to change them.

C. *Science Taught by Vocational Education Teachers:* In May of this year, the Kentucky State Board of Education changed the Program of Studies so that certain courses taught by Vocational Education teachers may give credit in science. A high school student must still take a minimum of two courses in science in academic areas. However, a vocational student may take certain vocational subjects taught by vocational teachers and have them counted as science courses. One course is "Special Topics in Biological Science 2512" which was designed to be taught as an academic course. The new guidelines allow Horticulture, Health Sciences III, Cosmetology and Practical Nursing to be taught as this course. Another course is "Special Topica in Physical Science 2564". Again, this was originally designed as an academic course. The new guidelines allow Electronics, Electricity, Radio/TV Repair and Air Conditioning to be taught as this course.

Vocational Education teachers are not usually certified in science, many are not college graduates and some only have the GED. The main reason for this change is a requirement of the last legislature that 60% of the clock time of students in secondary schools must be spent in academic subjects. Thus ruling has caused a drastic drop in vocational enrollments.

At a time when tremendous efforts are being made to upgrade science education, this can only be described as a step backward. There is some evidence that this movement is occurring in other states and perhaps should be attacked on a national scale. We are proposing that a resolution be approved to send to AAAS to the effect that they should investigate this tendency across the country and consider taking action on a national scale.

6. MEMBERSHIP COMMITTEE. Dr. Larry Elliott made the following report.

The contact people who have served this year are as follows: Dr. Bill Hettinger, Ashland Petroleum Co.; Dr. Thom Strickler, Berea College; Dr. Gordon Weddle, Campbellsville College; Dr. Susan Studlar, Centre College; Dr. Blaine Early, Cumberland College; Dr. Ted George, Eastern Kentucky University; Dr. Charles Cantrell, Elizabethtown Community College; Dr. Thomas Seay, Georgetown College; Dr. Valina Hurt, Hazard Community College;
Dr. Cathy Hunt, Henderson Community College; Dr. Mike McClure, Hopkinsville Community College; Dr. Gertrude Ridgel, Kentucky State University, Dr. Jonnie Blair, Lee's Junior College; Dr. Michael Trover, Madisonville Community College; Drs. Herb Richey and Ladonna Barnett, Maysville Community College; Drs. John Philley and Herbert Berry, Morehead State University; Dr. Harold Eversmeyer, Murray State University; Dr. Jerry Carpenter, Northern Kentucky University; Dr. Bill Beasley, Jr., Paducah Community College; Dr. Charles Robertson, Prestonburg Community College; Dr. James Anderson, Somerset Community College; Dr. Jim Fedders, St. Catherine College; Dr. Lynn Allen, Sue Bennett College; Dr. Mary Fox, Thomas More College; Dr. Ron Rosen, Union College; Dr. Manuel Swartz, University of Louisville; Dr. Paul Freytag, University of Kentucky and Dr. Joe Winstead, Western Kentucky University.

A membership list from the secretary of KAS, Dr. Robert Creek, was received in January. Each contact person was sent a list of inactive members at their institution and asked to contact these people for reenlistment. They were also asked to recruit new members from their place of employment and in the community. To the other inactive members in the KAS, the KAS membership chairman sent a letter reminding them they were inactive. This was useful as our membership roll was corrected and updated.

The secretary of KAS sent me an updated computer list of members in the spring and the same procedure described above was repeated. At this mailing more contact people were enlisted at the various institutions for recruitment. The president of KAS was very helpful in overall recruitment of members as letters were sent to members who were behind in their dues urging them to renew their membership.

If the board would suggest contact people for other organizations that have none, the committee would appreciate it since this would enable KAS to optimize recruitment. The following colleges need contact people for recruitment: Alice Lloyd, Asbury and Brescia.

Dr. Elliot stated that in 1985 there were 55 new members thereby giving a total of 513 paid-up members for this year.

7. RARE AND ENDANGERED SPECIES COMMITTEE. Mr. John MacGregor made the report.

He stated that the committee had been updating the old endangered species list which was five years old. The new list has approximately 570 species. The committee will continue to work on finalizing the list and will publish it in the Transactions upon completion.

8. NOMINATIONS COMMITTEE. The nominating committee nominated the following candidates, who were presented to and duly approved by, the Executive Committee and Board of Directors of the Kentucky Academy of Sciences:

1. William Hettinger - Vice President
2. Jerry F. Howell, Jr. (1987)
   (to fill unexpired term of Dr. Hettinger)
3. Ralph L. Thompson (1987)
   (to fill unexpired term of Dr. Boucher)
4. Douglas L. Dahlman (1989)

Nominees from the floor were called for by President Winstead but none were forthcoming. The state was accepted by the membership and voted in by acclamation.

9. RESOLUTION COMMITTEE. Dr. J. G. Rodriguez presented the following resolutions.

RESOLUTION NO. 1:

Whereas during the past year these members of the Kentucky Academy of Science have departed this life, be resolved that we extend condolences to their families:

Dr. Robert Kuehne
Dr. Michael Loeb

RESOLUTION NO. 2:

Whereas the Kentucky Academy of Science has enjoyed the gracious hospitality of Morehead State University for the 1985 meeting, be it resolved that we express appreciation to the administration, faculty and staff of MSU, and especially to President Herbert Reinhard, Dean Robert Burns, and to Dr. John Philley and his Local Arrangements Committee.

RESOLUTION NO. 3:

Whereas our friends at Mineral Laboratories, Inc. have sponsored the Coffee Breaks at the 1985 meeting of the Kentucky Academy of Science, be it resolved that we thank Mineral Laboratories, Inc. and President E. Paul Lyon, for this feature which added to the ease and comfort of the meeting.

RESOLUTION NO. 4:

Whereas all our Exhibitory have added substantially to the edification of our Academy members, be it resolved that each participating company be thanked appropriately by our Secretary.

RESOLUTION NO. 5:

Whereas the officers and Board of Directors of the Kentucky Academy of Science have labored diligently for many months to make the 71st Annual Meeting the resounding success that it was, be it resolved that we thank them for an excellent program.

RESOLUTION NO. 6:

Whereas education in science is basic to understanding the modern world, and

Whereas education in science is necessary for informed participation in a democratic society and for productive work in a modern industrial nation, and

Whereas there is growing evidence of a decline in support of the commitment to precollege science education in the United States while other industrial nations are placing heavy emphasis on science education at all levels, and
Whereas there is a national trend toward the practice of offering science credit for courses taught in a vocational setting by teachers who do not have at least a minor in the science courses being taught, and

Whereas the validity of labeling such vocational offerings as science courses is questionable,

Therefore be it resolved that the Kentucky Academy of Science requests that the American Association for the Advancement of Science investigate the potential impact of these practices on the secondary science curricula in the United States.

Resolution 6 on Qualified Science Teachers was forwarded to Dr. Joe King, the AAAS representative for the Academy, for presentation to the authorities of AAAS.

Each resolution was passed as presented.

10. NEW BUSINESS.

A. A motion was made and seconded to raise the Life Member dues to $250. Motion passed.
B. Dr. Donald Batch said the present endangered species list had no authority and he suggested the Committe have the list made official. Mr. MacGregor responded that the Committee would be working toward this goal but felt that the list should have the endorsement of the Academy. Dr. Winstead recommended that the Executive Committee act upon this at their spring meeting. Dr. Hettinger suggested approaching industries and explaining the purpose of the list so as to develop a better understanding for the necessity of such a list.
C. Dr. Winstead reported that a total of $1,000 had been donated by the Past Presidents toward the KAS Endowment Fund. Dr. Winstead concluded his tenure as President by giving a slide presentation reflecting the activities of the past year.
D. Dr. Winstead introduced the President for 1986, Dr. Charles V. Covell, Jr., and presented him with the gavel.
E. President Covell presented Dr. Winstead with a plaque for his service as President and his contribution to the Academy.

   He announced the appointment of an *an hoc* committee to study the constitution and by-laws of the Academy and to recommend changes. The members of the committee are Drs. Rodrigues (chair), Boggess, and George.

Following a brief address by President Covell, the meeting was adjourned at 10:25.

KENTUCKY ACADEMY OF SCIENCE
71st ANNUAL MEETING
PROGRAM

Friday, November 8, 1985

0930-1200 *Community College Faculty Meeting* - Riggle Room, Adron Doran University Center

1130-1300 *Executive Committee Luncheon* - Gold Room, Adron Doran University Center

1200-1600 *Registration* - Lobby, Claypool — Young Art Building

1200-1700 *Scientific Exhibits* - Lobby, Claypool Young Art Building

1300-1500 *Sectional Meetings* - See Following Pages

1500-1530 *Coffee Break* - Lobby, Claypool — Young Art Building

1530-1700 *Plenary Session* - Auditorium, Claypool - Young Art Building

1730-1830 *Social Hour* - President's Home

1900-2100 *KAS Annual Banquet* - Crager Room, Adron Doran University Center

2100-2300 *Hospitality Time* - Holiday Inn

Saturday, November 9, 1985

0730-1000 *Registration* - Lobby, Claypool — Young Art Building

0800-1200 *Scientific Exhibits* - Lobby, Claypool— Young Art Building

0800-0900 *Sectional Meetings* - See Following Pages

0900-0915 *Coffee Break* - Lobby, Claypool - Young Art Building

0915-1015 *Annual Business Meeting* - Auditorium, Claypool - Young Art Building

1030-1200 *Sectional Meetings* - See Following Pages

1300-1600 *Sectional Meetings* - See Following Pages

PLENARY SESSION

Friday, November 8

1530 Auditorium, Claypool-Young ARM Building "THE NSF-EPSCoR PROJECT - ENHANCING KENTUCKY'S RESEARCH POTENTIAL"

Speakers:

Dr. James Durig
Dean of Science and Mathematics
University of South Carolina

Dr. Leonard Peters
Associate Dean of Research
University of Kentucky
Project Director of EPSCoR Program in Kentucky

ANNUAL BANQUET

Friday, November 8

1900 Crager Room, Adron Doran University Center

Speaker:

Mr. Harry M. Synder
Executive Director
Kentucky Council on Higher Education

"SCIENCE AND TECHNOLOGY IN KENTUCKY A HISTORY OF DEFICIENCY"

ANTHROPOLOGY SECTION

James Murray Walker, Chairperson and Acting Secretary, Presiding
Room 219 - Rader Hall

Saturday, November 9, 1985

0800 Excavations at 400B6, a Mississipian Mound in Northwest Tennessee. Jack Michael Schock, Western Kentucky University.

0 8 2 0 Cognitive vs. Ecological Niches in Prehistoric Egypt. Elizabeth Finkenstaedt, University of Kentucky

0 8 4 0 Kentucky Archeology and the Public. James Edward Henson. Kentucky Dept. of Parks. (Sponsored by Murray Walker)

0 9 0 0 Coffee Break

0 9 1 5 Annual Business Meeting

1 0 3 0 Diffuse Idiopathic Skeletal Hyperostosis. Joseph F. Powell (sponsored by James Murray Walker), Eastern Kentucky Univer-sity.

1 0 5 0 Not for Evil: An Ethnographic Interpretation of the Third Commandment (Protestant Enumeration). James Murray Walker, Eastern Kentucky University.

1 1 1 0 Socio- Political Discourse in the Muslim Cult of the Saints. Ed Reeves, Morehead State University.

1 1 3 0 Who's to Blame?: Anthropological Insights into Industrial Disasters. Cara E. Richards, Transylvania University.

BOTANY AND MICROBIOLOGY SECTION

Ronald L. Jones, Chairman, Presiding
Ralph L. Thompson, Secretary
Room 126 - Lappin Hall

Friday, November 8, 1985

1 3 0 0 *Endangered, threatened and rare animals and plants of Kentucky-a second look. Richard Hannan, Kentucky Nature Preserves Commission.*

1 3 1 5 *Geographical origin of the specimens of Orbexilum stipulatum* (T. & G.) Rydb. (*Psoralea stipulata* T. & G.). *Jerry Baskin* and Duane Isley, University of Kentucky and Iowa State University.

1 3 3 0 Possible determining factors for low host specificity in VA fungi. Frederick M. Rothwell, USDA Forest Service, Northeastern Forest Experiment Station.

1 3 4 5 Germination of the seeds of *Euonymus americanus* L. with the use of *Clostridium cellobioparum*. *G.T. Howard* and L.P. Elliott, Western Kentucky University.

1 4 0 0 Development of mixed mesophytic forest through succession and recovery: monitoring through time. *William H. Martin,* and James M. Fedders, Eastern Kentucky University and West Virginia University.

1 4 1 5 Structure and diversity of Bluegrass forests. William S. Bryant, Thomas More College.

1 4 3 0 The role of state native plant societies in conservation. Ronald L. Jones, Eastern Kentucky University.

1 4 4 5 Election of sectional officers

1 5 0 0 Coffee Break

1 5 3 0 Plenary Session

Saturday, November 9, 1985 - Room 126 - Lappin Hall

0 8 0 0 Culture of cucumber protoplasts. *Larry A. Giesmann* and Karen W. Hughes, Northern Kentucky University and University of Tennessee.

0 8 1 5 The effects of benzimidazole on duckweed. James J. Dyar, Bellarmine College.

0 8 3 0 Scanning electron microscope studies of tobacco leaf epidermis subjected to simulated acid rain. *M.V. Currier,* J.E. Winstead, and J.R. McCurry, Western Kentucky University.

0 8 4 5 Sulfur accumulation in xylem tissue of tree species from Kentucky and Tennessee correlated with growth and atmospheric sulfur pollution. J.L. Sharp, Western Kentucky University.

0 9 0 0 Coffee Break

0 9 1 5 Annual Business Meeting

1 0 3 0 Effects of blossom-set on fruit production and retention in the California Wonder cultivar of *Capsicum. Mary Susan Mardon,* and Thomas L. Keefe, Eastern Kentucky University. (Sponsored by David Mardon)

1 0 4 5 Cloning of the gene for glutamine synthetase from soybean. *Valgene L.*

Dunham and Brian Cummings, Western Kentucky University and Native Plants Incorporated, Utah.

1100 Effect of heavy metal pollutants on the growth and development of *Lemna minor*. Sue Ellen Hugan, Notre Dame Academy, sponsored by H.A. Leopold.

1115 Chemical influences on root gravitropism. Kathy Seggerson, Notre Dame Academy, sponsored by H.A. Leopold.

1130 Using centrifugal accelerations to determine the effect of applied voltage on root geotropism in *Zea mays*. Gaylon R. Lovelace, Jr. Grant County High School, sponsored by H.A. Leopold.

1145 Limnological studies on Taylorsville Lake, a new reservoir in Kentucky. James D. Mayfield, University of Louisville.

1200 Lunch

1300 A reinvestigation of Claiborne Formation (Middle Eocene) fruit and seed floras from western Kentucky and Tennessee. *Paul J. Grote* and David L. Dilcher, Indiana University.

1315 Peat Moss in Kentucky. *Willem Meijer* and Ray Cranfill, University of Kentucky.

1330 Preliminary report on the violets of Kentucky. Landon E. McKinney, Barcon, Inc.

1345 Some plant communities of the Fort Knox Army Base. *Hal D. Bryan* and John R. MacGregor, Kentucky Department of Highways and Kentucky Department of Fish and Wildlife Resources.

1400 A floristic study of Panther Glade - a unique natural area in Hardin County, Kentucky. *Marc Evans* and Jeffrey Sole, Kentucky Nature Preserves Commission and Kentucky Department of Fish and Wildlife Resources.

1415 Preliminary studies of plant biomass patterns on strip mine spoil. *R.G. Reiss* and J.E. Winstead, Western Kentucky University.

1430 Surface-mine reclamation and native species from forest topsoil seed banks. Gary L. Wade, USDA Forest Service, Northeastern Forest Experiment Station.

1445 Vascular flora of Log Mountain Surfacemine Demonstration Area, Bell County, Kentucky. Ralph L. Thompson, Berea College.

1530 Discussion: A Kentucky Native Plant Society?

CHEMISTRY

Audrey L. Campanion, Chairperson
Laurence J. Boucher, Secretary

Friday, November 8, 1985

Tutorial Session: Coal Chemistry
Laurence J. Boucher, Presiding
Eagle Meeting Room
Adron Doran University Center

0800 Introduction. Laurence J. Boucher, Arkansas State University.

0815 Organic Chemistry of Coal. John W. Reasoner, Western Kentucky University

0915 Coffee Break

0930 Analytical Chemistry of Coal. John T. Riley, Western Kentucky University.

1030 Conversion of Coal to Liquid and Gaseous Products, William G. Lloyd. Western Kentucky University.

Session I. David A. Owen, Presiding
Room 129 - Lappin Hall

1300 Polylithiation and Subsequent Derivatization Reactions of Bis-Fulvalenyl Diiron. *Danny J. Garland* and David A. Owen, Murray State University.

1315 Investigations on Thermoplasticity of Some Kentucky Coals. *William D. Schulz* and Kenneth R. Rose, Eastern Kentucky University.

1330 Mechanistic Studies of the Induced Decomposition of Diacylperoxides. T.G. Taylor and *Shamala Nuggehalli*, University of Louisville.

1345 Functional Group Effect on the Solvent-induced Swelling of Coal. *Elizabeth K. Sutton* and Joan Reeder, Eastern Kentucky University.

1400 Analysis of Rainwater Precipitation in Southwest Kentucky. *Mustafa I. Selim*, Murray State University.

1415 Analysis of Hair and Nail by INAA: Relationship of Trace Element Levels to Alzheimer's Disease. *D.E. Vance*, W.D. Ehmann and W.R. Marksbery, University of Kentucky.

1430 Preliminary Plasmid Studies of the Slane Isolate of *Acinetobacter Calcoaceticus*. *Thomas Maudru* and Vaughn Vandergrift, Murray State University.

1445 Software for Instrumental Analysis. *Jeff Anderson*, Murray State University.

1500 Coffee Break

1530 Plenary Session

Session II. John T. Riley, Presiding
Room 129 - Lappin Hall

Saturday, November 9, 1985

0800 Axioms of Kinetics and a Thermodynamic Rate Law. *M.L. Trover* and P.L. Corio, University of Kentucky.

0815 Construction and Use of an Adiabatic Calorimeter to Study the Self-Heating of Coal. *G.S. Yates*, S.M. Fatemi and J.T. Riley, Western Kentucky University.

0830 Use of an Alkali Extraction Test as a Prediction for Self-Heating in Coal. A. Parvez, J.W. Reasoner and *J.T. Riley*, Western Kentucky University.

0900 Coffee Break

0915 Annual Business Meeting

1030 Laboratory Microcomputing. Samuel L. Cooke, University of Louisville.

1115 Panel Discussion: Computers in Chemistry; John M. Chamberlin, Western Kentucky University, Audrey L. Companion, University of Kentucky, Morris Taylor, Eastern Kentucky University, Jeff Anderson, Murray State University.

1200 Chemistry Section Meeting: Election of Officers

Session III. Laurence J. Boucher, Presiding
Room 130 - Lappin Hall

0800-0900 Poster Session

Assay of Soluble Fractions from the Hydro-Liquefication of Micronized Coals. *Cindy Elder* and W.G. Lloyd, Western Kentucky University.

Kinetics of Proton Removal from Ethylbis (2, 4-dinitrophenyl)acetate by Thiethylamine. *Carl D. Slater*, Northern Kentucky University.

Hydrogen Transfer Catalysis with Anchored Palladium Anthranilic Acid Polystyrene Polymers. Cindy Elder and *L.J. Boucher*, Western Kentucky University.

GEOGRAPHY SECTION

Glen Conner, Chairperson, Presiding
Gary Cox, Secretary
Room 221 - Rader Hall

Friday, November 8, 1985

1300 "A Geographical Analysis of the 1985 Kentucky Essential Skills Test." *Wayne Hoffman* and James Bingham, Western Kentucky University.

1315 "Places Rated Almanac and Kentucky Cities." Michael J. Pirani, University of Kentucky.

1330 "Napier Cave: A Case of Groundwater Pollution From Leaking Underground Storage Tanks." James W. Webster and Nicholas Crawford, Western Kentucky University.

1345 "Hot Spells, Cold Spells, and Folklore Climatology." Glen Conner, Western Kentucky University.

1400 "Names and Landscape Change in Kentucky, 1955-1985." William A. Withington, University of Kentucky.

1415 "Geography of Death: The Case of Kentucky Farming." Milos Sebor, Eastern Kentucky University.

1430 "Built to Last: Brick Architecture of Cumberland County, Kentucky." Albert Peterson, Jr., Western Kentucky University.

1445 "Microclimatological Changes Incurred During a Social Gathering." L. Michael Trapasso, Western Kentucky University.

1500 Coffee Break

1530 Plenary Session

Saturday, November 9, 1985 - Room 221, Rader Hall

1030 "Karst Hydrology of the Sunken Spring Drainage Basin, Warren County, Kentucky." *Christopher G. Groves* and Nicholas Crawford, Western Kentucky University.

1045 "Differences Between Kentucky Counties With and Without Interstate Highways: A Discriminant Analysis." Henry E. Moon, Jr., University of Kentucky.

1100 "Transportation Design Process Study of Bowling Green, Kentucky." Hong Liu, Western Kentucky University.

1115 "Impact of Early Mills on the Landscape of Central Kentucky." William A. Bladen, University of Kentucky.

1130 "Urban Reclamation of a British Coal Mining Area." James L. Davis, Western Kentucky University.

1145 "Changing Patterns of Black Residential Location in Covington, Kentucky, 1860-1980." Edwin T. Weiss, Jr., Northern Kentucky University.

1200 "Black Surbanization in Jefferson County, Kentucky: A Preliminary Report." John L. Anderson, University of Louisville.

GEOLOGY SECTION

Gary L. Kuhnhenn, chairperson, Presiding
Alan D. Smith, Secretary
Room 210 - Lappin Hall

Friday, November 8, 1985

1300 Jeptha Knob, Iridium and extinctions. C. Ronald Seeger, Western Kentucky University.

1315 Structural geology and mineral distribution in the Boonesboro limestone mine, Ford quadrangle, Madison County, Kentucky. Timothy J. Gustafson, Eastern Kentucky University, sponsored by G. Kuhnhenn.

1330 Is a geologic methods course important to undergraduate training? David K. Hylbert, Morehead State University.

1345 Textural evidence for multiple metamorphism, Brevard Fault zone, Rosman, North Carolina. *Timothy R. McKinsey* and John R. Monrad, Eastern Kentucky University, sponsored by G. Kuhnhenn.

1400 Petroleum drilling in eastern Kentucky. Graham H. Hunt, University of Louisville.

1415 Analysis of phosphate nodules from the Borden Formation of northeastern Kentucky *Jeffrey T. Stewart,* Charles E. Mason and Richard L. Hunt, Morehead State University.

1430 Condonts from the upper Farmers and lower Nancy Members of the Borden Formation of northeastern Kentucky. George B. Clarke, *Anthony R. Hatton* and Charles E. Manson, Morehead State University.

1445 Evaluation of coal beneficiation by high-gradient magnetic separation: a case study at TVA's Paradise coal preparation facility. Kenneth W. Kuehn, Western Kentucky University, sponsored by R. Seeger.

1500 Sectional Business Meeting

1515 Coffee Break

1530 Plenary Meeting

Saturday, November 8, 1985

0900 Coffee Break

0915 Annual Business Meeting

PHYSICS SECTION

Joel Gwinn, Chairman, Presiding
Raymond McNeil, Secretary
Eagle Meeting Room
Adron Doran University Center

Friday, November 8, 1985

1500 Coffee Break

1530 Plenary Session.

Saturday, November 9, 1985

0800 What Can You Do with One Sheet of Paper? *Vincent A. DiNoto, Jr.*, Jefferson Community College Southwest.

0815 Physics Lab Safety Instruction. *Neil D. Adams,*Paducah Community College.

0830 Computer-Assisted Lab Evaluation. *William T. Luyster,* DeSales High School.

0845 Selected "Outstanding?" Demonstrations in Physics. *Michael Schmidt*, Thomas More College.

0900 Comic Strip Physics: Humor as a Mode of Knowledge. *Russell M. Brengelman*, Morehead State University.

0915 Annual Business Meeting

1030 Counting Stars at the South Galactic Pole. *Raymond C. McNeil*, Northern Kentucky University.

1045 Impact Ionization of Laser-Excited Atoms. *K.B. MacAdam*, N.L.S. Martin, and D.B. Smith, University of Kentucky; R.G. Rolfes, Presbyterian College.

1100 Inelastic Scattering of ^{28}Si on ^{208}Pb. *D.L. Humphrey* and G. Vourvopoulos, Western Kentucky University; D.C. Hensley, J.R. Beene, F.E. Bertrand, and M.L. Halbert, Oak Ridge National Laboratory.

1115 Automobile Deceleration Force by the Coast Down Method. *William S. Wagner*, Northern Kentucky University.

1130 Stopping Distances and the Coefficient of Kinetic Friction. *Marshall Wilt*, Centre College.

1145 Using the Apple II Computer to Take and Analyze Pendulum Data. *Kevin Cahill*, Thomas More College.

1200 Lunch

1300 Proton Reactions on Indium from 60 to 200 MeV. *John Fisher* and C.E. Laird, Eastern Kentucky University; Tom Ward and Lei Wan Woo, I.U.C.F.

1315 Level Structure of ^{120}Sn from (n, n) Studies. *J.L. Weil*, Xiamin Shi, Z. Zhou, and J. Sa, University of Kentucky.

1330 Measuring c with a Pulsed LED. *Mike Cihoas*, Centre College.

1345 Wave Analysis Using Apple Computers. *J.P. Stewart*, Warren East High School; F.D. Bryant and D.L. Humphrey, Western Kentucky University.

1400 Physics Section Business Meeting.

PHYSIOLOGY, BIOPHYSICS, BIOCHEMISTRY AND PHARMACOLOGY SECTION

John Calkins, chairperson, Presiding
David I. Wiegman, Secretary
Room 113 - Lappin Hall

Friday, November 8, 1985
Workshop - Room 130 - Lappin Hall

1300-1500 Integrative Study in Physiology and Medicine. Scientific, philosophic, and pedagogic principals in the study of the human organism at the level of its wholeness: the milticellular organism. Joseph Engelberg, University of Kentucky.

Friday, November 8, 1985

1300 Separation and identification of phenolic and trimethylsilyl derivatives by gas chromatography and fourier transform infrared spectroscopy. John H. Melhuish, Jr., Raymond B. Willis and *Charles S. Wright*, Northeastern Forest Experiment Station.

1315 Flowering requirements of *Tussilago farfara*. *John H. Melhuish, Jr.*, Peter R. Beckjord and Willis G. Vogel, Northeastern Forest Experiment Station.

1330 Kinetics of glucuronidation of 4'-Chloro-4-biphenylol. M.A. Davis and *R.F. Volp*, Murray State University.

1345 Photomutagens in synthetic fuel. *Christopher Selby*, John Calkins and Harry G. Enoch, University of Kentucky and Kentucky Energy Cabinet.

1400 The effect of the fescue endophyte on the rat estrus cycle. *Dan R. Varney* Michael Ndefru and Sanford L Jones, Eastern Kentucky University.

1415 The effect of the fescue endophyte on the physiology of the female rat. *Hugh Hem-Lee*, Dan R. Varney and Sanford L. Jones, Eastern Kentucky University.

1430 Reproductivity and lactation in rats as effected by the fescus endophyte. *Joseph Kappes*, Dan R. Varney and Sanford L. Jones, Eastern Kentucky University, 1445 The distribution of orally administered BHT in tissues of New Zealand white rabbits. *D.R. Hartman,* B.R. Ferrell and L. Breiwa, Western Kentucky University.

1500 Coffee Break

1530 Plenary Session

Irvin G. Joshua, Presiding
Room 113 - Lappin Hall

Saturday, November 9, 1985

0800 Positioning kinetics of the colonial algae *Volvox* in response to visible and ultraviolet radiation. *Mary Blakefield* and John Calkins, University of Kentucky.

0815 Caffeine as an inhibitor of repair radiation damage and as a toxic agent. *John Calkins* and John Wheeler, University of Kentucky.

0830 The relationship of the sensitization factor observed with UV repair inhibition at wavelength from 254 to 320 nm. *John Wheeler,* Cindy I. Keller and John Calkins, University of Kentucky.

0845 Effect of pulmonary C-fiber stimulation an left ventricular contractility. *Michael A. Kurz,* William B. Wead, Milton T. Kosfeld and Cary Schooly, University of kentucky.

0900 Coffee Break

0915 Annual Business Meeting

1030 Serotonin has a differential effect on arterioles in the rat cremaster muscle. *Andreas S. Luebbe* and Nancy L. Alsip, University of Louisville.

1045 Enkephalin-induced changes in microvascular luminal diameter. *J.W. Brock,* J.P. Dowe, I.G. Joshua and F.N. Miller, University of Louisville.

1100 Nutrient and non-nutrient circulatory channels in the canine kidney. *Jamie S. Young* and John C. Passmore, Univeristy of Louisville.

1115 Relationship between glucose 6-phosphate dehydrogenase activity, corticosterone levels, and diet in 7, 12-dimethylbenz (a) anthracene induced rat mammary tumors. James A. Vansant and David Magrane (Sponsored by Jerry Howell, Jr.), Morehead State University.

1130 Relationship between glucose-6-phosphate dehydrogenas activity and hormone dependency in DMBA-induced rat mammary cancer. Lila S. Berry and David Magrane, sponsored by Jerry Howell, Jr., Morehead State University.

1145 The effect of various levels of dietary fat on DMBA-induced mammary carcinomas. Brent Butler and David Magrane, sponsored by Jerry Howell, Jr., Morehead State University.

SCIENCE EDUCATION SECTION

Don Birdd, Chairperson
Ed Story, Secretary, Presiding
East Room A
Adron Doran University Center

Friday, November 8, 1985

1300 *Using Readability Scales in Selecting Science Texts. Dan Varney,* Eastern Kentucky University, Judith Cunningham, Eastern Kentucky University and Juanita Cox, Madison County Schools.

1315 "Science in the Tackle box". Dr. Randy Falls, Morehead State University.

1330 50 Minute Chemical Computer Course. Ted C. Shields, Ashland Community College.

1345 Plants Used By The Pre-Historic Indians of Kentucky. by Mel Hankla, Western Kentucky University. Sponsored by Dr. Charles T. Crume, Jr.

1400 Commitment True/False Tests. Dr. Charles T. Crume, Jr., Western Kentucky University.

1415 Pictures and Recall from Science Text. Gary J. Anglin and J. Truman Stevens, University of Kentucky.

1430 Go For A Slide!!. Larry Pursell, Elizabethtown Community College.

1445 Identification of Learning-skill Difficulties of Students Technical Allied Health Programs. Cathy Hunt, Henderson Community College.

1500 Coffee Break

1530 Plenary Session

East Room A
Adron Doran University Center

Saturday, November 9, 1985

0800 Crown Jewels of Science Historic Scientific Instruments. Dr. Norman W. Hunter, Western Kentucky University.

0815 From Amulets To Anesthetics: Some Views of the History of Science. Ms. Dawne Durbin, Western Kentucky University.

0830 Kentucky Governor's Scholars and the Creation Science/Evolution Issue. Dr. Ray Hammond, Centre College.

0845 Opportunities to Teach Science During the Elementary Student Teaching Experience: A Survey. Herbert Simmons, Western Kentucky University.

0900 Coffee Break

0915 Annual Business Meeting

1030 The Biology of Cancer: An Innovative Approach In Teaching Upper Level Biology Students, Dr. David Magrane, Biology Department, Morehead State University. Sponsored by Jerry Howell, Jr.

1045 An Economical Microcomputer System and Interface for Laboratory Data and Collection. John Meisenheimer, Eastern Kentucky University.

1100 Science/Society/Environmental Education Curriculum Inventory; An Aid For Teachers. Dr. Ron Gardella, Northern Kentucky University.

PSYCHOLOGY SECTION

Virginia Falkenberg, Chair
Barney Beins, Secretary, Presiding
Room 112 - Ginger Hall

Friday, November 8, 1985

1300 Eye movements during polygraph exams: A nonverbal clue to deception? *Debbie Finkel* and Jack G. Thompson, Centre College.

1310 Time estimation in blind individuals. Robert C. Meyer, Murray State University. Sponsored by Terry R. Barrett.

1320 Misattribution and reinforcement. Thomas D. Valentine, Murray State University. Sponsored by Terry R. Barnett.

1330 Evidence for multiple memories of identical stimuli learned at different times. Barney Beins, Steve Chrisman and *Susan Potzick*, Thomas More College.

1340 Relation of self-esteem to accuracy of self-knowledge: To know me is to love me? John W. Porter and *Melanie Lucas*, Thomas More College. Sponsored by Barney Beins.

1350 The relationships between personality, aerobic efficiency and exercise preferences. *Margi Lacy* and Jack G. Thompson, Centre College.

1400 Apomorphine-induced sensitization of locomotor activity: Effects of dose level. Bruce A. Mattingly, J.E. Gotsick, and *J. Salamanca*, Morehead State University.

1410 Apomorphine-induced sensitization of locomotor activity: Effects of interinjection intervbal. J.E. Gotsick, B.A. Mattingly and *C. Duff*, Morehead State University.

1420 Birth order: Its relation to motivation and achievement. Ralph C. Sweet, Murray State University. Sponsored by Terry R. Barrett.

1430 Age differences in memory distortion. Elizabeth Yates, Murray State University. Sponsored by Terry R. Barrett.

1440 Self-identity and bereavement. Linda R. Dann, Murray State University. Sponsored by Terry R. Barrett.

1450 Value modulation as a function of marital longevity. Frank Kodman and *Shari Shields-Dzurny*, Murray State University.

1500 Coffee Break

1530 Plenary Session

Terry R. Barrett, Presiding
Room 112 - Ginger Hall

Saturday, November 9, 1985

0900 Coffee

0915 Annual Business Meeting

1030 Aesthetic preference as a function of personality characteristics. Gary G. Bruton, Murray State University. Sponsored by Terry R. Barrett.

1040 The psychological effects of music. Joan M. Reeves, Murray State University. Sponsored by Terry R. Barrett.

1050 Alcohol-related domestic violence. Margaret A. Laster, Murray State University. Sponsored by Terry R. Barrett.

1100 Physical attractiveness and physical effectiveness in high school and college students. Robert E. Kramp, Eastern Kentucky University. Sponsored by William Watkins.

1110 Interpretation of gender differences in perceptions of rape. Gerry F. Gibson, Murray State University. Sponsored by Terry R. Barrett.

1120 Empathy and its association with altruistic and egotistic helping behavior. Judith L. Kaelin, Eastern Kentucky University. Sponsored by William Watkins.

1130 Visual-Spatial abilities: Sex-differences, training difference, or is there really a difference? Heidi L. Tilenius, Murray State University. Sponsored by Terry R. Barrett.

1140 Personality differences in women: Traditional versus nontraditional roles. Krista L. Tunnell, Murray State University. Sponsored by Terry R. Barrett.

SOCIOLOGY SECTION

Reid Luhman, Co-chairperson
Craig Taylor, Co-chairperson
Room 225 - Rader Hall

Friday, November 8, 1985

1300 Victimization, etiology, and social reaction. John Curra and Steven Savage, Eastern Kentucky University.

1320 Faculty perceptions of international education at Murray State University. J. Allen Singleton, Eastern Kentucky University.

1340 Toward a sociology of war. Richard Voorhees, Minneapolis, Minnesota.

1400 Socialization for expressiveness and instrumentality. Craig Taylor, Western Kentucky University.

1420 Speed and high tech vs. practical application and sustainable tech in the Human Powered Vehicle Association. Dick Futrell, Eastern Kentucky University.

1440 Research notes on race, class and life satisfaction in the United States. Reid Luhman, Eastern Kentucky University.

1500 Coffee Break

1530 Plenary Session

Saturday, November 9, 1985

0900 Coffee Break

0915 Annual Business Meeting

ZOOLOGY AND ENTOMOLOGY SECTION

Thomas C. Rambo, Chairperson, Presiding
W. Blaine Early, Secretary
Room 224 - Lappin Hall

Friday, November 8, 1985

1300 A distributional study of stream fishes in Taylor County, Kentucky (Green River). Gordon K. Weddle, Campbellsville College.

1315 Home range and food habits of the Barn Owl in central Kentucky. Peter G. David and *Gary Ritchison*, Eastern Kentucky University.

1330 Wintering population dynamics of the Bald Eagle (*Haliaeetus leucocephalus*) at Ballard County Wildlife Management Area. *Jeffrey Sole*, Department of Fish and Wildlife Resources, Terry Siemsen, U.S. Army Corps of Engineers, Louisville District, Brian Anderson and Marc Evans, Kentucky Nature Preserves Commission.

1345 Feeding patterns of Bald Eagles (*Haliaeetus leucocephalus*) at Ballard County Wildlife Management Area, Winter 1985/85. *Terry Siemsen*, U.S. Army Corps of Engineers, Louisville District and Jeffrey Sole, Department of Fish and Wildlife Resources.

1400 Habitat separation in sympatric shews in Kentucky. Hal D. Bryan, Kentucky Transportation Cabinet.

1415 The effect of pericarp texture on oviposition by the maize weevil, *Sitophilus zeamais* Motsch. *Philip W. Tipping*, J.G. Rodriguez, and C.G. Peneleit, University of Kentucky and D.E. Legg, Kentucky State University.

1430 Preliminary notes on *Madeophylax* sp. (Insecta:Trichoptera) Guenter Shuster. Eastern Kentucky University.

1445 Election of Sectional Officers

1500 Coffee Break

1530 Plenary Session

Room 224 - Lappin Hall

Saturday, November 9, 1985

0800 Incidence of lead poisoning in Canada Geese from Ballard County, Kentucky. *Kevin D. Flowers* and Stephen B. White, Murray State University.

0815 New distributional records for some Kentucky mammals. *Les Meade* and Matt Meadows, Morehead State University.

0830 Additional records of the Redside Dace, *Clinostomus elongatus* (Kirtland) in Northeastern Kentucky. *Les Meade* and Dave McNeely, Morehead State University and Lew Kormman, Kentucky Department of Fish and Wildlife Resources.

0845 Development of the urinary bladder in *Rana catesbiana* tadpoles. *Theresa L. Powell* and John J. Just, University of Kentucky.

0900 Coffee Break

0915 Annual Business Meeting

1030 The status and present distribution of the River Otter in Kentucky. *Charles W. Logsdon* and Stephen B. White, Murray State University and Thomas Edwards, Kentucky Department of Fish and Wildlife Resources.

1045 Parasitization and its effects on the lipid content in *Heliothis virescens*. *D.L. Coar* and Douglas L. Dahlman, University of Kentucky.

1100 A diabetic insect - Result from parasitization. *Douglas I. Dahlman* and Rosalyn Moore, University of Kentucky.

1115 A novel form of antibiosis in Nicotiana. *Joseph Huesing* and Davy Jones, University of Kentucky. Sponsored by B.C Pass, University of Kentucky.

1130 Interspecific interactions of insects at the unopened buds of platanillo (*Heliconia latispatha*). *Thomas C. Rambo*, Northern Kentucky University, Woddbridge A. Foster, The Ohio State University, and Richard B. Buchanan, Northern Kentucky University.

1145 Ecology and feeding behavior of *Cerion* sp. (Gastropoda: Pulmonata) on San Salvador, Bahamas. James B. Sickel, Murray State University.

1200 A model of foraging behavior in antlions (Neuroptera:Myrmeleontidae). *Mary Linton*, Kevin Strohmeier, Pat Dillon, Jeff Williams, and Hasan Aral, University of Kentucky.

MATHEMATICS AND COMPUTER SCIENCE SECTION

Herbert Berry, Chairperson
Russel M. Brengelman, Secretary, Presiding
East Room B
Adron Doran University Center

Friday, November 8, 1985

1500 Coffee Break

1530 Plenary Session

Saturday, November 9, 1985

0900 Coffee Break

0915 Annual Business Meeting

1100 Organizational Meeting

Abstracts of Some Papers Presented at the Annual Meeting

BOTANY AND MICROBIOLOGY

Cloning of the gene for glutamine synthetase from soybean. VALGENE L. DUNHAM,* Department of Biology, Western Kentucky University, Bowling Green, KY 42101 and BRIAN A. CUMMINGS, Native Plants Incorporated, Salt Lake City, UT 84112.

Total RNA was isolated from 4-day, etiolated soybean hypocotyls. Poly (A) RNA was isolated by using d(T)-cellulose chromatography and was purified in sucrose gradients. The resulting four peaks of mRNA were separately translated in vitro. Glutamine synthetase (GS) was purified from the translation products, indicating the presence of mRNA. Double stranded cDNA was prepared from the mRNA and inserted into pBR322 using dG˙ dC tailing. *Escherichia coli* strain RRI was transformed with the recombinant plasmid, selected by resistance to tetracycline and transferred into media to induce the synthesis of GS. Soybean GS was isolated and partially purified from transformed cells by using agarose and DEAE-cellulose chromatography.

A reinvestigation of Claiborne Formation (Middle Eocene) fruit-and-seed flora from western Kentucky and Tennessee. PAUL J. GROTE* and DAVID L. DILCHER, Department of Biology, Indiana University, Bloomington, IN 47405.

A fruit-and-seed flora from the Middle Eocene Claiborne Formation (western Kentucky and Tennessee) is being reinvestigated. Morphological and anatomical studies are in progress on both previously described and newly discovered undescribed fossil material. While some fossil fruit types can be placed into extant genera (e.g., *Nyssa*), other types can be assigned only to extinct genera in extant families (e.g., Euphorbiaceae, Theaceae, Juglandaceae). Fruit and seed evidence agrees with interpretations based on leaves that the Middle Eocene climate of the area was warm temperate to cool subtropical. (Supported by a KAS Grant-in-Aid.)

Germination of seeds of *Euonymus americanus* with the use of *Clostridium cellobioparum*. GARY T. HOWARD* and L.P. ELLIOT, Department of Biology, Western Kentucky University, Bowling Green, KY 42101.

The use of *Clostridium cellobioparum* was successful in stimulating germination of *Euonymus americanus* seeds. Scarified and unscarified seed received the following treatments:40 were treated with thioglycollate-broth-grown *C. cellobioparum* under anaerobic conditions; 40, with the membrane filter filtrate from thioglycollate-grown *C. cellobioparum; 40, with pasteurized C. cellobioparum* culture; and 40, with only thioglycollate broth. Germination occurred only when seeds were nonscarified and subjected to the bacterium under anaerobic conditions; and it began 6 days after incubation in the growth chamber. Imbibition occurred in scarified and nonscarified seeds under all three treatments but control seeds did not imbibe.

Preliminary studies of plant biomass patterns on strip mine spoil. RALPH G. REISS* and JOE E. WINSTEAD, Department of Biology, Western Kentucky University, Bowling Green, KY 42101.

A strip mine (abandoned 1963) in Butler County, Kentucky, provided specific subplots for comparison of biomass production between seasons in 1985 and less harsh controlled growth-chamber conditions. Field growth to 28 May averaged .014 gm/ cm^2 dry matter increasing to 0.022 gm/ cm^2 130 days later. Comparative subplots moved from the field 28 May to laboratory conditions of 16-hr daylengths and 12-hr temperature cycles of 32-16°C averaged only .017 gm/cm^2 dry biomass from the spring until harvest after 130 days, indicating more growth control by spoil than by climate. Principal species in the test were *Bidens polyiepis, Lechea tenuifolia,* and *Polygonum pensylvanicum*.

CHEMISTRY

Functional group effects on solvent-induced swelling of coal. JOAN REEDER and ELIZABETH K. SUTTON,* Department of Chemistry, Eastern Kentucky University, Richmond, KY 40475.

Solvents with various functional groups were examined to observe their effect on the degree of swelling of several Kentucky coals. The observations showed that increasing the methyl substitution or an increase in the nucleophilicity of the solvent caused an increase in the degree of swelling. This general trend could, however, be overshadowed by hydrogen bonding and steric effects. Although the results are far from conclusive, it appears that nucleophilicity, hydrogen bonding, and steric factors play the most important role in determining the degree of swelling. However, no quantitative correlation parameter has yet been developed.

Investigation on thermoplasticity of some Kentucky coals. KENNETH R. ROSE, DAVID A. ROSE, and WILLIAM D. SCHULTZ,* Department of Chemistry, Eastern Kentucky University, Richmond, KY 40475.

Data from proximate and ultimate analysis of 11 Kentucky Coals were obtained. These coals were extracted with N,N-dimethylformamide and pyridine. Extracts (bitumen portions) were analyzed by reverse phase high performance liquid chromatography

(R.P.H.P.L.C.) and size exclusion chromatography (S.E.C.). Extracted coals were subjected to swelling experiments to determine relative cross link density. All data were examined for correlation with thermoplasticity. The average weight of the extracts, from S.E.C., was 450 with varying molecular weight distributions. Neither molecular weight nor polarity distribution (from R.P.H.P.L.C.) correlated well with thermoplasticity. The known correlation between carbon content of the coals was observed, and an excellent correlation between the extractibility of the coals and thermoplasticity was found. No other correlation could be detected.

Analysis of hair and nail by INAA: relationship of trace element levels to Alzheimer's disease. D.E. VANCE,* W.D. EHMANN, Department of Chemistry, and W.R. MARKESBERY, Departments of Neurology, Pathology and Sanders Brown Research Center on Aging, University of Kentucky, Lexington, KY 40506.

Alzheimer's disease (AD) is a dementing disorder afflicting some 5% of older Americans. Its cause is unknown. One hypothesis regarding its etiology implicates trace elements as causative factors. In our study, hair and fingernail samples from both AD and control patients were analyzed for 25 trace elements by instrumental neutron activation analysis (INAA) in an attempt to demonstrate significant differences between disease and control groups. Preliminary results for six of these elements were discussed. Several elemental imbalances previously observed in AD brains were also seen in fingernail samples. Hair analysis revealed no significant control-AD differences, probably due largely to the high inherent variability in hair.

GEOLOGY

Conodonts from the upper Farmers and lower Nancy Members of the Borden Formation of northeastern Kentucky. GEORGE B. CLARK, ANTHONY R. HATTON,* and CHARLES E. MASON, Department of Physical Sciences, Morehead State University, Morehead, KY 40351.

Seven trench samples were examined from one locality along Interstate-64, 2.9 km west of the Morehead, Kentucky, exit. Four samples were taken from the shale intervals of the uppermost Farmers Member and three from the lower four meters of the Nancy Member. All samples contained conodonts, which ranged in abundance from 3 to 129 conodonts per kilogram. The most abundant taxon was *Polygnathodus communis* followed by the genus *Gnathodus*. Other associated microfossils include arenaceous forminifera, ostracodes, and scolecodonts. Also found in all three processed samples from the Nancy Member were biostratigraphically important ammonoids. This association (conodonts and ammonoids) will be significant in the biostratigraphic zonation of this interval of geological time both locally and internationally.

Petroleum drilling and brine pollution in Kentucky. GRAHAM HUNT,* Department of Geology, University of Louisville, Louisville, KY 40292.

Saline connate water known as brine is often found in drilling for hydrocarbon accumulations. Lately, the government is attempting to stop possible brine pollution of Kentucky's streams, thus forcing oil operators to make hard economic decisions regarding control of the brine until it evaporates. After evaporation, the remaining salts are collected and may be used in water on the public roads. Because the location for petroleum drilling is directed by geologists it is concluded that the method of site selection for wells should include this growing problem of brine pollution.

Analysis of phosphate nodules from the Borden Formation of northeastern Kentucky. JEFFREY T. STEWART,* CHARLES E. MASON, and RICHARD L. HUNT, Department of Physical Sciences, Morehead State University, Morehead, KY 40351.

Phosphate nodules from five different stratigraphic horizons were collected from the Borden Formation. Most phosphate nodules contained fossils, three-dimensional burrows, and preserved sedimentary lamina. The phosphate contents determined by the vandomolyb-date spectrophotometric method ranged from 19 to 27% $P_2 0_5$, with an overall average of 23.2% $P_2 0_5$. Light and dark nodules from the Nada Member showed no significant difference in phosphate content. The Borden Formation does contain phosphate nodules in all members, and they were formed within the sediments below the sediment-water interface before much compaction of sediment had occurred. Submarine erosion exhumed and concentrated them at times into thin layers.

PHYSIOLOGY, BIOPHYSICS, BIOCHEMISTRY, AND PHARMACOLOGY

Kinetics of glucuronidation of 4'-chloro-4-biphenylol. M.A. DAVIS and R.F. VOLP,* Department of Chemistry, Murray State University, Murray, KY 42071.

We measured kinetic constants for glucuronidation of 4'-chloro-4-biphenylol (MCBol), the major metabolite of 4-chloro-biphenyl. Rat liver microsomes (0.2 mg protein/ml) were incubated in 50 mM Tris, pH 7.4 at 37°C, with 5 mM MgCL2, 3 mM UDPGA, and various concentrations of MCBol (total volume: 2ml). Incubations were stopped with 2 ml methanol and centrifuged. The supernatant (20μl) was injected onto a 5-μm cyanopropyl-silane column eluted with 0.01 M KH2PO4/ acetonitrile, 4:1 (ph 2.8), at 1.0 ml/min. Eluate absorbance was monitored at 280 nm. Area under the glucuronide peak was measured and converted to concentration of MCBol via a Lineweaver-Burke plot. Kinetic constants were: Vmax 6.35 μM/min. mg protein and Km ^{5} 300 μ M.

The distribution of orally administered butylated hydroxytoluene in tissues of New Zealand white rabbits. D.R. HARTMAN,* B.R. FERRELL, and L.F. BREIWA, Department of Chemistry, Western Kentucky University, Bowling Green, KY 42101.

Two rabbits were given carbon-14 labled butylate hydroxytoluene (BHT). Sixteen tissues, urine, and feces were sampled; They were homogenized in chloroform:methanol and that fraction was extracted with water. Carbon-14 determinations were made on the three fractions. The male excreted more carbon-14 in the urine in 24 hours than the female. BHT levels were lower in male tissues, except in the chloroform fraction, which showed no difference. Liver, kidney, and feces contained BHT equally distributed between lipid and insoluble fractions. Blood and lung tissue had a high percentage of BHT associated with the insoluble fraction.

Flowering requirements of *Tussilago farfara*. J.H. MELHUISH. JR.,* P.R. BECKJORD, and W.G. VOGEL, USDA-Forest Service, Northeastern Forest Experiment Station, Rt. 2, Hwy. 21 East, Berea, KY 40403.

Tussilago farfara (coltsfoot) has become naturalized on disturbed and waste places in the northeast United States and may have a role in some aspects of surface mine revegetation. However, the seed has short viability, and germination drops to 50% or less in 4 weeks, thus limiting the species' usefulness in artificial revegitation. Artificial induction of flowers can be stimulated by cold temperatures or by long-day photoperiod and cold temperature (60°C day, 40°C night) or short-day photoperiod and warm temperature (80°C day, 60°C night). Flower production could probably be accomplished most easily by growing the plants in a greenhouse and then subjecting them to cold temperature for a period of time.

Separation and identification of phenolic acid trimethylsilyl derivatives by gas chromatography and Fourier transform infrared spectroscopy. J.H. MELHUISH, JR., R.B. WILLIS, and C.S. WRIGHT,* USDA-Forest Experiment Station, Rt. 2, Hwy. 21 East, Berea, KY 40403.

Phenolic acid trimethylsilyl derivatives were separated by gas chromatography using three separate columns. One of these columns was coupled to a Fourier transform infrared spectrophotometer. The derivatives could be separated and identified by comparing the relative retention times of the three different columns. However, where there was overlap, the accompanying infrared data clearly distinguished between the questionable derivatives, thus enabling characterization of all derivatives.

SCIENCE EDUCATION

Kentucky Governor's Scholars and the creation science issue. RAY HAMMOND, Division of Science, Centre College, Danville, KY 40422.

The 1984 and 1985 Scholars were surveyed (as rising seniors) regarding their attitudes about creation science and evolution (response total was 466). With regard to religious beliefs, 35% considered themselves fundamental, 49% liberal, and 14% agnostic or atheistic. In the eastern and western quarters of the state, 46% claimed to be fundamental compared to only 18% in the Louisville area. Statewide, one quarter claimed never to have been taught about evolution in the classroom. More favor creationism than evolution (1.5X), but a majority favors a combination of the two as an explanation of origins. Nearly three-fourths favor giving creation science equal time with evolution in the classroom.

An Economical (100.00) microcomputer system and interface for laboratory data collection. JOHN L. MEISENHEIMER,* Department of Chemistry, Eastern Kentucky University, Richmond, KY 40475.

The development of software to effect laboratory data collection by a microcomputer was described. Temperature data can be conveniently collected by using the inexpensive Atari 400 system with a thermistor wired to a resistance-reading gameport. The thermistor must be calibrated to obtain a curve of resistance readings plotted against temperature change. Values from this non-linear curve permit calculation of coefficients using a fourth order regression equation. These coefficients are programmed into the software to afford an internally corrected temperature for any resistance reading effected by the thermistor. The computer acquisition of a cooling curve for paradichlorobenzene was also described.

ZOOLOGY AND ENTOMOLOGY

Development of the urinary bladder in tadpoles of three anuran species. THERESA L. POWELL* and JOHN J, JUST, Thomas Hunt Morgan School of Biological Sciences, University of Kentucky, Lexington, KY 40506.

Adult frogs have three osmoregulatory organs: kidney, skin, and bladder. Although much is known about the development of kidney and skin, little information exists on bladder development. We investigated bladder development in three species by dissecting and weighing the bladder at various Taylor Kollros stages for metamorphosis. Ratios of bladder weight (mg) to animal weight (g) in *Rana catesbiana* ranged from 0.12 0.09 at stage XVIII to 1.13 0.16 at stage XXIV; in *R. palustris* and *R. clamitans* they *were, respectively, 0.14 0.02 and 0.14 0.04 at stage* XVIII to 1.04 0.11 and 1.02 0.05 at stage XXIV. In all species studied, 2- and 4-week post metamorphic ratios (approximately 1.4) are not significantly different from each other.

NEWS AND COMMENTS

ANNUAL MEETING

The 72nd annual meeting of the Kentucky Academy of Science will be a joint meeting with the School Science and Mathematic Association (SSMA), the Kentucky Association for Progress in Science (KAPS), and the Kentucky Council of Teachers of Mathematics (KCTM), on 20-22 November at the Radisson Plaza Hotel in Lexington Convention Center. The deadline for submitting papers for this meeting is 16 May 1986.

CONFERENCE

The Holden Arboretum is co-sponsoring with the Center for Plant Conservation and the Lakeland Community College a conference on Plant Conservation Strategies: Options for the Future on 16-18 May 1986 at the Holden Arboretum, 9500 Sperry Road, Mentor, Ohio. For more information write Paul C. Spector, Director of Education, at the arboretum.

Instructions for Contributions

Original [illegible] will be considered for publication in the Transactions [illegible] notes and announcements of interest to the membership will be included as received.

Manus[illegible] Each manuscript will be reviewed by one or more [illegible] and once accepted, an attempt will be made to publish papers in the [illegible] should be typed double spaced throughout on good quality [illegible] format of feature articles and notes see Volume 43(3-4) 198[illegible] the Editor and the author should retain a copy for use in [illegible] for all measurements. The basic pattern of pres[illegible] manuscripts. The Style Manual of the Council of Biological Editors [illegible] Authors of the American Institute of Physics [illegible] Manual of Style (Chicago University Press) are [illegible] spelling. Only those words intended to be itali[illegible] must be members of the Academy.

The [illegible] manuscripts should be: title page, body of the manuscript [illegible] table headings and figure legends and figures.

1. The title [illegible] names and addresses, and any footnote material concerning credits, changes of address, and so forth.

2. The abstract should be [illegible] contained in the paper. It should be complete in itself without reference to the paper.

3. The body [illegible] sections: Introduction, Materials and Methods [illegible] and Literature Cited. All Tables and figures, as well as all literature cited, must be referred to in the text.

4. All [illegible] double spaced, and should provide complete information on the materials referred to. See Volume 43(3-4) 1982 for style.

5. F[illegible] meetings, see Volume 43(3-4) 1982.

6. Each table [illegible] numbered in Arabic numerals, and set on a separate page. The heading of the table should be informative of its contents.

Each figure [illegible] 8 X 10 inches. Line drawings in India ink [illegible] than 8½ X 11 inches. Photographs should [illegible] All figures should be numbered in Arabic numerals and should be accompanied by an appropriate legend. It is strongly [illegible] Allen's (1977) "Steps Toward Better Scientific Illustrations" published by the Allen Press, Inc., Lawrence, Kansas 66044.

The author [illegible] He is also responsible for checking all literature [illegible] correctly. Extensive alterations on the galley [illegible] Reprints are to be ordered when the galley proofs are returned by the Editor.

CONTENTS

NOTES

TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

Volume 47
Numbers 3 - 4
November 1986

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.

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 $15.00 for Active Members; $7.00 for Student Members; $20.00 Family.

Subscription rates for nonmembers are: domestic, $30.00; foreign, $30.00, 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 40292, the exchange agent for the Academy.

Educational Affiliates

Sustaining Member
University of Kentucky

Member

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

Associate Member

Alice Lloyd College
Bellarmine College
Berea College
Brescia College
Campbellsville College
Centre College
Georgetown College
Kentucky Wesleyan College
Lees College
Lindsey Wilson College
Spalding College
Thomas More College
Union College

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

November 1986
Volume 47
Numbers 3-4

Endangered, Threatened, And Rare Plants And Animals Of Kentucky[1]

Melvin L. Warren, Jr.
Department of Zoology
Southern Illinois University at Carbondale
Carbondale, Illinois

Wayne H. Davis
Department of Biological Sciences
University of Kentucky, Lexington, Kentucky

Richard R. Hannan
Kentucky Nature Preserves Commission
407 Broadway, Frankfort, Kentucky

Marc Evans
Kentucky Nature Preserves Commission
407 Broadway, Frankfort, Kentucky

Donald L. Batch
Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky

Brian D. Anderson
Illinois Nature Preserves Commission
524 South Second Street, Springfield, Illinois

Brainard Palmer-Ball, Jr.
Kentucky Nature Preserves Commission
407 Broadway, Frankfort, Kentucky

John R. MacGregor
Department of Fish and Wildlife Resources
Game Farm, Frankfort, Kentucky

Ronald R. Cicerello
Kentucky Nature Preserves Commission
407 Broadway, Frankfort, Kentucky

Raymond Athey
701 Woodland Drive
Paducah, Kentucky

Branley A. Branson
Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky

Glen J. Fallo
United States Army
Schweinfurt, West Germany

Brooks M. Burr
Department of Zoology
Southern Illinois University at Carbondale
Carbondale, Illinois

Max E. Medley
Department of Biology
University of Louisville, Louisville, Kentucky

Jerry M. Baskin
Department of Biological Sciences
University of Kentucky, Lexington, Kentucky

ABSTRACT

The Endangered Species Committee of the Kentucky Academy of Science and the Kentucky Nature Preserves Commission have updated and revised the rare animal and plant list originally published in 1981. The new list includes 337 plant and 242 animal taxa identified as Endangered, Threatened, Special Concern, or Category 1 or 2 at the state and/or federal levels.

[1] The order in which the authors of this paper are presented has been determined randomly.

INTRODUCTION

The passage of the Endangered Species Act of 1973 marked a significant change in the conservation ethic of the United States as a nation. The Act is a declaration that those species which have been endangered by extinction "...are of esthetic, ecological, educational, historical, recreational, and scientific value to the Nation and its people" (1). The stated purposes of the Act "...are to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, [and] to provide a program for the conservation of such endangered species and threatened species..." These objectives are to be accomplished in part through the publication of a list of endangered and threatened species that become the targets of protective regulations. The subsequent amendments and reauthorizations of the Endangered Species Act have reaffirmed the United States' commitment to this course of action.

In the absence of a Kentucky endangered species act and list with the same objectives, the Endangered Species Committee of the Kentucky Academy of Science (KAS) and the Kentucky Nature Preserves Commission (KNPC) published the "Endangered, Threatened, and Rare Animals and Plants of Kentucky" (2). This non-regulatory list served to identify those native species of Kentucky plants and animals that are in need of protection, research, and/or management because they are rare, the number of populations known for a species is declining or low, or their distribution has been reduced. The overall goal of the publication of the list was to assist in the recovery and preservation of Kentucky's rich natural diversity.

A wealth of new information regarding the flora and fauna of Kentucky has been collected since 1981. The distribution and ecology of many of the species included in Branson et al. (2) are much better known. One species, *Epioblasma sampsoni*, has been officially delisted by the United States Fish and Wildlife Service (3) because of extinction and may portend similar action at the federal level for a group of related species. Several species previously unknown from Kentucky have been discovered and others not collected in many years were rediscovered. Thus, this new information has provided the impetus to reevaluate the species listed by Branson et al. (2) and to generate the updated list and status designations presented herein.

METHODS

The Kentucky Nature Preserves Commission, a state agency mandated to identify and protect natural areas, worked jointly with the Endangered Species Committee of the Kentucky Academy of Science to identify those species which are rare or threatened in the Commonwealth. The Nature Conservancy's standardized Natural Heritage Program methodology (4) was used to revise the list by Branson et al. (2). The program stores distributional and ecological information on selected species in map, manual, and computer files and is used by KNPC to locate aggregations of rare species and other natural entities that become the target of its preservation efforts. The program was therefore ideally suited for the revision which followed a process that will be briefly outlined.

Each species listed by Branson et al. (2) and many previously unlisted species were evaluated to determine if they should be retained or added to the list. The criteria utilized included, but were not limited to, the number, recency, and accuracy of occurrences; historic and present geographic distribution; habitat requirements; relative threat of habitat destruction; and ecological fragility. The information used to make the evaluation was that available as of June 30, 1985. Each species was subjectively assigned a conservation status or suggested for delisting.

The resultant list and statuses were submitted to knowledgeable individuals for peer review and suggestions for additions and deletions. All comments received were considered and in many cases discussed with the commentor before final statuses were assigned. The finalized list and statuses were forwarded to the Endangered Species Committee for review and were approved by the Kentucky Academy of Science at the 71st Annual Meeting held in Morehead, Kentucky on November 9, 1985. The only exceptions to this process were that all species officially listed or under status review for listing (excepting insects) by the United States Fish and Wildlife Service under the Endangered Species Act were included on the list (3,5,6,7,8,9).

STATUS CATEGORIES

The intent of assigning status designations is to (1) indicate the degree of rarity of the species, (2) indicate the degree of threat to the continued survival of the species, and (3) aid in establishing priorities for conservation and/or preservation efforts. The status designations assigned have no legal or statutory implication but rather were established as a tool by the Endangered Species Committee and KNPC to monitor the survival potential of the species. The three KAS-KNPC status categories utilized are coded in capital letters and defined as follows:

Endangered (E). A species which is in danger of extirpation and/or extinction throughout all or a significant part of its range in Kentucky.

Threatened (T). A species which is likely to become endangered within the forseeable future throughout all or a significant part of its range in Kentucky.

Special Concern (S). A species that should be monitored because (a) it exists in a limited geographic area, (b) it may become threatened or endangered due to modification or destruction of habitat, (c) certain characteristics or requirements make it especially vulnerable to specific pressures, (d) experienced researchers have identified other factors that may jeopardize it, or (e) it is thought to be rare or declining but insufficient information exists for assignment to the threatened or endangered status categories.

Federal status categories and definitions used include:

Endangered (E). "...any species which is in danger of extinction throughout all or a significant portion of its range..." (1).

Threatened (T). "...any species which is likely to become an endangered species within the forseeable future thoughout all or a significant portion of its range" (1).

Category 1 (C1). Status review taxa for which the United States Fish and Wildlife Service "...has substantial information on hand to support the biological appropriateness of proposing to list as endangered or threatened" (7).

Category 2 (C2). Status review taxa for which information now in possession of the United States Fish and Wildlife Service "...indicates that proposing to list as endangered or threatened is possibly appropriate, but for which conclusive data on biological vulneralbility and threat are not currently available to support proposed rules" (7).

Introduction To The Plant And Animal Lists

The nomenclature utilized for plant species follows Kartesz and Kartesz (10). The sources consulted for the common and scientific names of animals are as follows: crustaceans—Hobbs (11), Holsinger (12), United States Fish and Wildlife Service (5,13); gastropods—Thompson and Porter (14); pelecypods—Stansbery and Bogan (15); fishes—Bailey et al. (16), Carney (17), Robins et al. (18), Stauffer et al. (19); amphibians and reptiles—Collins et al. (20); birds—American Ornithologist's Union (21); mammals—Hall (22).

Discussion

This new KAS-KNPC list includes 337 plant and 242 animal taxa. Based on generally accepted estimates of the number of native species occurring in Kentucky, the following approximate per cent of the groups indicated can be considered Endangered, Threatened, or of Special Concern: plants—11%, pelecypods—36%, fishes—31%, amphibians and reptiles—23%, birds—15%, and mammals—33%. Although extensive, the list does not adequately treat or include several groups of organisms found in Kentucky. The thallophytes, bryophytes, insects, amphipods, isopods, terrestrial and freshwater gastropods, and other groups are also important elements of our natural heritage, but are poorly known in Kentucky. Researchers are encouraged to undertake studies that will provide information needed to determine the status of members of these groups in Kentucky.

The bird monitoring strategies presented by Branson et al. (2) are no longer being used. The list and monitoring activities are now limited to species that nest or historically nested in Kentucky, and those listed or under status review by the United States Fish and Wildlife Service.

All of the species listed are being monitored in Kentucky by KNPC. However, information regarding species that have been delisted and many others that were not included in Branson et al. (2) or this list is being maintained in manual files at KNPC. This is being done so that we can respond to unforseen changes in distribution or status.

We invite input from knowledgeable individuals on native species they believe deserve a status change or should be added to or deleted from the list. Each such petition should include the scientific name of the organism, its habitat requirements, collection information (i.e., localities, number of specimens, dates, disposition of specimens), historic and present distribution, whether the species has been specifically sought during field work, threats, and recommended KAS-KNPC status. Petitions should be forwarded to the Director, KNPC, who will contact the Endangered Species Committee Chairperson and appropriate committee members for timely petition review and comment. The petitioner will be notified regarding the outcome of the review. In an effort to make the list more responsive to changes in information, all changes resulting from this petition process will be succinctly reported in the *Transactions* as revisions of the list.

We reiterate the hope expressed by Branson et al. (2) that this updated list of Kentucky's rare plants and animals will assist developers and decisionmakers in reaching informed decisions concerning the most effective use of Kentucky's natural resources. Only by focusing attention on the rarest elements of our natural heritage can we avoid the unnecessary destruction of our diverse flora and fauna.

PLANT LIST

	KAS-KNPC	STATUS FEDERAL
Acer spicatum Mountain Maple	T	
Aconitum uncinatum Monkshood	T	
Adiantum capillus-veneris Venus Hair Fern	E	
Adlumia fungosa Allegheny Vine	E	
Agalinis decemloba Purple False Foxglove	E	
Agalinis obtusifolia Purple False Foxglove	S	
Agalinis skinneriana Purple False Foxglove	T	
Agrimonia gryposepala Agrimony	S	
Allium burdickii Narrow-leaved Wild Leek	E	
Amianthium muscaetoxicum Fly Poison	T	
Angelica triquinata Filmy Angelica	E	
Apios priceana Price's Groundnut	E	C1
Arabis glabra Tower Mustard	S	
Arabis missouriensis Missouri Rock Cress	E	
Arabis perstellata var. perstellata Rock Cress	E	C1
Arenaria cumberlandensis Sandwort	E	C1
Arenaria fontinalis Water Stitchwort	T	C1
Armoracia aquatica Lake Cress	T	
Aster concolor Aster	E	
Aster pilosus var. priceae White Heath Aster	S	
Aster sericeus Silky Aster	T	
Aster texanus Texas Aster	E	
Aureolaria patula False Foxglove	E	C1
Baptisia leucophaea Creme Wild Indigo	S	
Baptisia tinctoria Yellow Wild Indigo	T	
Bartonia virginica Screwstem	E	
Berchemia scandens Rattan Vine	E	
Botrychium matricariifolium Matricary Grape Fern	E	
Botrychium oneidense Blunt-lobed Grape Fern	E	
Bouteloua curtipendula Side-oats Grama	S	
Boykinia aconitifolia Brook Saxifrage	T	
Cabomba caroliniana Fanwort	S	
Calamagrostis canadensis Blue Joint Grass	E	
Calamagrostis cinnoides Cinna-like Reed Grass	S	
Calamagrostis porteri Porter's Reed Grass	E	
Calopogon tuberosus Grass Pink	E	
Caltha palustris Marsh Marigold	E	
Calycanthus floridus Sweet Shrub	T	
Calylophus serrulatus Evening Primrose	S	
Carex austrina Sedge	E	
Carex buxbaumii Sedge	E	

	KAS-KNPC	STATUS FEDERAL
Carex crawei Sedge	S	
Carex decomposita Sedge	T	C2
Carex gigantea Sedge	T	
Carex hystricina Sedge	S	
Carex joorii Sedge	E	
Carex lanuginosa Sedge	S	
Carex leptalea Sedge	S	
Carex leptonervia Sedge	S	
Carex picta Sedge	E	
Carex socialis Sedge	S	
Carex stricta Sedge	E	
Carex tenera Sedge	S	
Carex triangularis Sedge	S	
Carya aquatica Water Hickory	S	
Carya ovata var. *australis* Hickory	S	
Castanea pumila Chinquapin	E	
Castilleja coccinea Indian Paintbrush	E	
Cayaponia grandifolia Cayaponia	S	
Ceanothus herbaceus Redroot	E	
Cheilanthes alabamensis Smooth Lip Fern	E	
Cheilanthes feei Slender Lip Fern	E	
Chelone obliqua var. *obliqua* Pink Turtlehead	T	
Chelone obliqua var. *speciosa* Pink Turtlehead	S	
Chrysogonum virginianum Green and Gold	E	
Chrysosplenium americanum Golden Saxifrage	E	
Cicuta bulbifera Bulblet-bearing Water Hemlock	S	
Cimicifuga rubifolia Bugbane	T	C2
Circaea alpina Small Enchanter's Nightshade	E	
Cleistes divaricata Spreading Pogonia	S	
Clematis crispa Leather Flower	T	
Clematis glaucophylla Leather Flower	E	
Clematis viorna var. *flaccida* Leather Flower	E	
Comptonia peregrina Sweet Fern	E	
Conradina verticillata Cumberland Rosemary	E	C1
Convallaria montana Lily-of-the-Valley	E	
Corallorhiza maculata Spotted Coral-root	E	
Coreopsis pubescens Downy Coreopsis	S	
Corydalis sempervirens Pale Corydalis	S	
Cotinus obovatus Smoke Tree	E	
Crotonopsis linearis Linear Rushfoil	E	
Cymophyllus fraseri Fraser's Sedge	T	
Cyperus diandrus Umbrella Sedge	S	
Cyperus retrorsus Umbrella Sedge	S	
Cypripedium candidum White Lady's-Slipper	E	
Cypripedium kentuckiense Kentucky Lady's-Slipper	S	C2
Cypripedium parviflorum Small Yellow Lady-slipper	E	
Cystopteris fragilis var. *mackayi* Mackay's Fragile Fern	S	
Decodon verticillatus Swamp Loosestrife	T	
Delphinium carolinianum Carolina Larkspur	T	
Deschampsia flexuosa Hair Grass	S	
Dichanthelium acuminatum var. *villosum* Panic Grass	S	
Dichanthelium boreale Panic Grass	S	
Dichanthelium sabulorum Panic Grass	S	
Didiplis diandra Water Purslane	S	
Diplachne panicoides Feather Grass	E	

	KAS-KNPC	STATUS FEDERAL
Dodecatheon frenchii French's Shooting Star	S	C2
Draba aprica Whitlow Grass	E	C2
Draba cuneifolia Whitlow Grass	E	
Drosera brevifolia Dwarf Sundew	E	
Drosera intermedia Sundew	E	
Dryopteris ludoviciana Southern Wood Fern	E	
Dryopteris spinulosa Spinulose Wood Fern	S	
Echinodorus rostratus Burhead	T	
Echinodorus tenellus Burhead	E	
Erigeron pulchellus var. *brauniae* Lucy Braun's Robin Plantain	S	
Eriogonum longifolium var. *harperi* Umbrella Plant	E	C2
Eryngium integrifolium Button Snakeroot	E	
Eupatorium luciae-brauniae Lucy Braun's White Snakeroot	E	C1
Eupatorium maculatum Joe Pye Weed	E	
Eupatorium rugosum var. *roanense* Roan Mountain White Snakeroot	E	
Euphorbia mercurialina Spurge	E	
Fimbristylis puberula Sedge	E	
Floerkea proserpinacoides False Mermaid	S	
Forestiera ligustrina Upland Privet	T	
Fuirena squarrosa Umbrella Grass	E	
Gaylussacia brachycera Box Huckleberry	S	
Gentiana alba Yellowish Gentian	E	
Gentiana decora Showy Gentian	T	
Gentiana puberulenta Prairie Gentian	E	
Glyceria acutiflora Manna Grass	S	
Glyceria melicaria Manna Grass	S	
Gratiola pilosa Hedge Hyssop	E	

	KAS-KNPC	STATUS FEDERAL
Gratiola viscidula Hedge Hyssop	T	
Gymnopogon ambiguus Beardgrass	S	
Gymnopogon brevifolius Beardgrass	E	
Halesia carolina Silverbell Tree	T	
Hedeoma hispidum Hairy Pennyroyal	E	
Hedyotis michauxii Thyme-leaved Bluets	T	
Hedyotis uniflora Oldenlandia	E	
Helianthus atrorubens Sunflower	E	
Helianthus eggertii Eggert's Sunflower	E	C2
Helianthus silphioides Silphium-like Sunflower	S	
Heracleum lanatum Cow Parsnip	E	
Heteranthera dubia Water Star Grass	T	
Heteranthera limosa Mud Plantain	T	
Heterotheca latifolia Golden Aster	S	
Hexastylis contracta Heart-leaf	E	C2
Hexastylis heterophylla Heart-leaf	S	
Hexastylis shuttleworthii Shuttleworth's Wild Ginger	S	
Hieracium longipilum Long-haired Hawkweed	T	
Hierochloe odorata Sweet Grass	S	
Hydrocotyle americana Water Pennywort	S	
Hydrolea ovata Hydrolea	E	
Hydrophyllum virginianum Virginia Waterleaf	S	
Hypericum adpressum St. Johns-wort	E	
Hypericum stans St. Johns-wort	S	
Iris fulva Copper Iris	E	
Isoetes butleri Butler's Quillwort	E	
Isoetes melanopoda Midland Quillwort	E	
Juncus articulatus Rush	S	

	KAS-KNPC	STATUS FEDERAL
Juncus elliottii Rush	S	
Juncus longistylis Rush	S	
Koeleria cristata June Grass	E	
Lathyrus palustris Marsh Pea	S	
Lathyrus venosus Bushy Vetch	S	
Leavenworthia exigua var. *laciniata* Glade Cress	E	C1
Leavenworthia torulosa Glade Cress	E	
Leiophyllum buxifolium Sand Myrtle	E	
Lesquerella globosa Bladder-pod	T	C2
Lesquerella lescurii Bladder-pod	E	
Leucothoe recurva Fetterbush	E	
Liatris microcephala Blazing-star	S	
Liatris pycnostachya Prairie Blazing-star	E	
Lilium philadelphicum Wood Lily	S	
Lilium superbum Turk's-cap Lily	T	
Limnobium spongia Frog's Bit	T	
Linum sulcatum Grooved Yellow Flax	E	
Listera australis Southern Twayblade	E	
Listera smallii Small's Twayblade	T	
Lobelia appendiculata var. *gattingeri* Gattinger's Lobelia	E	C2
Lobelia nuttallii Nuttall's Lobelia	T	
Lonicera prolifera Grape Honeysuckle	S	
Ludwigia hirtella False Loosestrife	E	
Lycopodium appressum Southern Bog Clubmoss	E	
Lysimachia fraseri Fringed Loosestrife	E	
Lysimachia radicans Creeping Fringed Loosestrife	E	
Lysimachia terrestris Swamp Candles	S	
Maianthemum canadense Canada Mayflower	T	
Malus angustifolia Crab Apple	S	
Malus ioensis Crab Apple	S	
Marshallia grandiflora Barbara's Buttons	E	C2
Matelea carolinensis Carolina Anglepod	E	
Mecardonia acuminata Mecardonia	T	
Melampyrum lineare Cow Wheat	E	
Melanthium virginicum Bunch Flower	E	
Minuartia glabra Sandwort	E	
Mirabilis albida Four-o'clock	S	
Monarda punctata Dotted Monarda	E	
Monarda russeliana Russell's Horsemint	S	
Monotropsis odorata Sweet Pinesap	T	
Muhlenbergia bushii Bush's Satin Grass	S	
Muhlenbergia cuspidata Prairie Satin Grass	E	
Muhlenbergia expansa Hair Grass	E	
Muhlenbergia glabriflora Hair Grass	S	
Myriophyllum heterophyllum Water Milfoil	S	
Myriophyllum pinnatum Water Milfoil	S	
Najas gracillima Slender Naiad	S	
Nemophila aphylla Nemophila	S	
Oenothera linifolia Thread-leaved Sundrops	T	
Oenothera perennis Small Sundrops	E	
Oenothera triloba Sundrops	T	
Onosmodium hispidissimum Hairy False Gromwell	E	
Onosomodium molle ssp. *molle* Soft False Gromwell	E	
Onosmodium molle ssp. *occidentale* Western False Gromwell	E	

	KAS-KNPC	STATUS FEDERAL
Orontium aquaticum Golden Club	T	
Oryzopsis racemosa Black-seeded Rice Grass	T	
Oxalis priceae Price's Yellow Wood Sorrel	E	
Pachistima canbyi Mountain Lover	E	C2
Parnassia asarifolia Ginger-leaved Grass-of-Parnassus	E	
Parnassia grandifolia Grass-of-Parnassus	E	
Paronychia argyrocoma Silver Whitlow-wort	E	
Paspalum boscianum Lens Grass	S	
Paspalum distichum Lens Grass	S	
Paspalum setaceum var. *psammophilum* Lens Grass	S	
Pedicularis lanceolata Swamp Wood Betony	E	
Perideridia americana Perideridia	T	
Phacelia ranunculacea Phacelia	S	
Philadelphus hirsutus Mock Orange	E	
Philadelphus inodorus Mock Orange	E	
Philadelphus pubescens Mock Orange	T	
Phlox bifida ssp. *stellaria* Cleft Phlox	T	C2
Physostegia intermedia False Dragonhead	E	
Plantago cordata Heart-leaved Plantain	E	C2
Platanthera cristata Crested Fringed Orchid	E	
Platanthera integrilabia White Fringeless Orchid	E	C2
Platanthera psycodes Purple Fringed Orchid	E	
Poa languida Weak Bluegrass	E	
Podostemon ceratophyllum Riverweed	T	
Pogonia ophioglossoides Rose Pogonia	E	
Polemonium reptans var. *villosum* Hairy Jacob's Ladder	S	C2
Polygala cruciata Cross Milkwort	E	
Polygala nuttallii Nuttall's Milkwort	E	
Polygala polygama Purple Milkwort	E	
Polymnia laevigata Leaf Cup	E	C2
Pontederia cordata Pickerel Weed	S	
Potamogeton praelongus Pond Weed	S	
Potamogeton pulcher Spotted Pondweed	S	
Prenanthes alba Lion's Foot	E	
Prenanthes aspera Rough White Lettuce	E	
Psoralea stipulata Scurf Pea	E	C1
Psoralea tenuiflora Scurf Pea	E	
Ptilimnium capillaceum Mock Bishop's-weed	T	
Ptilimnium nuttallii Mock Bishop's-weed	E	
Pycnanthemum albescens Mountain Mint	E	
Pyrola americana Wintergreen	E	
Ranunculus allegheniensis Allegheny Crowfoot	T	
Ranunculus ambigens Water Spearwort	S	
Rhododendron canescens Honeysuckle Bush	E	
Rhynchosia tomentosa Erect Rhynchosia	E	
Rhynchospora globularis Grass Beak Rush	E	
Rhynchospora macrostachya Horned Rush	E	
Rubus whartoniae Wharton's Bramble	S	C2
Rudbeckia subtomentosa Sweet Coneflower	T	
Sabatia campanulata Rose Pink	E	
Sagittaria brevirostra Arrowhead	S	
Sagittaria graminea Grass-leaved Arrowhead	T	
Salvia urticifolia Sage	E	
Sambucus racemosa Red-berried Elder	T	

	KAS-KNPC	STATUS FEDERAL
Sanguisorba canadensis American Burnet	E	
Saxifraga michauxii Michaux's Saxifrage	E	
Saxifraga micranthidifolia Brook Lettuce	E	
Schizachne purpurascens False Melic	E	
Schwalbea americana Chaffseed	E	C2
Scirpus expansus Bulrush	S	
Scirpus fluviatilis Bulrush	T	
Scirpus hallii Bulrush	E	
Scirpus heterochaetus Bulrush	E	
Scirpus microcarpus Bulrush	E	
Scleria ciliata Nut Rush	E	
Scutellaria leonardii Small Skullcap	S	
Sedum telephioides Live Forever	T	
Sida hermaphrodita Virginia Mallow	E	
Silene ovata Catchfly	T	
Silene regia Royal Catchfly	E	C2
Silphium laciniatum Compass Plant	S	
Silphium terebinthinaceum var. *lucy-brauniae* Lucy Braun's Prairie Dock	S	
Smilacina strellata Starry-flowered False Solomon's Seal	E	
Solidago albopilosa White-haired Goldenrod	E	C1
Solidago buckleyi Buckley's Goldenrod	S	
Solidago curtisii Curtis' Goldenrod	S	
Solidago puberula Puberulent Goldenrod	T	
Solidago radula Rough Goldenrod	E	
Solidago roanensis Roan Mountain Goldenrod	T	
Solidago rupestris Goldenrod	E	
Solidago shortii Short's Goldenrod	E	E
Solidago spathulata Goldenrod	S	
Solidago squarrosa Squarrose Goldenrod	E	
Sparganium eurycarpum Common Bur Reed	E	
Sphenopholis pensylvanica Swamp Oats	E	
Spiraea alba Meadow Sweet	E	
Spiranthes lucida Shining Ladies' Tresses	T	
Spiranthes magnicamporum Ladies' Tresses	E	
Spiranthes odorata Sweet Lady's Tresses	E	
Sporobolus clandestinus Dropseed	E	
Sporobolus heterolepis Prairie Dropseed	E	
Stachys eplingii *Hedge-nettle*	S	
Stellaria longifolia Switchwort	S	
Streptopus roseus Twisted Stalk	E	
Styrax grandifolia Storax	S	
Sullivantia sullivantii Sullivant's Sullivantia	E	
Symphoricarpos albus Snowberry	E	
Synandra hispidula Synandra	--	C2
Taxus canadensis Canadian Yew	S	
Tephrosia spicata Goat's-rue	E	
Thalictrum coriaceum Maid-of-the-Mist	E	
Thalictrum mirabile Meadow Rue	S	
Thaspium pinnatifidum Cutleaf Meadow Parsnip	S	
Thermopsis mollis Bush Pea	E	
Thuja occidentalis Northern White Cedar	S	
Torreyochloa pallida Pale Manna Grass	E	
Trepocarpus aethusae Trepocarpus	E	
Trichomanes boschianum Filmy Fern	S	
Trichostema setaceum Blue Curls	S	

	KAS-KNPC	STATUS FEDERAL
Trifolium reflexum Buffalo Clover	E	
Trifolium stoloniferum Running Buffalo Clover	E	C1
Trillium nivale Snow Trillium	E	
Trillium pusillum var. *ozarkanum* Ozark Wake Robin	E	C2
Trillium undulatum Painted Trillium	T	
Ulmus serotina September Elm	S	
Utricularia vulgaris Bladderwort	E	
Vallisneria americana Tape Grass	S	
Veratrum parviflorum False Hellebore	T	
Veratrum woodii Wood's False Hellebore	T	
Vernonia fasciculata Fascicled Ironweed	S	
Vernonia noveboracensis New York Ironweed	E	
Viburnum lentago Nannyberry	E	
Viburnum nudum Possum Haw	E	
Viola egglestonii Glade Violet	T	
Viola pedatifida Prairie Violet	S	
Viola tripartita Yellow Violet	E	
Viola walteri Walter's Violet	E	
Woodsia scopulina Mountain Cliff Fern	E	
Xerophyllum asphodeloides Turkey Beard	S	
Zizania aquatica Wild Rice	E	
Zizaniopsis miliacea Southern Wild Rice	E	

ANIMAL LIST

	KAS-KNPC	STATUS FEDERAL
CRUSTACEANS		
Caecidotea barri Clifton Cave isopod	--	C2
Cambarellus puer Crayfish	E	
Cambarellus shufeldtii Crayfish	S	
Cambarus batchi Crayfish	E	C2
Cambarus bouchardi Big South Fork crayfish	E	C2
Cambarus cornutus Crayfish	S	
Cambarus ornatus Crayfish	S	
Cambarus parvoculus Crayfish	E	
Cambarus sciotensis Crayfish	E	
Gammarus bousfieldi Bousfield's amphipod	E	C2
Orconectes australis Crayfish	T	
Orconectes bisectus Crayfish	E	
Orconectes inermis Crayfish	T	
Orconectes jeffersoni Louisville crayfish	E	C2
Orconectes lancifer Crayfish	E	
Orconectes palmeri Crayfish	E	
Orconectes pellucidus Crayfish	S	
Palaemonias ganteri Kentucky cave shrimp	E	E
Procambarus viaeviridis Crayfish	T	
GASTROPODS		
Leptoxis praerosa Onyx rocksnail	--	C2
Lithasia armigera Armored rocksnail	--	C2
Lithasia geniculata Ornate rocksnail	--	C2
Lithasia salebrosa Rustic rocksnail	--	C2
Lithasia verrucosa Varicose rocksnail	--	C2
PELECYPODS		
Alasmidonta atropurpurea Cumberland elktoe	E	C2
Alasmidonta marginata Elktoe	T	
Cumberlandia monodonta Spectacle case	E	C2
Cyprogenia stegaria Fanshell	T	C2
Dromus dromas Dromedary mussel	E	E

	KAS-KNPC	STATUS FEDERAL
Epioblasma arcaeformis	E	
Sugarspoon		
Epioblasma biemarginata	E	
Angled riffleshell		
Epioblasma brevidens	E	C2
Cumberland combshell		
Epioblasma capsaeformis	E	C2
Oyster mussel		
Epioblasma florentina	E	E
Yellow-blossom pearlymussel		
Epioblasma florentina walkeri	E	E
Tan riffleshell		
Epioblasma haysiana	E	
Acornshell		
Epioblasma lewisi	E	
Forkshell		
Epioblasma obliquata	E	C2
Catspaw		
Epioblasma stewardsoni	E	
Cumberland leafshell		
Epioblasma torulosa rangiana	E	
Northern riffleshell		
Epioblasma torulosa torulosa	E	E
Tubercled blossom		
Epioblasma triquetra	S	
Snuffbox		
Fusconaia subrotunda subrotunda	T	
Long-solid		
Hemistena lata	E	C2
Crackling pearlymussel		
Lampsilis orbiculata	E	E
Pink mucket		
Lampsilis ovata	E	
Pocketbook		
Lasmigona compressa	T	
Creek heelsplitter		
Lasmigona subviridis	T	
Green floater		
Leptodea leptodon	E	C2
Scaleshell		
Obovaria retusa	E	C2
Ring pink		
Pegias fabula	E	C2
Little-winged pearlymussel		
Plethobasus cicatricosus	E	E
White wartyback		
Plethobasus cooperianus	E	E
Orange-footed pimpleback		
Plethobasus cyphyus	S	
Bullhead		
Pleurobema clava	E	C2
Clubshell		
Pleurobema oviforme	E	C2
Tennessee clubshell		
Pleurobema plenum	E	E
Rough pigtoe		
Pleurobema pyramidatum	E	C2
Pyramid pigtoe		
Potamilus capax	E	E
Fat pocketbook		
Ptychobranchus subtentum	T	
Fluted kidneyshell		
Quadrula cylindrica	E	C2
Rabbitsfoot		
Quadrula fragosa	E	C2
Winged mapleleaf		
Quadrula sparsa	E	E
Appalachian monkeyface		
Simpsonaias ambigua	T	C2
Salamander mussel		
Toxolasma lividus	E	
Purple lilliput		
Villosa fabalis	E	C2
Bean villosa		
Villosa lienosa	S	
Little spectacle case		
Villosa ortmanni	E	C2
Kentucky creekshell		
Villosa trabalis	E	E
Cumberland bean mussel		
Villosa vanuxemensis	T	
Mountain creekshell		
FISHES		
Acipenser fulvescens	E	C2
Lake sturgeon		
Alosa alabamae	S	
Alabama shad		
Amblyopsis spelaea	S	C2
Northern cavefish		
Ammocrypta asprella	E	C2
Crystal darter		
Ammocrypta clara	E	
Western sand darter		
Ammocrypta pellucida	S	C2
Eastern sand darter		
Ammocrypta vivax	E	
Scaly sand darter		
Clinostomus elongatus	S	
Redside dace		
Clinostomus funduloides	S	
Rosyside dace		
Cycleptus elongatus	--	C2
Blue sucker		
Erimyzon sucetta	T	
Lake chubsucker		
Esox niger	S	
Chain pickerel		
Etheostoma cinereum	T	
Ashy darter		

	KAS-KNPC	STATUS FEDERAL
Etheostoma fusiforme Swamp darter	E	
Etheostoma maculatum Spotted darter	T	
Etheostoma microlepidum Smallscale darter	E	
Etheostoma microperca Least darter	E	
Etheostoma nigrum susanae Johnny darter	E	C2
Etheostoma parvipinne Goldstripe darter	S	
Etheostoma proeliare Cypress darter	T	
Etheostoma sagitta spilotum Arrow darter	S	
Etheostoma swaini Gulf darter	S	
Etheostoma tippecanoe Tippecanoe darter	S	
Etheostoma lynceum Banded darter	S	
Etheostoma (Nanostoma) sp. Firebelly darter (undescribed)	S	
Fundulus chrysotus Golden topminnow	E	
Fundulus notti (=dispar) Starhead topminnow	E	
Hemitremia flammea Flame chub	E	
Hybognathus hayi Cypress minnow	T	
Hybognathus placitus Plains minnow	S	
Hybopsis gelida Sturgeon chub	S	C2
Hybopsis gracilis Flathead chub	S	
Hybopsis insignis Blotched chub	E	
Hybopsis meeki Sicklefin chub	S	C2
Hybopsis x-punctata Gravel chub	E	
Ichthyomyzon castaneus Chestnut lamprey	S	
Ichthyomyzon fossor Northern brook lamprey	T	
Ichthyomyzon gagei Southern brook lamprey	E	
Ichthyomyzon greeleyi Mountain brook lamprey	T	
Ictiobus niger Black buffalo	S	
Lampetra appendix American brook lamprey	T	
Lepisosteus spatula Alligator gar	E	
Lepomis marginatus Dollar sunfish	E	
Lepomis punctatus Spotted sunfish	T	
Lota lota Burbot	S	
Menidia beryllina Inland silverside	T	
Moxostoma atripinne Blackfin sucker	S	
Moxostoma poecilurum Blacktail redhorse	S	
Nocomis biguttatus Hornyhead chub	S	
Notropis amnis Pallid shiner	E	
Notropis camurus Bluntface shiner	S	
Notropis hudsonius Spottail shiner	S	
Notropis maculatus Taillight shiner	T	
Notropis venustus Blacktail shiner	E	
Notropis sp. Palezone shiner (undescribed)	E	C2
Notropis sp. Sawfin shiner (undescribed)	E	
Noturus exilis Slender madtom	E	
Noturus hildebrandi Least madtom	S	
Noturus phaeus Brown madtom	S	
Noturus stigmosus Northern madtom	S	
Percina burtoni Blotchside logperch	E	
Percina evides Gilt darter	S	
Percina macrocephala Longhead darter	T	C2
Percina squamata Olive darter	E	
Percopsis omiscomaycus Trout-perch	S	
Phenacobius uranops Stargazing minnow	S	
Phoxinus cumberlandensis Blackside dace	E	C1
Rhinichthys cataractae Longnose dace	S	
Scaphirhynchus albus Pallid sturgeon	E	C2

	KAS-KNPC	STATUS FEDERAL
Typhlichthys subterraneus Southern cavefish	S	
Umbra limi Central mudminnow	T	
AMPHIBIANS		
Ambystoma platineum Silvery Salamander	E	
Amphiuma tridactylum Three-toed Amphiuma	E	
Aneides aeneus Green Salamander	--	C2
Cryptobranchus alleganiensis Hellbender	--	C2
Eurycea longicauda guttolineata Three-lined Salamander	T	
Hyla avivoca Bird-voiced Treefrog	T	
Hyla cinerea Green Treefrog	S	
Hyla versicolor Gray Treefrog	S	
Plethodon cinereus Redback Salamander	S	
Plethodon wehrlei Wehrle's Salamander	E	
Rana pipiens Northern Leopard Frog	S	
REPTILES		
Chrysemys picta dorsalis Southern Painted Turtle	S	
Clonophis kirtlandii Kirtland's Snake	E	C2
Elaphe guttata Corn Snake	S	
Eumeces anthracinus anthracinus Northern Coal Skink	S	
Eumeces anthracinus pluvialis Southern Coal Skink	E	
Farancia abacura Mud Snake	S	
Lampropeltis triangulum elapsoides Scarlet Kingsnake	S	
Macroclemys temminckii Alligator Snapping Turtle	T	C2
Masticophis flagellum Coachwhip	E	
Nerodia cyclopion Green Water Snake	E	
Nerodia erythrogaster neglecta Copperbelly Water Snake	S	C2
Nerodia fasciata Southern Water Snake	E	
Ophisaurus attenuatus Slender Glass Lizard	S	
Pituophis melanoleucus Pine Snake	S	
Sistrurus miliarius Pigmy Rattlesnake	T	
Thamnophis proximus Western Ribbon Snake	T	
Thamnophis sauritus Eastern Ribbon Snake	S	
Trionyx muticus Smooth Softshell	S	
BIRDS		
Accipiter cooperii Cooper's Hawk	S	
Accipiter striatus Sharp-shinned Hawk	S	
Actitis macularia Spotted Sandpiper	E	
Aimophila aestivalis Bachman's Sparrow	T	C2
Ammodramus henslowii Henslow's Sparrow	S	
Anas discors Blue-winged Teal	E	
Anhinga anhinga Anhinga	E	
Ardea herodias Great Blue Heron	S	
Bartramia longicauda Upland Sandpiper	E	
Botaurus lentiginosus American Bittern	E	
Bubulcus ibis Cattle Egret	S	
Campephilus principalis Ivory-billed Woodpecker	--	E
Casmerodius albus Great Egret	E	
Charadrius melodus Piping Plover	--	T
Chondestes grammacus Lark Sparrow	T	
Cistothorus platensis Sedge Wren	S	
Corvus corax Common Raven	E	
Corvus ossifragus Fish Crow	S	
Dendroica fusca Blackburnian Warbler	T	
Dendroica kirtlandii Kirtland's Warbler	--	E
Dolichonyx oryzivorus Bobolink	S	
Egretta caerulea Little Blue Heron	E	

	KAS-KNPC	STATUS FEDERAL
Elanoides forficatus forficatus American Swallow-tailed Kite	--	C2
Empidonax minimus Least Flycatcher	T	
Falco peregrinus Peregrine Falcon	E	E
Fulica americana American Coot	E	
Gallinula chloropus Common Moorhen	E	
Haliaeetus leucocephalus Bald Eagle	E	E
Ictinia mississippiensis Mississippi Kite	S	
Ixobrychus exilis Least Bittern	E	
Junco hyemalis Dark-eyed Junco	S	
Lanius ludovicianus migrans Migrant Loggerhead Shrike	--	C2
Lophodytes cucullatus Hooded Merganser	E	
Nycticorax nycticorax Black-crowned Night-Heron	E	
Nycticorax violaceus Yellow-crowned Night-Heron	T	
Pandion haliaetus Osprey	E	
Passerculus sandwichensis Savannah Sparrow	S	
Phalacrocorax auritus Double-crested Cormorant	E	
Pheucticus ludovicianus Rose-breasted Grosbeak	S	
Picoides borealis Red-cockaded Woodpecker	E	E
Podilymbus podiceps Pied-billed Grebe	E	
Pooecetes gramineus Vesper Sparrow	S	
Rallus elegans King Rail	E	
Riparia riparia Bank Swallow	S	
Sterna antillarum athalassos Interior Least Tern	E	E
Thryomanes bewickii Bewick's Wren	S	C2
Tyto alba Common Barn-Owl	S	
Vermivora bachmanii Bachman's Warbler	E	E
Vermivora chrysoptera Golden-winged Warbler	S	
Vireo bellii Bell's Vireo	S	

	KAS-KAS-KNPC	STATUS FEDERAL
Wilsonia canadensis Canada Warbler	S	
MAMMALS		
Clethrionomys gapperi maurus Gapper's Red-backed Mouse	S	C2
Felis concolor couguar Mountain Lion	E	E
Lutra canadensis River Otter	S	
Microsorex hoyi winnemana Pygmy Shrew	--	C2
Mustela nivalis Least Weasel	S	
Myotis austroriparius Southeastern Myotis	E	C2
Myotis grisescens Gray Myotis	E	E
Myotis keenii Keen's Myotis	S	
Myotis sodalis Indiana Myotis	E	E
Myotis subulatus leibii Small-footed Myotis	E	C2
Neotoma floridana magister Eastern Wood Rat	--	C2
Nycticeius humeralis Evening Bat	T	
Peromyscus gossypinus Cotton Mouse	S	
Plecotus rafinesquii Rafinesque's Big-eared Bat	T	C2
Plecotus townsendii virginianus Virginia Big-eared Bat	E	E
Sorex cinereus Masked Shrew	S	
Sorex dispar Long-tailed Shrew	E	C2
Spilogale putorius Spotted Skunk	S	
Sylvilagus aquaticus Swamp Rabbit	S	
Sylvilagus transitionalis New England Cottontail	E	C2
Ursus americanus Black Bear	E	

ACKNOWLEDGMENTS

Individuals who significantly contributed to this effort include the following: Carol C. Baskin, Julian Campbell, and William C. McComb, University of Kentucky; Hal Bryan, Kentucky Transportation Cabinet; Sherri A. Evans and Albert Westerman, Kentucky

Natural Resources and Environmental Protection Cabinet; Horton H. Hobbs III, Wittenburg College; Horton H. Hobbs, Jr., National Museum of Natural History; Ronald Jones, William H. Martin, and Guenter A. Schuster, Eastern Kentucky University; Lewis E. Kornman and Jeffery D. Sole, Kentucky Department of Fish and Wildlife Resources; Michael J. Lodato; Charles Logsdon; David L. McNeely and Les Meade, Morehead State University; William D. Pearson, University of Louisville; Anne L. Stamm; James B. Sickel and Tom J. Timmons, Murray State University; John W. Thieret, Northern Kentucky University; Robert E. Todd, Jr.; John O. Whitaker, Jr., Indiana State University.

LITERATURE CITED

1. United States Congress. 1983. The Endangered Species Act as amended by Public Law 97-304 (The Endangered Species Act Amendments of 1982). U.S. Gov. Printing Office, Washington, District of Columbia.
2. Branson, B.A., D.F. Harker, Jr., J.M. Baskin, M.E. Medley, D.L. Batch, M.L. Warren, Jr., W.H. Davis, W.C. Houtcooper, B. Monroe, Jr., L.R. Phillippe, and P. Cupp. Endangered, threatened, and rare animals and plants of Kentucky. Trans. Ky. Acad. Sci. 42:77-89.
3. United States Fish and Wildlife Service. 1986. Endangered and threatened wildlife and plants. U.S. Dep. Inter., Washington, District of Columbia.
4. The Nature Conservancy. 1982. Natural heritage program operations manual. Revised 1985. The Nat. Conservancy, Arlington, Virginia.
5. United States Fish and Wildlife Service. 1984. Endangered and threatened wildlife and plants; review of invertebrate wildlife for listing as endangered or threatened species. Federal Register 49:21664-21675.
6. United States Fish and Wildlife Service. 1986. Piping plover. Endangered Species Tech. Bull. 11:3.
7. United States Fish and Wildlife Service. 1985. Endangered and threatened wildlife and plants; review of vertebrate wildlife. Federal Register 50:37958-37967.
8. United States Fish and Wildlife Service. 1985. Interior least tern. Endangered Species Tech. Bull. 10:7,12.
9. United States Fish and Wildlife Service. 1985. Endangered and threatened wildlife and plants; review of plant taxa for listing as endangered or threatened species; notice of review. Federal Register 50:39526-39527.
10. Kartesz, J.T., and R. Kartesz. 1980. A synonymized checklist of the vascular flora of the United States, Canada and Greenland. Univ. N.C. Press, Chapel Hill, North Carolina.
11. Hobbs, H.H., Jr. 1976. Crayfishes (Astacidae) of North and Middle America. Water Pollut. Control Res. Ser. 18050 ELD05/72, U.S. Environ. Prot. Agency, Cincinnati, Ohio.
12. Holsinger, J.R. 1972. The freshwater amphipod crustaceans (Gammaridae) of North America. Water Pollut. Control Res. Ser. 18050 ELD04/72, U.S. Environ. Prot. Agency, Cincinnati, Ohio.
13. United States Fish and Wildlife Service. 1980. Endangered and threatened wildlife and plants; proposed endangered status and critical habitat for the Kentucky cave shrimp. Federal Register 45:68975-68977.
14. Thompson, F.G. and C.M. Porter. 1985. Class Gastropoda - freshwater snails. Pp. 48-55 *in* American Malacological Union suggested draft list of common names for mollusks occurring from America north of Mexico. Shells and Sea Life 17.
15. Stansbery, D.H., and A.E. Bogan. 1985. Class Bivalvia - bivalve mollusks. Pp. 60-65 *in* American Malacological Union suggested draft list of common names for mollusks occurring from America north of Mexico. Shells and Sea Life 17.
16. Bailey, R.M., J.E. Fitch, E.S. Herald, E.A. Lachner, C.C. Lindsey, C.R. Robins, and W.B. Scott. 1970. A list of common and scientific names of fishes from the United States and Canada. 3rd Ed. Am. Fish. Soc. Spec. Publ. No. 6.
17. Carney, D.A. 1985. Comparative morphology and reproductive biology of two species of darters of the subgenus *Nanostoma* (Percidae: *Etheostoma*) in western Kentucky. Thesis. South. Ill. Univ. Carbondale, Carbondale, Illinois.
18. Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. 4th Ed. Am. Fish. Soc. Spec. Publ. No. 12.
19. Stauffer, J.R., Jr., B.M. Burr, C.H. Hocutt, and R.E. Jenkins. 1982. Checklist of the fishes of the central and northern

Appalachian Mountains. Proc. Biol. Soc. Wash. 95:27-47.

20. Collins, J.T., R. Conant, J.E. Huheey, J.L. Knight, E.M. Rundquist, and H.M. Smith. 1982. Standard common and current scientific names for North American amphibians and reptiles. 2nd Ed. Soc. Study Amphibians and Reptiles, Herpetol. Circ. No. 7.

21. American Ornithologist's Union. 1983. Checklist of North American birds. 6th Ed. Am. Ornithologist's Union, Lawrence, Kansas.

22. Hall, E.R. 1981. The mammals of North America. 2nd Ed. Vols. I and II. John Wiley and Sons, New York, New York.

Thuja occidentalis L. in Kentucky

Arland T. Hotchkiss
Harry H. Woodward
Louis F. Muller
Max E. Medley
University of Louisville, Louisville, Kentucky 40292

Abstract

The distribution of *Thuja occidentalis* in the Lake Cumberland region of Kentucky is described. The steep limestone cliff habitat of the Russell County sites is compared to Braun's descriptions of similar habitats in Scioto and Adams Counties in southern Ohio.

Observations

In 1833, *Thuja occidentalis* (White Cedar, Arbor Vitae), was included by Short, Peter and Griswald in their Plant Catalogue of Kentucky without dates, locations, or specimens. Gattinger (1) discovered it in Tennessee and it was reported subsequently in most neighboring states. The impoundment of Lake Cumberland in 1950 provided ease of access to some of the more isolated cliffs with stands of *T. occidentalis* in Kentucky. In 1965, the third author sighted *T. occidentalis* near the entrance to Pumpkin Creek and took specimens for planting. Continued search in the area by the first three authors revealed the presence of *T. occidentalis* in the upper drainage area of the Cumberland River in at least 5 distinct locations near Jamestown, Russell County. The fourth author (2) reported collecting some very small specimens in 1978 on the side of a large sandstone boulder in the Big South Fork of the Cumberland River in McCreary County, and, (3) recorded its presence "on or below limestone bluffs" on Buck Creek, Pulaski County.

The areas in Russell County are fairly extensive and occur on high, steep limestone cliffs. There are 2 separate areas of *T. occidentalis* on Boundary Low Cut Island in Lake Cumberland, east of Cumberland Lake State Park. A third location is on the east side of Lily Creek, southeast of Jamestown. The fourth and fifth locations are on points on the south sides of Pumpkin and Greasy Creeks, south of Jamestown. All the sites are on generally north-facing cliffs in isolated, rugged country and were apparently little visited by botanists until the building of a dam and the impoundment of Lake Cumberland by the T.V.A. With the opening of the lake to boating and fishing in 1950, the bold cliffs, close to the deeply entrenched Cumberland River and in the sinuous, narrow canyon tributaries, as in Greasy Creek, became accessible by water. Boats could move right up the face of the cliff at a point well above the valley floor. At this time, and in this manner, the third author first became aware of *T. occidentalis* along the shoreline near the western end of Lake Cumberland. All subsequent discoveries were also made by boat.

Specimens of *T. occidentalis* were taken by the first author from a station on the south side of Greasy Creek, which is easily accessible by land from U.S. Highway 127, for distribution to Kentucky and national herbaria. Some of the distributions were made October 28, 1978 at the Kentucky Academy of Science Meetings. The site is about 1.6 km south of Jamestown and about 1.6 km east of the bridge, where the highway crosses Greasy Creek. Around the next bend of the valley, below the bridge, can be seen a higher, north-facing, 0.8 km of cliff, to which conifers are clinging. These include *Juniperus virginiana, Tsuga canadensis, Pinus virginiana,* and in the middle of the highest part of the cliff, compact trees of *T. occidentalis* dominating this area. The cliffs here stand over 61 m above the normal pool level of the lake and even higher above the winter draw-down level of the valley floor before impoundment.

Trees of *T. occidentalis* growing on the cliffs appear to have the same habit often seen in Hemlock and Yellow Birch, that of growing in thin soil on narrow ledges and of gaining a foothold by sending roots into deep crevices and apertures in the rocks. The trunks of many trees are bent down and grow up again in a u-shaped turn. One healthy tree, viewed from the top of the cliff, was in a completely inverted position. Most trees appeared to be mature but a wide range of sizes was evident. Some seedlings were taken in 1977 for growth studies. *Thuja occidentalis* did not extend across to the south-facing slopes on the opposite side of the valley. There, instead, was an abundance of Virginia Pine, Red Cedar, and in the steeper areas, Hemlock which extends up Greasy Creek to a point east of the highway.

Above the White Cedar cliffs, the land slopes gently upward another 30+ m, through meadows, pastures with small creeks, fence rows and wooded areas, to high points at the 305 m contour line, which marks the summit of nearby hills. This altitude provides sufficient head to supply seepages and springs in the limestone cliffs below. Vegetation noted in a transect taken along the cliff tops and wooded slopes above the cliffs, has a generally mixed mesophytic appearance, including the following species: *Pinus virginiana, Tsuga canadensis, Juniperus virginiana, Magnolia tripetala, Asimina triloba, Prunus serotina, Carya sp., Quercus alba, Quercus borealis, Quercus falcata, Acer saccharum, Acer rubrum, Rhamnus caroliniana, Aralia spinosa, Oxydendrum arboreum, Vibernum acerfolium, Dryopteris marginalis, Polystichum acrostichoides, Pachysandra sp.,* and seen above the cliffs at nearby Pumpkin Creek, *Aesculus octandra* and *Kalmia latifolia*. Near the edge of the water at the normal pool level, the vegetation included *Albizzia julibrissin, Alnus serrulata. Platanuc occidentalis, Acer saccharinum* and *Cephalanthus occidentalis*. All these species are a part of the apparently new strand vegetation.

Discussion

The prospect of finding *T. occidentalis* in the flora of Kentucky was always a good one. In West Virginia, Virginia and Tennessee, (4) *T. occidentalis* is found well within the Appalachian region. Strausbaugh and Core (5), for example, reported it from 6 counties in West Virginia, growing on "riverbanks and rocky hillsides, often on limestone." On the western edge of the Appalachian Plateau, in southern Ohio, Braun (6,7) found White Cedar on calcareous outcrops in Scioto County, and clinging on dolomite cliffs in Adams County, in the same manner as seen on higher cliffs in Russell County, Kentucky. White cedar populations in 4 counties of northern Illinois (8,9) and in 2 counties of northern Indiana (10), are more like those in several counties of west central Ohio (7), and are found in cedar swamps and marl bogs, which are more common habitats for *T. occidentalis* in the northern states and Canada. The Russell County populations of *T. occidentalis* on Lake Cumberland appear to be related to, although as far as is known, not contiguous with, the nearby Tennessee population, through the Cumberland River and the South Fork of the Cumberland, which penetrates southward into the *T. occidentalis* region in Tennessee (4).

These isolated populations of *T. occidentalis* in restricted topographically and ecologically circumscribed areas, are relic communities. As Braun (6) said of the Arbor Vitae groves of southern Ohio: "past influences....together with edaphic conditions make possible the persistence of the relics among the communities of the climatic vegetation." Braun's statement appears to describe the *T. occidentalis* communities around Lake Cumberland in Kentucky equally well.

Literature Cited

1. Gattinger, Augustin. 1901. The flora of Tennessee and a philosophy of botany. Bur. of Agric. St. of Tenn., Nashville, TN.
2. Medley, Max E. and B. Eugene Wofford. 1980. *Thuja occidentalis* L. and other noteworthy collections from the big south fork of the Cumberland River in McCreary County, Kentucky. Castanea 45:213-215.
3. Medley, Max E., Ray Cranfill and John W. Thieret. 1983. Vascular flora of Kentucky: additions and other noteworthy collections. Sida 10:114-122.
4. Little, Elbert L. Jr. 1971. Atlas of United States Trees. Volume 1. Conifers and Important Hardwoods. Misc. Publ. No. 1146., U.S. Govnm. Printing Office, Washington, D.C.
5. Strausbaugh, P.D. and Earl L. Core. 1978. Flora of West Virginia. Revised Second Edition. Seneca Books, Inc., Grantsville, WVA.
6. Braun, E. Lucy. 1928. The vegetation of the Mineral Springs region of Adams County, Ohio. Ohio Biol. Suvr. Bull. 15:381-515.
7. Braun, E. Lucy. 1969. The Woody Plants of Ohio. Hafner Publ. Co., New York, NY.
8. Mohlenbrock, Robert H. 1975. Guide to the Vascular Flora of Illinois. So. Ill. U. Press, Carbondale, IL.
9. Mohlenbrock, Robert H. and Douglas M. Ladd. 1978. Distribution of Illinois vascular plants. So. Ill. U. Press, Carbondale, IL.
10. Deam, Charles C. 1932. Trees of Indiana. St. of Ind. Dept. Consv. Publ. No. 13. Fort Wayne Printing Co., Fort Wayne, IN.

A Beech-Hemlock Stand in the Knobstone Escarpment of Madison County, Kentucky

Ronald L. Jones
Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky 40475

and

Ralph L. Thompson
Department of Biology
Berea College
Berea, Kentucky 40404

ABSTRACT

The species composition and forest structure were determined for a small beech-hemlock stand in the Knobstone Escarpment of southeastern Madison County, Kentucky, in 1984. *Fagus grandifolia* and *Tsuga canadensis* comprised 66% of the total basal area, and ranked first and second in importance values. The major canopy associates of these 2 dominants were *Quercus alba, Liriodendron tulipifera,* and *Acer rubrum*. In the understory, *Fagus grandifolia, Acer rubrum,* and *Tsuga canadensis* made up 83% of seedlings and 68% of saplings. Total tree species at the site were 33, of which 22 were represented in the canopy. Tree densities were 11578 seedlings/ha, 1887 saplings/ha, and 501 canopy trees/ha, with a total basal area of 29.9 m^2/ha. *Pinus strobus* is recorded for the first time as native to Madison County. This community is similar in composition and structure to beech-hemlock forests of the Cumberland Plateau, but is unusual for the Knobstone Escarpment of Kentucky.

INTRODUCTION

The vegetation of the Knobstone Escarpment of the Interior Low Plateaus was described by Quarterman and Powell (1) as varying from oak-hickory on drier slopes to beech-yellow poplar on mesic slopes to mixed mesophytic forest relics in some deep ravines. Wharton (2) described the mixed mesophytic forests in the black shale Knobstone as being restricted to small hollows, bases of white oak-wooded hills, and north slopes above steep stream banks. According to Braun (3), the lower slopes in the Knobs Border Area were once covered by an all deciduous mixed mesophytic forest. The beech-hemlock mixed mesophytic community has not been quantitatively documented for the Knobstone Escarpment. The objectives of this study were to determine the species composition of seedling, sapling, and canopy layers, and to describe the community structure of a stand of beech-hemlock in the Knobstone Escarpment of Madison County.

THE STUDY SITE

The study site is located at latitude 37° 34' 51" N and longitude 84° 06' 38" in extreme southeastern Madison County near Estill and Jackson counties. (Fig. 1). It lies in Anglin Hollow, 1.9 km off Long Branch Road and 2.4 km southeast of Red Lick Road (KY 594). The site is under private ownership but lies within the congressional boundaries of the Daniel Boone National Forest. The beech-hemlock community occupies a mesic, lower, northeast-trending slope from 240 m to 300 m. It is bordered on the east by an intermittent stream leading to Shirley Creek, on the south and north by a contiguous lower slope, and on the west by a midslope bench of oak-hickory-pine forest.

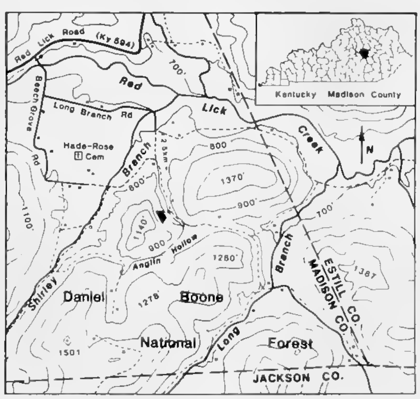


Figure 1. Beech-Hemlock Stand in southeastern Madison County, at Anglin Hollow, 2.5 km from junction of Red Lick Road (Ky. 594) southeast off Long Branch Road. Map adapted from Alcorn Quadrangle 7.5 minute topographic series, U.S. Geological Survey, 1952.

The stand is within the portion of Madison County designated as the Knobs Border Area of the Cumberland Plateau (3) but recently classified as the Knobstone Escarpment of the Bluegrass Section of the Interior Low Plateaus (1). The bedrock at the site belongs to the Nancy and Cowbell siltstones and shales of the Borden Formation within the Mississippian System, while bedrock of the streambed is New Albany shale of the Devonian System (4). The forest soil on the moderately steep, colluvial slopes belong to the Shelocta soil series which are deep, acid, and well-drained gravelly silt loams (5). The mean annual temperature for this region is 13.7° C, mean annual precipitation is 119.4 cm, and mean frost-free growing season is 189 days (6).

METHODS

The beech-hemlock community occupied an area of 6700 m^2 (0.67 ha). A single macroplot was established to include this area, and all seedlings, samplings, and canopy trees were tabulated. Dead saplings and trees were recorded separately. Seedlings were designated as individuals under 1.0 m tall; saplings were classified as those over 1.0 m tall and under 1.0 dm dbh. No attempt was made to distinguish seedlings and saplings from root suckers and stump sprouts. Diameters (dbh) of canopy trees were measured with Haglof tree calipers and recorded by species in size-classes to the nearest cm. Total tree density was determined for each stratum, and relative density was

Table 1. Structural analysis of beech-hemlock stand at Anglin Hollow, Madison County, Kentucky

Species	Seedlings	Saplings*	Decimeter Size-Classes (dbh)								Species Total	Relative Density
			1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9		
Fagus grandifolia	3644	134	26	18	12	5	4	4	3	2	3852	41.17
Acer rubrum	1542	285 (5)	13	4	3	0	0	1 (1)	0	0	1848	19.75
Tsuga canadensis	1207	448	32	19 (1)	21	4	1	2	1	0	1735	18.54
Magnolia tripetala	248	68 (12)	4 (3)	0	0	0	0	0	0	0	320	3.42
Cornus florida	164	40	1	0	0	0	0	0	0	0	205	2.19
Sassafras albidum	186	10 (22)	2 (1)	0	0	0	0	0	0	0	198	2.12
Oxydendrum arboreum	86	51 (25)	26 (4)	1	0	0	0	0	0	0	164	1.75
Nyssa sylvatica	82	34	7	1	1	0	0	0	0	0	125	1.34
Fraxinus americana	88	26	3	0	0	0	0	0	0	0	117	1.25
Quercus alba	58	15 (11)	23 (1)	4	9	1	0	0	1	0	111	1.19
Quercus rubra	83	14 (2)	6	1	1	0	0	0	0	0	105	1.12
Liriodendron tulipifera	33	13 (4)	19	5	1	2	0	0	0	0	73	0.78
Carya glabra	59	6	0	0	0	0	0	0	0	0	65	0.70
Carpinus caroliniana	37	24 (2)	1	0	0	0	0	0	0	0	62	0.66
Ostrya virginiana	36	18	0	0	0	0	0	0	0	0	54	0.58
Quercus coccinea	30	5 (4)	4 (1)	2	4	0	0	0	0	0	45	0.48
Pinus strobus	23	16	2	0	1	0	0	0	0	0	42	0.45
Acer saccharum	14	21	6	0	0	0	0	0	0	0	41	0.44
Quercus prinus	25	4 (1)	3	2	0	0	0	0	0	0	34	0.36
Amelanchier arborea	30	4	0	0	0	0	0	0	0	0	34	0,36
Quercus velutina	19	2 (1)	1 (1)	1	0	0	0	0	0	0	23	0.25
Carya ovata	11	8 (3)	2	0	0	0	0	0	0	0	21	0.22
Juniperus virginiana	10	4	0	0	0	0	0	0	0	0	14	0.15
Castanea dentata	10	3	0	0	0	0	0	0	0	0	13	0.14
Pinus virginiana	0	1 (8)	8	1	1	1	0	0	0	0	12	0.13
Diospyros virginiana	8	1	0	0	0	0	0	0	0	0	9	0.10
Cercis canadensis	5	3	0	0	0	0	0	0	0	0	8	0.09
Prunus serotina	5	0	1	0	0	0	0	0	0	0	6	0.06
Carya cordiformis	4	1	0	0	0	0	0	0	0	0	5	0.05
Robinia pseudoacacia	3	2	0	0	0	0	0	0	0	0	5	0.05
Ulmus americana	3	2	0	0	0	0	0	0	0	0	5	0.05
Aesculus octandra	1	1	1	0	0	0	0	0	0	0	3	0.03
Ilex opaca	3	0	0	0	0	0	0	0	0	0	3	0.03
Total Species: 33	7757	1264	191	59	54	13	5	7	5	2	9357	100.00

(*) Dead saplings and trees are designated within parenthesis.

then calculated for each species. Relative density (RD) and relative basal area (RBA) were calculated for canopy trees, and these 2 values were summed and multiplied by 100 to calculate importance value (IV). Observations were also made on the presence of shrubs and vines within the community. Nomenclature for trees herein follows Little (7).

Results

There were 7757 seedlings, 1264 saplings, and 336 canopy trees counted in the 0.67 ha site (Table 1). On a per hectare basis, the tree densities were 11578 seedlings, 1887 saplings, and 501 canopy trees. Thirty three trees species were present at the site, and 22 of these species were represented in the canopy. Based on relative density of all strata, the 3 dominant species were *Fagus grandifolia* (41.17%), *Acer rubrum* (19.75%), and *Tsuga canadensis* (18.54%). These 3 species comprised 83% of the seedlings and 68% of the saplings, with *Fagus* most numerous among seedlings, and *Tsuga* most numerous among saplings. The seedlings and saplings of the oaks, hickories, and pines were notably sparse at the site. For canopy trees, *F. grandifolia* was first in all size-classes above 4.0 dm dbh, while *T. canadensis* was first from 1.0-4.0 dm dbh. The only other species with individuals above 4.0 dm dbh were *A. rubrum*, *Quercus alba*, *Liriodendron tulipifera*, and *Pinus virginiana*.

In the canopy, *Fagus* and *Tsuga* were the dominants with IVs of 62.23 and 49.89, respectively (Table 2). These 2 species contributed over 50% of the total IV, and were the clear dominants over the other major constituents in the stand. The calculated basal area 20.02 m^2/0.67 ha, or 29.9 m^2/ha, and 66% of this total was contributed by *Fagus* and *Tsuga*. Major trees in the lower diameter classes were *Magnolia tripetala*, *Cornus florida*, *Carpinus carolinana*, and *Ostrya virginiana* (Tables 1,2).

A total of 115 dead saplings and trees were counted at the site (Table 1). The leading species in this group were *Oxdendrum arboreum*, *Sassafras albidum*, *M. tripetala*, *Q. alba*, and *P. virginiana*. No dead *Fagus* was found and only one dead *Tsuga* was recorded.

The most abundant shrubs were *Viburnum acerifolium* and *Lindera benzoin*. More sparsely distributed shrubs and suffrutescent species were *Vaccinium stamineum*, *Hydrangea arborescens*, *Gaultheria procumbens*, *Chimaphila maculata*, and *Mitchella repens*. Vines present were *Vitis aestivalis*, *Parthenocissus quinquefolia*, *Rhus radicans*, *Smilax glauca*, and *S. rotundifolia*.

Table 2. Canopy tree number (N), relative density (RD), Relative Basal Area (RBA), and Importance Value (RD + RBA=IV) at beech-hemlock stand at Anglin Hollow, Madison County, Kentucky.

Species	N	RD	RBA	IV (RD+RBA)
Fagus grandifolia	74	22.02	40.21	62.23
Tsuga canadensis	80	23.81	26.08	49.89
Quercus alba	38	11.31	11.65	22.96
Liriodendron tulipifera	27	8.04	5.44	13.48
Acer rubrum	21	6.25	4.97	11.22
Oxydendrum arboreum	27	8.04	2.00	10.04
Quercus coccinea	10	2.98	2.35	5.33
Pinus virginiana	11	3.27	1.79	5.06
Nyssa sylvatica	9	2.68	1.30	3.98
Quercus rubra	8	2.38	1.16	3.54
Quercus prinus	5	1.49	0.88	2.37
Acer saccharum	6	1.79	0.29	2.08
Pinus strobus	3	0.89	0.59	1.48
Magnolia tripetala	4	1.19	0.08	1.27
Fraxinus americana	3	0.89	0.37	1.26
Sassafras albidum	2	0.59	0.23	0.82
Quercus velutina	2	0.59	0.21	0.80
Carya ovata	2	0.59	0.09	0.68
Prunus serotina	1	0.30	0.19	0.49
Carpinus caroliniana	1	0.30	0.04	0.34
Cornus florida	1	0.30	0.40	0.34
Aesculus octandra	1	0.30	0.04	0.34
Total Species: 22	336	100.00	100.00	200.00

Discussion

The Anglin Hollow site is occupied by a mature beech-hemlock stand with the 2 species dominant in the canopy and in the understory. *Fagus* and *Tsuga* are very shade tolerant (8), and their presence in all size-classes indicate continued dominance. The presence of *Tsuga* is of particular significance because it is more restricted than *Fagus* in distribution, being more common in protected habitats of the Cumberland Plateau, and in a few outliers west of the Plateau (3).

The canopy associates of beech and hemlock at the study site have become established during previous seral stages. *Quercus alba*, *Liriodendron tulipifera*, and *Acer rubrum* are the most important of these associates with only the latter reproducing well in the understory. *Acer rubrum* and *Q. alba* are classified as intermediate to shade intolerant, but *L. tulipifera* is very shade intolerant (8). Thus, the continued perpetuation of these species in the community depends partially on the periodic canopy openings created by windthrow and dead trees. These canopy gaps will also enhance the persistence of *Nyssa sylvatica, Fraxinus americana, Quercus rubra,* and *Pinus strobus.* The remaining oaks, hickories, and pine are less likely to survive because of their shade intolerance and site requirements. Other invaders being shaded out of the community include *Oxydendrum arboreum, Sassafras albidum, Prunus serotina, Robinia pseudoacacia,* and *Juniperus virginiana. Castanea dentata* persists only from a few stump sprouts. The subcanopy in the stand should remain stable with *Magnolia tripetala, Cornus florida,* and *Carpinus caroliniana* as the major species.

This is the first report of *P. strobus* occurring natively in Madison County. The species is associated with mixed mesophytic communities of the Cumberland Plateau, and in a few sites west of the Plateau (3). *Pinus strobus* may also spread from plantings, so the original range of the species is now obscure. Regardless of its origin at the Anglin Hollow site, the presence of this northern species together with mature beech and hemlock give this community a very attractive Alleghenian aspect.

Beech-hemlock communities have been reported from several sites on the Cumberland Plateau by Braun (3). She classified these communities as hemlock-mixed mesophytic, and noted that *F. grandifolia, L. tulipifera, A. rubrum,* and *Q. alba* were typical associates, and that *A. saccharum, Aesculus octandra,* and *Tilia heterophylla* were often infrequent. Communities with similar species compositions have been reported from Lilley Cornett Woods, Letcher County (9,10), and from Robinson Forest, Breathitt County (11,12) of the Cumberland Plateau. West of the Plateau, in Edmonson County, similar communities have been reported from gorges of Wolf Creek (13) and Mammoth Cave National Park (14). *Tsuga* communities lacking *Fagus* as an important associate have been studied at Tight Hollow, Wolf County (15), and at Rock Creek Gorge, Laurel County (16).

This is the first quantitative study of a mature beech-hemlock community in the Knobstone Escarpment. The basal area of 29.9 m^2/ha matches that proposed by Held and Winstead (17) for a climax mesic forest stand. Wharton (2) did not include *Tsuga* as a major constituent of her mixed mesophytic association segregates in the Knobs. The species was present, but the trees were usually of small diameters and the communities very limited in size. The beech-hemlock community was not described by either Fedders (18) or Godbey (19) in their more recent studies within the Knobs. The Anglin Hollow site thus appears to be unique for the Knobstone Escarpment, and is an outlying representative of the Mixed Mesophytic Forest Region of the Cumberland Plateau.

Additional studies are needed to determine the distribution and compostion of the varied community types in this complex, transitional Knobstone Escarpment, which Braun (3) referred to as one of the best examples of the "interrelations between vegetation and underlying rock and between vegetation and physiographic history."

LITERATURE CITED

1. Quarterman, E. and R. Powell. 1978. Potential ecological/geological landmarks on the Interior Low Plateaus. U.S. Department of Interior, Washington, D.C.
2. Wharton, M.E. 1945. Floristics and vegetation of the Devonian-Mississippian black shale region of Kentucky. Ph.D. Dissertation, University of Michigan, Ann Arbor.
3. Braun, E.L. 1950. Deciduous forests of eastern North America. Hafner Publishing Co., Inc., New York, N.Y.
4. Rice, C.L. 1972. Geologic map of the Alcorn Quadrangle, east central Kentucky, GQ-963. U.S. Geological Survey, Washington, D.C.
5. Newton, J.H. 1973. Soil survey of Madison County, Kentucky. U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C.
6. Conner, G. 1980. Climate of Berea, Kentucky: Climatology of Kentucky Series. Kentucky Climate Center, Western Kentucky University, Bowling Green.
7. Little, E.L. 1979. Checklist of United States trees (native and naturalized). U.S. Department of Agriculture, Forest Service, Agric. Handb. No. 541:1-375.
8. Fowells, H.A. (Comp.). 1965. Silvics of forest trees of the United States. U.S. Department of Agriculture, Forest Service. Agric. Handb. No. 271:1-762.
9. Martin, W.H. 1975. The Lilley Cornett Woods: A stable mixed mesophytic forest in Kentucky. Bot. Gaz. 136:171-183.
10. Muller, R.N. 1982. Vegetation patterns in the mixed mesophytic forest of eastern Kentucky. Ecology 63:1901-1917.

11. Carpenter, S.B. 1976. Stand structure of a forest in the Cumberland Plateau of eastern Kentucky fifty years after logging and burning. Castanea 41:325-337.

12. Phillippi, M.A. and A. Boebinger. 1986. A vegetational analysis of three small watersheds in Robinson Forest, eastern Kentucky. Castanea 51:11-30.

13. Van Stockum, Jr., R.R. 1979. Hemlock-mixed mesophytic forest communities in southern Indiana, western Kentucky, and Highlands, North Carolina. Ph.D. Dissertation, University of Louisville.

14. Faller, A. 1975. The plant ecology of Mammoth Cave National Park, Kentucky. Ph.D. Dissertation, Indiana State University, Terre Haute.

15. Herman, T. and M. See. 1973. Secondary succession following fire in "Tight Holler," Kentucky. Castanea 38:275-285.

16. Cameron, M.R. and J.E. Winstead. 1978. Structure and compostion of a climax mixed mesophytic system in Laurel County, Kentucky. Trans. Ky. Acad. Sci. 39:1-11.

17. Held, M.E. and J.E. Winstead. 1975. Basal area and climax status in mesic forest systems. Ann. Bot. 39:1147-1148.

18. Fedders, J.M. 1980. The vegetation and its relationships with selected soil and site factors of the Spencer-Morton Preserve, Powell County, Kentucky. M.S. Thesis, Eastern Kentucky University, Richmond.

19. Godbey, D.A. 1984. The vascular flora of Maywoods Environmental and Educational Laboratory. Garrard and Rockcastle Counties, Kentucky. M.S. Thesis, Eastern Kentucky University, Richmond.

Fishes of the Tradewater River System, Kentucky

Lewis G. Miller and Michael R. Mills
Kentucky Natural Resources and Environmental Protection Cabinet
Division of Water, 18 Reilly Road, Frankfort, Kentucky 40601

Abstract

Although ecological integrity in portions of the Tradewater River system has been severely damaged, the ichthyofauna remains relatively diverse. Sixty two species are known from recent verifiable collections, with an additional 10 species of probable, though unsubstantiated status. Presence of *Hypentelium nigricans* is questionable and in need of substantiation. Six records are known or probable misidentifications. *Percina phoxocephala* is considered extirpated. Three species (*Lepisosteus oculatus, Erimyzon sucetta, Elassoma zonatum*) listed by the Kentucky Academy of Science and Kentucky Nature Preserves Commission as Threatened, of Undetermined Status, and of Special Concern are present in the Tradewater River system. The future integrity of the Tradewater River ichthyofauna is dependent upon: (1) the identification and protection of ecologically important habitat areas which serve as refugia and reinvasion epicenters; (2) protection of water-quality buffer areas; and (3) implementation of effective reclamation practices to maintain and improve stream-water quality.

Introduction

Non-point pollutants issuing from abandoned and active coal mines have greatly altered the ecological integrity of many streams in the Tradewater River system (1,2,3). A water-quality inventory of the Tradewater River system revealed that 499 stream km were affected by coal-mine drainage (3), with 393 km or 79% of the total affected stream km being impacted by acid-mine drainage (AMD). Generation of much of this AMD can be traced to the advent of large-scale surface mining which began in the 1930's. Habitat alteration, resulting from stream channelization projects, has also adversely affected ecological integrity in portions of the Tradewater River system. Such projects were initiated as early as 1916.

Knowledge of the Tradewater River ichthyofauna prior to the 1900's is limited to a single collection by Woolman (4). His collection from the mainstream near Dawson Springs revealed a diverse community which included several species now considered environmentally sensitive. Mainstream collections conducted in 1940 as part of an Ohio River pollution survey by the United States Public Health Service (5) included several riverine and lowland species.

In recent years, studies of the Tradewater River fishes have been directed toward the evaluation of sensitive habitats (2,6), water quality (7,8,9), and fishery potential (10,11,12,13,14). Burr (15), in a distributional checklist of Kentucky fishes, included the Tradewater River system with the lower Green River system. Burr et al. (16) assessed the distributional status of several cyprinids which range into the Tradewater River system.

The purpose of this paper is to bring together published and institutional collection records to provide a concise documentation of the Tradewater River ichthyofauna. Locality and habitat distributional information for each species are included. Comments regarding species of questionable status are also provided.

Description of Study Area

Located in western Kentucky between the Green and Cumberland rivers, the Tradewater River system drains 2,442 km^2 in portions of Christian, Caldwell, Hopkins, Webster, Crittenden, and Union counties. An area of 194 km^2 in the upper Cypress Creek watershed in Union County has been diverted through the Dennis O'Nan Ditch to discharge directly to the Ohio River (17). The Tradewater River heads in northwestern Christian County and flows northwestwardly 212 km to its confluence with the Ohio River near Sturgis, Kentucky. Major tributaries include: Sandlick Creek, Caney Creek, Flynn Fork, Donaldson Creek, Clear Creek, Craborchard Creek, Piney Creek, and Cypress Creek.

Lowland stream habitats (i.e. low-gradient streams, wetlands, ditches) predominate in interior and eastern portions of the watershed, while upland stream habitats (i.e. moderate- to high- gradient streams) are afforded only by mainstream and western tributary headwaters. For more details concerning habitat types and basin topography, consult Grubb and Ryder (1) and Warren and Cicerello (6).

Collection Sites

This compilation of the Tradewater ichthyofauna is based on a total of 106 collections at 86 sites (Fig. 1). Following is a listing of these collection sites. Acronyms and literature references accompanying site locations indicate origin of collection information.

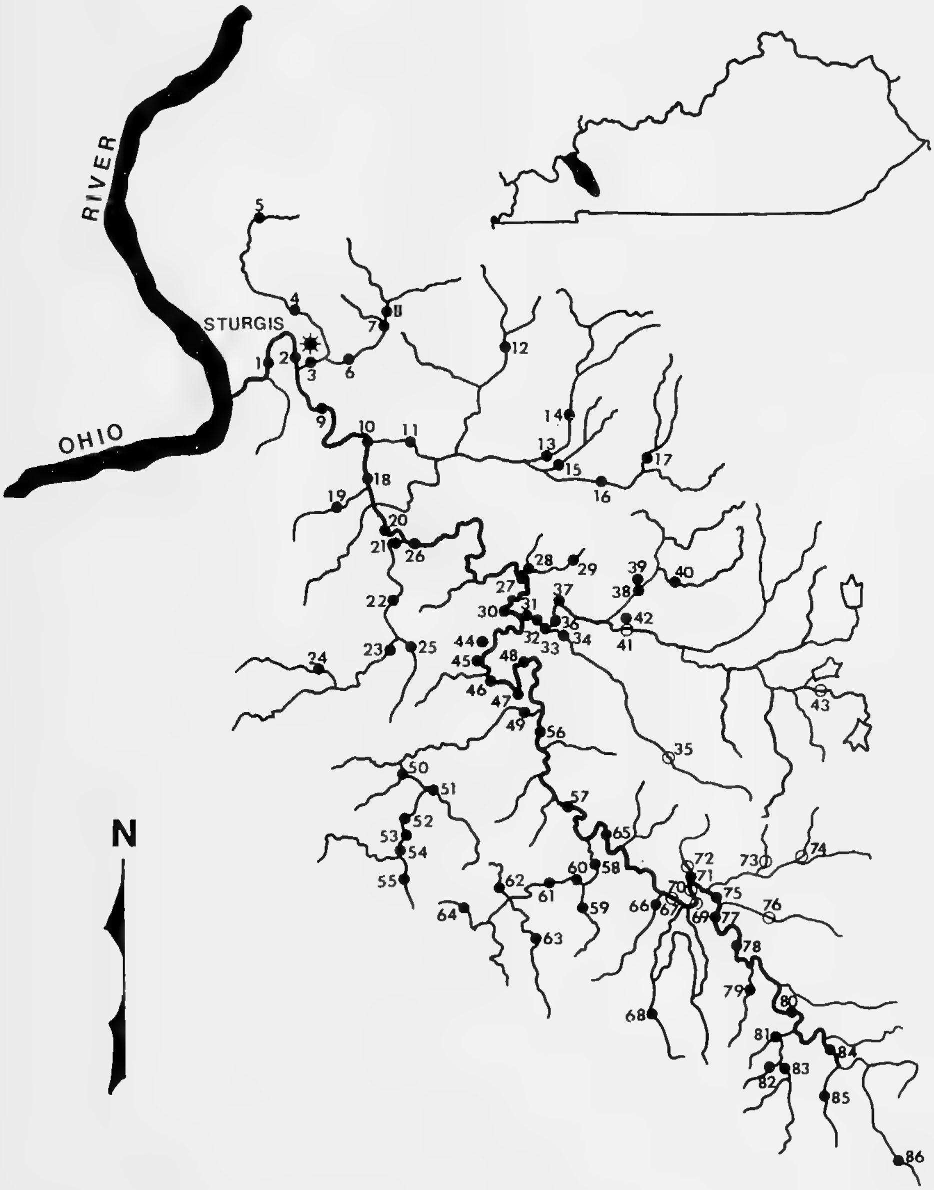


Figure 1. Map of Tradewater River drainage, Kentucky, showing locations of collection sites. Open circles indicate that no fish were collected at site—warmwater aquatic habitat use impaired by AMD.

1. Tradewater River, 4.5 km SW of Sturgis, Union and Crittenden cos., at end of Locust Lick Road. 15:XII:1981 (Kentucky Division of Water (DOW)).
2. Tradewater River, 2.1 km SW of Sturgis, Union and Crittenden cos., 180 m downstream of KY 365. 13:VIII:1981 (12).
3. Cypress Creek, 460 m upstream from confluence with Tradewater River, Union Co. 24:VIII:1981 (12).
4. Cypress Creek, 2.0 km N of Grangertown, Union Co., at Urton Gap Road. 25:VIII:1981 (12).
5. Cypress Creek, 0.8 km NE of Henshaw, Union Co., at KY 130. 25:VIII:1981 (Southern Illinois University at Carbondale (SIUC)).
6. Smith Ditch, 3.0 km SE of Sturgis, Union Co., at US60/641. 9:XII:1981 (DOW).
7. Smith Ditch, 3.1 km E of Sturgis, Union Co., at Ky 270. 8:X:1978 (SIUC).
8. Smith Ditch, 5.5 km NE of Sturgis, Union Co., at Bryon Smith Road. 8:X:1978 (SIUC), 25:VIII:1981 (12).
9. Tradewater River, 2.1 km SW of Sullivan, Union-Crittenden cos., at US60/641. 25:VIII:1981 (12), 16:XII:1981 (DOW).
10. Tradewater River, at mouth of Vaughn Ditch, Webster-Crittenden cos. 29:V:1985 (14).
11. Vaughn Ditch, 0.7 km NE of Derby, Webster Co., at KY 143. 9:XII:1981 (8).
12. Caney Fork, 2.5 km SE of Hearin, Webster Co., at KY 270. 3:XI:1979 (SIUC), 26:VIII:1981 (12).
13. Craborchard Creek, 3.7 km SE of Clay, Webster Co., at KY 270. 27:VI:1974 (11), 8:X:1978 (SIUC).
14. Craborchard Creek, 5.1 km E of Clay, Webster Co., at KY 1340. 9:XII:1981 (8).
15. Fredricks Ditch, 4.2 km SE of Clay, Webster Co., at KY 270. 27:VII:1974 (11).
16. Slover Creek, 2.9 km SW of Lisman, Webster Co., at Lisman-Providence Road. 9:XII:1981 (DOW).
17. Slover Creek, 1.0 km S of Jolly, Webster Co., at US 41A. 26:X:1979 (SIUC), 10:III:1980 (Kentucky Department of Transportation (DOT)).
18. Tradewater River, at Blackford, upstream of railroad trestle, Crittenden and Webster cos. 22:VIII:1974 (11).
19. Hoods Creek, at Nunn, Crittenden Co., at Manley Road. 26:IX:1979 (SIUC).
20. Tradewater River, 0.5 km downstream of Piney Creek confluence, Webster-Crittenden cos. 29:V:1985 (14).
21. Piney Creek, 1.4 km NW of Piney, Crittenden Co., at Cool Spring Hollow Road. 11:IX:1980 (2,6).
22. Piney Creek, at Deanwood, Crittenden Co., at KY 120. 24:X:1973 (Illinois Natural History Survey (INHS)).
23. Piney Creek, 3.4 km S of Deanwood, Crittenden Co., at Sugar Grove Church Road. 10:IV:1977 (INHS), 4:VIII:1982 (13).
24. Piney Creek, 3.0 km S of Tribune, Crittenden Co., at Copperas Spring Road. 10:IV:1977 (INHS).
25. Little Piney Creek, 2.1 km S of Deanwood, Crittenden Co., at Sugar Grove Church Road. 4:VIII:1982 (13).
26. Tradewater River, 0.3 km N of Piney, Crittenden and Webster cos., at Fishtrap Bridge on KY 132. 16:XII:1981 (DOW).
27. Tradewater River, 3.3 km SW of Providence, Crittenden and Webster cos., at Bellville Road. 8:XII:1981 (DOW).
28. Owens Creek, immediately upstream of confluence with Tradewater River, Webster Co. 8:XII:1981 (7).
29. Owens Creek, at Providence, Webster Co., at KY 293. 8:XII:1981 (7).
30. Tradewater River, 0.5 km downstream of Clear Creek confluence, Webster-Caldwell cos. 3:VI:1985 (14).
31. Clear Creek, 1.6 km downstream of KY 293 Bridge, Hopkins Co. 3:VI: 1985 (14).
32. Clear Creek, 0.2 km downstream of KY 293 Bridge, Hopkins Co. 31:V:1985 (14).
33. Clear Creek, 6.7 km SW of Providence, Hopkins Co., at KY 293. 26:VII:1973 (10).
34. Lick Creek, 0.4 km upstream of confluence with Clear Creek, Hopkins Co. 31:V:1985 (14).
35. Lick Creek, 1.8 km W of Beulah, Hopkins Co., at KY 70. 26:VII:1973 (10).
36. Clear Creek, 1.6 km upstream of KY 293 Bridge, Hopkins Co. 4:VI:1985 (14).
37. Clear Creek, 2.4 km upstream of KY 293 Bridge, Hopkins Co. 4:VI:1985 (14).
38. Weirs Creek wetland, 4.1 km SE of Providence, Hopkins Co., at KY 109. 2:X:1980 (SIUC).
39. Weirs Creek wetland, 1.3 km upstream of KY 109, Hopkins Co. 13:VIII:1980 (2,6).
40. Rose Creek wetland, 2.3 km SW of Nebo, Hopkins Co., at Schmetzer Crossing Road. 12 and 13:VIII:1980 (2,6).

41. Clear Creek, 5.8 km NW of Rabbit Ridge, Hopkins Co., at KY 109. 7:XII:1981 (DOW).
42. Clear Creek, slough parallel to KY 109, Hopkins Co. 14:VII:1980 (2,6).
43. Clear Creek, at Oriole, Hopkins Co., KY 70. 11:XII:1981 (DOW).
44. Land Branch, 1.3 km upstream of confluence with Tradewater River, 10.2 km NW of Fryer, Caldwell Co. 22:VIII:1980 (2,6).
45. Tradewater River, 2.4 km downstream of Towery Bridge, Caldwell and Hopkins cos. 30:V:1985 (14).
46. Tradewater River, 0.8 km downstream of Towery Bridge, 1.7 km SE of Shady Grove, Caldwell and Hopkins cos. 30:V:1985 (14).
47. Tradewater River, 1.6 km upstream of Towery Bridge, 2.7 km north of Fryer, Caldwell and Hopkins cos. 30:V:1985 (14).
48. Tradewater River, 5.8 km N of Fryer, Caldwell and Hopkins cos., at KY 293. 26:VI:1974 (11), 10:XII:1981 (DOW).
49. Donaldson Creek, 2.2 km N of Fryer, Caldwell Co., at KY 293. 26:VI:1974 (11), 10:XII:1981 (DOW).
50. Donaldson Creek, 2.7 km NE of Flat Rock, at KY 70, Caldwell Co. 16:V:1985 (14).
51. Caney Creek, 1.1 km W of Rufus, Caldwell Co., at KY 109. 29:VII:1954 (University of Louisville (UL)), 7:X:1978 (SIUC), 4:VIII:1982 (13).
52. Donaldson Creek, 1.4 km NW of Farmersville at Sons Bridge, Caldwell Co., Pleasant Grove Road. 4:VIII:1982 (13).
53. Donaldson Creek, 0.8 km W of Farmersville, at Flat Rock - Enon Road Bridge, Caldwell Co., 15:V:1985 (14).
54. Donaldson Creek, 2.3 km SW of Farmersville, Caldwell Co., below confluence of Black Creek. 14:VIII:1982 (DOW).
55. Kennedy Creek, 2.5 km S of Farmersville, Caldwell Co., at KY 139. 10:IV:1977 (INHS).
56. Tradewater River, 2.5 km NE of Fryer, Caldwell and Hopkins cos., at KY 70. 25:VI:1974 (11), 7:X:1978 (SIUC).
57. Tradewater River, at Olney, Caldwell and Hopkins cos., at Princeton-Olney Road. 24:VII:1973 (10), 12:VIII:1980 (2).
58. Flynn Fork, at Creekmur Bridge, 1.9 km upstream of confluence with Tradewater River, Caldwell Co. 25:VII:1973 (10), 8:VIII:1980 (2,6).
59. East Fork of Flynn Fork, 6.2 km W of Dawson Springs, Caldwell Co., at US 62. 29:VII:1954 (UL).
60. Flynn Fork, at former site of Morton Bridge, Mount Olivet Road, Caldwell Co. 25:VII:1973 (10).
61. Flynn Fork, 2.8 km N of Lewistown, Caldwell Co., at Lewistown Church Road. 5:VIII:1982 (13), 14:VIII:1982 (DOW).
62. Pratt Creek, 6.9 km NE of Princeton, Caldwell Co., at Princeton-Olney Road. 8:IX:1981 (12).
63. Ward Creek (also referred to as Lamb Creek), 3.7 km E of Princeton, Caldwell Co., at US 62. 29:VII:1954 (UL), 7:X:1978 (SIUC), 14:VIII:1982 (DOW).
64. Phelps Creek, 3.1 km NE of Princeton, Caldwell Co., at KY 293. 28:X:1979 (SIUC).
65. Tradewater River 5.8 km NW of Dawson Springs, Caldwell and Hopkins cos., at White School/Shell Poe Road. 20:VII:1973 (10), 7:VIII:1980 (2), 10:XII:1981 (9).
66. Montgomery Creek, 1.2 km SW of Dawson Springs, Caldwell Co., at KY 672. 26:X:1979 (SIUC), 7:VIII:1980 (2,6).
67. Tradewater River, approximately 0.6 km upstream of US 62, at old grist mill, 0.9 km SW of Dawson Springs, Caldwell and Hopkins cos. 19:VII:1973 (10). Near Woolman's 1892 collection site.
68. Piney Creek, 5.3 km NE of Friendship, Caldwell Co., at unimproved road off Haile Road. 14:VIII:1982 (DOW).
69. Tradewater River, 2.1 km SE of Dawson Springs, Caldwell and Hopkins cos., at KY 109. 19:VII:1973 (10).
70. Tradewater River, below confluence of Hurricane Creek, Hopkins Co. 19:VII:1973 (10).
71. Hurricane Creek swamp, small pond 0.5 km E of Pententiary Bend and SE of Dawson Springs, Hopkins Co. 15:VII:1980 (Kentucky Nature Preserves Commission (KNPC)).
72. Hurricane Creek, 2.3 km NE of Dawson Springs, Hopkins Co., at Maple Swamp Road. 19:VII:1973 (10).
73. Copperas Creek, 1.1 km S of Ilsley, Hopkins Co., at US 62. 19:VII:1973 (10).
74. Caney Creek, 0.2 km S of Hamby, Hopkins Co., at KY 1338. 19:VII:1973 (10).
75. Tradewater River, 61 m downstream of confluence with Buffalo Creek, Hopkins Co. 18:VII:1973 (10).
76. Buffalo Creek, 5.1 km SW on KY 1338 from junction with US 62, Hopkins Co. 19:VII:1973 (10).

77. Tradewater River, 4.3 km SE of Dawson Springs, Hopkins Co., at Murphy Ford. 18:VII:1973 (10).
78. Tradewater River, 6.7 km SE of Dawson Springs, Christian Co., at Hopkins Park Road. 7:XII:1981 (9).
79. McKnight Creek, 0.8 km E of Macedonia, Christian Co., at KY 109. 18:VII:1973 (10), 27:X:1979 (SIUC).
80. Tradewater River, at Pod, Christian Co., approximately 180 m upstream of KY 1348 (Pooles Mill Bridge). 17:VII:1973 (10).
81. Sandlick Creek, 5.5 km NW of Era, Christian Co., at KY 109. 17:VII:1973 (10), 7:X:1978 (SIUC).
82. Tugler Creek, 3.9 km NW of Era, Christian Co., upstream of confluence with Sandlick Creek. 27:X:1979 (SIUC).
83. Sandlick Creek, 3.9 km upstream of confluence with Tradewater River, 4.4 km NW of Era, Christian Co. 15:VII:1980 (2,6).
84. Tradewater River, 5.8 km NE of Era, Christian Co., at KY 800. 19:IV:1970 (Eastern Kentucky University (EKU)), 10:VII:1973 (10), 27:X:1979 (SIUC).
85. Brushy Fork, 2.3 km E of Era, Christian Co., at Pleasant Green Hill Road. 27:X:1979 (SIUC).
86. Tradewater River, 3.0 km NW of Kelly, Christian Co., at T. Sparkman Road. 7:X:1978 (SIUC).

Annotated List of Species

This compilation resulted in a list of 76 species, representing 42 genera in 18 families. Taxonomic arrangement, and scientific and common names, are those of Robins et al. (18). Following the scientific and common names for each species, a listing of collection site records is presented with notes on distribution. Use of statements concerning distributional status (i.e. generally distributed, occasional, or sporadic) follow the definitions of Smith (19). Voucher specimens are housed at the institutions or agencies which made collections with the following exceptions. Kentucky Nature Preserves Commission collections have been deposited into the SIUC collection. Specimens collected by the Kentucky Department Fish and Wildlife Resources are not extant.

Lepisosteidae—gars

1. *Lepisosteus oculatus* (Winchell). Spotted gar. Stations 31, 37, 39, 47. Sporadic in mainstream, occasional in lower Clear Creek system. A species of clear pools with vegetation (20), the drainage of suitable habitat has undoubtedly led to its reduction and current sporadic distribution.
2. *Lepisosteus osseus* (Linnaeus). Longnose gar. Reported by Woolman (4) to be very abundant. There are no recent records. Present in backwater areas of the Smithland Pool (21), it is of probable occurrence in the lower river.
3. *Lepisosteus platostomus* Rafinesque. Shortnose gar. Stations 3, 4, 6, 46. Sporadic in mainstream, occasional in Cypress Creek system. Woolman (4) reported this species as being less common than the longnose gar.

Amiidae—bowfins

4. *Amia calva* Linnaeus. Bowfin. Stations 1, 30-32, 34, 36, 37, 39, 45-47, 49, 50. Confined to the lowlands where it is occasional in mainstream pools, streams, and swamps.

Anguillidae—freshwater eels

5. *Anguilla rostrata* (Lesueur). American eel. Reported by Woolman (4) to be common. Although there are no recent records, this catadromous species possibly occurs infrequently in the river.

Clupeidae—herrings

6. *Alosa chrysochloris* (Rafinesque). Skipjack herring. Stations 48, 56. Sporadic in the mainstream, the only records are from the mid-reach of the river. These records are in need of substantiation. Probably ascends lowermost reaches of the river as it is common in the Ohio River (15).
7. *Dorosoma cepedianum* (Lesueur). Gizzard shad. Stations 10, 20, 30, 31, 39, 40, 44, 47-49, 56, 57, 66, 77. Generally distributed in lowland creeks, swamps, and mainstream pools.

Hiodontidae—mooneyes

8. *Hiodon alosoides* (Rafinesque). Goldeye. Station 30. Recently reported by Pearson (14), it occurs sporadically in the mainstream.

9. *Hiodon tergisus* (Lesueur). Mooneye. Station 9. The occurence of this species is based on a record by Axon (12). This record is in need of substantiation. The mooneye is occasional in most large and medium-size rivers throughout the state (15).

Esocidae—pikes

10. *Esox americanus vermiculatus* Lesueur. Grass pickerel. Stations 10, 13, 17, 19, 23, 30, 36, 38, 40, 42, 44, 45, 47, 51, 53, 54, 56, 60, 63, 65, 66, 75, 77, 81, 84. Generally distributed in creeks, swamps, and mainstream. Axon's (13) record of *E. niger* is probably a misidentification of this species.

Cyprinidae—carps and minnows

11. *Campostoma anomalum* (Rafinesque). Central stoneroller. Station 84. Woolman (4) reported the occurrence of this species as rare. There is only a single recent record from the system (Dr. Branley Branson, pers. comm.). An inhabitant of headwater streams, the stoneroller is common in the upper reaches of the physiographically similar Pond, Mud, and Rough river systems (2,6,22). Seasonal desiccation of upland headwater streams and general lack of suitable habitat areas in the Tradewater system have probably contributed to the present rareness of this otherwise widely distributed minnow.

12. *Cyprinus carpio* Linnaeus. Common carp. Stations 1-6, 8, 10, 12, 18, 20, 27, 31, 32, 36, 37, 39, 40, 45-47, 49, 51, 57, 77, 80. Generally distributed, most records are from lower reaches of the system.

13. *Ericymba buccata* Cope. Silverjaw minnow. Stations 12, 14, and 17. Sporadic in headwaters of Craborchard Creek system.

14. *Hybognathus nuchalis* Agassiz. Mississippi silvery minnow. Stations 11, 14, 21, 26. Sporadic, apparently rare in river, though occasional in Craborchard Creek system.

15. *Hybopsis amblops* (Rafinesque). Bigeye chub. Reported by Woolman (4) to be uncommon. Woolman's record is considered by Melvin Warren (pers. comm.) to be a misidentification, probably of *Hybopsis storeriana*. It has not been recently reported.

16. *Notemigonus crysoleucas* (Mitchell). Golden shiner. Stations 5, 14, 21-23, 25, 40, 42, 44, 48-52, 57-59, 62, 65, 66, 75, 77, 79, 81. Occasional in lowland streams and swamps which have not been channelized or impacted by AMD.

17. *Notropis atherinoides* Rafinesque. Emerald shiner. Stations 2, 6, 8, 13, 14, 18, 21, 49. Generally distributed in lower reach of system.

18. *Notropis chrysocephalus* (Rafinesque). Striped shiner. Stations 19, 22, 24, 25, 50, 54, 58, 60, 63, 64, 80, 81, 83, 84, 86. Generally distributed in western tributaries and upland reach of mainstream.

19. *Notropis emiliae* (Hay). Pugnose minnow. Stations 50, 53, 66, 80, 81. Sporadic, though locally abundant. A fish of clear, well-vegetated lakes and sloughs, the pugnose minnow was probably common in the Tradewater system prior to drainage of suitable habitat areas and/or water quality degradation. Smith (23) attributed decimation of this species in southern Illinois to excessive siltation in streams and drainage of lakes and swamps.

20. *Notropis fumeus* Evermann. Ribbon shiner. Stations 1, 9, 11, 22, 23, 25-28, 45, 49, 51, 53, 54, 56, 57, 61, 65, 66, 78, 81, 83, 84, 86. Generally distributed in mainstream and lower portions of tributaries.

21. *Notropis lutrensis* (Baird and Girard). Red shiner. Stations 1, 5-7, 11, 12, 14, 16, 49. Generally distributed in lower reaches of system in lowland streams and ditches.

22. *Notropis spilopterus* (Cope). Spotfin shiner. Station 5. Reported from a single site (SIUC) in upper Cypress Creek.

23. *Notropis umbratilus* (Girard). Redfin shiner. Stations 5, 12, 14, 16, 17, 22-25, 50, 53, 54, 57, 58, 63, 78, 83, 84. Generally distributed in western tributaries, upper mainstream, and headwaters of Cypress and Craborchard creek systems. Woolman (4) stated that this species was quite common.

24. *Notropis volucellus* (Cope). Mimic shiner. This is probably the species reported by Woolman (4)

as *N. deliciosus.* Trautman (24) listed *N. deliciosus* under the current names of *N. stramineus, N. volucellus volucellus,* and possibly of *N. volucellus wickliffi. Notropis stramineus* has not been reported from the lower Green River, while *N. volucellus wickliffi* is abundant in the Ohio and Wabash rivers and is known to ascend tributaries (23,25). Though probable in the lower mainstream, its presence is in need of substantiation.

25. *Phenacobius mirabilis* (Girard). Suckermouth minnow. Stations 11, 12, 14. Occasional in channelized portions of Craborchard creek system.
26. *Pimephales notatus* (Rafinesque). Bluntnose minnow. Stations 5-7, 11-17, 21, 22, 24, 25, 49, 50, 53-58, 60-63, 66, 77, 78, 81, 82, 84, 86. Generally distributed in western tributaries, upper reaches of mainstream, and headwaters of Cypress and Craborchard Creeks. Sporadic in lowland streams and lower reach of river.
27. *Pimephalis vigilax* (Baird and Girard). Bullhead minnow. Station 83. Woolman (4) reported this species as abundant. The only recent record is from Sandlick Creek (2,6).
28. *Semotilus atromaculatus* (Mitchill). Creek chub. Stations 5, 12, 14-17, 23, 24, 29, 53-55, 57, 58, 62, 66, 68, 79, 84. Occasional in headwaters of western tributaries.

Catostomidae—suckers

29. *Carpiodes carpio* (Rafinesque). River carpsucker. Station 1. Only recent collection from lowermost section of mainstream (DOW). Woolman (4) collected several specimens in the river near Dawson Springs.
30. *Carpiodes velifer* (Rafinesque). Highfin carpsucker. Station 10. Recently reported by Pearson (14), it occurs sporadically in mainstream.
31. *Catostomus commersoni* (Lacépède). White sucker. Stations 14, 25, 50, 58, 63, 66, 77, 79, 81, 83. Occasional in upper reach of system in mainstream and upland tributaries. An isolated record exists from headwaters of Craborchard Creek.
32. *Erimyzon oblongus* (Mitchill). Creek chubsucker. Stations 12, 14, 17, 22, 24, 25, 40, 44, 51, 53, 57-60, 63, 65, 66, 79, 81, 84, 86. Generally distributed in swamps, headwaters of lowland streams in Craborchard Creek system, mid-and upper reaches of mainstream, and western tributaries.
33. *Erimyzon sucetta* (Lacépède). Lake chubsucker. Stations 42, 44. Sporadic in wetland habitats (2, 6). An inhabitant of well-vegetated backwaters and sloughs (23), it was probably more widespread before drainage of favored habitats. Woolman's (4) record of this species was a misidentification of the spotted sucker *Minytrema melanops* (Dr. Brooks Burr, pers. comm.).
34. *Hypentelium nigricans* (Lesueur). Northern hog sucker. Woolman (4) reported this species as uncommon. It has not been reported recently from the Tradewater River system, nor has it been recently from the lower Green River system (25). In view of an absence of recent records, its presence is questionable and in need of substantiation.
35. *Ictiobus bubalus* (Rafinesque). Smallmouth buffalo. Stations 10, 18, 45, 46, 31. Occasional in mainstream, sporadic in lower Clear Creek system.
36. *Ictiobus cyprinellus* (Valenciennes). Bigmouth buffalo. Stations 20, 30-32, 34, 47. Occasional in mainstream and lower Clear Creek system.
37. *Minytrema melanops* (Rafinesque). Spotted sucker. Stations 1, 2, 13, 21, 48, 51, 56, 57, 66, 77, 79-81, 84. Generally distributed in mainstream. Sporadic in tributaries.
38. *Moxostoma duquesnei* (Lesueur). Black redhorse. Reported to be common by Woolman (4). Melvin Warren (pers. comm.) considers this record a misidentification. It has not been reported recently.
39. *Moxostoma erythrurum* (Rafinesque). Golden redhorse. Stations 1, 13, 25, 58, 77. Sporadic in system.

Ictaluridae—bullhead catfishes

40. *Ictalurus furcatus* (Lesueur). Blue catfish. Station 2. Only record of this large river species is from lowermost reach of mainstream (12). This record is in need of substantiation.
41. *Ictalurus melas* (Rafinesque). Black

bullhead. Stations 14, 27, 40, 44, 59, 66, 71, 79, 81. Occasional in swamps and streams.

42. *Ictalurus natalis* (Lesueur). Yellow bullhead. Stations 4, 5, 8, 12, 14, 17, 21, 27, 40, 42, 44, 48, 49, 57-60, 65, 66, 83. Occasional in lowland streams, swamps, mainstream, and lower portions of western tributaries.

43. *Ictalurus punctatus* (Rafinesque). Channel catfish. Stations 1-3, 9-11, 18, 20, 21, 31, 45. Generally distributed in lower reach of mainstream; occasional in lower reaches of Cypress, Craborchard, Piney and Clear creeks. This species supports a limited commercial fishery in the lower section of the river (Donan Jenkins pers. comm.).

44. *Noturus gyrinus* (Mitchill). Tadpole madtom. Stations 2, 3, 9, 14, 18, 21-23, 25, 27, 48, 49, 58, 60, 66, 77, 78, 84. Occasional in the mainstream and in lower reaches of tributaries.

45. *Noturus miurus* Jordan. Brindled madtom. Station 3. Rare; a single record reported from Cypress Creek near its mainstream confluence (12). This record is in need of substantiation.

46. *Pylodictis olivaris* (Rafinesque). Flathead catfish. Stations 2, 3, and 9. Occasional in lowermost portion of system in mainstream and mouth of Cypress Creek. These records are in need of substantiation.

Aphredoderidae—pirate perches

47. *Aphredoderus sayanus* (Gilliams). Pirate perch. Stations 4-6, 11, 15, 17, 18, 21, 22, 24, 25, 27, 28, 38-40, 42, 44, 48, 49, 52, 56-60, 63, 65, 66, 77-79, 83, 84. Generally distributed in mainstream, lowland and upland streams, and in relatively unimpacted portions of swamps in the Clear Creek system.

Cyprinodontidae—killfishes

48. *Fundulus notatus* (Rafinesque). Blackstripe topminnow. Station 5. Collected from one headwater site in the Cypress Creek system (SIUC).

49. *Fundulus olivaceous* (Storer). Blackspotted topminnow. Stations 5, 6, 8, 10-12, 14, 16, 17, 21-23, 25, 27, 31, 38-40, 42, 44, 45, 47-51, 53, 55-59, 61, 63, 65, 66, 68, 78, 79, 82-84, 86. One of the most widespread and common fishes in the system, occurring in a variety of habitats. Woolman (4) reported the occurrence of *Zygonectes notatus* as rare in the river. It is not certain whether this reference is to the blackspotted or blackstriped topminnow as, at the time of his collection, these species were synonymous (23).

Poecillidae—live bearers

50. *Gambusia affinis* (Baird and Girard). Mosquitofish. Stations 1, 5, 6, 8, 11, 13-15, 21, 26, 28, 39, 40, 44, 48, 49, 57, 58, 66. Occasional in the mainstream, lowland streams and ditches, and swamps.

Atherinidae—silversides

51. *Labidesthes sicculus* (Cope). Brook silverside. Station 3. Reported from a single site at the mouth of Cypress Creek. Woolman (4) reported its collection. Its presence is in need of substantiation.

Percichthyidae—temperate basses

52. *Morone chrysops* (Rafinesque). White bass. Station 1. Known from a single site in the lowermost reach of the mainstream; this species is probably seasonally abundant in spring during spawning runs.

Centrarchidae—sunfishes

53. *Centrarchus macropterus* (Lacépède). Flier. Stations 40, 42, 44-46, 48, 49, 58, 60, 66, 71, 77, 80. Occasional in swamps, lowland streams, and the mainstream. A species of clear, heavily vegetated waters (20), it was probably more widespread and abundant historically prior to drainage and channelization of lowland swamps and streams. AMD has eliminated this species from otherwise suitable habitat in the Clear and Cany creek systems in particular.

54. *Elassoma zonatum* Jordan. Banded pygmy sunfish. Station 40. Sporadic, the only reported record is that of Warren and Cicerello (6) from the Rose Creek Wetland. Like the flier, this species has experienced a reduction in suitable habitat.

55. *Lepomis cyanellus* Rafinesque. Green sunfish. Stations 1, 3-6, 8, 11, 12,

14-18, 24, 28, 40, 44, 48, 49, 51, 57, 58, 60, 62-66, 68, 77-79, 81, 84. Generally distributed, it is one of the most common fishes in the system.

56. *Lepomis gulosus* (Cuvier). Warmouth. Stations 1, 3, 15, 18, 21, 26, 28, 39, 40, 42, 44, 48, 49, 51, 56-60, 65, 66, 71, 75, 77, 79, 81-84, 86. Generally distributed in the mainstream, lower reaches of tributaries, and swamps.

57. *Lepomis humilis* (Girard). Orangespotted sunfish. Stations 14, 16, 50. Sporadic; the only collections have been taken in Craborchard and Donaldson creeks.

58. *Lepomis macrochirus* Rafinesque. Bluegill. Stations 1-4, 6, 8-12, 14, 15, 18, 20, 21, 28, 30, 31, 36-38, 40, 42, 44, 47-54, 56-61, 65, 66, 68, 75, 77-84, 86. Generally distributed. Woolman (4) reported both the occurence of *L. macrochirus* and, the now synonymized, *L. pallidus*.

59. *Lepomis megalotis* (Rafinesque). Longear sunfish. Stations 1-3, 5, 6, 8, 11-15, 17, 18, 21, 23, 25-27, 30, 31, 37, 45-51, 53, 56-58, 60, 61, 63, 65, 66, 77-79, 81, 84, 86. Generally distributed in the mainstream, and in the Cypress, Craborchard, and Flynn Fork systems in particular. Common to abundant at most reported sites.

60. *Lepomis microlophus* (Günther). Redear sunfish. Stations 5, 44, 49, 51, 53, 56. Sporadic; present in lowland streams, mainstream, and Land Branch swamp. Pflieger (20) stated that it inhabits waters which are warm and clear, with no noticeable current and an abundance of aquatic plants.

61. *Micropterus punctulatus* (Rafinesque). Spotted bass. Stations 9, 18, 21, 63. Sporadic in lower mainstream and in lower tributaries near their confluences. A single record from upper Flynn Fork system. Woolman's (4) record of *Micropterus dolomieui* from the Tradewater River is probably either a misidentification of *M. punctulatus* or *M. salmoides*. Hubbs (26) stated that the spotted bass was not generally recognized by fishery workers as a distinct species before 1927. The smallmouth bass has not been reported recently from the Tradewater River, nor has it been taken from the lower Green River system (25).

62. *Micropterus salmoides* (Lacépède). Largemouth bass. Stations 1, 2, 13, 18, 21, 23, 25, 31, 36-40, 42, 44, 46-49, 51, 56-59, 65, 66, 77, 79-81, 83, 84, 86. Generally distributed in the mainstream and in swamps. Occasional in streams.

63. *Pomoxis annularis* Rafinesque. White crappie. Stations 1, 3, 14, 18, 21, 30, 39, 48-52, 66, 83. Occasional in the lower mainstream, and in swamps. Sporadic in streams. Reported by Woolman (4) as common. The white crappie supports a locally important sport fishery in the lower Tradewater River (William McLemore, pers. comm.).

64. *Pomoxis nigromaculatus* (Lesueur). Black crappie. Stations 1, 21, 26-28, 31, 37, 39, 40, 42, 44, 48, 49, 58. Occasional; most reported collections are from middle reach of system.

Percidae—perches

65. *Etheostoma asprigene* (Forbes). Mud darter. Stations 1, 3, 21, 26, 27, 48, 49, 58. Occasional in lower- and mid-reach of mainstream and near mouths of tributaries.

66. *Etheostoma chlorosomum* (Hay). Bluntnose darter. Stations 21, 39, 40, 48, 49, 56, 66, 81-83. Occasional; it has been collected in the mainstream, swamps, and streams.

67. *Etheostoma gracile* (Girard). Slough darter. Stations 11, 17, 21, 22, 26, 39, 40, 42, 48, 49, 51, 56, 58, 59, 63, 66. Occasional in the mainstream, lowland streams, and swamps. Woolman's (4) reported collection of *E. fusiforme* has been regarded as a misidentification of this species (27).

68. *Etheostoma kennicotti* (Putnam). Stripetail darter. Stations 19, 22-25, 39, 40, 42, 48, 49, 55, 58, 63, 64, 66, 78, 79, 81, 82, 84-86. Generally distributed in western tributaries and upper mainstream. Page and Smith (28) stated that abundance of the stripetail darter in southeastern Illinois was related to lack of direct competition with other species of the subgenus *Catonotus*. The only other member of this subgenus in the system is the distantly related spottail darter, *E. squamiceps*. Records of *E. flabellare* by McLemore (10) are

probable misidentifications of the stripetail darter.

69. *Etheostoma nigrum*. Rafinesque. Johnny darter. Stations 23-25, 49, 54, 58, 60, 64, 81-84, 86. Generally distributed in western tributaries and upper mainstream. Woolman (4) reported this species as common.

70. *Etheostoma squamiceps*. Jordan. Spottail darter. Stations 23-25, 49, 54, 55, 58, 63, 64, 68, 81, 84. Generally distributed in headwaters of western tributaries.

71. *Percina maculata* (Girard). Blackside darter. Stations 9, 11, 17, 22, 25, 48, 49, 52, 57, 58, 60, 63, 66, 79, 84, 86. Occasional in the mainstream and in lowland and upland streams.

72. *Percina phoxocephala* (Nelson). Slenderhead darter. Woolman (4) (as *Etheostoma phoxocephalum*) described its occurence as rare. It has not been taken recently and is considered extirpated.

73. *Percina sciera* (Swain). Dusky darter. Stations 9, 56, 57, 84. Sporadic in mainstream.

74. *Stizostedion canadense* (Smith). Sauger. Several specimens of this riverine species were taken in the lowermost reach of the mainstream by students of Dr. James Sickel (pers. comm.). Although this was the first reported collection from the system, it is probably occasional upstream of the river's confluence with the Ohio. This record is in need of substanstantiation.

Sciaenidae—drums

75. *Aplodinotus grunniens* Rafinesque. Freshwater drum. Stations 1-3, 9, 18, 21, 30, 31, 36, 46, 47, 49. Generally distributed in lower mainstream and mouths of lower tributaries. Isolated record from mouth of Donaldson Creek.

Cottidae—sculpins

76. *Cottus carolinae* (Gill). Banded sculpin. Stations 53-55. Sporadic in headwaters of western tributaries. The only records are from the upper Donaldson Creek system.

Discussion

Although the ecological integrity in portions of the Tradewater River system has been severely damaged, much of the ichthyofauna remains. Of the 76 species listed, 62 species are known from recent verifiable collections. An additional ten species (*Lepisosteus osseus, Anguilla rostrata, Alosa chrysochloris, Hiodon tergisus, Notropis volucellus, Ictalurus furcatus, Noturus miurus, Pylodictis olivaris, Labidesthes sicculus, Stizostedion canadense*) are of probable, though unsubstantiated status. Six records are probable misidentifications (*Esox niger, Hybopsis amblops, Moxostoma duquesnei, Micropterus dolomieui, Etheostoma fusiforme, E. flabellare*). Presence of *Hypentelium nigricans* is questionable and in need of substantiation. *Percina phoxocephala*, not represented in recent collections, is considered extirpated. The Tradewater River system presently supports three species (*Lepisosteus oculatus, Erimyzon sucetta, Elassoma zonatum*) listed by the Kentucky Academy of Science and Kentucky Nature Preserves Commission (29) as threatened, of undetermined status, and of special concern, respectively.

Ichthyofaunal communities of Clear Creek, Lick Creek, Cany Creek, Buffalo Creek, Hurricane Creek, and the Tradewater River mainstream in the vicinity of Dawson Springs, Kentucky, are severely degraded or eliminated by AMD (2,9,10,14) (Figure 1).

The future integrity of the Tradewater River ichthyofauna is dependent upon: (1) the identification and protection of ecologically important habitat areas which serve as refugia and reinvasion epicenters, (2) protection of water quality buffer areas, and (3) implementation of effective reclamation practices to improve water quality conditions in streams presently impacted by AMD.

Ecologically important habitat areas in the Tradewater River system have been identified by the KNPC (30). Land Branch Wetland, Flynn Fork, Montgomery Creek, Piney Creek, Sandlick Creek, and Rose Creek Wetland are recommended for immediate or potential designation as Outstanding Resource Waters. These systems support ichthyofaunas that are characteristic of relatively undisturbed aquatic habitats in the Western Kentucky Coalfield.

Acknowledgements

Several persons were particularily helpful in sharing collection records: Dr. Brooks M. Burr, SIUC; Dr. William D. Pearson, UL; Dr. Branley A. Branson, EKU; Dr. James B. Sickel, Murray State University; Melvin L. Warren, Jr., SIUC; and William N. McLemore, Kentucky Department of Fish and Wildlife Resources. Appreciation is further extended to Dr. Burr, Dr. Pearson, Melvin Warren, Ronald R. Cicerello and William L. Fisher (KNPC), and Terry Anderson (DOW) for their review of the manuscript. Field assistance was provided by Melvin Wyatt of Earlington, Kentucky, during supplemental collections. Ms. Billie Miller kindly typed the manuscript. Ms. Elisabeth Portis prepared the map of the Tradewater River drainage and collection sites.

The senior author would like to acknowledge the late Dr. Morgan E. Sisk, whose interest in the study of fishes and advice greatly contributed to the author's development in the field of aquatic biology.

LITERATURE CITED

1. Grubb, H.F. and P.D. Ryder. 1972. Effects of coal mining on the water resources of the Tradewater River basin, Kentucky. Geol. Sur. Water - Supply Pap. 1940.
2. Harker, D.F., Jr.,M.L. Warren, Jr., K.E. Camburn and R.R. Cicerello. 1981. Aquatic biota and water quality survey of the Western Kentucky Coal Field. Ky. Nat. Pres. Comm. Tech. Rept., Frankfort.
3. Kentucky Natural Resources and Environmental Protection Cabinet, Department of Environmental Protection, Division of Water. 1981. The effects of coal mining activities on the water quality of streams in the Western and Eastern Coalfields of Kentucky. Ky. Nat. Res. Environ. Protect. Cab. Tech. Rept., Frankfort.
4. 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.
5. United States Public Health Service. 1942. Ohio River Pollution Survey. Final Rept. to the Ohio River Comm. Suppl. F-Biological Studies. Cincinnati.
6. Warren, M.L., Jr. and R.R. Cicerello. 1982. New records, distribution, and status of ten rare fishes in the Tradewater and lower Green rivers, Kentucky. Proc. Southeast. Fishes Council 3:1-7.
7. Kentucky Natural Resources and Environmental Protection Cabinet, Department of Environmental Protection, Division of Environmental Services. 1983. Owens Creek drainage biological and water quality investigation for stream use designation. Ky. Nat. Res. Envirn. Protect. Cab., Preliminary Draft, Tech Rept. No. 5, Frankfort.
8. Kentucky Natural Resources and Environmental Protection Cabinet, Department of Environmental Protection, Division of Environmental Services. 1984(a). Craborchard Creek - Vaughn Ditch drainage biological and water quality investigation for stream use designation. Ky. Nat. Res. Environ. Protect. Cab., Tech. Rept. No.4, Frankfort.
9. Kentucky Natural Resources and Environmental Protection Cabinet, Department of Environmental Protection, Division of Environmental Services. 1984(b). Tradewater River (segments 10012 and 10014) drainage biological and water quality investigation for stream use designation. Ky. Nat. Res. Environ. Protect. Cab., Tech Rept. No. 6, Frankfort.
10. McLemore, W.N. 1974. Annual performance report. Proj. No. F-41-1. Ky. Dept. Fish Wildl. Resour., Frankfort.
11. McLemore, W.N. 1975. Annual performance report. Proj. No. F-41-2. Ky. Dept. Fish Wildl. Resour., Frankfort.
12. Axon, J.R. 1982. Annual performance report for statewide fisheries management project, Part III of IV, Subsection III: Streams research and management. Proj. No. F-20, Seg. 4. Ky. Dept. Fish Wildl. Resour., Fish. Div., Frankfort.
13. Axon, J.R. 1983. Annual performance report for statewide fisheries management project, Part III of IV, Subsection III: Streams research and management. Proj. NO. F-20, Seg. 4. Ky. Dept. Fish Widl. Resour., Fish. Div., Frankfort.
14. Pearson, W.D. No Date. Fish population survey of the Tradewater River and tributaries. Contract No. DACW27-85-R-0037. Tech. Rept. U.S. Army Corps of Engineers, Louisville.
15. Burr, B.M. 1980. A distributional checklist of the fishes of Kentucky. Brimleyana 3:53-84.
16. Burr, B.M., M.E. Retzer and R.L. Mayden. 1980. A reassessment of the distributional status of five Kentucky cyprinids. Trans. Ky. Acad. Sci. 41:48-54.
17. Bower, D.E. and W.H. Jackson. 1981. Drainage areas of streams at selected locations in Kentucky. Open File Report 81-61. U.S. Dept. Interior, Geol. Sur., Louisville.
18. Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea and W.B. Scott. 1980. A list of common and scien-

tific names of fishes from the United States and Canada. 4th ed. Am.Fish. Soc. Spec. Publ. No. 12. 174 p.

19. Smith, P.W. 1965. A preliminary annotated list of the lampreys and fishes of Illinois. Ill. Nat. Hist. Sur. Biol. Note No. 54. 12 p.

20. Pfleiger, W.L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City.

21. Axon, J.R. 1983. Annual performance report for statewide fisheries management project, Part III of III, Subsection III: Ohio River sport fishery investigation. Proj. No. F-40, Seg. 5. Ky. Dept. Fish Wildl. Resour., Fish. Div., Frankfort.

22. Laflin, B.D. 1980. Inventory and classification of streams in the Rough and Nolin River drainages. Ky. Dept. Fish Wildl. Resour. Fish. Bull. No. 65.

23. Smith, P.W. 1979. The fishes of Illinois. University of Illinois Press, Urbana.

24. Trautman, M.B. 1981. The Fishes of Ohio. The Ohio State University Press, Columbus.

25. Retzer, M.E., B.M. Burr and M.L. Warren, Jr. 1983. Fishes of the Lower Green River Drainage, Kentucky. Ky. Nat. Pres. Comm., Scientific and Technical Sers., No. 3. 1-48.

26. Hubbs, C.L. 1927. *Micropterus pseudaplites*, a new species of black bass. Oce. Pap. Mus. Zool. Univ. Mich. No. 184:1-15.

27. Hubbs, C.L. and M.D. Cannon. 1935. The darters of the genera *Hololepis* and *Villosa*. Misc. Publ. Mus. Zool. Univ. Mich. No. 30. 1:93. 93p.

28. Page, L.M. and P.W. Smith. 1976. Variation and systematics of the stripetail darter, *Etheostoma kennicotti*. Copeia 1976:532-541.

29. Branson, B.A., D.F. Harker, Jr., J.M. Baskin, M.E. Medley, D.L. Batch, M.L. Warren, Jr., W.H. Davis, W.C. Houtcooper, B. Monroe, Jr., L.R. Phillippe and P. Cupp. 1981. Endangered, threatened, and rare animals and plants of Kentucky. Trans. Ky. Acad. Sci. 42:77-89.

30. Hannan, R.R. and M.L. Warren, Jr., K.E. Camburn, R.R. Cicerello. 1982. Recommendations for Kentucky's outstanding resource water classifications with water quality criteria for protection. Ky. Nat. Pres. Tech. Rept., Frankfort.

A Causative Agent of Reddening in Lettuce

Robert W. Wall and L.P. Elliott
Department of Biology
Western Kentucky University
Bowling Green, Kentucky 42101

Abstract

Koch's postulates were used in attempts to determine the causative agent of the reddening of lettuce. The results indicate that the predominant causative agents are pseudomanads, particularly *Pseudomonas fluorescens.*

Introduction

Lettuce *(Lactuca sativa L.)* is high in water content, low in firm tissue, has a high respiratory rate, and is easily bruised, broken, or crushed during harvesting and packing. Intact surfaces prevent rapid microbial decomposition after harvest, but bacteria proliferate when the plant has suffered mechanical breakage such as a severed stalk. Several diseases occur in the field (14) and marketing process. When head lettuce is cooled by water spray in the retail store, a reddish brown color often appears, particularly on the tip. This type of spoilage also develops during storage of lettuce in the home refrigerator. Frazier (5) noted that investigators disagree as to the cause of this spoilage, and Frazier and Westhoff (6) simply called this lettuce disorder a bacterial soft rot. Palmore (12) suggested that fluorescing pseudomanads were a cause of this disorder. He found that wrapping the lettuce in 100 gauge Saran Wrap and holding it at 9° C proved to be the best preservation procedure for the maintaining of lettuce that is free of the red discoloration under commercial conditions.

This work was initiated to further substantiate the fact that pseudomonads are involved in the reddening of lettuce. The protocol for establishing the causative agent of a bacterial disease was outlined following Koch's postulates (13). Significant numbers of a specific bacterium were continually observed to be associated with the disease in question. The suspected bacterium was isolated, grown in pure culture, and inoculated into a susceptible host. The susceptible host, sterile (bacteria-free) lettuce, was expected to display the symptoms of the disease and the organism re-isolated and identified.

Materials and Methods

Sterilization of the lettuce—Before sterilization was attempted, reddened areas of the store purchased lettuce were excised. Through experimentation with procedures found in the literature, it was found that immersing the lettuce in clorox diluted 1:4 with distilled water and agitating the lettuce for 10 min was ample for sterilization (8,9). The lettuce was rinsed in two sterile distilled water baths for 2 min, each, then placed into a sterile holding container. One cm^2 portions of the butt, stalk, and leaf of each head was excised, ground in saline in a sterile mortar and plated on nutrient agar (Difco) which was incubated at 30° C for 48 h.

Bacterial Specimens Utilized—The bacteria utilized were 5 cultures isolated by Palmore (12) (designated isolate 2,3,15,16, and 23 in Table 1) as the major flora found in the reddened portions of market lettuce. These 5 cultures were identified and confirmed by using the API 20E (Analytab Products, Plainview, NY), oxidase test (Marion Scientific, Kansas City, MO), motility test (hanging-drop preparation),and flagella staining (16).

A standard inoculum (4.0×10^7 CFU/ml) from each culture was injected into the butt, stalk, and leaf of three heads of sterile lettuce. The 15 inoculated and control heads of lettuce were held in containers at refrigeration temperature (5° C) and observed for discoloration and sample-plated for bacteria (as previously described) at 3-day intervals during a 12-day period. Indentification of the predominant flora on the inoculated lettuce was achieved by use of the API 20E system.

Controls—Three types of control lettuce were used: heads sterilized and not inoculated, heads into which a sterile hypodermic needle was inserted at sites similar to those where the experimental heads were inoculated, and heads into which sterile nutrient broth (Difco) was injected at sites similar to those where the experimental heads were inoculated.

Table 1. Reidentification of the Flora Found After Inoculation with Palmore's Isolates Utilizing the API-20E System.*

Isolate from Sterile Lettuce Inoculated with Bacteria Number	API-20E Profile	API-20E Identification
2	0002004-01**	*Flavobacterium odoratum*
3	0102004-51	*Pseudomonas putrefaciens*
15	2002004-03	*Pseudomonas fluorescens*
16	2000004-43	*Psedomonas fluorescent group*
23	2002004-43	*Pseudomonas fluorescens*

* These are the same profile numbers that were obtained before the isolates were inoculated into the lettuce.

** Also closely related to *Moraxella* spp., other *Pseudomonas* spp., CDC Group IIF and *Alcaligenes* spp.

Results and Discussion

Inoculation of the lettuce with Palmore's (12) isolates resulted in the reddening of the lettuce over the 12-day period. By day 6, isolate 3, 15, 16, and 23 (Table 1) caused the lettuce to redden. Isolate number 2 did not cause any reddening until day 9. When these heads of lettuce were sampled the bacteria isolated were identified as the bacteria initially inoculated as illustrated in Table 1.

None of the control lettuce reddened or yielded bacteria upon testing, indicating that the sterilization procedure was effective. The data indicate that bacteria, particularly *Pseudomonas fluorescens*, cause the lettuce to redden. The motile pseudomonads could easily gain entrance into the lettuce plant from the surrounding soil. The sampling for surface pseudomonads might be negative as the pseudomonads could find their way up into the plant through the root system. This study emphasized the need to grind the lettuce and to assay for other than surface pseudomonads.

That *P. fluorescens* acting alone is the only cause of reddening of lettuce is questionable. Perhaps ethylene produced by plant tissues is involved in this defect. Williamson (18) studied ethylene production by diseased and healthy tissues of 12 species of plants. The evolution of ethylene was apparently in response to injury and occurred only as long as the infected tissue was alive. Injury by certain pathogenic fungi was sufficient to induce ethylene production. *Penicillium digitatum* was found to produce ethylene while growing on potatoe-dextrose agar. The genus *Pseudomonas*, as described in Bergey's Manual (10), is also quite complex, with phenotypic similarities to many other genera. Differentiation is made on the basis of rRNA/DNA homology studies which are beyond the reach of many laboratories. Thus, since the pseudomonads are ubiquitous and have metabolic versatility, species other than *P. flourescens* are likely to be isolated from lettuce. Some of the pseudomonads that have been isolated from lettuce in the past have only been partially characterized and some have been reclassified. For example, *P. marginalis*, described by Ceponis and Friedman (3) and Billing (2), causes soft rot of lettuce is now assigned to *P. fluorescens* biovar II.

The reddening of lettuce might be associated with the pigmentation of *Pseudomonas*. Palmore (12) found that his isolates 3, 16, and 23 formed a red pigment on egg-yolk agar. Austin and Goodfellow (1) isolated a gram-negative, nonphototrophic, non-nitrogen-fixing, pink bacterium from the leaf surfaces of *Lolium perenne* (perennial rye grass) and classified it as a new species, *P. mesophilica*. Smith and Park (15) noticed that *P. putida* ATCC 31752 and *Pseudomonas* sp. ATCC 31753 formed a red pigment in a fermenter under controlled conditions when certain bile acids were used as a sole carbon source. In our study, browning and reddening were noted in the test lettuce. The red and brown were two distinct colors. The red color was Plate 1 (E-3) and the brown was Plate 6 (K-11) as categorized in the "Dictionary of Color" (11).

Natural sources, such as fresh marketed lettuce (120 samples) and fennel (89 samples) were found by Ercolani (4) in Italy to be contaminated with bacteria indicating fecal contamination. In addition, 68.3% of the lettuce and 71.9% of the fennel samples yielded 6 different serotypes of *Salmonella*. Kominoes et al. (9) found high counts of *P. aeruginosa* in raw vegetables such as tomatoes, radishes, celery, carrots, endive, cabbage, cucumbers, onions and lettuce in hospital kitchens and suggested that these foods could act as primary vehicles for introducing the organisms to patients. This study prompted Green et al. (7) to determine whether agricultural soils act as natural reservoirs of *P. aeruginosa* and to determine whether food plants are commonly colonized by *P. aeruginosa* from soil in the field. Their results suggested that soil is a reservoir for *P. aeruginosa* and that this bacterium can colonize plants during favorable conditions of temperature and moisture. Wright et al. (19) studying the flora of foods served to patients in a hospital found *Klebsiella*, *Enterobacter*, *Serratia* and *P. aeruginosa* in salads which may serve as a reservoir for the above bacteria to colonize and infect susceptible patients. *Pseudomonas* strains may be the cause of nosocomial infections, particularly in the compromised host where their normal host defenses are depressed (neoplasias, burns, cystic fibrosis, etc.).

Certainly pseudomonads are associated with lettuce and further investigations are needed to completely elucidate the factors involved in reddening which could be the result of bacterial pigment, enzymes, or enzymes (3) plus some other metabolic product (s) (17).

Literature Cited

1. Austin, B., and M. Goodfellow. 1979. *Pseudomonas mesophilica*, a new species of pink bacteria isolated from leaf surfaces. Int. J. Syst. Bacteriol. 29:373-378.
2. Billing, E. 1970. Further studies on the phage sensitivity and the determination of phytopathogenic *Pseudomonas* spp. J. Appl. Bact. 33:478-491.
3. Ceponis, M.J., and B.A. Friedman. 1959. Pectolytic enzymes of *Pseudomonas marginalis* and their effects on lettuce. Phytopathology 49:141-144.
4. Ercolani, G.L. 1976. Bacteriological quality assessment of fresh marketed lettuce and fennel. Appl. Environ. Microbiol. 31:847-852.
5. Frazier, W.C. 1967. Food Microbiology, 2nd ed., McGraw-Hill Book Company, Inc., New York.
6. Frazier, W.C., D.C. Westhoff. 1978. Food Microbiology, 3rd ed. McGraw-Hill Book Company, Inc., New York.
7. Green, S.K., M.N. Schroth, J.J. Cho, S.D. Kominos, and V.B. Vitanza-Jack. Agricultural plants and soil as a reservoir for *Pseudomonas aeruginosa*. Appl. Microbiol. 28:987-991.
8. Hesseltine, C.W., O.L. Shotwill, W.F. Kwolek, E.B. Lillehoj, W.K. Jackson, and R.J. Bothost. 1976. Aflatoxin occurence in 1973 corn at harvest. II. Mycological studies. Mycologia. 68:341-353.
9. Kominos, S.D., C.E. Copeland, B. Grosiak, and B. Postic. 1972. Introduction of *Pseudomonas aeruginosa* into a hospital via vegetables. Appl. Microbiol. 24:567-570.
10. Krieg, N.R. (ed.) 1984. Bergey's Manual of Systematic Bacteriology. Vol. I, Williams and Wilkins. Baltimore.
11. Maerz, A., and M.R. Paul. 1950. Dictionary of Color. McGraw-Hill Book Company, Inc., New York. pp. 25, 35.
12. Palmore, W.E. 1971. Cause and control of a common market disease of lettuce. Unpublished Masters Thesis, Western Kentucky University, Bowling Green, Kentucky, USA. 56 p.
13. Penn, M., and M. Dworkin. 1976. Robert Koch and two visions of microbiology. Bacteriol. Rev. 40:276-283.
14. Pieczarka and J.W. Lorbeer. 1975. Microorganisms associated with bottom rot of lettuce grown on organic soil in New York State. Phytopathology. 65:16-21.
15. Smith, M.G., and R.J. Park. 1984. Effect of restricted aeration on catabolism of cholic acid by two *Pseudomonas* species. Appl. Environ. Microbiol. 48:108-113.
16. Smith, P.B., K.M. Tomfohrde, D.L. Rhodin, and A.Balows. 1972. API system: a multitubemicromethod for identification of Enterobacteriaceae. Appl. Microbiol. 24:449-452.
17. Starr, M. 1959. Bacteria as plant pathogens. Ann. Rev. Microbiol. 13:211-238.
18. Williamson, C.E. 1950. Ethylene, a metabolic product of diseased or injured plants. Phytopathology. 40:205-208.
19. Wright, C.S. S.D. Kominos, and R.B. Yee. 1976. Enterobacteriaceae and *Pseudomonas aeruginosa* recovered from vegetable salads. Appl. Environ. Microbiol. 31:453-454.

New Records of the Redside Dace, *Clinostomus elongatus* (Kirtland) in Kentucky, With Comments About Its Habitat Requirements

Les Meade and David L. McNeely
Department of Biological and Environmental Sciences
Morehead State University
Morehead, Kentucky 40351

Lew Kornman and Al Surmont
Northeastern Fishery District
Kentucky Department of Fish and Wildlife Resources
Morehead, Kentucky 40351

Abstract

The present distribution of *Clinostomus elongatus* in Kentucky is based on specimens from Lick Fork in Rowan County and Edward Branch in Menifee County. Recent research indicates that substantial populations occur in headwater tributaries of North Fork of Licking River, Beaver Creek and Red River. In fact, *C. elongatus* was the dominant species in Slabcamp Creek, Devils Fork and Upper Lick Fork. Streams located in remote, unpolluted hollows may act as refuges for this species in Kentucky.

Clinostomus elongatus was found in pools with gravel and sandy substrates; here this minnow was common in cool and clear water, of near neutral pH, in forested watersheds with canopy over the streams.

Introduction

Clinostomus elongatus is sporadically distributed in the northeastern United States and southern Canada. It has a discontinuous range with several widely disjunct populations from New York to southern Ontario, southeastern Michigan, Wisconsin and southeastern Minnesota. It reaches southward in the Appalachian Mountains to northeastern Kentucky (1,2). *Clinostomus elongatus* is threatened by habitat alteration and pollution in much of its range (2,3).

The present distribution of *C. elongatus* in Kentucky is based on specimens from 2 localities. This species has been considered to be rare, and possibly extirpated in Kentucky (4,5). Clark (6) reported *C. elongatus* from Lick Fork, a tributary of North Fork of Licking River in Rowan County. Kuehne (7) reported a single specimen from Edward Branch, a tributary of Red River in Menifee County. The purpose of this study was to determine the distribution of *C. elongatus* in Kentucky and to provide preliminary comments about its habitat requirements.

Materials and Methods

Fishes were collected from tributaries of North Fork of Licking River, Beaver Creek, and Red River (Fig.1) by using standard seining and electroshocking techniques. Specimens were fixed in 10% formalin and stored in 10% formalin or 70% ethanol. Voucher specimens were deposited in fish collections at Morehead State University, Morehead, Kentucky and at Southern Illinois University at Carbondale. Thirty five collecting sites were examined from May 1984-April 1986. The selection of collecting sites was primarily based on accessibility by roads and/or trails. The number of specimens collected was recorded for each species so that a rough estimate of species abundance could be determined. Collecting sites 1-18 were located in the Licking River Drainage; sites 19-35 were in the Red River Drainage. Collecting sites examined were as follows:

1. Lick Fork, ca. 2.4 km N of Ky. 801, Rowan Co. July, 1985.
2. Wallace Branch of Upper Lick Fork, Rowan Co. 5 July, 1985.
3. Upper Lick Fork at mouth of Wallace Branch, Rowan Co. 5 July, 1985.
4. Upper Lick Fork at mouth of Laurel Hollow, Rowan Co. 11 April, 1986.
5. Slabcamp Creek, between Deer Lick Hollow and Stonecoal Branch, Rowan Co. 5 July, 1985.
6. Devils Fork, SE. of Blairs Mills, Elliott-Morgan Co. line. 16 July, 1985.
7. North Fork of Licking River 0.80 km S of

Wrigley along Ky. 711, Morgan Co. 25 July, 1985.

8. Minor Creek, 0.40 km N of confluence with Craney Creek, Morgan-Rowan Co. line. 2 July, 1985.
9. Headwaters of Yocum Creek, nr. Blaze, Morgan Co. 12 July, 1985.
10. Brushy Fork of Beaver Creek, Menifee Co. 24 October, 1985.
11. Meyers Fork of Beaver Creek, Menifee Co. 24 October, 1985.
12. Blackwater Creek, ca. 3.2 km S of Ezel, Morgan Co. October, 1985.
13. Skidmore Creek, ca. 2.4 km NW of Scranton, Menifee Co. November, 1985.
14. Ratliff Creek, ca. 2.4 km NW of Ky. 1274, Menifee Co. November, 1985.
15. Buck Creek at F.S. 918, Menifee Co. November, 1985.
16. Leatherwood Creek, nr. Joes Branch, Menifee Co. November, 1985.
17. Clear Creek, nr. Clear Creek Iron Furnace, Bath Co. November, 1985.
18. Clark Fork of Salt Lick Creek, Ky. 36 at Ky. 211, Bath Co. November, 1985.
19. Gladie Creek, nr. Cane Branch, Menifee Co. 5 August, 1985.
20. Dry Fork of Gladie Creek, 100 m upstream from mouth, Menifee Co. 31 July, 1985.
21. Laurel Fork of Gladie Creek, 100 m upstream from mouth, Menifee Co. 31 July, 1985.
22. Salt Fork of Gladie Creek, 200 m upstream from mouth, Menifee Co. 31 July, 1985.
23. Salt Fork of Gladie Creek, 0.30 km. upstream from mouth, Menifee Co. 4 May, 1984.
24. Leatherwood Fork of Indian Creek, nr. Smallwood Branch, Menifee Co. 31 July, 1985.
25. East Fork of Indian Creek, 14.5 km upstream from mouth, Menifee Co. 5 July, 1985.
26. East Fork of Indian Creek, between Blackstand Branch and Hall Sink Branch, Menifee Co. 20 July, 1985.
27. Powell Branch of East Fork of Indian Creek, 100 m upstream from mouth, Menifee Co. 30 July, 1985.
28. Chimney Top Creek, 100 m upstream from Rough Trail, Wolfe Co. 5 July, 1985.
29. Right Fork of Chimney Top Creek, 100 m upstream from mouth, Wolfe Co. 5 July, 1985.
30. Clifty Creek, 200 m upstream from Osborne Branch, Wolfe-Menifee Co. line. 16 July, 1985.
31. Clifty Creek, 100 m upstream from mouth, Wolfe-Menifee Co. line. 30 July, 1985.
32. Osborne Branch of Clifty Creek, ca. 75 m upstream from mouth, Menifee Co. 16 July, 1985.
33. Wolfpen Creek, 200 m upstream from Ky. 715. Menifee Co, 2 July, 1985.
34. Parched Corn Creek, at Rough Trail 221 crossing, Wolfe Co. 3 July, 1985.
35. Rockbridge Fork of Swift Camp Creek, ca. 0.60 km upstream from mouth, Wolfe Co. 3 July, 1985.

Because surface mining has occurred in the past near Redwine, Kentucky (Morgan Co.), water samples were collected at 5 sites in the North Fork of Licking River and 3 sites in Devils Fork for comparison of various chemical characteristics. Additional samples were collected at a site downstream from the confluence of these 2 streams (Fig.1). Four water samples were collected at each site. Two samples were acidifed to a pH of 2.0 or less with HNO_3 and two were not; all samples were then cooled to 4°C until analyzed in the lab. A Fisher combination pH electrode was used to measure pH in the field. In the lab, non-acidified water samples were analyzed for sulfate concentration by the barium chloride turbidimetric method using an HF Instruments Model DRT-100 nephelometer according to standard methods (8.) Acidified samples were analyzed for a series of metals by atomic absorption spectrophotometry.

Results and Discussion

Populations of *C. elongatus* have been found in several tributaries of North Fork of Licking River, Beaver Creek and Red River (Fig.1). *Clinostomus elongatus* was common in Upper Lick Fork, Slabcamp Creek, Devils Fork, Minor Creek, Yocum Creek and Gladie Creek. In fact, *C. elongatus* was one of the dominant fish species at most of these sites. Brushy Fork of Beaver Creek and Meyers Fork of Beaver Creek also had substantial numbers of this fish. *Clinostomus elongatus* was rare at sites 7, 27 and 28; only 1 specimen was found at each locality. *Clinostomus elongatus* was not found at sites 12-18, 24-26 and 29-35.

Species of fish commonly found with *C. elongatus* included *Campostoma anomalum, Phoxinus erythrogaster, Rhinichthys atratulus, Semotilus atromaculatus, Catostomus commersoni, Etheostoma caeruleum, Etheostoma nigrum* and *Cottus bairdi*. *Notropis chrysocephalus* was common in the Licking River

Fig. 1. Kentucky locality records for *Clinostomus elongatus*. The Lick Fork record was reported by Clark (6); the Edward Branch record is from Kuehne (7). Other locality records are reported for the first time herein. L = Leisure, W = Wrigley, and R = Redwine, Kentucky. Water samples were collected at sites 1-9.

Drainage, but not in the Red River Drainage (Table 1). Species found in low numbers with *C. elongatus* included *Lampetra aepyptera, Ericymba buccata, Notropis rubellis, Pimephales notatus, Hypentelium nigricans, Ambloplites rupestris, Lepomis macrochirus, Lepomis megalotis, Micropterus dolomieui, Percina caprodes* and *Percina (Odontophiles)* sp.

Table 1. *The Abundance of Clinostomus elongatus* and Commonly Associated Species in Kentucky. MC = Minor Creek; SC = Slabcamp Creek; DF = Devils Fork; ULF = Upper Lick Fork; YC = Yocum Creek; BF = Brushy Fork; SFG = Salt Fork of Gladie Creek; DFG = Dry Fork of Gladie Creek; LFG = Laurel Fork of Gladie Creek; GCB = Gladie Creek nr. Cave Branch; PB = Powell Branch of East Fork of Indian Creek; CTC = Chimney Top Creek.

	Licking River Drainage						Red River Drainage						
Species	MC	SC	DF	ULF	YC	BF	SFG	DFG	LFG	GCB	PB	CTC	Total
Clinostomus elongatus	13	137	102	95	63	12	4	22	6	5	1	1	461
Phoxinus erythrogaster	4	29		27	93		6	28	2	13	68	4	274
Semotilus atromaculatus	97	121	71	28	26	14	30	19	2	39	29	35	511
Rhinichthys atratulus	8	28	4	6	25	1	3	9	2	2	8	11	107
Notropis chrysocephalus	72	2	102	45	4	25	2				4		256
Campostoma anomalum	4	60		10	1	5	3		2	7	3	1	96
Etheostoma caeruleum	14		1	6		8	45	12	6	1	17	3	113
Etheostoma nigrum	29	12	16	1	1	15	6			7	4	1	92
Cottus bairdi	28	3	1	23	2	2	20	12	10	18	5	15	139

Generally, streams with populations of this species shared certain physiochemical traits; these included cool and clear water, of near neutral pH, in forested watersheds with canopy over the stream. The streamside forest often included hemlock, *Tsuga canadensis* and white laurel, *Rhododendron maximum*. *Clinostomus elongatus* was found in pools with gravel and sandy substrates; current was moderate, and little or no silt was present. Many similar streams in eastern Kentucky occur in isolated hollows and are not readily accessible by roads. This may account for the rarity of this fish in earlier collections.

Attempts to relocate the population of *C. elongatus* reported by Clark (6) were not successful. Lick Fork is greatly modified from former conditions. It has a mostly unforested watershed used for agriculture, receives seepage from rural septic fields and serves as a source for gravel. Apparently, *C. elongatus* has been eliminated from this stream. Because this fish needs relatively pristine streams for survival, there is a need to monitor and protect its habitat to insure its survival in Kentucky. Gladie Creek (Fig.1) has recently been included in the Clifty Creek National Wilderness Area.

North Fork of Licking River has an abandoned and partially reclaimed surface mine as its source. Only one specimen of *C. elongatus* was found south of Leisure; this juvenile fish was probably a stray from an adjacent tributary. The pH values in this area ranged from 4.50-6.90; sulfate, iron and manganese levels ranged upward to 300 ppm., 1.20 ppm and 1.52 ppm respectively. In Devils Fork, a relatively undisturbed tributary of North Fork of Licking River, *C. elongatus* was very common. The pH values here ranged from 6.94-7.03; sulfate, iron and manganese levels ranged upward to 14.9 ppm, 0.50 ppm and 0.05 ppm respectively (Table 2). The North Fork of Licking River values are comparable to those for polluted Cumberland Plateau streams; the Devils Fork values are similar to those of unpolluted Cumberland Plateau streams (9,10).

Table 2. Selected Chemical Characteristics for 9 Sites in North Fork of Licking River and Devils Fork. Values Other Than pH are in mg/L. Sites 1-9 are Shown in Figure 1.

	North Fork of Licking River						Devils Fork		
	1	2	3	4	5	6	7	8	9
pH	4.5	4.55	6.90	6.97	7.17	6.96	7.08	7.01	6.94
Sulfate	76.9	310.0	97.8	109.5	52.4	32.8	14.9	14.5	14.5
Iron	0.57	0.60	0.34	1.20	0.43	0.55	0.50	0.45	0.43
Manganese	1.43	1.52	0.12	0.25	0.05	0.05	0.05	0.04	0.04

Sexual dimorphism is very noticeable in coloration of adult *C. elongatus*. Adult males are dark olive-green on the dorsal surface of their head and body, and bright red on their sides. Adult females are lighter green on their dorsum and have pinkish to pale reddish sides. Schwartz and Norvell (11) used shape and length of genital papillae, length of pectoral and pelvic fins, body coloration and internal examination of gonads to determine sex. Schwartz and Norvell (11) found that pectoral fin lengths were always greater in males; they indicated that the ratio of pectoral fin length to head length could be used to determine sex with certainty. In fish 2-4 years old, this ratio ranged from 1.15-1.19 in males and 1.36-1.41 in females.

Clay (12) and Trautman (3) indicated that *C. elongatus* is distinguished from a related species, *C. funduloides*, by having 60 or more lateral-line scales and a jaw length greater than caudal peduncle depth. Systematic values for number of lateral-line scales, lower jaw length and caudal peduncle depth in *C. elongatus* agree with comments given by these authors. Systematic values for *C. elongatus* from Licking River tributaries and Red River tributaries are recorded in Table 3.

Table 3. Systematic Data from Kentucky Specimens of *Clinostomus elongatus*.

Morphological Characters	Range	n	$\bar{x}$	SD
Lateral-Line Scales				
Licking River Drainage	58-70	99	62.60	2.79
Red River Drainage	59-73	39	63.46	2.33
Lower Jaw Length (mm)				
Licking River Drainage	4.9-10.9	113	7.04	1.33
Red River Drainage	4.3-11.9	39	8.54	1.88
Caudal Peduncle Depth (mm)				
Licking River Drainage	3.5-7.1	113	4.96	.897
Red River Drainage	3.1-7.6	39	5.75	1.09

ACKNOWLEDGEMENTS

Thanks and appreciation are extended to Susan King, Steve Yates, Chuck Burchett, David Provost and former ichthyology students at Morehead State University for their assistance in the field; to Brooks Burr, Southern Illinois University at Carbondale, for confirming the identification of specimens and for reviewing this manuscript; to Susan King and Greg Hignite for assistance with preparation of distribution maps; to Richard Hunt for advice and assistance with the chemical analysis of water, and to Janie Strunk for typing the manuscript.

LITERATURE CITED

1. Gilbert, C.R. 1980 *Clinostomus elongatus* (Kirtland), Redside Dace. p. 148 in D.S. Lee, et.al. Atlas of North American Freshwater Fishes. N.C. State Mus. Nat. Hist., Raleigh.
2. McKee, P.M. and R. Parker. 1981. The distribution, biology, and status of the fishes *Campostoma anomalum*, *Clinostomus elongatus*, *Notropis photogenis* (Cyprinidae) and *Fundulus notatus* (Cyprinodontidae) in Canada. Can.J.Zool. 60:1347-1358.
3. Trautman, M.B. 1981. The Fishes of Ohio, Rev. ed. Ohio State Univ. Press, Columbus.
4. Burr, B.M. 1980. A distributional checklist of the fishes of Kentucky. Brimleyana. 3:53-84.
5. Branson, B.A., D.F. Harker, Jr., J.M. Baskin, M.E. Medley, D.L. Batch, M.L. Warren, Jr., W.H. Davis, W.C. Houtcooper, B.L. Monroe, Jr., L.R. Phillippe and P. Cupp. 1981. Endangered, Threatened, and Rare animals and plants of Kentucky. Trans. Ky. Acad. Sci. 42(3-4):77-89.
6. Clark, M.E. 1940. A list of the fishes in northeastern Kentucky. Ky. Game and Fish Comm., Frankfort. 11 pp. (unpublished mimeo.)
7. Kuehne, R.A. 1984. A new Kentucky record for the minnow, *Clinostomus elongatus* (Kirtland). Trans. Ky. Acad. Sci. 45:77-78.
8. American Public Health Association. 1985. Standard Methods for the Examination of Water and Wastewater. 16th ed. American Public Health Association, Washington.
9. Harker, D.F., Jr., S.M. Call, M.L. Warren, Jr., K.E. Camburn, and P. Wigley. 1979. Aquatic biota and water quality survey of the Appalachian Province, eastern Kentucky. Tech. Rep., Kentucky Nature Preserves Commission, Frankfort.
10. Branson, B.A., D.L. Batch, and W.R. Curtis. 1984. Small-stream recovery following surface mining in east-central Kentucky. Trans. Ky. Acad. Sci. 45:55-72.
11. Schwartz, F.H. and J. Norvell. 1958, Food, growth and sexual dimorphism of the redside dace *Clinostomus elongatus* (Kirtland) in Linesville Creek, Crawford County, Pennsylvania. Ohio Jour. Sci. 58:311-316.
12. Clay, W.M. 1975. The Fishes of Kentucky. Ky. Dept. of Fish Wildl. Res., Frankfort.

Male Preference for Females of Different Sizes in *Gambusia affinis:* A Response to Size Specific Female Mortality?

Raymond E. Hampton
Laboratory of Animal Behavior and Behavioral Ecology,
Department of Biology,
Central Michigan University, Mt. Pleasant, Michigan 48859

Abstract

Males of *Gambusia affinis* from populations in which there are few large females direct most of their courtship time toward smaller females, even though large females produce more offspring than do smaller females. Males from populations which contain relatively larger numbers of large females either do not discriminate among females of different sizes or preferentially court large females. The hypothesis that the potential reproductive success that a male might expect from investing courtship time and energy in a female is apparently determined not only by the fecundity of the female but also by the probability that she will survive at least through the approximately 28-day gestation period is proposed and tentatively supported.

Introduction

Males of promiscuous species in which males have little or no parental investment are generally expected to be nondiscriminating in their choice of or preference for mates, since male reproductive success is presumed to be not limited by sperm production but by the ability of males to distribute their sperm among available females (1,2,3). However, as Dewsbury (4) has recently pointed out, sperm production and delivery is probably not a trivial cost to males and may in fact limit the number of females that a male can successfully inseminate. When this is the case, and when different patterns of allocating ejaculates or spermatophores to females results in differences in male fitness, selection should favor those males who exercise some degree of selectivity among available females (4). In promiscuous species, in which female fecundity increases with size, males who selectively or preferentially inseminate larger females should sire more offspring, on the average, than males who do not discriminate.

While observing courtship behavior of the mosquitofish, *Gambusia affinis* Baird and Girard, collected in July 1983 from Jap Beaver Lake in south-central Oklahoma and from Hubbard Creek in central Texas (5), I noticed that males from the Jap Beaver population exhibited a preference for smaller females while males from the Hubbard Creek population exhibited a slight preference for large females. Large females were scarce in the Jap Beaver population and more abundant in the Hubbard Creek population, although the samples collected were too small to permit statistical analysis. The assumption was made that this difference was caused by a higher mortality rate of large females in the Jap Beaver population than in the Hubbard Creek population.

The following working hypothesis was formulated: in *G. affinis*, size-specific mortality of females influences male preference. If larger females have a low probability of surviving the approximately 28-day gestation period, perhaps because of selective predation, males who selectively inseminate smaller females might be more successful, even though smaller females produce fewer offspring. On the other hand, in populations in which large females have a higher probability of surviving, males should not discriminate or should discriminate in favor of large females. In the summers of 1984 and 1985, additional data from several populations of *G. affinis* were collected to test this hypothesis.

Gambusia affinis is widely distributed throughout the southern United States, where its preferred habitats include small streams and densely to moderately vegetated shallow areas in small lakes and ponds. Males grow little after reaching sexual maturity (6) and rarely exceed 3 cm total length, whereas females, which are sexually mature at 2.5 to 3 cm, continue growing throughout their life and may grow to over 6 cm total length. Female fecundity increases with female size (7). Both sexes are promiscuous and courtship and mating are almost continuous throughout the warmer months. Females have a gestation period of approximately 28 days, after which they deliver from a few to over 100 well-developed offspring. Females apparently store sperm for extended periods (7), and males virgorously court any female present regardless of her gestational stage. Females are more receptive to males, or perhaps more attractive to males, within a few days after delivering a brood (8). However, even non-receptive females are inseminated (9). Rapid habituation of males to individual females insures that males do not waste time or ejaculates with any one female but rather allocate a minimal number of ejaculates to many females (5).

The primary sex ratio in most poeciilid populations studied is usually skewed in favor of females (7,10,11,12,13,14). This is usually attributed to greater predation on males or greater longevity of females. Recently, however, Britton and Moser (15) found that several species of herons selectively prey on larger female *G. affinis* in France. In marshy areas where heron predation occurred, the primary sex ratio was skewed in favor of males and the average size of females was smaller than in roadside ditches where heron predation was absent.

Methods

Specimens of *G. affinis* were collected in June and July of 1984 from a small tributary stream of Lake Texoma, Marshall County, Oklahoma; from a shallow bay in Lake Texhoma at the mouth of Wilson Creek, Love County, Oklahoma; and from Jap Beaver Lake in Jefferson County, Oklahoma. Additional specimens were collected in April of 1985 from Hubbard Creek below Hubbard Creek Dam in Stephens County, Texas; from Quana Parker Lake on the Wichita Mountain Wildlife Refuge in Oklahoma; from the Brazos River approximately 200 meters below Morrison Dam in Palo Pinto County, Texas; and from Jap Beaver Lake. Specimens were collected with dip nets in adequate numbers to permit accurate estimation of primary sex ratios, mean size of both sexes, frequency distribution of various size classes, and female fecundity as a function of size. Seining was not an effective method of sampling in the sites studied because of various factors such as underwater brush, emergent vegetation, or the shallow, narrow nature of the creeks. Live specimens from each population were retained for observations of male preference for females of different sizes.

Jap Beaver and Quana Parker lakes are both small (ca 20 acres), artificial impoundments with no permanent tributary streams. Both are near the top of their respective watersheds and are thus isolated from other bodies of water from which *G. affinis* might immigrate. Quana Parker Lake was impounded in the mid-1930's and Jap Beaver Lake in the mid-1950's. Since *G. affinis* is not used as a bait minnow, introduction of *G. affinis* from other populations into either of these populations is probably rare. Both lakes have areas of shoreline characterized by shallow water with moderate to dense submerged vegetation where *G. affinis* are found.

The Brazos is a major river flowing generally southward from north-central Texas. Morrison Dam is the first of several major dams on the river and was constructed in the 1940's. Hubbard Creek flows into the Clear Fork of the Brazos River which, in turn, joins the main branch of the river well above Morrison Dam. The dam, which creates a large reservoir, probably provides an effective barrier to intermixing of populations of *G. affinis* above and below the dam. Current flow and water depth below the dam are variable, depending on the release of water from the reservoir.

Lake Texoma is a large artificial impoundment on the Red River between Texas and Oklahoma. In the summer of 1984, a period of very low water level, those small tributary streams which were not dry supported abundant populations of *G. affinis*. Collections were made from a small stream adjacent to the University of Oklahoma Biological Station. Since this is an unnamed stream, it will be referred to in this paper as UOBS Creek. Although the water flow in UOBS creek was extremely slow, it was prevented from becoming completely dry by periodic discharge of water from large research tanks of the University of Oklahoma Biological Station.

Hubbard Creek was sampled just below Hubbard Creek Dam where, even during dry periods, there is at least some standing water present. Hubbard Creek and UOBS Creek are in separate watersheds and are therefore well isolated from each other and from any small lakes similar to Jap Beaver and Quana Parker Lakes.

Female fecundity as a function of size was determined by dissecting preserved specimens and counting the number of fully developed eggs or embryos (7). A simple linear regression model was used for statistical analysis of the data (16).

Male mate preference for females of different sizes was determined using males from UOBS Creek, Hubbard Creek, Jap Beaver

Lake, Quana Parker Lake, and the Brazos River. These populations were chosen because they are well isolated from each other and because they represent 2 distinct population types with respect to size distribution of females. The Jap Beaver Lake, Quana Parker Lake and Brazos River populations had few large females, while the UOBS Creek and Hubbard Creek populations had relatively more large females.

Six males from each population were tested by placing them one at a time into a 57-liter aquarium containing 4 females of different sizes. The total time that each male courted each female in a 20-min observation period was recorded using an OS-3 electronic event recorder (Observational Systems, Inc., Redmond, Washington, USA). Males were considered to be courting when performing any of the courtship behaviours described by Itzkowitz (17).

Since there was a great deal of variation in the total time that each male spent in courtship, the time that a male spent courting any one female was expressed as the percentage of the total courtship time by that male. The mean per cent courtship time by the 6 males was determined by the arcsine transformation method (16). The Friedman two-way analysis of variance (18) was used to test for differences among the mean per cent courtship time directed to each of the four females. Males from UOBS Creek and Jap Beaver Lake were tested in August, 1984, using females from the Clear Fork of the Brazos River.

Males from Hubbard Creek and Quana Parker Lake were tested in May 1985, using females from Jap Beaver Lake. Females which were not sympatric with either of the 2 populations from which the test males were collected were used, since there is evidence that males can recognize and prefer females from their own population over females from other populations (19). It is also possible that females might recognize and be more receptive to males from their own population, although there is no evidence to support this. Since a female's receptivity to males or her attractiveness to males changes with her gestational stage (8), males from the 2 populations which were being compared were tested alternately over a period of not more than 2 days.

Brazos River males were tested in December, 1985, in a slightly different way. Males were placed in a 38-1 aquarium containing 2 large females (45 mm and 46 mm TL) and 2 small females (27 mm and 30 mm TL). Since the Brazos River males were not being tested at the same time as males from other populations, females from the Brazos River population were used. The time spent courting either large female and either small female was recorded as described above. The Wilcoxon test (18) was used to test for differences between the mean percent courtship time directed to large females and small females.

RESULTS

Because collections were made at different times of the year in 1984 and 1985, it is not possible to directly compare the size distributions and sex ratios from all of the populations. However, the samples taken within the same year may be compared directly. Since very few immature individuals and no fry were observed in the April, 1985, collections, I assume that these populations consisted only of individuals which had overwintered.

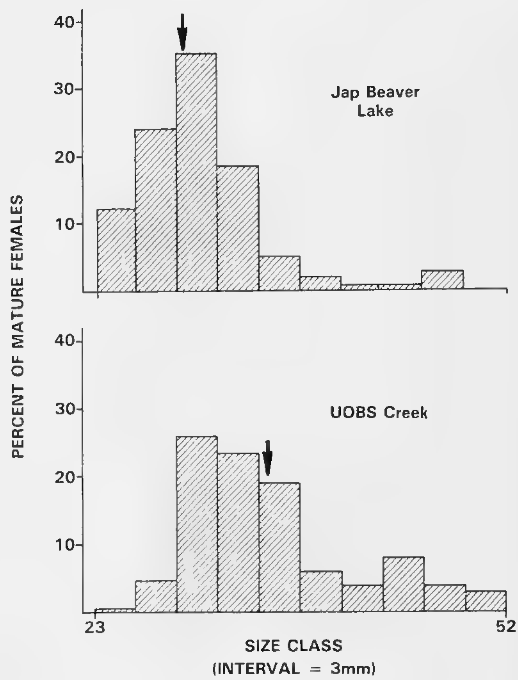


Figure 1. Size distribution (total length) of mature female *G. affinis* collected in July 1984 from Jap Beaver Lake and UOBS Creek. Class Interval = 3 mm. The position of the arrow indicates the mean size.

Table 1. Sex ratios and mean sizes of mature males and females from five populations of *G. affinis*.

Collected	Jap Beaver	UOBS Creek	Brazos River	Quana Parker	Hubbard Creek
	July 1984		April 1985		
N Females	125	128	102	107	91
N Males	172	135	133	161	45
F/M	0.73	0.95	0.77	0.66	2.0
P*	< 0.1	N.S.	< 0.05	< 0.01	< 0.01
Mean Female Size (mm)**	30.2 ±0.8	35.7 ±1.1	35.0 ±0.7	32.8 ±0.5	39.8 ±1.0
Mean Male Size (mm)**	21.8 ±0.3	23.5 ±0.4	26.6 ±0.4	25.3 ±0.3	27.3 ±0.6

* The null hypothesis that F/M=1 was tested by the chi squared test.

** Total length (mm) ±95% confidence interval

In those populations which contained few large females (Jap Beaver Lake, Quana Parker Lake, Brazos River) males significantly outnumbered females, while in those populations in which large females were more abundant (UOBS Creek, Hubbard Creek) the numbers of mature females equalled or exceeded the numbers of mature males (Table 1). Females in Jap Beaver Lake were significantly smaller than females from UOBS Creek when both were sampled in late July 1984 (Table 1, Fig. 1), and females from both the Brazos River and Quana Parker Lake were significantly smaller than females from Hubbard Creek when these sites were sampled in April, 1985 (Table 1, Fig. 2). Great egrets and little blue herons were often observed foraging in Jap Beaver Lake, Quana Parker Lake, and, at times of low water, the Brazos River. These birds were not observed in either Hubbard Creek or UOBS Creek, nor was any indirect evidence of their presence noted. This was probably because of the steep banks and overhead tree canopy of both creeks. Both UOBS Creek and Hubbard Creek support fish species which might prey on adult *G. affinis* (*Lepomis qulosus*, *L. cyanellus*, *L. macrochirus*, and, in Hubbard Creek only, *Lepisosteus oculatus* were positively identified).

The fecundity of female *G. affinis* is known to increase with size, but not in a consistent relationship from one habitat to another or from one time of year to another (7). Regression analysis of eggs or embryos against fe-

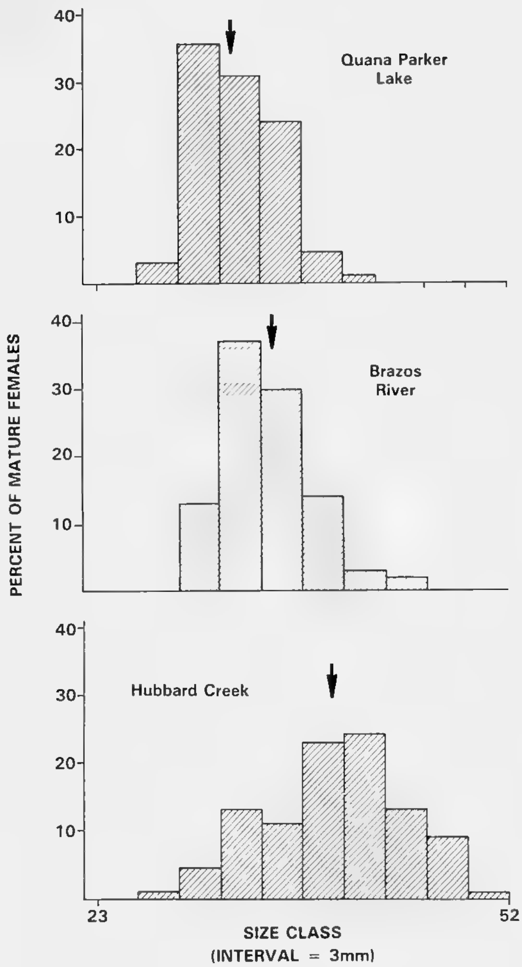


Figure 2. Size distribution (total length) of mature female *G. affinis* collected in April 1985 from Quana Parker Lake, the Brazos River, and Hubbard Creek. Class interval = 3 mm. The position of the arrow indicates the mean size.

Table 2. Female fecundity as a function of size in five populations of *G. affinis*.

Population	Regression Equation	Slope*	r
Jap Beaver	Y = - 26.5 + 1.46X	1.46 ± 0.28	0.83
UOBS Creek	Y = - 67.4 + 2.88X	2.88 ± 0.44	0.87
Quana Parker	Y = - 80.0 + 3.33X	3.33 ± 0.97	0.79
Hubbard Creek	Y = 5.7 + 0.66X	0.66 ± 0.46	0.49
Brazos River	Y = - 81.7 + 3.38X	3.38 ± 1.44	0.76

* ± 95% confidence interval.

male size for the various populations which I sampled revealed a close linear relationship between the 2 variables except in the Hubbard Creek population (Table 2). Males from Quana Parker Lake, Jap Beaver Lake, and the Brazos River devoted significantly more courtship time to smaller females, whereas males from Hubbard Creek had a significant preference for larger females and males from UOBS Creek did not discriminate significantly among the test females (Table 3).

Table 3. Mean percent courtship time of males from 5 populations of *G. affinis* directed to females of different sizes.

Males (n=6)	Female Size (mm, tl)					
	46-47	38-39	31-32	27-30	26-28	p
Jap Beaver Lake	10	11	62	-	14	< 0.01
UOBS Creek	41	11	28	-	15	N.S
Quana Parker Lake	8	16	37	-	36	< 0.01
Hubbard Creek	24	34	19	-	20	< 0.05
Brazos River	27	-	-	79	-	< 0.05

Discussion and Conclusions

In the populations which I studied, males show a clear preference for females of different sizes. This preference varies among the populations in a manner that is consistent with the hypothesis stated previously. Whether or not this behavior may be regarded as a male adaptation to size-specific female mortality depends on the validity of two assumptions: that the observed differences in female size distribution and sex ratios in these populations are caused by a higher rate of mortality of large females in some populations than in others, and that the ability of males to inseminate females is not unlimited. Neither of these assumptions is supported by direct evidence obtained in this study, but both are supported by previous investigations or by convincing circumstantial evidence discussed below.

The differences in female size distribution among these populations could be caused by differences in food availability or quality, or by differences in selective predation or other causes of differential mortality of large females. The possibility that differences in food availability among the various habitats account for the observed differences may be discarded, since such differences would be reflected by corresponding differences in female fecundity (20). On the other hand, there is some evidence to conclude that the differences in female size distribution in these populations resulted from selective predation on large females by herons and egrets in those populations in which there were few large females.

Those populations in which there were few large females and in which males were more abundant than females were in habitats in which great egrets, little blue herons, and greenbacked herons were frequently observed foraging, while those populations in which large females were more abundant and in which the number of females equalled or exceeded the number of males in habitats in which these birds were not observed. The female size distributions and sex ratios in these populations were consistent with the data of Britton and Moser (15), who demonstrated that several species of herons and egrets selectively prey on large female *G. affinis* in France. The Wilson Creek sample is especially interesting in this regard.

The wide, shallow bay formed by the mouth of Wilson Creek at its confluence with Lake Texoma is frequented by foraging great egrets, great blue herons, green backed herons, and little blue herons. In the summer of 1984, when this site was sampled, the *G. affinis* which would normally be expected in the creek itself were apparently forced into the bay as the creek became dry. Of the 157 mature specimens of *G. affinis* collected at Wilson Creek, only 6 were females and none of these females exceeded 33 mm (tl).

The possibility that the reproductive success of male *G. affinis* is limited by their ability to produce sperm or by their ability to deliver sperm to many simultaneously available females has not been tested. However, the assumption that male reproductive success is not limited in these ways in some promiscuous species has recently been challenged on theoretical grounds (4) and there is some empirical support for this challenge. Males of the lemon tetra (*Hyphessobrycon pulchripinnis*), a promiscuous characid, exhibited declining fertilization rates with spawning frequency, and recently spawned males were less attractive to females than were males which had not recently spawned (21). In a previous paper (5), I reported that males of *G. affinis* rapidly habituated to individual females and exhibited a declining frequency of copulatory attempts with sequentially presented females, which indicates that sperm exhaustion might occur.

There are two additional considerations, based on the peculiarities of the mating system of *G. affinis*, which indicate that male selectivity might be advantageous. Since an individual female *G. affinis* is likely to be inseminated by many males, the probability that any one male fertilizes a substantial proportion of her eggs might be very small. Thus, males might have to deliver large quantities of sperm to many females in order to achieve a few fertilizations. In this case, it could be to the advantage of males to exercise some degree of selectivity. A second and perhaps more compelling reason to assume that male sperm production or ability to deliver sperm to many simultaneously available females is limited is that males will attempt to inseminate any mature female regardless of her gestational stage (8,9) and that females that have been previously inseminated still remain attrative to males.

In many promiscuous species, a female is no longer available as a potential mate once she has been inseminated and the pool of available females is thus limited. This is not the case in *G. affinis*. In effect, the pool of available females remains constant and large no matter how many times they have been inseminated. Since the probability that an individual male could inseminate all of the available females in the population in competition with all other males is very small, male selectivity would be advantageous. As Burley (3) pointed out, males of promiscuous species are not expected to be discriminating except when factors such as sperm depletion limit access to simultaneously available mates. *Gambusia affinis* seems to represent such an exception.

In view of these considerations and the observation that males of *G. affinis* do in fact exhibit selectivity in mate preference, it seems likely that the "sperm is cheap" concept may be overgeneralized and inappropriately applied to some species as suggested by Dewsbury (4).

The initial hypothesis, which is at least tentatively supported by the data presented here and elsewhere and which is consistent with the prediction of Dewsbury (4), predicts that the potential reproductive success that a male might expect from investing courtship time, energy, or sperm in a female of any particular size is: $pS(x) \times E(x)$, where $pS(x)$ is the probability that a female of size X will survive at least the 28-day gestation period and $E(x)$ is the average number of eggs per brood produced by a female of size X. This equation provides only a relative estimate of male success, since it does not take into account the probability that a male actually fertilizes all or a fraction of the eggs of any particular female that he inseminates. The hypothesis thus predicts that there should be an optimum size female in any population which represents the most profitable trade-off between increasing female fecundity and decreasing probability of survival with female size. Whether males of *G. affinis* or other species with similar mating systems discriminate in favor of large females or small females or do not discriminate should be adequately predicted by this relationship. The hypothesis should be especially useful in investigating possible relationships between predation and male mate preferences in *G. affinis* and species with similar reproductive strategies.

Acknowledgements

A portion of this research was conducted while I was a visiting investigator at the University of Oklahoma Biological Station. I thank the faculty and staff of that institution, and especially Dr. William Matthews, for their hospitality and encouragement. I also wish to express my appreciation to Dr. Jack Crabtree for his efforts on my behalf in obtaining the necessary permit to collect on the Wichita Mountain National Wildlife Refuge. The research was supported by grants from the Faculty Research and Creative Endeavors Committee and the Summer Research Fellowship Committee of Central Michigan University.

Literature Cited

1. Bateman, A. J. 1948. Intra-sexual selection in *Drosophila*. Heredity 2:349-368.
2. Trivers, R. L. 1972. Parental investment and sexual selection. In B. Campbell, ed. Sexual selection and the descent of man. Heinemann, London.
3. Burley, N. 1977. Parental investment, mate choice, and mate quality. Proc. Nat. Acad. Sci. 74: 3476-3479.
4. Dewsbury, D. A. 1982. Ejaculate cost and male choice. Amer. Nat. 119: 601-610.
5. Hampton, R. E. 1984. A possible role of habituation in the sexual behavior of male

mosquitofish (*Gambusia affinis* Baird and Girard). Animal Behavior 32: 1262-1263.

6. Turner, C. L. 1941. Morphogenesis or the gonopodium in *Gambusia affinis*. J. Morph. 69: 161-185.
7. Krumholz, L. A. 1948. Reproduction in the western mosquitofish, *Gambusia affinis* (Baird and Girard) and its use in mosquito control. Ecological Monographs 18: 1-43.
8. Carlson, D. R. 1969. Female sexual receptivity in *Gambusia affinis* (Baird and Girard). Texas J. Sci. 21: 167-173.
9. Hughes, A. L. 1985. Male size, mating success, and mating strategy in the mosquitofish *Gambusia affinis*. Behav. Ecol. Sociobiol. 17: 271-278.
10. Barney, R. L. and B. J. Anson. 1921. Seasonal abundance of the mosquito destroying top-minnow, *Gambusia affinis*, especially in relation to male frequency. Ecology 2: 53-69.
11. Farr, J. A. 1975. The role of predation in the evolution of social behavior of natural populations of the guppy, *Poecillia reticulata* (pisces: poeciliidae). Evolution 29: 151-158.
12. Krumholz, L. A. 1963. Relationships between fertility, sex ratio, and exposure to predation in populations of the mosquitofish, *Gambusia manni* Hubbs at Bimini, Bahamas. Int. Rev. fes. Hydrobiol. 48: 201-256.
13. Sohn, J. J. 1977. The consequences of predation and competition upon the demography of *Gambusia manni* (Pisces: poeciliidae). Copeia 1977: 224-227.
14. Snelson, F. F., and J. D. Wetherington. 1980. Sex ratio in the sailfin molly, *Poecilia latipinna*. Evolution 34: 308-319.
15. Britton, R. H., and M. E. Moser. 1982. Size specific predation by herons and its effect on the sex-ratio of natural populations of the mosquitofish *Gambusia affinis* Baird and Girard. Oecologia 53: 146-151.
16. Sokal, R. R. and F. J. Rolf. 1973. Introduction to Biostatistics. W. H. Freeman, San Francisco.
17. Itzkowitz, M. 1971. Preliminary study of the social behavior of male *Gambusia affinis* Baird and Girard (pisces: poeciliidae) in aquaria. Chesapeake Science 12: 219-224.
18. Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill, New York.
19. Hubbs, C., and E. A. Delco, Jr. 1962. Courtship preferences of *Gambusia affinis* associated with the sympatry of the parental population. Copeia 1962: 396-400.
20. Trendall, J. T. 1983. Life history variation among experimental populations of the mosquitofish, *Gambusia affinis*. Copeia 1983: 953-963.
21. Nakatsuru, K., and D. L. Kramer. 1982. Is sperm cheap? Limited male fertility and female choice in the lemon tetra (pisces: characidae). Science 216: 753-755.

Nest Box Use by Starlings: Does It Inhibit Bluebird Production? [1]

Wayne H. Davis
School of Biological Sciences
University of Kentucky
Lexington, Kentucky 40506

William C. McComb
Department of Forestry
University of Kentucky
Lexington, Kentucky 40546

Pierre N. Allaire [2]
Lees College
Jackson, Kentucky 41339

Abstract

During a study of bluebird use of different style nest boxes on reclaimed surfaces mines, observations were made of European Starling *(Sturnus vulgaris)* and Eastern Bluebird *(Sialia sialis)* productivity. Boxes admitted starlings the first two years of the study; starlings were excluded the third year. Vandalism resulted in 38, 47, and 44 sites available for nesting, respectively, in the 3 years. Starlings used 40% of the sites the first year and 60% the second. Bluebirds fledged 104, 157 and 169 young, respectively. Starlings raised a single brood; bluebirds raised two and three broods. The resource was partitioned temporally; bluebirds nested before and after the starlings, sometimes building over an old nest after starlings had fledged. We found no evidence of starlings evicting bluebirds.

Introduction

It has been reported (1) that Eastern Bluebird *(Sialia sialis)* populations have declined because introduced House Sparrows *(Passer domesticus)* and European Starlings *(Sturnus vulgaris)* appropriate most of the nesting sites. The adverse effect of House Sparrows has been well established. House sparrows will evict bluebirds at any stage of the nesting cycle, sometimes even killing adult bluebirds (1, 2, 3).

The effect of starlings on bluebird populations remains undocumented. Although Zeleny (1) writes that bluebirds "can *never* compete successfully with starlings for the use of any cavity that a starling can enter," he presents no evidence to support the statement. In our search of the literature we could find almost nothing on starlings evicting bluebirds. During our studies of bluebirds, we gathered data on bluebird productivity when many of the boxes were used by starlings.

Materials and Methods

Two reclaimed surface mines (Press Howard and Two Mile) in Breathitt County, Kentucky, served as the study sites. Both areas were created by mountaintop removal 3-10 years prior to the study. Vegetation on both sites was primariy tall fescue *(Festuca arundinacea)*, lespedeza *(Lespedeza cuneata)*, crown-vetch *(Coronilla varia)*, black locust *(Robinia pseudoacacia)*, and autumn olive *(Eleagnus angustifolia)*. Ponds ranging in size from 0.1-1 ha were located at about 400-m intervals. Twenty five nest box stations were established 320 m apart along gravel roads at each site and maintained from 1982 through 1985. All nest boxes had internal dimensions of 13 x 13 x 25 cm.

In 1982 we erected 3 boxes at each site: a standard box with a circular entrance 38 mm in diameter; a box with a slot entrance at the top of the front; and one with a slot entrance in the roof (4). Only the slot-entrance boxes

[1] The information reported in this paper (86-8-48) was collected in association with Kentucky Agricultural Experiment Station Project No. 624 and is published with the approval of the Director.

[2] Present address: Corporate and Foundation Relations, University of Florida Foundation, P. O. Box 14425, Gainesville, FL 32604.

were accessible to starlings. In 1983 at each station we placed 3 boxes with front slot-entrance widths measuring 38 mm, 35 mm, and 31 mm. All were accessible to starlings. In 1985, a single box with a 30 mm front-slot entrance was erected at each site. These boxes excluded starlings but admitted bluebirds.

Stations were established 8 April, 24 March and 1 March, 1982, 1983, and 1985, respectively. Inspection began one week after placement. Each box was inspected every 1 to 2 weeks until boxes were no longer being used for nesting by bluebirds (4 September). Stations were in the same locations each year except for 6 moved in 1985 due to active mining. Nest boxes (3 slot-entrance boxes per station) were left on site during 1984 but were not monitored. Vandalism resulted in 38, 47, and 44 sites available for nesting in 1982, 1983, and 1985, respectively.

Results and Discussion

Boxes received heavy use by bluebirds and starlings. Bluebirds preferred the slot-entrance boxes (4) and they fledged 104, 157, and 169 young in 1982, 1983, and 1985, respectively. Starling use of the sites was 40% in 1982 and 60% in 1983. Thus, bluebirds successfully fledged young despite heavy use of boxes by starlings. Egg-to-young success rate was 72%, 67% and 63%, respectively for bluebirds; thus exclusion of starlings in 1985 did not result in an increased success rate of bluebirds.

At one station, bluebirds and starlings raised broods at the same time. After the starlings established their nest the bluebirds moved into a neighboring box that was not accessible to starlings. This box had previously fledged a brood of bluebirds. With this exception, no more than one box per station was in used at the same time. Thus, if individuals of one species were nesting, the site was generally not available for individuals of the other species. In spite of this, bluebirds fledged nearly as many young in 1983 when more than half the sites were used by starlings as in 1985 when starlings were excluded.

Several factors seemed responsible for the apparent minimal effect of starlings on bluebird production. Bluebirds establish their nests earlier than starlings. Stewart (5) found that the average date of nest-box exploration for bluebirds in North Carolina was 18 March and for starlings 9 April. We found that bluebirds began nesting before starlings (Fig. 1).

Figure 1. Eastern Bluebird and European Starling nestlings present during inspection of 47 nest sites on reclaimed surface mines, Breathitt County, Kentucky, 1983. Data for 1982 were similar.

Secondly, starlings always chose empty stations (some sites on both areas were never used); in no case did we find evidence suggesting that they evict bluebirds. In one box, starlings nested after bluebirds had fledged. Although there are reports of starlings evicting woodpeckers (e.g., 6, 7), we found few records of bluebird evictions, and these involved only bluebirds in the earliest stages of nesting. Kalmbach and Gabrielson (6) described starlings taking over a site after bluebirds had started to build a nest, and they reported that among 8 bluebird nests started in their experimental boxes, the bluebirds were driven away from 3 by starlings. They also described incidences where starlings and bluebirds nested "in close proximity" without conflict. Gowaty (2) presented data on eviction of bluebirds by House Sparrows. She found that sparrows were more likely to take an empty box than to evict, and that the farther into the bluebird nesting cycle eviction was attempted, the less likely it would occur. Apparently eviction is difficult work and is usually avoided if alternatives are available.

A third factor was that starlings on our study areas produced a single brood, whereas bluebirds often raised two or more broods. Most boxes were available for the exclusive use of bluebirds by early June (Fig. 1). Thus, there seemed to be temporal partitioning of the resource, rather than competition, with neither species appearing to have a significant negative impact on the other.

Although heavy use by starlings had little, if any, effect on the successful production of bluebirds in our nest boxes, this situation may not hold in other circumstances or other areas. In western Kentucky (8), New York (9), Ontario (10), Colorado (11), and Arizona (12) second clutches of starlings were reported in 50 to 92 per cent of boxes from which young starlings had fledged. On our study area, starlings were rarely seen except during their short nesting season. Perhaps the absence of agriculture or other human activities attractive to starlings rendered the area marginal habitat for this species and unsuitable for later nestings. Perhaps starlings could not tolerate summer heat in these small boxes in open sites. Four broods of starlings near fledging died in the boxes, perhaps because of heat. Clutch size averaged 4.1 (1982) and 4.4 (1983), similar to that reported by others (8, 13) in Kentucky. Egg-to-fledging success was low (43% and 51%), however.

We suspect that the commonly accepted view on the adverse effect of starlings on bluebird populations may be exaggerated. The situation may be analogous to what has been found with woodpeckers. Starlings appropriate many woodpecker nesting sites and some writers (e.g., 7, 14) have expressed concern for the survival of the woodpeckers. Nevertheless, Dennis (15), in a study of the decline of the common flicker *(Colaptes auratus)* on Nantucket Island during a time when the starling was becoming increasingly abundant, concluded that factors other than appropriation of nest sites were primarily responsible.

Summary

Bluebirds were nearly as successful at fledging young when 40% and 60% of the stations were used by starlings as when starlings were excluded from the boxes. Bluebirds began nesting earlier and were not evicted by starlings; the starlings chose empty boxes. Starlings produced a single brood, whereas bluebirds produced two or more. Bluebirds sometimes built nests over old starling nests and raised broods after the starlings had left.

Acknowledgements

We thank Falcon Coal Company for allowing us to work on their lands; S. Bonney, F. Lassiter, S. Cross, P. Groetsch, G. Jacoby, D. Ross, and G. McPeek for assistance with field work; F. C. Fackler for assistance with nest box construction. P. A. Gowaty and E. H. Burtt, Jr. provided constructive criticisms of an earlier draft.

Literature Cited

1. Zeleny, L. 1976. The Bluebird. Indiana Univ. Press, Bloomington.
2. Gowaty, P. A. 1981. Aggression of breeding eastern bluebirds *(Sialia sialis)* toward their mates and models of intra- and inter-specific intruders. Anim. Behav. 19:1013-1027.
3. Gowaty, P. A. 1984. House sparrows kill eastern bluebirds. J. Field Ornithol. 55:378-380.
4. McComb, W. C., W. H. Davis, and P. N. Allaire. 1987. Excluding starlings from a slot-entrance bluebird box. Wildl. Soc. Bull. 15: *(in press)*.
5. Stewart, P. A. 1976. Movements of cavity-hunting starlings and eastern bluebirds. Bird-banding 47:274-275.

6. Kalmbach, E. R. and I. N. Gabrielson. 1921. Economic value of the starling in the United States. Bull. No. 868, U.S. Dept. Agr. 66 pp.

7. Sutton, G. M. 1967. Oklahoma Birds. Univ. of Oklahoma Press, Norman.

8. Twedt, D. J. and R. S. Oddo. 1984. Breeding biology of the starling in Kentucky. Kentucky Warbler 60:35-40.

9. Kessel, B. 1957. A study of the breeding biology of the European starling *(Sturnus vulgaris)* in North America. Amer. Midl. Nat. 58:257-331.

10. Collins, V. B. and A. DeVos. 1966. A nesting study of the starling near Guelph, Ontario. Auk 83: 623-636.

11. DeHaven, R. W. and J. L. Guarino. 1970. Breeding of starlings using nest-boxes at Denver, Colorado. Colorado Field Ornithol. 8:1-10.

12. Royall, W. C., Jr. 1966. Breeding of the starling in central Arizona. Condor 68:196-205.

13. Lovell, H. B. 1942. The nesting of the starling in Kentucky. Kentucky Warbler 18:29-34.

14. Lowery, G. H., Jr. 1955. Louisiana Birds. Louisiana State Univ. Press, Baton Rouge.

15. Dennis, J. V. 1969. The yellow-shafted flicker *(Colaptes auratus)* on Nantucket Island, Massachusetts. Bird-Banding 40:290-308.

NOTES

RANGE EXTENSIONS FOR THE MOSQUITO FERN IN KENTUCKY AND TENNESSEE. — *Azolla caroliniana* Willdenow (Azollaceae) is a small, floating fern found in quiet waters of the Atlantic and Gulf Coastal plains and along the east side of the Mississippi River valley (Lellinger, Ferns and Fern Allies of the United States and Canada, Smithsonian Institution Press, 1985). Common associates are various taxa of Lemnaceae, including *Lemna*, *Spirodela*, *Wolffia*, and *Wolffiella*. Rapid asexual growth, documented by Shaver (Ferns of Tennessee, George Peabody College, Nashville, 1954), often results in masses that may cover the surface of a pond or pool within a few weeks. However, populations are ephemeral and often absent some years. The presence of reddish pigmentation, especially in autumn, is also a noticeable characteristic.

Although sometimes locally abundant, documented Kentucky and Tennessee records for *Azolla*, as resported in recent fern surveys, are scanty and confined to the Mississippian Embayment section of the Coastal Plain. Eight of the 9 counties with reported populations adjoin the Mississippi River. The purpose of this note is to report the discovery of *Azolla* in Trigg County, Kentucky and adjacent Stewart County, Tennessee, thus extending the known distribution eastward for about 110 km and onto the Interior Low Plateaus Province in both states.

Azolla was not known from Kentucky until 1950 when McCoy (Amer. Fern Journ. 40:211-212, 1950) found a colony in Fulton County near the northern end of Reelfoot Lake. The recent compendium of Kentucky ferns by Cranfill (Ferns and Fern Allies of Kentucky, Nature Preserves Comm., Sci. and Tech. Series 1, 1980) added the three counties directly north of Fulton (Figure 1).

Wofford and Evans (Journ. Tenn. Acad. Sci. 54:32-36, 1979), in their atlas of Tennessee plants, showed *Azolla* from 5 West Tennessee counties. Previous reports from East Tennessee, *i.e.*, by Gattinger (Flora of Tennessee, Bureau of Agriculture, Nashville, 1901) from McMinn County and by Anderson (Univ. Tenn. Ext. Series 6:1-40, 1929; Amer. Fern Journ. 21:64-71, 1931) from Bradley County (based on an 1856 Gattinger collection), could not be confirmed by Shaver (loc. cit., 1954) in his extensive field and herbarium studies. Likewise, the Shaver report from Davidson County, based on a liquid-preserved specimen at Peabody College (now a part of Vanderbilt University), was not verified by Wofford and Evans (loc. cit., 1979) and their distribution map, based on documented records, includes only the Coastal Plain counties indicated in Figure 1.

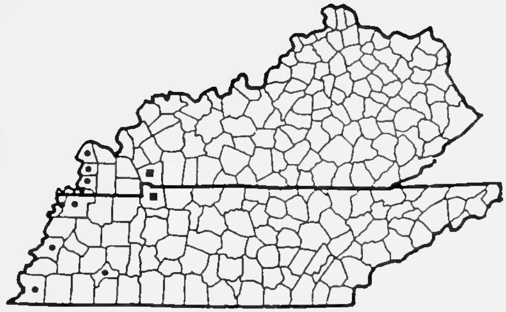


Figure 1. Documented distribution of *Azolla* in Kentucky and Tennessee; circles represent previously-cited reports, squares represent new records.

During October of 1984 an extensive population of *Azolla* was found in a swamp covering several ha and resulting from beaver dams on Crooked Creek, a Cumberland River tributary in Trigg County, Kentucky. The swamp is within the TVA-managed Land Between the Lakes (LBL). The population was also present in 1985, and examination of several other beaver ponds and wetlands managed for wildlife within LBL also revealed large *Azolla* colonies in adjacent Stewart County, Tennessee (Figure 1). All collections were from relatively clean pools and were associated with *Lemna minor* L. No specimens were found in any of the upland ponds or waterholes which are abundant in LBL.

Azolla is probably a recent immigrant into the LBL area since the habitat types mentioned (extensive beaver ponds, waterfowl management pools) have developed since conversion of the region to public ownership. Cranfill (loc. cit., 1980) related the importance of waterfowl in dispersing this species and the large flocks attracted to LBL by extensive management practices may account for its presence there.

Voucher specimens for the new records mapped in Figure 1 are preserved in the herbarium of Austin Peay State University (APSC) with the following data (collection numbers are those of the first author). STEWART COUNTY: Bear Creek Wildlife Management Area, Snake Pond, 85-1052, 8 November 1985; Gray Hollow beaver pond, 85-1051, 8 November 1985. TRIGG COUNTY: Crooked Creek beaver swamp, 84-518, 6 September 1984; 85-988, 11 October 1985. — EDWARD W. CHESTER, Department of Biology, Austin Peay State University, Clarksville, Tennessee 37044 and KEVIN SOUZA, Department of Biology, Vanderbilt University, Nashville, Tennessee 37235.

ALOPECURUS ARUNDINACEUS (POACEAE) ESTABLISHED IN KENTUCKY — *Alopecurus arundinaceus* Poiret, a perennial European grass, has been recorded in North America from two widely separated areas: North Dakota and Newfoundland-Labrador (Hitchcock and Chase, Manual of the Grasses of the United States, U.S.D.A. Misc. Publ. 200, 1950; Scoggan, Flora of Canada, Part 2, Natl. Mus. Nat. Sci. Publ. Bot. 7(2), 1978; Soil Conservation Service, U.S.D.A., National List of Scientific Plant Names, Vol. 1, 1982; Staff, L. H. Bailey Hortorium, Hortus Third, Macmillan Publ. Co., New York, 1976; Sutherland, In Great Plains Flora Association, Flora of the Great Plains, University Press of Kansas, 1986; Weintraub, Grasses Introduced into the United States, U.S.D.A. Agric. Handb. 58, 1953). This species has now been documented in Kentucky, the collection being apparently the first in the eastern United States.

Collection data are as follows: KENTUCKY: Bell Co.: Log Mountain Surface Mine Demonstration Area, 18 km W of Middlesboro off Ky. 74 at Maiden Ridge; seasonally wet depression from east highwall seep at Scots pine plantation; locally occasional; associates, *Scirpus cyperinus, Carex lurida, C. vulpinoidea, Panicum clandestinum*, R. L. Thompson and R. A. Straw *85-179*; 9 May 1985 (BEREA, KNK, EKY).

The Log Mountain site, a 14.2 ha area at 866 m elevation, was contour surface-mined on the Red Springs coal bed in 1963. A grass-legume reclamation mix of tall fescue *(Festuca arundinacea)* and Korean lespedeza *(Lespedeza stipulacea)* was seeded on the mine bench for initial ground cover in the spring of 1964, and 11 tree species, including Scots pine *(Pinus sylvestris)*, were planted in 1965 toward forestry postmining land use. Also, in 1965, *Alopecurus arundinaceus* 'Garrison' was seeded experimentally in a wet depression adjacent to the east highwall and the Scots pine plantation. In the 21 years since the planting, creeping foxtail has locally persisted, reproduced, and expanded its area of occurrence. At the Log Mountain site, the source of the Kentucky collections, the species appears thoroughly established.

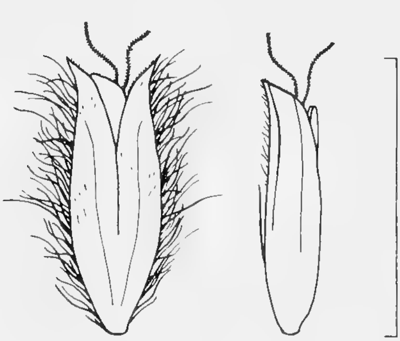


Figure 1. *Alopecurus arundinaceus*. Left, spikelet; right, floret.

Alopecurus arundinaceus (syn: *A. ventricosus* Pers.) is distinguished from other U. S. species of its genus by the combination of rhizomatous habit, relatively large spikelets (ca. 5.0 mm long), included awns, somewhat outcurved glume apices, and obliquely truncate lemma tip (Fig. 1). It is most closely similar in general aspect to *A. pratensis* L., also an introduced European species, which shares the general shape and size of inflorescence and the long-ciliate glume keels. However, *A. arundinaceus* has included awns, blackish caryopses, and vigorous rhizomes, while *A. pratensis* has excluded awns, predominantly white caryopses, and weak rhizomes. Creeping foxtail should be searched for in other parts of the eastern United States, especially in wet meadowland environments that have been artifically seeded. — RALPH L. THOMPSON, Department of Biology, Berea College, Berea, KY 40404, and JOHN W. THIERET, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41076.

LIPARIS LOESELII (ORCHIDACEAE) DOCUMENTED IN KENTUCKY — *Liparis loeselii* (L.) L. C. Richard, Loesel's twayblade or fen orchid, had not previously been recorded for Kentucky (Braun, An annotated Catalog of Spermatophytes of Kentucky, J. S. Swift, Co., 1943; Ettman, An Annotated Checklist of the Orchidaeceae of Bell County, Kentucky, Annals of Ky. Nat. Hist. 3 1-7, 1976; Fernald, Gray's Manual of Botany, Eighth Edition, Van Nostrand Co., 1950; Gleason and Cronquist, Manual of the Vascular Plants of the Northeastern United States and Adjacent Canada, Van Nostrand Co., 1963; Luer, The Native Orchids of the United States and Canada Excluding Florida, New York Botanical Garden, 1975; McFarland, A Catalogue of the Vascular Plants of Kentucky, Castanea 7:77-108, 1942), until its discovery in 1982 in southeastern Kentucky (MacGregor, Two New Orchid Records from Harlan County, Kentucky, Trans. Ky. Acad. Sci. 44 (1-2):90, 1983). This inconspicuous orchid has now been documented from Bell County, the southeastern most Kentucky county within the Cumberland Mountains. Luer (1975) mapped its distributional range from Quebec to Saskatchewan, south to Kansas, Missouri, Illinois, Ohio, West Virginia, North Carolina, and Alabama.

The first collection data are: KENTUCKY: Harlan Co.: Pine Mountain Settlement School, near town of Pine Mountain, NNW slope of Pine Mountain at 2200 feet, along upper edge of an old road in a rather dry and weedy situation, Nolansburg Quadrangle. A colony of plants were present in fruit, J. R. MacGregor; 25 July 1982 (EKY). Identification confirmed by C. S. Sheviak.

The second site data are as follows: KENTUCKY: Bell Co.: Log Mountain Surface Mine Demonstration Area, 18 km W of Middlesboro off Ky. 74 at

Maiden Ridge, 866 m elevation; seasonally wet highwall seep at yellow-poplar plantation; locally occasional; associates, *Scirpus cyperinus, Carex incomperta, Spiranthes cernua, Platanthera lacera,* R. L. Thompson, P. S. Thompson, and M. E. Medley *85-1017;* 27 May 1985 (BEREA, EKY), and R. L. Thompson and R. A. Straw *85-1600;* 27 August 1985 (BEREA).

In the eastern United States excluding Florida, there are two species of *Liparis: L. loeselii* inhabits low wet woodlands, calcareous wet meadows, wet swampy thickets, seeps, and streams, and *L. lilifolia,* the mauve or lily-leaved twayblade, occurs in dry forest slopes, sandy rocky ledges and ridges, and upland wooded clearings and borders. These two twayblades may be distinguished by the following diagnostic key:

1. Flowers yellow-green, lip 4-6 mm long, opaque; pedicels 4-5 mm long; capsules 10-12 mm long; leaves elliptic-lanceolate . . . . *L. loeselii.*
1. Flowers brown-purple, lip 7-12 mm long, translucent; pedicels 6-10 mm long; capsules 14-17 mm long; leaves elliptic-ovate. . . . . . . *L. lilifolia.*

Observations and field data indicate the rarity in distribution and relative sparsity in numbers of *L. loeselii* in Kentucky. Since the fen orchid has not been included in the most recent publication (Warren et al., Endangered, Threatened, and Rare Plants and Animals of Kentucky, Trans. Ky. Acad. Sci. 1986), we believe *L. loeselii* should merit consideration as an endangered species of Kentucky in future addenda. Loesel's twayblade should be sought in wet sedge-grass meadowlands especially those environments created by disturbances through surface-mining within the Cumberland Mountains. — Ralph L. THOMPSON, Department of Biology, Berea College, Berea, KY 40404, and John R. MacGREGOR, Department of Fish and Wildlife Resources, Nongame Wildlife Program, Frankfort, KY 40601.

NEWS AND COMMENTS

KENTUCKY ACADEMY OF SCIENCE CITIZEN SCIENTIST AWARD TO RAYMOND ATHEY

The development of science has periodically been enhanced by individuals whose principal profession was far removed from the aspect of scientific inquiry. In our country a prime example has been Thomas Jefferson and in Kentucky a significant citizen in documenting rare plants of the Commonwealth was Sadie Price of Warren County. On behalf of the Officers, Board of Directors and Membership of the Kentucky Academy of Science it is indeed an honor and privilege to present this day a special Citizen Scientist Award to Raymond Athey of Paducah, Kentucky, 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 midsouth.

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 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.

From his work as a field botanist, herbaria at Memphis State University, Southern Illinois University, Murray State University, Western Kentucky University, University of Louisville and others have received important specimens to add to such reference collections that are of immeasurable value in enhancing our scientific knowledge of plants.

Raymond Athey's contributions to the scientific well being of Kentucky are a permanent legacy. He has, by his leadership and personal example of botanical field work, contributed greatly to enhancing the spirit of inquiry in Kentucky.

THE MORTON B. RYERSON FELLOWSHIP

The MORTON B. RYERSON FELLOWSHIP is established through funds contributed by the Chicago Community Trust. Applications are being solicited for fellowships-in-residence to begin anytime in 1987.

Open to any student, with preference to graduate students, the fellowship awards a monthly stipend of $800, plus room, for any period from two to nine months. Fellows are granted full and private use of a comfortable four-room log cabin with kitchen, spectacularly situated amidst floodplain, hardwood forest on the banks of the DesPlaines River in the Edward L. Ryerson Conservation Area, managed by the Lake County Illinois Forest Preserve District.

Fellows will be expected to conduct independent field research on any topic relating to ecology and/or conservation in northern Illinois forests. Cooperation with a local interpretive nature center is encouraged, but the research project is paramount.

Applicants should send a two to three page proposal, a resume or CV, two letters of recommendation, and a proposed schedule of residency at the Ryerson Conservation Area.

Address application or requests for complete fellowship description to:

Dr. John W. Fitzpatrick
Chairman
Morton B. Ryerson Fellowship Committee
Department of Zoology
Field Museum of Natural History
Roosevelt Road at Lake Shore Drive
Chicago, IL 60605

Deadline for receipt of 1987 application is 1 February 1987.

ACADEMY BUSINESS

COMMITTEES OF THE KENTUCKY ACADEMY OF SCIENCE: 1985-1986

President Covell thanks all of the individuals listed below for graciously accepting the committee assignments. He especially thanks those individuals who accepted chairperson responsibilities.

EXECUTIVE COMMITTEE

Charles V. Covell Jr. (President)
Department of Biology
University of Louisville
Louisville, KY 40292
(502) 588-5942 or 588-6771 (home: 456-6122)

Larry Giesmann (President-Elect)
Department of Biology
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5110

William P. Hettinger, Jr. (Vice-Pres.)
Ashland Petroleum Co.
Ashland, KY 41101
(606) 329-3333, ext. 4650

Joe Winstead (Past-President)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6004

Robert O. Creek (Secretary)
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1539

Morris D. Taylor (Treasurer)
Department of Chemistry
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1465

Branley A. Branson (Editor)
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1537

Joe King (AAAS Representative)
Dept. of Biological Sciences
Murray State University
Murray, KY 42071
(502) 762-2786

Joseph P. "Pat" Stewart (Dir., KJAS)
Warren East High School
Bowling Green, KY 42101
(502) 781-1277

Manuel Schwartz (Chairman, Board of Directors)
Department of Physics
University of Louisville
Louisville, KY 40292
(502) 588-6787

BOARD OF DIRECTORS

Manuel Schwartz (1986), Chairman
Department of Physics
University of Louisville
Louisville, KY 40292
(502) 588-6787

William A. Baker (1986)
The General Electric Company
Appliance Park A 35-1301
Louisville, KY 40225
(502) 452-4642

William Bryant (1988)
Department of Biology
Thomas More College
Box 85
Ft. Mitchell, KY 41017
(606) 341-5800

Douglas L. Dahlman (1989)
Department of Entomology
University of Kentucky
Lexington, KY 40546
(606) 257-4962

Jerry Howell (1987)
Dept. of Biology & Environmental Science
Morehead State University
Morehead, KY 40351

Gerrit Kloek (1986)
Department of Biology
Kentucky State University
Frankfort, KY 40601
(502) 227-6931

William F. Beasley, Jr. (1988)
Department of Biology
Paducah Community College
Paducah, KY 42002
(502) 442-6131

Ralph Thompson (1987)
Department of Biology
Berea College
Berea, KY 40404
(606) 986-9341

Committee on Publications

Branley A. Branson (Chairman)
Department of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1537

Donald L. Batch (1986)
College of Natural & Mathematical Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1818

Gerrit Kloek (1987)
Department of Biology
Kentucky State University
Frankfort, KY 40601
(502) 227-6931

Varley E. Wiedeman
Department of Biology
University of Louisville
Louisville, KY 40292
(502) 588-5943

Charles V. Covell, Jr. (KAS President)
Department of Biology
University of Louisville
Louisville, KY 40292
(502) 588-5942

KAS Foundation Botany Fund Committee

William S. Bryant (1986) Chairman
Thomas More College
Box 85
Ft. Mitchell, KY 41017
(606) 341-5800

Ralph Thompson (1986)
Dept. of Biology
Berea College
Berea, KY 40403
(606) 986-9341

Ronald Jones (1987)
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475

KAS Foundation Marcia Athey Fund committee

Paul H. Freytag (1986), Chairman
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-7452

James L. Lee (1987)
Dept. of Psychology
Eastern Kentucky University
Richmond, KY 40475
(606) 236-5211

Ray K. Hammond (1987)
Division of Science
Centre College
Danville, KY 40422
(606) 236-5211

William S. Wagner (1986)
Dept. of Physical Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 257-7452

William S. Davis (1988)
Department of Biology
University of Louisville
Louisville, KY 40292
(502) 588-5937

Committee on Legislation: State Government Science Advisory Committee

Charles E. Kupchella (1986), Chairman
Ogden College of Science, Technology & Health
Western Kentucky University
Bowling Green, KY 42101
(502) 745-4448

Joe Musacchia (1987)
Graduate School
University of Louisville
Louisville, KY 40292
(502) 588-6495

Gary W. Boggess
College of Science
Murray State University
Murray, KY 42071
(502) 762-2886

Ex Officio

Charles V. Covell Jr. (President)
Department of Biology
University of Louisville
Louisville, KY 40292
(502) 588-5942 or 588-6771

Larry Giesmann (President-Elect)
Department of Biology
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5110

Joe E. Winstead (Past-President)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6004

SCIENCE EDUCATION COMMITTEE

Ted M. George (1986), Chairman
Department of Physics
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1521

Patricia Pearson (1987)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6009

Ron Gardella (1988)
Dept. of Education, BEP 160
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5237 or 572-5229

Manuel Schwartz (1988)
Department of Physics
University of Louisville
Louisville, KY 40292
(502) 588-6787

Dan Ochs (1986)
Science Education
University of Louisville
Louisville, KY 40292
(502) 588-6591

Bill Hettinger (Vice Pres.)
Director of Research
Ashland Petroleum Company
P. O. Box 391
Ashland, KY 41101
(606) 329-3333, ext. 4650

COMMITTEE ON RARE AND ENDANGERED SPECIES

John MacGregor (Chairman)
Ky. Fish and Wildlife Resources
Arnold L. Mitchell Bldg.
#1 Game Farm Road
Frankfort, Ky 40601
(502) 564-5448

Jerry Baskin
Dept. of Biological Sciences
University of Kentucky
Lexington, KY 40406-0225
(606) 257-8770

Donald Batch
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1818

Wayne Davis
Dept. of Biological Sciences
University of Kentucky
Lexington, KY 40406-0225
(606) 257-1828

Richard Hannan
Director, Ky. Nature Preserves Comm.
407 Broadway
Frankfort, KY 40601
(502) 564-2886

Melvin Warren Jr.
Dept. of Zoology
Southern Illinois University
Carbondale, IL 62901
(618) 536-2314

Branley A. Branson
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-2635

NOMINATING AND RESOLUTIONS COMMITTEE 1986

Rudy Prins, Chairman
Dept. of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6004

John C. Philley
Department of Physical Sciences
Morehead State University
Morehead, KY 43501
(606) 783-2913

Gerrit Kloek
Department of Biology
Kentucky State University
Frankfort, Ky 40601
(502) 227-6931

AUDIT COMMITTEE 1986

Modesto del Castillo
Department of Science
Elizabethtown Community College
Elizabethtown, KY 42701
(502) 769-2371

Alan W. Reed
P. O. Box 471
Columbia, KY 42728

Gordon Weddle, Chairman
Department of Biology
Campbellsville College
Campbellsville, KY 42718
(502) 465-8158

MEMBERSHIP COMMITTEE

Douglas L. Dahlman, Chairman
Department of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4962

Thomas C. Rambo (1987)
Department of Biology
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5305

Herbert Berry (1986)
Computer & Information Science
Morehead State University
Morehead, KY 40351
(606) 783-2749

James Murray Walker (1988)
Department of Anthropology
Eastern Kentucky University
Richmond, KY 40475-0959
(606) 622-1648 or 622-1644

COMMITTEE TO STUDY THE CONSTITUTION

J. G. Rodriguez, Chairman
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4902

Gary W. Boggess
College of Science
Murray State University
Murray, KY 42071
(502) 762-2886

Ted M. George
Department of Physics
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1521

INDEX TO VOLUME 47

Instructions for Contributions

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 X 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, body of the manuscript, acknowledgements, literature cited, tables with table headings and figure legends and figures.

1. The title page should include the title of the paper, the author's names and addresses, and any footnote material concerning credits, changes of address, and so forth.

2. The abstract should be concise and informative 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, Acknowledgements, 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 materials 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 X 7 or 8 X 10 inches. Line drawings in India ink on white paper are acceptable, but should be no larger than 8½ X 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

RANSACTIONS F THE KENTUCKY ACADEMY OF SCIENCE

Volume 48
Numbers 1–2
March 1987

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.

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 $15.00 for Active Members; $7.00 for Student Members; $20.00 for Family; $250.00 for Life Members.

Subscription rates for nonmembers are: domestic, $30.00; foreign, $30.00; 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.

EDUCATIONAL AFFILIATES

Sustaining Members

University of Kentucky

Member

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

Associate Member

Alice Lloyd College
Bellarmine College
Berea College
Campbellsville College
Centre College
Cumberland College
Georgetown College
Kentucky Wesleyan College
Lees College
Lindsey Wilson College
Spalding College
St. Catherine's College
Thomas More College

CORPORATE AFFILIATES

Alltech, Inc.
Ashland Oil
IBM

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

March 1987
Volume 48
Numbers 1–2

Trans. Ky. Acad. Sci., 48(1–2), 1987, 1–4

Flowering Requirements of *Tussilago farfara*

J. H. Melhuish, Jr.
Plant Physiologist, USDA Forest Service, Northeastern Forest Experiment Station,
Berea, Kentucky 40403

P. R. Beckjord
Research Forester, USDA-ARS, Nitrogen Fixation Soybean Genetics Laboratory,
Beltsville, Maryland 20705

and

W. G. Vogel
Range Scientist (retired), USDA Forest Service, Northeastern Forest Experiment Station,
Berea, Kentucky 40403

Abstract

Tussilago farfara L. (coltsfoot) has become naturalized and occurs on disturbed and waste places in the northeastern United States; consequently, it may have some potential in surface-mine reclamation. Seeding would be more practical and economical than planting rhizomes, but fresh seeds are only viable for about a month, interfering with planting schemes. It was determined that flowers can be uniformly generated by placing mature plants in cold storage for 3 months any time of year to ultimately generate seeds when needed for various revegetation/reclamation planting schemes.

Introduction

Tussilago farfara L. (coltsfoot), a member of the compositae and a rhizomatous herbaceous perennial native of the Old World, has become naturalized on disturbed and waste places in the northeastern United States (3). Coltsfoot's ecological niche for open, unstable habitats where surface soils are frequently deficient in nutrients, aeration, or moisture (4) are subject to the invasion of this pioneering plant where other plants fail to survive. It may be less competitive than agronomic grasses and legumes for light, space, and moisture and might be used as a low-profile companion crop for tree establishment on areas to be reforested. Coltsfoot also aids in soil erosion control.

The anatomical and physiological adaptations of coltsfoot enhance its pioneering abilities on diverse sites. Under very moist soil conditions, coltsfoot survival and growth depends primarily on rhizomes for nutrient and water uptake. On the other hand, under very dry soil conditions, adventitious roots may develop and penetrate the soil (to more than a meter deep) to obtain nutrients and water (1). When plant population densities become high, photosynthate is directed primarily toward seed production rather than vegetative production resulting in an increase in plant mortality. Coltsfoot will flower and produce seed in early spring, but seeds have a brief viability period and germination is reduced to 50 per cent or

TABLE 1. Anthocyanin and flower production of coltsfoot plants subjected to various temperature and photoperiod conditions in growth chambers.

Warm				Cold				Cold			
Short day		Long day		Short day		Long day		Even day fluorescent		Even day sodium-vapor	
Fa	16 wk	A	8 wk	Rb	12 wk	Fa	6 wk	Fa	36 wk	Fb	36 wk
		Fa	48 wk	X	22 wk	A	6 wk				
						Fb	52 wk				

Fa = flowering on vegetative stems. Fb = flowering from below ground. A = anthocyanin production. X = dormant.

less after 4 weeks from seed collection (1). This study was initiated to examine the flowering and seed-setting requirements of coltsfoot in order to determine how to maximize propagules necessary for applicable planting schemes.

MATERIALS AND METHODS

Greenhouse and Cold Room.—Four rhizomes[1], approximately 6 cm long, were planted in each of 4 flats filled with a vermiculite-peat mixture (5:1) (V/V) and grown in a greenhouse from November 1983 to September 1984 with overhead lights that extended the photoperiod to 18 hours. They were then placed in cold dark storage (4°C, 9 weeks) and subsequently moved back to the greenhouse. Two flats were placed on a greenhouse bench under overhead lighting to extend the photoperiod to 18 hours, and the other 2 flats were placed on a bench that was covered and uncovered each day with an opaque plastic sheet to simulate a short-day photoperiod of 8 hours. Additional flats of 10-month-old plants were placed in cold storage for 9, 14, and 16 weeks as a check on the cold requirement.

Greenhouse Only.—Four rhizomes were planted in each of 10 flats in February 1984. Flats were placed on a greenhouse bench with overhead lighting that extended the photoperiod to 18 hours. Five of these 10 flats were put on a greenhouse bench in June 1984 with an 8-hour photoperiod by using the plastic sheet procedure. After 8 weeks, these 5 flats were transferred back to long-day conditions by permanently removing the plastic sheet. The remaining 5 flats were on an extended 18-hour photoperiod for the entire period.

[1] Rhizomes for all experiments were denuded of most shoots, flower buds, and roots by gingerly pulling them between two fingers.

Growth Chambers.—Thirty-six 6½-inch planter pots were filled with a mixture of sand, vermiculite, and peat—5:5:1 (V/V/V). Two coltsfoot rhizomes (6 cm long) were planted in each pot. Groups of 9 pots each were placed in each of 4 growth chambers, each group in a different chamber with a different temperature and photoperiod regime. The treatments were: (1) cold × long day, (2) warm × long day, (3) cold × short day, and (4) warm × short day. The long day was an 18-hour photoperiod; the short day was an 8-hour photoperiod; the cold day was 60°C day, 40°C night and the warm day was 80°C day, 60°C night (Table 1). The growth chambers had standard fluorescent lights with supplemental incandescent lights.

Two additional growth chambers with 9 pots each were set up under cold temperature with an even-day 12-hour photoperiod (instead of 8 or 18 hours). The first chamber had standard fluorescent lights with supplemental incandescent lights. The second chamber had high-pressure sodium vapor lighting, which was on for 4 hours during the middle phase of the day length, with supplemental incandescent lighting for 12 hours. Because there was little or no growth, the cold-day temperature was raised after 6 weeks from 60°C to 70°C in the chamber with high-pressure sodium lighting.

RESULTS

Greenhouse and Cold Room.—The coltsfoot plants in all 4 flats were growing vigorously with immature flowers on extended stalks in all 4 trays when put into the cold room. Trays were removed from the cold room and put on the greenhouse bench and after 1 week, new flower buds were extending from below the ground in both long-day and short-day treatments. Of the additional flats placed in the cold room then back to the greenhouse, those that were in the cold for 9 weeks did not flower; however, after 1 week, flower buds from above and below the surface appeared in those flats taken out of the cold after 14 and 16 weeks. The apparent discrepancy in the two 9-week treatments may be that 9 weeks is about the minimum cold requirement.

Greenhouse Only.—The coltsfoot planted in flats and grown only in the greenhouse grew vigorously during the spring months. During the hot summer months, the plants showed stress, particularly those under the short-day treatment, but plants in all flats resumed their vigor during the fall. After 9 months, flowers appeared on vegetative shoots in all flats regardless of day length. During the entire experiment, anthocyanin was not usually evident on either short- or long-day plants.

Growth Chamber.—After 8 weeks in the growth chamber, one flower stalk in the cold short-day treatment and one flower stalk in the cold long-day treatment had formed from below the surface. Anthocyanin was also prevalent in both cold and warm long-day treated plants. There was some discoloration of the lower leaves of the warm short-day treated plants. After 12 weeks, several flower stalks emerged from below the soil media surface under cold short days; and in 16 weeks, flower buds formed on top of vegetative shoots and flowered in cold long-day treated plants and in warm short-day treated plants. At about 22 weeks, the cold short-day treated plants became moribund and went dormant. Flower buds on vegetative shoots formed in about 48 weeks under the warm long-day treatment (Table 1).

A few flower buds emerged from below the surface under the cold 12-hour day treatment after about 8 weeks, and leaves developed 3 weeks later. Flower buds sprouted from below the soil surface at about 36 weeks in the chamber with high-pressure sodium vapor lighting, but developed on top of vegetative shoots under the fluorescent lighting (Table 1).

DISCUSSION

In the greenhouse and cold room tests, flower buds formed in the leaf axils of coltsfoot in late summer and flowered the following spring. A cold temperature of no more than 9 to 14 weeks is apparently the only requirement for breaking bud dormancy. Coltsfoot can also form flower buds on top of vegetative shoots in about 40 weeks when grown in the greenhouse with an 18-hour-day length. This may be a secondary requirement for flowering to ensure reproduction.

In the growth chambers, a few flowers in the cold short-day and 1 flower in the cold long-day treatments emerged from below the soil surface. These flowers may have come from leaf axils not completely broken off the rhizome, and dormancy was broken by the cold temperature. The time requirement of 40 weeks for flower buds to develop on top of the vegetative shoots in the greenhouse can be shortened to about 16 weeks by either short days or cold temperatures. The production of anthocyanin in the leaves of only the long-day plants indicated the plant response to photoperiod. The plants growing under cold short-day conditions went dormant after about 22 weeks. They started to leaf out after about 33 weeks when the chamber failed.

Under the 12-hour-day cold treatment, flower buds formed after 36 weeks on top of vegetative shoots. Since no anthocyanin was produced, the long-day response was probably not stimulated; this may answer why the elapsed time of 36 weeks was similar to that of the response of the greenhouse plants.

The establishment of vegetation on drastically disturbed sites such as surface mines is influenced by organic material and soil mixture (2). The range of soil types and consequently level of soil moisture varies widely from site to site (5). Many of the plants currently used in revegetating disturbed sites are very vigorous but hinder tree growth because of competition for light, water, and nutrients. Coltsfoot is a low profile, intolerant pioneering plant that grows on wet or dry sites, provides erosion control, intercepts rain, has low requirements for nutrients, and produces leaf biomass. Investigation of coltsfoot for its potential usefulness as a nurse crop may be beneficial to reforestation programs on some drastically disturbed lands. Coltsfoot seed would be easier and more economical to use than rhizomes in planting schemes. One way of culturally producing seed is to grow plants in the greenhouse under long-day conditions for maximum growth and then put the plants in a cold room to be brought out at the appropriate time. Further studies would now be justified to determine the optimum conditions for producing viable seed from these flowers.

LITERATURE CITED

1. Bakker, D. 1960. A comparative life-history study of *Cirsium arvense* (L.) Scop. and *Tussilago farfara* L., the most troublesome weeds in the newly reclaimed polders of the former Zuiderzee. Pp. 205–222. In J. L. Harper (ed.) The biology of weeds. Blackwell Scientific Publications, Oxford, England.

2. Brenner, Fred J. and Connie Goughler. 1983. Role of nurse, cover crops in encouraging establishment of natives on reclaimed land: an evaluation (Pennsylvania). Restoration and Management Notes 1:31–32.

3. Gleason, Henry A. and Arthur Cronquist. 1963. Manual of vascular plants of northeastern United States and adjacent Canada. D. Van Nostrand Company, Inc., Princeton, New Jersey.

4. Ogden, John. 1974. The reproductive strategy of higher plants. II. The reproductive strategy of *Tussilago farfara* L. J. Ecol. 62:291–324.

5. Vogel, Willis G. 1977. Revegetation of surface-mined lands in the East. Pp. 167–172. In Proceedings, 1977 Annual Meeting of the Society of American Foresters, 2–5 October 1977, Albuquerque, New Mexico. Society of American Foresters, Washington, D.C.

Trans. Ky. Acad. Sci., 48(1–2), 1987, 5–10

Commuting Patterns Among Female Workers in Nonmetropolitan Manufacturing

ROBERT G. CROMLEY

Department of Geography, University of Connecticut, Storrs, Connecticut 06268

AND

ROBERT H. WEBSTER

Department of Geography, University of Kentucky, Lexington, Kentucky 40506

ABSTRACT

The recent movement of industry to nonmetropolitan America has increased the workforce participation rates for women. As production becomes standardized, companies have located in small towns where cheaper labor supplies are available. Because an unskilled and semi-skilled labor force is more important, availability of female workers is more attractive to employees. However, female workers in rural areas have distinctively different journey-to-work patterns than their metropolitan counterpart. Among a sample of nonmetropolitan industrial workers in Kentucky, no significant difference was found between male and female workers in journey-to-work patterns. More importantly, women workers in female-dominated and low-wage industries had a greater tendency to commute than either males in the same industry groups or workers in male-dominated and high-wage industry groups. The journey to work for women in nonmetropolitan areas is less likely to be a function of income but rather the distribution of job opportunities.

INTRODUCTION

As a larger percentage of women have entered the industrial labor force, there has been a growing interest in the problems that women encounter with respect to their work and home environment and its impact on family relationships. Recent research has been examining the relationship between female job opportunities and the journey to work. Most of these studies, however, reflect a strictly metropolitan perspective. It should not be assumed that the activity patterns of female workers in a metropolitan setting will directly transfer in a nonmetropolitan setting. Clemente and Summer suggest that in general models of metropolitan commuting are not necessarily applicable in nonmetropolitan regions (1, 2). The purpose here is to examine the commuting patterns for female industrial workers in a nonmetropolitan region. The results are compared with the patterns for male workers in the same region and findings for metropolitan regions to provide a better understanding of the female journey to work.

The expansion of economic activity in nonmetropolitan areas since the 1960s is now being well documented. An important facet of rural economic development has been the decentralization of manufacturing (3). Although the long term impacts that this phenomenon will have on rural community life are uncertain, numerous researchers are investigating the changes in the rural landscape that may be attributable to increased manufacturing in small towns (4, 5). The growth of nonmetropolitan manufacturing has been credited as a significant factor in the rural population turnaround that has occurred since 1970 (6, 7). By providing more job opportunities in the rural periphery, manufacturing has slowed the rate of out-migration from these areas and nonmetropolitan counties are experiencing positive net migration after decades of negative rates.

The rural economic revival has also meant more job opportunities for female workers. Several authors have characterized the spatial redistribution of manufacturing as a response to changes in the critical input requirements of a product (8, 9, 10). As every product undergoes its life-cycle and production becomes standardized, the price of labor in metropolitan areas may force a company to locate its production facilities in smaller towns where cheaper labor supplies are available. The result has been the establishment of a branch econ-

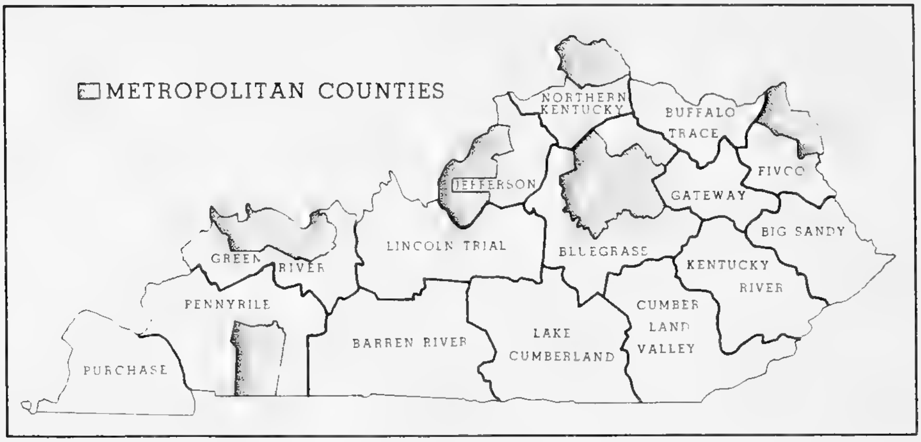


FIG. 1. Nonmetropolitan portion of area development districts.

omy in many nonmetropolitan communities (9, 10). A corollary to the product-cycle model is a greater participation rate by women in the labor force of those industries that have entered the mature phase of development. When unskilled and semi-skilled labor become important inputs in the production process, an available female work force is more appealing to employers.

These two facets of the evolving nonmetropolitan landscape, the increased importance of manufacturing employment and the increased participation of females in the work force, suggest that a significant number of women in rural areas are commuting to work. Several metropolitan studies have reported that work patterns for women differ from those of men (11, 12). Women are less likely to commute than men and those that do travel shorter distances to work. There is also a higher tendency among women to use urban transit systems in their journey to work. The general explanations for these patterns refer to the home responsibilities of women and the fact that monetary cost of commuting would consume a larger proportion of their wages (13). This is especially the case when the woman is a secondary wage earner and has a lower income than that of the primary income earner.

It is another matter, though, whether these patterns are relevant for nonmetropolitan communities where most often there are no mass transit systems and the range of local female job opportunities is frequently restricted. This study examines this situation by analyzing the journey to work patterns of women among a sample of industrial workers in nonmetropolitan Kentucky. Male commuting patterns are presented for benchmark comparisons. Three hypotheses are tested regarding female participation in nonmetropolitan manufacturing: (1) that branch plants have significantly increased job opportunities for women; (2) that women do not necessarily commute less than men; and (3) women in low-wage industries do not commute less than women in other industries.

MATERIALS AND METHODS

The nonmetropolitan portion of the 15 Area Development Districts (ADDs) in the state of Kentucky comprise the region for analysis (Fig. 1). The nonmetropolitan portion is defined as those counties that are not part of a Standard Metropolitan Statistical Areas (SMSA). Not unlike other nonmetropolitan areas across the United States, nonmetropolitan Kentucky has experienced rapid growth in its manufacturing sector over the last 2 decades although the rate of growth has declined dramatically during the 1970s. The percentage increase in manufacturing employment since 1960 has been significantly higher in the nonmetropolitan region than for the state as a whole (Table 1). A substantial proportion of this growth in nonmetropolitan manufacturing employment has resulted from an increase in branch plant activity. Cromley and Leinbach report that since

TABLE 1. Growth in manufacturing employment, 1960–1978.[a]

	1960	1970	1980	1960–1980 (% change)
State of Kentucky	198,160	278,827	292,495	47.6%
Nonmetropolitan Kentucky (as a percentage of total manufacturing employment)	36.1%	41.8%	43.2%	76.4%[b]

[a] Manufacturing data for 1960 and 1970 were compiled using *Census of Population: Characteristics of the Population, Kentucky*. The *1980 Kentucky Directory of Manufacturers* was used to compile the 1980 figures for nonmetropolitan Kentucky

[b] Significantly higher at the 0.05 level (one-tail test)

1960 branch employment increased from 60 per cent of the total nonmetro manufacturing employment to 79 per cent by 1980 (9).

Furthermore, increased manufacturing employment has been concurrent with increased female participation in the work force. Between 1960 and 1980, female manufacturing employment increased nearly 112 per cent in nonmetropolitan areas as compared to only 65 per cent for the state as a whole (Table 2). The importance of a female work force to branch plant activity is reflected in the fact that women comprised a significantly higher portion of their labor force; nearly 46 per cent of the branch plant work force in 1980 was female as compared to only 39 per cent of the indigenous firms' total labor force. This supports the hypothesis that the product-cycle of manufacturing has increased the role of women in the nonmetropolitan work force.

To analyze the commuting pattern of these women workers, a questionnaire was mailed to each of the 1,371 manufacturing firms located in nonmetropolitan Kentucky requesting the county of residence of its male and female employees. A total of 720 firms returned the questionnaire although 6 firms did not differentiate between their male and female employees. This sample was representative of the total population for both branch and indigenous firms with respect to both firm size and industrial classification (14). The remaining 714 firms produced a sample size of 53,356 workers or 42 per cent of the total number of manufacturing employees in the region. Males comprised 57 per cent of the sample while females accounted for 43 per cent, roughly the same percentages as for the region as a whole.

RESULTS AND DISCUSSION

The journey-to-work patterns of women in this nonmetropolitan setting were aggregated into two groups: 1) those workers who live and work in the same county, and 2) those who commute from a county removed from the place of employment. The journey-to-work patterns for male and female industrial workers were not significantly different for the study area as a whole (Table 3). Roughly 27 per cent of all females commuted to a nonmetro firm from another county while just over 29 per cent of the male workers did the same. This indicates that one sex is not necessarily travelling farther than the other for work. This

TABLE 2. Female manufacturing employment.[a]

	1960	1970	1980	1960–1980 (% change)
State of Kentucky (as a percentage of total manufacturing employment)	27.0%	30.9%	40.6%	65.4%
Nonmetropolitan Kentucky (as a percentage of total nonmetropolitan manufacturing employment)	33.8%	38.7%	44.0%	111.8%[b]
Branch employment (females as a percentage of total workers)			45.6%[b]	
Indigenous employment (females as a percentage of total workers)			39.0%	

[a] Manufacturing data for 1960 and 1970 were compiled using *Census of Population: Characteristics of the Population, Kentucky*. The *1980 Kentucky Directory of Manufacturers* was used to compile the 1980 figures for nonmetropolitan Kentucky.

[b] Significantly higher at the 0.05 level (one-tail test).

TABLE 3. The degree of commuting by sex.[a]

Area development district	Work and reside in same county			
	Female		Male	
	No.	%	No.	%
Total study area	16,245	(72.57)	21,753	(70.26)
Purchase	772	(67.90)	2,896	(56.26)[b]
Pennyrile	1,234	(68.94)[c]	1,772	(75.44)
Green River	526	(68.31)	589	(62.32)[b]
Barren River	1,805	(85.71)	3,045	(81.90)
Lincoln Trail	1,861	(80.39)	2,960	(72.25)[b]
KIPDA	288	(84.70)	326	(61.98)[b]
Northern Kentucky	592	(70.56)	729	(58.46)[b]
Bluegrass	3,005	(74.25)	3,111	(70.21)
Lake Cumberland	3,309	(67.21)[c]	3,114	(84.92)
Buffalo Trace	367	(93.15)	382[b]	(69.33)
Gateway	343	(61.69)	589	(60.60)
FIVCO	194	(85.46)	125	(93.98)
Big Sandy	209	(73.07)[c]	459	(80.10)
Kentucky River	50	(89.28)	148	(84.57)
Cumberland Valley	1,690	(65.00)	1,508	(62.08)

[a] Compiled by authors
[b] Male commuting significantly higher at the 0.05 level (one-tail test)
[c] Female commuting significantly higher at the 0.05 level (one-tail test)

aggregate pattern does not support the metropolitan differences found in work travel for both sexes.

This statewide pattern masks a large amount of local variations in the journey to work for both men and women. Historically, the western or non-Appalachian portion of the state has had a more diversified manufacturing base than its eastern, Appalachian counterpart. During the 1960s, the western part of the state experienced a major increase in nonmetropolitan manufacturing, while the eastern portion grew faster in manufacturing during the 1970s (15). The western portion today has a much higher proportion of the total amount of nonmetropolitan manufacturing jobs in Kentucky, while the eastern region is still dominated by mining in many of the counties. The western counties also have a higher percentage of manufacturing jobs associated with branch plants while the eastern counties have stronger local firms. Overall, manufacturing opportunities are more frequent in the west than in the eastern part of the state.

To analyze commuting patterns at a more local level, the 15 ADDs in Kentucky were used as the basis of observation. The labor sheds for 5 of the 15 districts were the same as the statewide pattern since the percentages of male and female commuters were not significantly different; these districts were Barren River, Bluegrass, Gateway, Kentucky River, and Cumberland Valley AADs (Table 3). Barren River and Kentucky River also had a significantly lower number of female commuters than the state as a whole while Gateway and Lake Cumberland had a significantly higher percentage of women commuters than the statewide average.

In 6 districts, a significantly higher percentage of the male industrial workers commuted from another county than their female counterparts. These 6 districts—Purchase, Green River, Lincoln Trail, KIPDA, Northern Kentucky, and Buffalo Trace—are all situated along the Ohio River. Among these 6 districts, female commuting percentages were significantly below the state average in the Lincoln Trail and KIPDA districts and significantly above average in the Purchase and Green River districts.

Finally, in 4 of the districts a significantly higher percentage of the female workforce commuted from another county; these were the Pennyrile, Lake Cumberland, FIVCO and Big Sandy. In the Pennyrile and Lake Cumberland districts, the female percentages were above the state average while in the FIVCO ADD the percentage was below the state figure.

Overall, women industrial workers in the eastern districts tended to commute more than their counterparts in the western districts reflecting in part the lack of job opportunities in

TABLE 4. Commuting by sex for female-dominated and male-dominated industries.[a]

	Work and reside in same county	
	No.	%
Female-dominated industries[b]		
Females	6,968[c]	(70.10)
Males	1,949	(79.32)
Male-dominated industries[c]		
Females	3,714	(78.12)
Males	13,039	(70.82)

[a] Compiled by authors

[b] Those industries in which females comprise at least 70 per cent of the work force. In this study those industries are apparel (87.2%), textiles (72.2%), and miscellaneous manufacturing (73.8%)

[c] Those industries in which males comprise at least 70 per cent of the work force. In this study those industries are lumber (92.6%), tobacco (91.8%), primary metals (89.0%), transportation equipment (84.7%), chemicals (83.5%), petroleum refining (81.8%), stone, clay, and glass (76.1%), food (73.2%), furniture (70.8%), and nonelectrical machinery (70.6%)

TABLE 5. Commuting by sex for low-wage and high-wage industries.[a]

	Work and reside in same county	
	No.	%
Low-wage industries[b]		
Females	7,887	(71.50)
Males	3,242	(78.21)
High-wage industries[c]		
Females	343	(78.31)
Males	1,915	(66.19)

[a] Compiled by the author

[b] In this study textiles, apparel, furniture, and lumber are identified as low-wage industries based on the average hourly wage for each industry group

[c] In this study petroleum refining, primary metals, and transportation equipment are identified as high-wage industries based on the average hourly wage for each industry group.

the eastern counties. Those areas in the east that did not have higher than expected levels of female commuting were dominated more by indigenous firms and mining operations. An earlier study found that workers tended to commute less among indigenous manufacturing firms than they did among branch plants (14). Finally, male/female differences also seem to be a function of the distribution of manufacturing jobs. The industries of the districts located along the Ohio River are more male oriented as many metalurgical and chemical companies have been attracted to this area. To examine this relationship fully it is necessary to examine commuting patterns among various industry types.

As previously discussed, several explanations are given for the shorter work trip of women in a metropolitan setting. The most common are (1) women tend to choose jobs closer to their residences because they value their commuting time differently than men; (2) they have less accessibility to private transportation; (3) their job provides secondary rather than primary income for a family; and, (4) they tend to work in low-wage industries thereby reducing the net-monetary benefit of employment if long distance commuting is necessary. Due to the constraints of the data set, the first 3 explanations cannot be examined here although some form of private transportation is the only option in most nonmetropolitan areas. If the fourth explanation holds true for women in a nonmetropolitan setting, then women in low-wage industries should commute less than their fellow workers in high-wage industries. In the last section, it was mentioned that more men commute from another county than women in those districts along the Ohio River because many male-dominated industries were located there. It is expected that women in a female dominated industry group will commute less than men and women in the male-dominated industry group. A female-dominated industry is defined here as one in which 70 per cent or more of its workers are women; likewise, a male-dominated industry is one in which men comprise at least 70 per cent of its work force.

As expected, there is a significant difference among women in a female-dominated industry and male-dominated industries (Table 4); however, women in the female-dominated industry group not only show a greater tendency to commute than males, they also show a greater tendency to commute than their female counterparts in the male-dominated industries (Table 5).

With respect to wage levels, women in the low-wage industry group once again not only had a greater tendency to commute than males in similar industries, they also show a greater tendency to commute than females in the high-wage industries. In this nonmetropolitan area, commuting patterns for women are contrary to expected results although the men follow the metropolitan pattern. Again, the availability of jobs is probably more of a factor in nonmetropolitan regions. Firms moving into nonmetro areas are seeking sites that have available pools of unskilled labor. The lack of competition from other firms in the area means that the female workers of these low-wage industries must travel longer distances in their journey to work.

SUMMARY

It is clear that the nonmetropolitan industrialization phenomenon has had a major impact on the social and economic life of nonmetropolitan America. One aspect that has not received attention in the literature has been nonmetro industrialization's impact on female participation in the industrial work force. This paper has shown that the filtering of industry to rural areas has increased the job opportunities for women in nonmetropolitan areas. However, unlike women in metropolitan areas, these nonmetropolitan workers have distinctive journey-to-work patterns.

The results of this study imply that the differentials in the commuting patterns of male and female industrial workers in a nonmetropolitan study are not the same as those in recent metropolitan investigations. As shown here, females are not restricted to shorter work trips among nonmetropolitan industrial workers in Kentucky and there is no significant difference in the journey-to-work patterns of males and females. Although hidden in the aggregate sample, important regional and industrial variations were identified. Women were more likely to commute in the less industrialized eastern regions of the state reflecting in part the lack of closer intervening opportunities in these areas. However, the most significant finding indicates that females in female-dominated and low-wage industries have a greater tendency to commute than males in those same industry groups and other females in male-dominated and high-wage industry groups.

Although this study has shown that nonmetropolitan commuting patterns among female are significantly different from metropolitan patterns, it does not fully explain why or how women are making the journey to work. More research is needed regarding the significance of women's contribution to total,family income and their relationship to the head of household. Is a woman's income more critical in nonmetro areas than in a nonmetropolitan setting? Secondly, how are women getting to work in a rural setting where private vehicles are the only mode of transportation? As the role of women in the work force continues to increase it is essential that we have a better understanding of their problems and patterns.

ACKNOWLEDGMENTS

The authors wish to thank John Diniz for preparation of all graphics.

LITERATURE CITED

1. Clemente, F. and G. F. Summers. 1975. The journey to work and rural industrial employees. Soc. Forces 54:212–219.

2. Wilson, F. D. 1975. Journey to work: metropolitan-nonmetropolitan comparisons. Discussion Paper 327-75, University of Wisconsin Institute for Research on Poverty, Madison, Wisconsin.

3. Summers, et al. 1976. Industrial invasion of nonmetropolitan America. Praeger Publishers, Inc., New York.

4. Fisher, J. S. and R. L. Mitchelson. 1981. Forces of change in the American settlement pattern. Geo. Rev. 71: 298–310.

5. Garrison, C. B. 1967. Economic impact of new industry on small towns. Unpubl. Doctoral Dissertation. University of Kentucky, Lexington.

6. Lonsdale, R. E. 1981. Industry's role in nonmetropolitan economic development and population change. In C. C. Roseman, J. J. Sofranko, and J. D. Williams (eds.) Population redistribution in the Midwest. Iowa State University, Ames, Iowa.

7. Wardwell, J. M. 1981. The reversal of nonmetropolitan migration loss. In D. A. Dillman and D. J. Hobbs (eds.) Rural society in the U.S.: issues for the 1980s. Westview Press, Boulder, Colorado.

8. Erickson, R. A. and T. R. Leinbach. 1979. Characteristics of branch plants attracted to nonmetropolitan areas. In R. E. Lonsdale and H. L. Seyler (eds.) Nonmetropolitan industrialization. Halstead Press, New York.

9. Cromley, R. G. and T. R. Leinbach. 1981. The pattern and impact of the filter down process in nonmetropolitan Kentucky. Econ. Geo. 57:208–224.

10. Park, S. O. and J. Wheeler. 1983. The filtering down process in Georgia: the third stage in the product life cycle. Prof. Geo. 35:18–31.

11. Andrews, H. F. 1978. Journey to work considerations in the labor force participation of married women. Regional Studies 12:16–20.

12. Ericksen, J. A. 1977. An analysis of the journey to work for women. Soc. Prob. 24:428–435.

13. Madden, J. F. and M. J. White. 1980. Spatial implications of increases in the female labor force: a theoretical and erupisical synthesis. Land Econ. 561:432–445.

14. Cromley, R. G. and R. H. Webster. 1983. Differences in the commuting fields of beach plants and indigenous industrial activity. Southeastern Geo. 23:15.

15. Leinbach, T. R. and R. G. Cromley. 1982. Appalachian Kentucky: the role of manufacturing in micropolitan development. Growth and Change 13:11–20.

Trans. Ky. Acad. Sci., 48(1–2), 1987, 11–19

Keys to the Aquatic Gastropoda Known from Kentucky

Branley Allan Branson

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

Diagnostic keys to the species of aquatic gastropods known from Kentucky are presented. Most species are illustrated. Some species from peripheral areas are included.

Introduction

In various environmental impact statements and many biological surveys of Kentucky waters, one group of organisms is practically always covered in a very cursory manner or omitted altogether. The aquatic snails form one of the most conspicuous and diverse groups of benthic organisms in the state. The most apparent reason for this hiatus in knowledge is the lack of easily available literature on the gastropod fauna, particularly the lack of identification guides. Other than the two checklists (1, 2), most of the literature is quite old and widely scattered.

The purpose of this contribution is to provide a set of keys designed specifically for the identification of the species of aquatic gastropods known to live in Kentucky (some of the keys include species which should be here but which have not been reported) and to summarize briefly the taxonomic changes that have been published during the last several years.

Taylor (3) excluded the genus *Antroselates* and its only known species, *A. spiralis*, described by Hubricht (4) from Kentucky cave waters, from the family Hydrobiidae, suggesting that the snail was probably an American representative of the family Micromelaniidae. *Somatogyrus integer* (Say) is synonymous with *S. subglobous* (Say) (5). The specimens reported from Kentucky as *Lioplax sulcosa* Menke are *L. subcarinata occidentalis* Pilsbry.

Some additional important taxonomic findings include the following. Hubendick (6) combined the families Ancylidae and Planorbidae, erected the new familial designation Ancyloplanorbidae, and fused several genera. *Planorbula* now includes *Menetus* and *Promenetus*, and the genus *Gyraulus* includes *Armiger*. This arrangement is followed here, although Burch (7) retained *Menetus* and *Promenetus* as separate genera. Finally, most American gastropod experts continue to separate the Pleuroceridae from the principally Asian Thiaridae, even though the two groups are virtually indistinguishable, as pointed out many years ago by Wenz (8) and Hyman (9). If this logic is followed, the name Thiaridae would have priority. However, to avoid confusion this author follows Burch (7) in retaining the very familiar name Pleuroceridae.

Key to Families of Kentucky Aquatic Snails

1a. Shell with an operculum 2
b. Shell lacking an operculum 5
2a. Operculum concentric (*Lioplax* has a spiral nuclear portion) . . Viviparidae . . . Key A
b. Operculum spiral 3
3a. Operculum circular with many spirals; shell less than 7 mm in diameter; gill external .... Valvatidae . . . Key B
b. Operculum not circular, usually with few spirals; gill internal 4
4a. Shell less than 10 mm long, usually thin .... Hydrobiidae . . . Key C
b. Shell more than 15 mm long, usually thick, heavy .... Pleuroceridae . . . Key D
5a. Shell sinistral and spiraled .... Physidae . . . Key E
b. Shell dextral and spiraled, hat-like, or flatly coiled in one plane 6
6a. Shell dextral and spiraled .... Lymnaeidae . . . Key F
b. Shell hat-like or flatly coiled in one plane .... Ancyloplanorbidae . . . 7
7a. Shell hat-like . . ancyliform snails . . . Key G
b. Shell coiled flatly in one plane .... planorbiform snails . . . Key H

Key A: Kentucky Viviparidae

1a. Shell globose, thin, 30 or more mm in length; epidermis sometimes banded; operculum wholly concentric 2
b. Shell turreted, thick, less than 30 mm in

length; epidermis never banded; operculum variable 3

2a. Adult shell 35 mm to over 50 mm in length; whorls not shouldered; epidermis never banded (introduced) . . . . *Cipangopaludina chinensis malleata* (Figs. 1, 2)

b. Adult shell usually less than 35 mm but usually greater than 30 mm; whorls shouldered; epidermis sometimes banded . . . . *Viviparus* . . . 4

3a. Early whorls of spire striate or keeled; nuclear part of operculum spiral, the rest concentric . . . . *Lioplax subcarinata* (Fig. 3)

b. Early whorls of spire smooth; operculum wholly concentric . . . . . . *Campeloma* . . . 6

4a. Shell with 4 revolving bands . . . . *Viviparus gorgianus* (Fig. 4)

b. Shell lacking bands 5

5a. Shell umbilicate, thin, with short spire and convex whorls . . . . *Viviparus intertextus* (Fig. 5)

b. Shell imperforate, thick, with everted spire and flatly rounded whorls . . . . *Viviparus subpurpureus*[1]

6a. Shell rather thin and fragile; radula with central tooth higher than wide; spire usually eroded (now includes *C. integrum*) . . . . *Campeloma decisum* (Fig. 6)

b. Shell solid, thick; radula with central tooth as wide as or wider than high; spire usually nearly to completely entire 7

7a. Spire equal to or shorter than aperture; shell white beneath epidermis . . . . *Campeloma crassula* (Fig. 7)

b. Spire longer than aperture; shell pinkish or pinkish-white beneath epidermis . . . . *Campeloma rufum*

KEY B: VALVATIDAE POSSIBLY IN KENTUCKY

1a. Shell lacking keels on whorls 2

b. Shell with keels on whorls 3

2a. Shell with 3 carinae, upper, middle, and lower; spire elevated above other whorls . . . . *Valvata tricarinata* (Fig. 8)

b. Shell with 2 carinae; spire depressed below other whorls . . . . *Valvata bicarinata*

3a. Umbilicus narrow and deep, well-like; whorls regularly enlarging; spire elevated . . . . *Valvata sincera*

b. Umbilicus wide and shallow; whorls rapidly enlarging to body whorl; spire depressed (doubtful occurrence) . . . *Valvata lewisi*

[1] Not reported from Kentucky but can be expected from waters in Purchase Area.

KEY C: KENTUCKY HYDROBIIDAE AND POMATIOPSIDAE

1a. Shell white; animal colorless and blind; basal dentacles lacking on central radular teeth; a cave species . . *Antroselates spiralis*

b. Shell with some coloration; animal with pigments and eyes; basal dentacles present on central radular teeth; surface dwellers 2

2a. Shell an elongated, slender cone (5–10 mm); foot divided by a vertical groove; amphibious . . . . (Pomatiopsidae) . . . *Pomatiopsis* . . . 6

b. Shell short or elongate-globose; foot not divided; aquatic 3

3a. Shell with nuclear (embryonic) whorl elevated above others 4

b. Shell with nuclear whorl sunken below others . . . . *Amnicola emarginata*

4a. Whorls increasing gradually in size; size small (5 mm) . . . . *Amnicola integer*

b. Body whorl very large; size larger (5.5–9 mm) 5

5a. Size larger (9 mm) . . . . *Somatogyrus subglobosus* (Fig. 10)

b. Size smaller (5.5 mm or less) . . . . *Amnicola cincinnatiensis* (Fig. 9)

6a. Aperture circular; whorls very inflated and convex . . . . *Pomatiopsis cincinnatiensis*

b. Aperture oval; whorls less inflated, flattened . . . . . *Pomatiopsis lapidaria* (Fig. 11)

KEY D: KENTUCKY PLEUROCERIDAE[2] (And Genera Elsewhere)

1a. Aperture drawn down into an obvious canal; columella twisted 2

b. Aperture angled or rounded, not canaliculate; columella not twisted 4

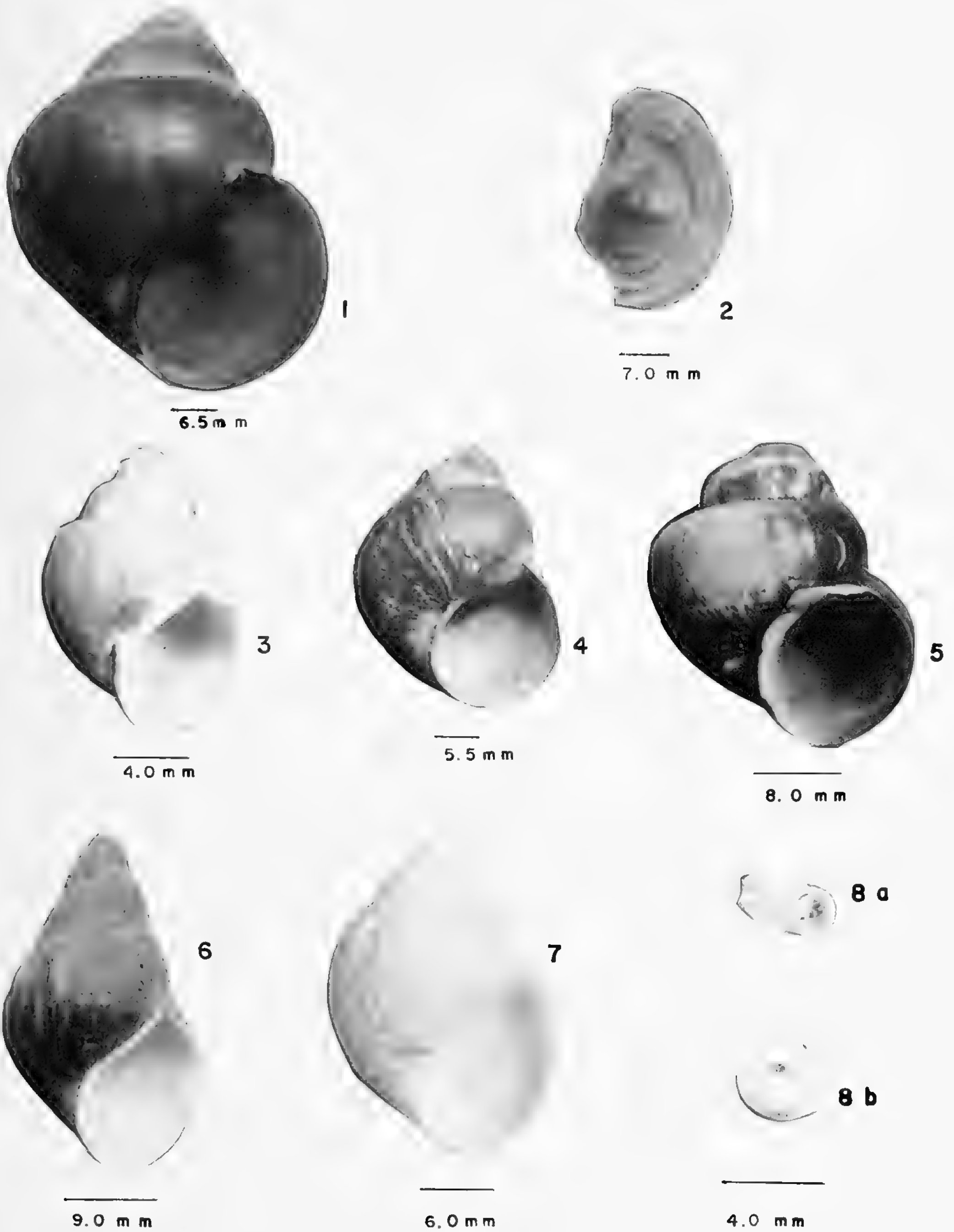
2a. Shell spindle shaped and inflated; large nodules or spines on periphery; no nacre on columella; canal nearly as long as spire; restricted to the upper Tennessee River in Tennessee . . . . *Io*

b. Shell conical or ovoid; nodules or spines low; canal much shorter than spire; columella with some nacre 3

3a. Shell elongate-ovoid to conical, the height much greater than width; columella thickened above but not below; nodules when present very low . . . . *Pleurocera* . . . 8

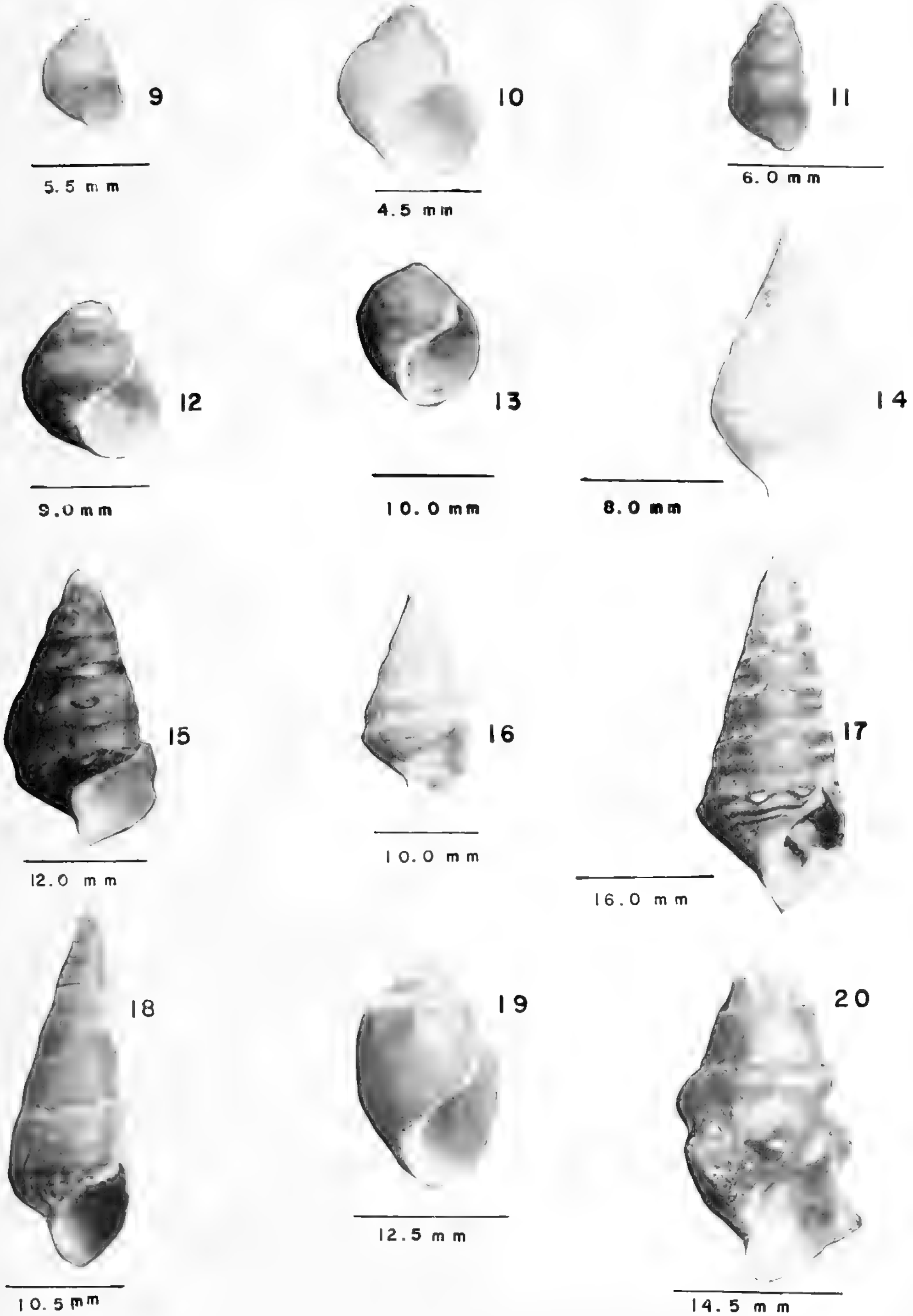
b. Shell oval, turban-shaped, or fusiform, smooth or with a series of nodules on upper portion of body whorl; columella thickened above and below . . . *Lithasia* . . . 12

[2] Generic names in parentheses are the ones used by Burch (1982).



FIGS. 1–8. 1, 2. *Cipangopaludina chinensis malleata*. 3. *Lioplax subcarinata*. 4. *Viviparus gorgianus*. 5. *Viviparus intertextus*. 6. *Campeloma decisum*. 7. *Campeloma crassula*. 8. *Valvata tricarinata*.

4a. Aperture with a deep notch above between the lip and body whorl; restricted to the Alabama River system .... *Gyrotoma*
b. Aperture without a notch above 5
5a. Shell obovate, heavy, angled at periphery with nodules and short spire; aperture ear-shaped; columella truncate; 2 species restricted to the French Broad, Powell and Clinch rivers, Tennessee .... *Eurycaelon*
b. Shell oval, elongate-oval, or turreted; aperture angled below or rounded 6
6a. Aperture angled below, entire above .. .. *Goniobasis* ... 17
b. Aperture entire, rounded in front 7
7a. Central denticles of radular teeth degenerate; laterals cleaver-like; shell globose and 20 mm or more in length .... *Anculosa (Leptoxis) praerosa* (Fig. 12)
b. Central denticles of radular teeth not degenerate; laterals not cleaver-like; shell subglobose and 15 mm or less in length ..... *Nitocris (Leptoxis) trilineata* (Fig. 13)
8a. Canal bent backward; shells mostly ovate to ovate-conical and relatively small (25–30 mm); with or without darker bands; lacking nodules and sulci .... *Pleurocera (Lithasia) curta* (Fig. 14)
b. Canal not bent backward; shells generally elongate-conical; usually nodulose or sulcate 9
9a. Shells with tubercles on body whorl and sometimes next whorls above as well 10
b. Shells sulcate to nearly smooth 11
10a. Shell short, its width about half the length; body whorl angled with a row of tubercles along the angle ....*Pleurocera (Pleurocera) alveare* (Fig. 15)
b. Shell elongate and large, its width much less than half the length; body whorl crenulate and sometimes nodulose .... *Pleurocera (Pleurocera) canaliculatum undulatum* (Fig. 16)
11a. Lower whorls with low, obtuse carinae which produce a sulcus; lip of aperture undulated by sulcus .... *Pleurocera (Pleurocera) canaliculatum* (Fig. 17)
b. Lower whorls nearly smooth, lacking distinct carinae; lip of aperture not undulated .... *Pleurocera (Pleurocera) acuta* (Fig. 18)
12a. Shell with a row of nodules on the periphery of the body whorl 13
b. Shell with nodules on upper portion of the body whorl or lacking 16
13a. Body whorl with a crown-like row of tubercles (sometimes a lower one also that parallels the upper one) 14
b. Body whorl with a central row of tubercles or numerous ones in parallel rows ...15
14a. Body whorl with a single row of tubercles; distinctly shouldered .... *Lithasia (Lithasia) geniculata* (Fig. 19)
b. Body whorl generally with a series of nodules on the shoulder and 2 series of smaller ones below ...*Lithasia (Lithasia) salebrosia*
15a. Body whorl with a central row of tubercles ....*Lithasia (Lithasia) armigera* (Fig. 20)
b. Body whorl with numerous tubercles in parallel rows .... *Lithasia (Lithasia) verrucosa* (Fig. 21)
16a. Shell large (30 to 35 mm), inflated, ovate, with plicae on whorls ....*Lithasia (Leptoxis) plicata*
b. Shell smaller (25 mm or less), compactly ovoid, without plicae .... *Lithasia (Lithasia) obovata* (Fig. 22)
17a. Shell with longitudinal plicae on lower whorls 18
b. Shell lacking longitudinal plicae on lower whorls 21
18a. In small tributary streams of the Upper Cumberland River .... *Goniobasis (Elimia) plicata-striata* (Fig. 23)
b. Not in small streams of the Cumberland River 19
19a. Body whorl smooth except near sutures; Green-Barren river system .... *Goniobasis (Elimia) curreyana* (Fig. 24)
b. Body whorl with plicae extending at least half-way down 20
20a. Lower half of body whorl smooth; base color pale yellow to horn; usually spirally striate (sometimes smooth); often with distinct bands; Green, Barren, and parts of the Cumberland River system .... *Goniobasis (Elimia) laqueata* (Fig. 25)
b. Lower half of body whorl with plicae; base color dark-horn to brownish; spiral striae strongly raised; usually without bands; tributaries of the Ohio River adjacent to Illinois .... *Goniobasis (Elimia) costifera* (Fig. 26)
21a. Upper whorls without carinae on periphery of whorls; shell obtusely conical, smooth; spire relatively short; aperture often with purplish tinge within; Cumberland River system .... *Goniobasis (Elimia) ebenum* (Fig. 27)
b. Upper whorls with sharp carinae on periphery; shell conical; spire elongated; aperture whitish within; common in Licking, Salt and Kentucky rivers; less common in Salt, parts of Green and western Kentucky streams ....



FIGS. 9–20. 9. *Amnicola cincinnatiensis*. 10. *Somatogyrus subglobosus*. 11. *Pomatiopsis lapidaria*. 12. *Anculosa praerosa*. 13. *Nitocris trilineata*. 14. *Pleurocera curta*. 15. *Pleurocera alveare*. 16. *Pleurocera canaliculatum undulatum*. 17. *Pleurocera canaliculatum canaliculatum*. 18. *Pleurocera acuta*. 19. *Lithasia geniculata*. 20. *Lithasia armigera*.

.... *Goniobasis (Elimia) semicarinata* (Fig. 28)

KEY E: TENTATIVE KEY TO KENTUCKY SPECIES OF *PHYSA*[3]

1. Shell rather thin, large (15 to 21 mm long); columella twisted and bearing a ridge or plait; penis sheath constricted near the middle, divided into two parts 2
b. Shell thicker, small (usually 13 mm or less in length); columella smooth, lacking a ridge or plait (usually); penis not divided into two parts ..... *Physa integra* (Fig. 29)
2a. Shell wide, the body whorl inflated; aperture wide and expansive 3
b. Shell narrow and nearly cylindric; aperture narrow, elongate .... *Physa anatina virgata* (Fig. 30)
3a. Spire short; shell without spiral lines; columella strongly twisted .... *Physa heterostropha* (Fig. 31)
b. Spire long; shell with distinct spiral lines; columella only slightly twisted or not at all .... *Physa gyrina* (Fig. 32)

KEY F: KEY TO KENTUCKY LYMNAEIDAE

1a. Spire as long as or longer than aperture 2
b. Spire usually shorter than aperture 3
2a. Spire longer than aperture; whorls regularly increasing in size; shell narrowly elongate; body whorl long and narrow ....*Lymnaea (Stagnicola) elodes* (Figs. 33, 34)
b. Spire about as long as aperture; whorls not regularly increasing in size (body whorl suddenly enlarged); shell not narrowly elongate ....*Lymnaea (Fossaria) humilis* (Fig. 35)
3a. Body whorl elongated, not greatly expanded; spire about one-half the length of aperture .... *Lymnaea (Pseudosuccinea) columella* (Fig. 36)
b. Body whorl greatly expanded; spire about one-third length of aperture .... *Lymnaea (Stagnicola) emarginata* (Fig. 37)

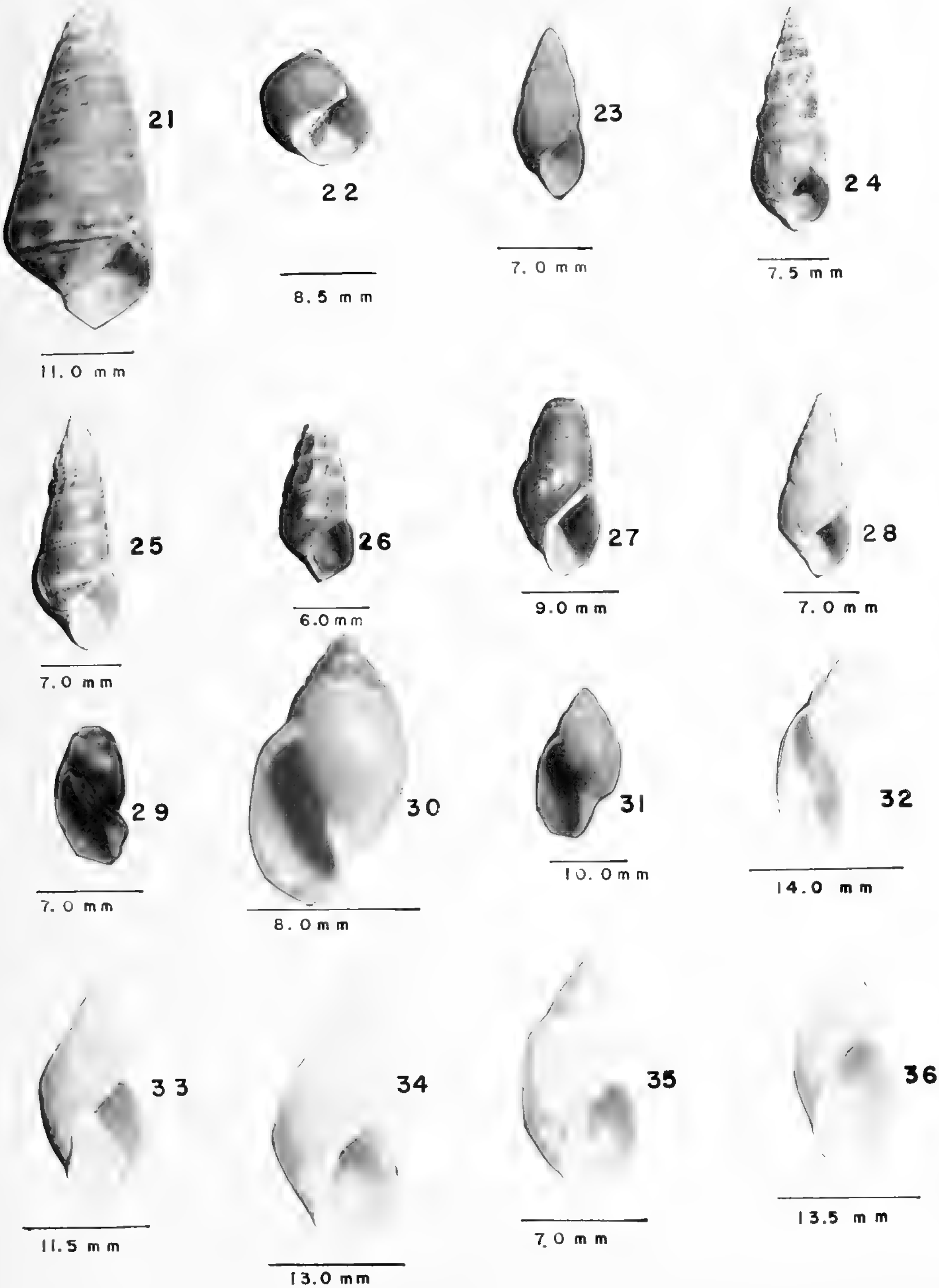
KEY G: KENTUCKY ANCYLIFORM SNAILS

1a. Shell distinctly radially striated; apex pinkish or reddish inside; radular teeth in rows about 30 microns apart, each with prominent inner cusps 3
b. Shell finely radially striate or smooth; apex same color as rest of shell; radular tooth rows about 6 to 10 microns apart, without prominent inner cusps 2
2a. Shell elevated (variable); apex with very fine radial striae; aperture sometimes with a shelf-life septum enclosing the posterior part; pseudobranch of one flat lobe; penis with a flagellum .... *Ferrissia* ... 4
b. Shell depressed; apex smooth, completely lacking radial striae; septa never formed; pseudobranch two-lobed, the lower one being elaborately folded; penis without a flagellum ....*Laevapex fuscus* (Fig. 44)
3a. Shell only moderately elevated; apex usually entire; posterior slope straight or slightly concave; anterior slope straight or slightly convex .... *Rhodacmea hinkleyi*
b. Shell very elevated; apex usually eroded in adult shells; posterior slope straight or slightly convex; anterior slope clearly convex .... *Rhodacmea elatior*
4a. Shell over 5 mm long, 1.4 to 1.7 mm wide, elevated; habitat mostly in creeks, rivers, and other flowing waters ....*Ferrissia rivularis* (Fig. 45)
b. Shell less than 4 mm long, depressed or slightly elevated; habitat in standing waters .... *Ferrissia fragilis*

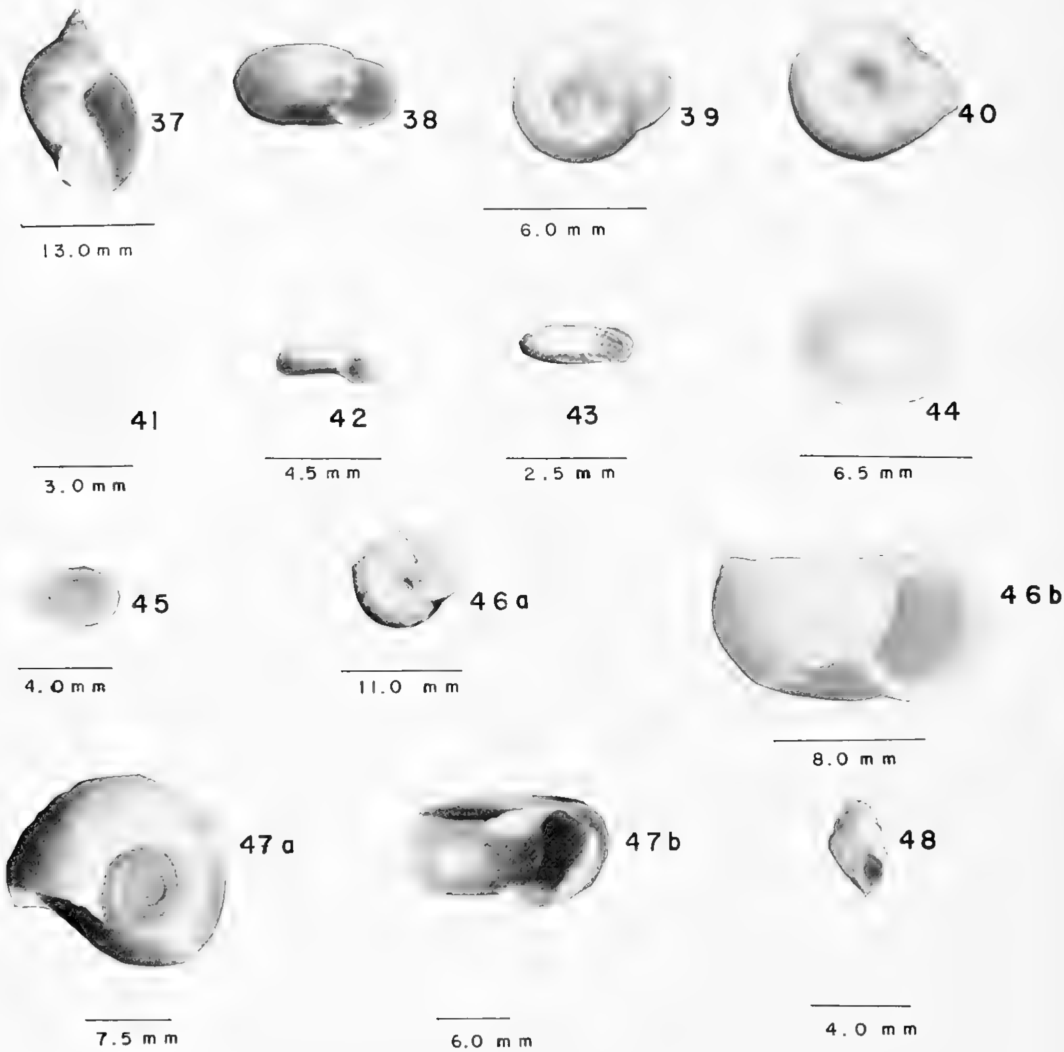
KEY H: KEY TO KENTUCKY PLANORBIFORM SNAILS

1a. Shell large, 12 to 30 mm in diameter .. ..*Helisoma* ... 2
b. Shell small, 1.5 to 7.0 mm in diameter 3
2a. Shell carinate above and below; aperture angular; umbilicus funicular .... *Helisoma anceps* (Fig. 46)
b. Shell not carinate; aperture not angular although it may be asymmetrical; umbilicus wide, not funicular. .... *Helisoma (Planorbella) trivolvis* (Fig. 47)
3a. Surface of shell not costate; periphery rounded to carinate 4
b. Surface of shell strongly costate; periphery acutely carinate .... *Gyraulus (Armigera) crista*
4a. Aperture bearing whitish barriers ("teeth") a short distance within; periphery rounded .... *Planorbula armigera* (Figs. 38–40)
b. Aperture edentate; periphery of shell rounded, bluntly angular, or carinate 5
5a. Aperture lunate; periphery of shell an-

[3] Placed in genus *Physella* by Burch (1982).



Figs. 21–36. 21. *Lithasia verrucosa*. 22. *Lithasia obovata*. 23. *Goniobasis plicata-striata*. 24. *Goniobasis curreyana*. 25. *Goniobasis laqueata*. 26. *Goniobasis costifera*. 27. *Goniobasis ebenum*. 28. *Goniobasis semicarinata*. 29. *Physa integra*. 30. *Physa anatina virgata*. 31. *Physa heterostropha*. 32. *Physa gyrina*. 33, 34. *Lymnaea elodes*. 35. *Lymnaea humilis*. 36. *Lymnaea columella*.



FIGS. 37–48. 37. *Lymnaea emarginata*. 38–40. *Planorbula armigera*. 41. *Gyraulus parvus*. 42. *Planorbula exacuous*. 43. *Planorbula dilatatus*. 44. *Laevapex fuscus*. 45. *Ferrissia rivularis*. 46. *Helisoma anceps*. 47. *Helisoma trivolvis*. 48. *Probythinella lacustris*.

gular or evenly rounded; shell 3 to 5 mm in diameter ..... *Gyraulus parvus* (Fig. 41)

b. Aperture angular; periphery of shell carinate 6

c. Aperture not lunate or angular; periphery of shell not evenly rounded; may have a peripheral keel or a malleated surface; periostracum sometimes hirsute; 4 to 7 mm in diameter (usually larger than 5 mm) .... *Gyraulus deflectus*

6a. Shell strongly depressed, the periphery being sharply carinate; penial gland flattened . . *Planorbula* (*Promenetus*) *exacuous* (Fig. 42)

b. Shell only moderately depressed, the periphery carinate but not sharply; penial gland sausage-shaped 7

7a. Umbilicus (spire pit on left side) shallow and wide . . *Planorbula* (*Menetus*) *sampsoni*

b. Umbilicus narrow and deep .... *Planorbulla* (*Menetus*) *dilatatus* (Fig. 43)

ADDITIONAL NOTE

Probythinella lacustris (Fig. 48), somewhat similar to *Pomatiopsis*, has been implied by range to occur in Kentucky (7).

LITERATURE CITED

1. Bickel, D. 1967. Preliminary checklist of Recent and Pleistocene Mollusca of Kentucky. Sterkiana 28:7–20.

2. Branson, B. A. 1972. Checklist and distribution of Kentucky aquatic gastropods. Kentucky Fish. Bull. 54:1–20, 45 maps.

3. Taylor, D. W. 1966. A remarkable snail fauna from Coahila, Mexico. Veliger 9:152–228.

4. Hubricht, L. 1963. New species of Hydrobiidae. Nautilus 76:138–140.

5. Goodrich, C. and H. van der Schalie. 1944. A revision of the Mollusca of Indiana. Amer. Midl. Nat. 32: 257–326.

6. Hubendick, B. 1978. Systematics and comparative morphology of the Basommatophora. Pp. 1–47. In V. Fretter and J. Peake (eds.) *Pulmonates*. Academic Press, New York.

7. Burch, J. B. 1982. Freshwater snails (Mollusca: Gastropoda) of North America. EPA-600/3-82-026:1-294.

8. Wenz, W. 1939–1944. Gastropoda Prosobranchia. In O. Schindewolf (ed.) Handbuch der Palaeozoologie, Vol. 6, Teil 1–7.

9. Hyman, L. H. 1967. The invertebrates, Vol. 6. Mollusca I. McGraw-Hill Book Co., New York.

Trans. Ky. Acad. Sci., 48(1–2), 1987, 20–25

A Bathtub Hazard Model and an Application to System Warranty

LLOYD R. JAISINGH

Department of Mathematical Sciences, Morehead State University,
Morehead, Kentucky 40351

WILLIAM J. KOLARIK

Department of Industrial Engineering, Texas Tech University,
Lubbock, Texas 79409

AND

DIPAK K. DEY

Department of Statistics, University of Connecticut,
Storrs, Connecticut 06268

ABSTRACT

This research effort has developed a mathematical model for bathtub-shaped hazards (failure rates) for operating systems with uncensored data. The model can be used to predict the reliability of systems with bathtub hazards. A warranty application is demonstrated. The model developed for the general bathtub pattern of failure takes into account all 3 failure regions (increasing, decreasing, and constant) simultaneously and is validated by least squares estimators. Also, the Kolmogorov-Smirnov (K-S) goodness-of-fit test is applied as an aid in selecting the best representation for the reliability function.

INTRODUCTION

Reliability modeling is an important tool in the design and evaluation of a system since it helps to enable one to understand the success-failure behavior of systems. One way of determining the model is to plot the failure data and evaluate it. Researchers, having plotted and examined failure data for several years, began to recognize several general models of failure; namely, increasing, decreasing, random and bathtub failures or hazard patterns.

The curve of Figure 1 has been discussed by early researchers on the subject of reliability (1) and is often called the BATHTUB CURVE because of its shape. A decreasing failure rate is usually encountered during the early life of a system, when failures are primarily due to initial weaknesses or manufacturing defects. This period is called the "infant mortality" period. A second type of failure occurs when the system fails by chance alone and the failure rate is nearly constant. This type of failure is generally observed when the environmental stresses exceed the design strength of the system. It is difficult to predict the environmental stress amplitudes or the system strengths as deterministic functions of time, thus these chance failures are often called "random failures." A third type of failure is characterized by an increasing failure rate as operating hours are accumulated and the system ages and deteriorates. This region of failure is called the "wearout" period. Graphing these failure rates simultaneously will result in a bathtub-shaped curve. Most investigators in the past have not considered the 3 phases of failure of the bathtub curve simultaneously. This investigation is concerned with the construction of a continuous hazard function that incorporates all 3 modes of failure simultaneously, the investigation of some of its properties and a warranty application.

In order to understand the state-of-the-art in bathtub hazard functions, a brief review and some basic definitions of terminology used are in order.

Definition 1: Reliability— is the probability of the system not failing by time t and is defined as

$R(t) = \int_t^{\infty} f(z)$ dz where f(z) is the probability density of failure as a function of time.

Definition 2: Hazard Rate—is the conditional probability of failure, given that the system has not failed by time t and is given as

$$h(t) = \frac{f(t)}{R(t)}.$$

From this it follows that $f(t) = h(t) \cdot R(t)$.

Hjorth (2) considered a survival probability or reliability function

$$R(t) = \frac{\exp(-\alpha t^2/2)}{(1 + \beta t)^{\theta/\beta}}, \qquad t \geq 0 \qquad [1]$$

where α, β, $\theta > 0$ with the corresponding hazard rate

$$h(t) = \alpha t + \frac{\theta}{1 + \beta t}, \qquad t \geq 0 \qquad [2]$$

When $0 < \alpha < \theta\beta$ in [2], the curve is bathtub. An equivalent form of equation [2] was given by Lawless (3) as

$$h(t) = t + \frac{\lambda}{t + \phi}, \qquad t \geq 0 \qquad [3]$$

where λ, $\phi > 0$.

Gaver and Acar (4) presented some general procedures for constructing bathtub hazards and a 4-parameter example given by them was of the form

$$h(t) = \frac{A}{t + C} + Bt + D, \qquad t \geq 0 \quad [4]$$

where A, B, C, and $D > 0$ and $B < A/C^2$.

Another model for the simultaneous continuous bathtub hazard function was given by Shooman (1). The method for deriving the model is not an exact one but an approximate method for describing the hazard function for a given bathtub curve. This method is often referred to as a piecewise-linear analysis method. The accuracy of the method increases as the number of fitted segments increases.

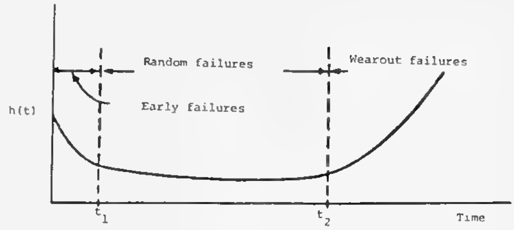


FIG. 1. General bathtub curve.

Considering Figure 2, the 3 regions chosen are $0 < t \leq t_1$, $t_1 < t \leq t_2$ and $t_2 < t < \infty$. In region 1, the hazard is given by

$$h(t) = \epsilon_1 - \eta_1 t, \; 0 < t \leq t_1. \qquad [5]$$

In region 2,

$$h(t) = \epsilon_2 - \eta_2(t - t_1), \; t_1 < t \leq t_2, \qquad [6]$$

and in region 3,

$$h(t) = \epsilon_3 + \eta_3(t - t_2), \; t_2 < t \leq \infty. \qquad [7]$$

Another general failure model that can be used to approximate h(t) is a polynomial of order n,

$$h(t) = K_0 + K_1 t + K_2 t^2 \ldots + K_n t^n, \; t \geq 0. \qquad [8]$$

The above model is extensively used in all branches of engineering (1) to fit experimental data. Since the various K's can be positive or negative constants, a very wide variety of curves, including the bathtub, can be modeled.

Krohn (5) discussed a procedure for constructing a bathtub-shaped hazard function. He selected an appropriate probability density for each of the 3 periods of decreasing, constant and increasing hazard rates shown in Figure 1 and called them $f_1(t)$, $f_2(t)$ and $f_3(t)$, respectively. He restricted only one of the failure causes to occur for a system where P_1, P_2 and P_3 were the probabilities for each of the 3 causes and $P_1 + P_2 + P_3 = 1$. Hence, a probability density (mixture) could be developed from

$$f(t) = P_1 f_1(t) + P_2 f_2(t) + P_3 f_3(t) \qquad [9]$$

with the corresponding hazard function derived from [9]. Krohn pointed out that this procedure will indeed yield complex hazard functions. The preceding references give an indication of some of the work that has been done specifically on the bathtub curve.

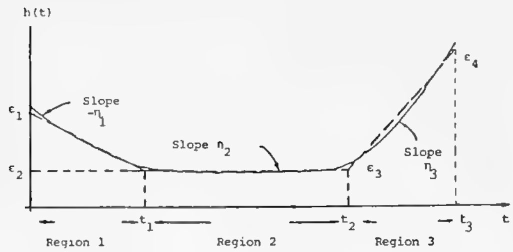


FIG. 2. Piecewise-linear failure model. Note: Although region 3 extends to ∞, the model is required to fit well only over the range $t \le t_3$.

THE MODEL

The assumptions for the model are:

1. The model is designed for nonrepairable systems only.
2. The model and analysis are developed for relatively large samples.
3. The model is designed to handle complete failure data only.

Let the hazard for this model be of the form (4)

$$h(t) = \lambda + g(t) + k(t) \qquad [10]$$

where $g(t) > 0$ is a decreasing function of t such that $\lim_{t\to\infty} g(t) \to 0$; k(t) is an increasing function of t such that $k(0) = 0$ and $\lim_{t\to\infty} k(t) \to \infty$, and $\lambda > 0$ is a real number. Such a function can yield a bathtub curve that satisfies the properties of a hazard function. Therefore, let

$$g(t) = \frac{\theta}{t + \phi}, \quad \phi > 0, \quad \theta > 0, \quad t \ge 0 \qquad [11]$$

and

$$k(t) = \alpha t^{\rho}, \quad \rho \ge 1, \quad \alpha > 0, \quad t \ge 0. \qquad [12]$$

The proposed model is then

$$h(t) = \lambda + \frac{\theta}{t + \phi} + \alpha t^{\rho}, \quad t \ge 0. \qquad [13]$$

This model simultaneously describes the bathtub hazard function when the parameters satisfy their restrictions and is indeed a flexible hazard function that can fit various bathtub patterns. Note that when $\rho = 1$, $\alpha < \theta/\phi^2$ for h(t) to be bathtub and for $\rho > 1$, h(t) is always bathtub shaped.

TABLE 1. Generated (observed) values for the reliability, hazard and density functions (4).

Age at failure time t, hr	Generated reliability, R(t)	Generated probability density, $f(t) \times 10^4$	Generated hazard, $h(t) \times 10^3$, fr/hr
600	0.74767	2.56150	0.34259
1,200	0.63830	1.31090	0.20537
1,800	0.57367	0.92564	0.16135
2,400	0.52111	0.85546	0.16416
3,000	0.46905	0.88706	0.18912
3,600	0.41445	0.93111	0.22466
4,200	0.35783	0.95046	0.26562
4,800	0.30114	0.93247	0.30964
5,400	0.24668	0.87730	0.35564
6,000	0.19647	0.79196	0.40308
6,600	0.15204	0.68674	0.45168
7,200	0.11424	0.57265	0.50126
7,800	0.08330	0.45960	0.55173
8,400	0.05891	0.35526	0.60300
9,000	0.04040	0.26460	0.65503
9,600	0.02684	0.18997	0.70776
10,200	0.01728	0.13149	0.76117

The corresponding density and reliability model for the proposed hazard in [13] are, respectively

$$f(t) = \left(\lambda + \frac{\theta}{t + \phi} + \alpha t^{\rho}\right) \cdot \exp\left[-\left\{\lambda t + \theta \ln(t/\phi + 1) + \frac{\alpha t^{\rho+1}}{\rho + 1}\right\}\right]. \qquad [14]$$

and

$$R(t) = \exp\left[-\left(\lambda t + \theta \ln(t/\phi + 1) + \frac{\alpha t^{\rho+1}}{\rho + 1}\right)\right] \qquad [15]$$

since $R(t) = \exp[-\int_0^t h(z)\,dz]$.

SPECIAL CASES FOR THE MODEL

1. For $\theta = 0$, $\alpha = 0$, and $\lambda > 0$, then

$$h(t) = \begin{cases} \lambda, & t > 0 \\ 0, & \text{e·w} \end{cases}. \qquad [16]$$

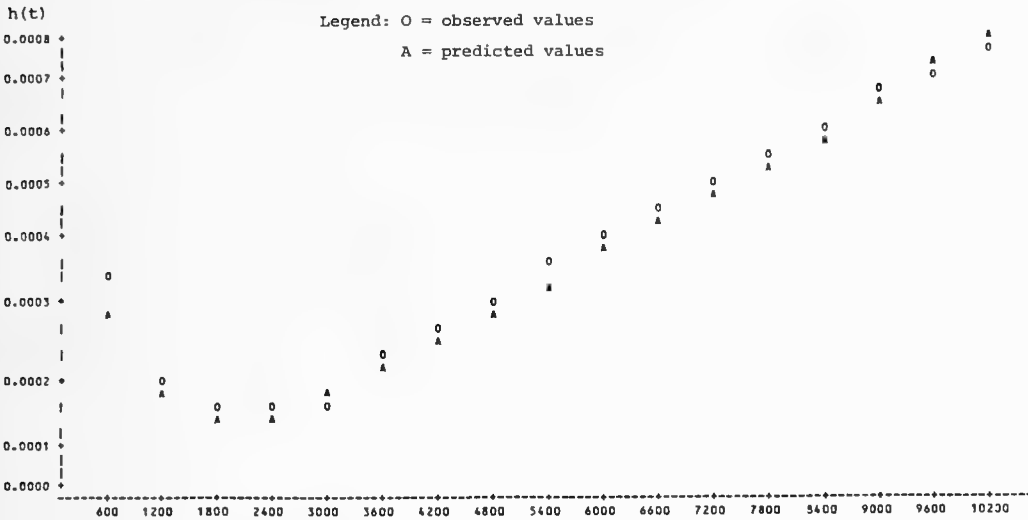


FIG. 3. Plot of the observed and predicted hazard values.

That is, the hazard rate is constant and the corresponding probability density function is

$$f(t) = \begin{cases} \lambda e^{-\lambda t}, & t > 0 \\ 0, & e \cdot w \end{cases} \qquad [17]$$

which is the exponential distribution.

2. For $\lambda = 0$, $\alpha = 0$, $\theta > 0$, $\phi > 0$

$$h(t) = \begin{cases} \dfrac{\theta}{t + \phi}, & t > 0 \\ 0, & e \cdot w \end{cases} \qquad [18]$$

and

$$f(t) = \begin{cases} \dfrac{\theta \phi^{\theta}}{(t + \phi)^{\theta+1}}, & t > 0 \\ 0, & e \cdot w \end{cases} \qquad [19]$$

Now, let $y = t + \phi$, then [19] is transformed to the density of y as

$$f_y(y) = \begin{cases} \dfrac{\theta \phi^{\theta}}{y^{\theta+1}}, & y > \phi \\ 0, & y \leq \phi \end{cases}$$

which is the Pareto distribution.

3. For $\lambda = 0$, $\theta = 0$, $\alpha > 0$, $\rho \geq 1$, then

$$h(t) = \begin{cases} \alpha t^{\rho}, & t > 0 \\ 0, & e \cdot w \end{cases} \qquad [20]$$

and

$$f(t) = \begin{cases} \alpha t^{\rho} \exp\left[-\dfrac{\alpha}{\rho + 1} t^{\rho+1} \right], & t > 0 \\ 0, & e \cdot w \end{cases} \qquad [21]$$

which is a "restricted" Weibull distribution since $\rho > 1$. For the Weibull, $\rho > -1$.

TABLE 2. Predicted hazard, reliability and the absolute differences of the reliability values.

Age at failure time t, hr	Predicted hazard, $h(t) \times 10^3$ fr·hr	Predicted reliability, $\hat{R}(t)$	Absolute differences, $\lvert R(t) - \hat{R}(t) \rvert$
600	0.29196	0.74003	0.00764
1,200	0.19725	0.64332	0.00492
1,800	0.17636	0.57611	0.00244
2,400	0.18143	0.51792	0.00319
3,000	0.19992	0.46217	0.00688
3,600	0.22695	0.40676	0.00769**
4,200	0.26019	0.35155	0.00628
4,800	0.29834	0.39739	0.00375
5,400	0.34059	0.24556	0.00112
6,000	0.38641	0.19747	0.00100
6,600	0.43542	0.15435	0.00231
7,200	0.48735	0.11704	0.00280
7,800	0.54196	0.08596	0.00266
8,400	0.59909	0.06105	0.00214
9,000	0.65859	0.04187	0.00147
9,600	0.72035	0.02769	0.00085
10,200	0.78430	0.01763	0.00035

** = D_{max} (reliability).

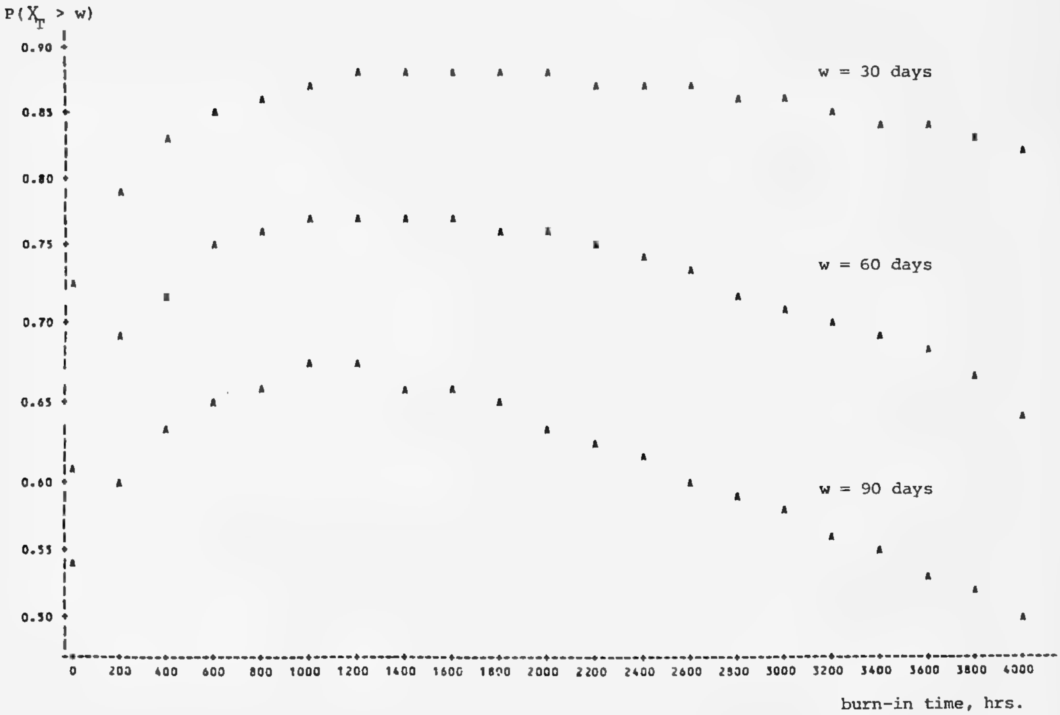


FIG. 4. Plot of $P(X_T > w)$ against burn-in times.

VALIDATION AND WARRANTY APPLICATION OF THE MODEL

The model was validated by using the information given in Table 1 (6). Table 1 gives the generated reliability, hazard rate and density values for ninety components over a period of 10,200 hours at 600-hour intervals. These values were obtained by Kececioglue (6) by grouping the failed components into two subpopulations.

The six-parameter mixed Weibull

$$f(t) = \frac{37}{90} \cdot \frac{0.96}{650}\left(\frac{t}{650}\right)^{-0.04} e^{-\left(\frac{t}{650}\right)^{0.96}} + \frac{53}{90} \cdot \frac{2.2}{5{,}750}\left(\frac{t}{5{,}750}\right)^{1.2} e^{-\left(\frac{t}{5{,}750}\right)^{2.2}} \quad [22]$$

generated the density values and

$$R(t) = \frac{37}{90} e^{-\left(\frac{t}{650}\right)^{0.96}} + \frac{53}{90} e^{-\left(\frac{t}{5{,}750}\right)^{2.2}} \quad [23]$$

generated the reliability values. The hazard rates, $h(t)$, were obtained from the relation $f(t) = h(t) \cdot R(t)$. For illustration purposes the derived model will be demonstrated using these generated values as the observed values.

The estimated least squares parameter values for the hazard function were $\hat{\lambda} = 9.946898 \times 10^{-6}$, $\hat{\theta} = 2222.97288 \times 10^{-4}$, $\hat{\phi} = 220$, $\hat{\alpha} = 7.696699 \times 10^{-10}$ and $\hat{\rho} = 149.44079 \times 10^{-2}$ with an R^2 (hazard) value of approximately 98% using SAS PROC NLIN. Figure 3 shows plots of the observed and predicted values for the hazard rate. In addition, Table 2 gives the predicted hazard and reliability values and the absolute differences (|observed-predicted|) for the reliability values. Using the K-S goodness-of-fit test, D_{max} (reliability) $= 0.00769 < D_c = 0.3180$ at the 5% level of significance. Therefore, the fitted reliability model does provide acceptable results in predicting the reliability values.

Example: Given a warranty period, determine the optimal burn-in time for a system with the simultaneous bathtub hazard rate such that the system does not fail before the warranty period expires.

Solution (values of $\hat{\lambda}$, $\hat{\theta}$, $\hat{\phi}$, $\hat{\alpha}$ and $\hat{\rho}$ determined above are used to work this example): Let X be the random variable for the life of the system from time zero. Let X_T be the random variable for the life of the system after burn-in of time T. Let w be the warranty period. Theoretically, one needs to compute $P(X_T > w)$. Now,

$$\begin{aligned} P(X_T > w) &= P(X - T > w \mid X > T) \\ &= P(X > T + w \mid X > T) \\ &= \frac{P(X > T + w, X > T)}{P(X > T)} \\ &= \frac{P(X > T + w)}{P(X > T)} \\ &= \frac{R(T + w)}{R(T)} \end{aligned} \qquad [24]$$

where R is the reliability of the system from time zero. Then by using equation [15],

$$\begin{aligned} &P(X_T > w) \\ &= \exp\left[-\lambda w - \theta \ln(1 + w/(T + \phi)) - \frac{\alpha}{\rho + 1}(T + w)^{\rho+1} + \frac{\alpha}{\rho + 1}T^{\rho+1}\right] \end{aligned} \qquad [25]$$

Observe from Figure 4 that the plot of $P(X_T > w)$ against burn-in times results in curves that are concave downwards. This is a direct result of the bathtub nature of the proposed hazard model. The optimal burn-in time will correspond to the time when $P(X_T > w)$ is a maximum. For w = 30, 60, and 90 days, the optimal burn-in times were 1,800, 1,400, and 1,000 hours, respectively. The corresponding probabilities that the system will survive beyond these warranty periods for these burn-in times were 0.88026, 0.77041 and 0.66752, respectively.

CONCLUSION

The purpose of this paper has been to construct a (flexible) bathtub hazard model for nonrepairable systems with uncensored data. Special cases of the model produced classical density functions that frequently arise in reliability studies. The validity of the model was established by the nonlinear least-squares estimation method. Potential applications of the model include the effect of burn-in to eliminate the infant mortality region so that the finished product will be operating in the region of near constant failure rate, and situations where one desires to model the entire lifetime of a product or population; where the lifetime is characterized by a period with a decreasing failure rate, a constant failure rate and an increasing failure rate. The example presented illustrates how the optimal burn-in time can be computed for different warranty periods.

LITERATURE CITED

1. Shooman, M. L. 1968. Probabilistic reliability: an engineering approach. McGraw-Hill Electrical and Electronic Engineering Series, McGraw-Hill, New York.

2. Hjorth, U. 1980. A reliability distribution with increasing, decreasing, constant and bathtub-shaped failure rates. Technometrics 22:99–107.

3. Lawless, J. F. 1982. Statistical models and methods for lifetime data. John Wiley and Sons, New York.

4. Gaver, D. P. and N. Acar. 1979. Analytical hazard representations for use in reliability, mortality, and simulation studies. Commun. Statis. Simula. Computa. B8(2): 91–111.

5. Krohn, C. A. 1969. Hazard versus renewal rate of electronic items. IEEE Trans. Reliability R-18:64–73.

6. Kececioglue, D. 1985. Lecture notes. 11th Annual Reliability Testing Institute 1985:215–257.

7. Griffith, W. S. 1982. Representation of distributions having monotone or bathtub-shaped failure rates. IEEE Trans. Reliability R-31:95–96.

NOTE

***Linum grandiflorum* (Linaceae), *Papaver dubium* (Papaveraceae), and *Salvia pratensis* (Labiatae): Additions to the Kentucky Flora**—The following 3 taxa represent additions to the known vascular flora of Kentucky. Voucher specimens are in the herbarium of Northern Kentucky University (KNK).

Linum grandiflorum Desf. Small population on a steep roadside slope N of the I-275 bridge, Ft. Thomas, Campbell Co., 15 Jun 1986, *JWT & JOL 56402*. This North African species is not included in the key to *Linum* in Gray's Manual of Botany (8th ed., American Book Co., New York, 1950) but is mentioned incidentally in the text. Among North American flaxes it is unmistakable because of its large (3–4 cm wide) flowers, its deep red petals, and its long (8–11 mm long) sepals. We suspect it was probably introduced to this site in seed sown for purposes of revegetation. The hillside was severely disturbed during highway construction about 7 years ago and is now highly eroded.

Papaver dubium L. Rare in railroad yard 2 miles S of Latonia, Kenton Co., 8 May 1985, *JWT 56066*; same locality, 2 Jun 1985, *JWT 56069* (in fruit); locally abundant along railroad tracks, 3.2 km SE of Ross, Campbell Co., 20 May 1986, *JWT 56350*. These plants have red-orange petals, dark brown anthers, and rather narrowly obovoid to obconic, glabrous capsules with 7–9 stigmatic rays. Their striking petal color makes them easy to see in their rather drab habitat. Although *P. dubium*, a European species, is said to be "very variable" (Mowat and Walters in Flora Europaea 1:248, 1964), our plants are quite uniform in basic vegetative and floral morphology, even though they vary considerably in stature. The capsules match well the one shown in Gleason (The New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada, New York Botanical Garden, New York, 1952).

Salvia pratensis L. Hundreds of plants on steep, open slope and eroding cutbank above Hands Road, 1.6 km S of junction of Hands Road and state route 17, Covington, Kenton Co., 4 May 1986, *JWT 56329*. With the leaves chiefly in a basal rosette (only 2–3 pairs of leaves on the stem); the nearly sessile flowers; the purple corollas with a strongly curved upper lip; and the 3-toothed upper calyx lip, this handsome European species is easily identified.—**James O. Luken** and **John W. Thieret**, Department of Biological Sciences, Northern Kentucky University, Highland Heights, Kentucky 41076.

Trans. Ky. Acad. Sci., 48(1–2), 1987, 27–32

ACADEMY AFFAIRS

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

Lexington Convention Center Ballroom 1
Lexington, Kentucky

20–22 November 1986

Minutes of the Annual Meeting

The meeting was called to order by President Covell at 0915, 22 November, in Ballroom 1 of the Lexington Convention Center. There were approximately 75 members in attendance.

The Secretary's report was made by Dr. Creek. The approval of the minutes of the 1985 annual meeting was deferred until the 1987 annual meeting since they were recorded in Vol. 47(1–2) of the *Transactions* which has not been published. Dr. Creek moved that all new members for 1986 be approved. Following a second from the floor, the motion passed.

The Treasurer's report was made by Dr. Taylor.

Treasurer's Report

Kentucky Academy of Science
November 1985–November 1986

Cash in the Madison National Bank 3 November 1985		$13,020.19
RECEIPTS		
Registration 1985	$ 4,461.22	
Membership	7,082.00	
Library Subscription	2,640.00	
Institutional Affiliations	4,650.00	
Page Charges	1,139.00	
Interest (MMF)	235.00	
	$20,207.22	
Total Cash and Receipts		$33,227.41
DISBURSEMENTS		
EKU	$ 588.62	
Fall Meeting 1985	1,104.61	
Hales Office Supply	581.95	
NAS	60.00	
Morehead State University	1,969.00	
Postmaster	224.36	
Miscellaneous	89.55	
KJAS	1,000.00	
Typing	18.00	
Food Service (Raddison)	71.92	
	$ 6,153.41	

BALANCE	
Total Cash and Receipts	$33,227.41
Total Disbursements	6,153.41
Cash on Hand 4 November 1986	$27,074.00
KENTUCKY ACADEMY OF SCIENCE FOUNDATION	
Botany Foundation Interest 1986	$ 751.20
Botany Foundation Residual from 1985	1,259.28
Subtotal	$ 2,010.48
Botany Foundation Grant	432.00
Ten Per Cent Interest Added to Principal	75.12
Total	$ 1,503.36
Marcia Athey Fund Interest 1986	5,334.68
Marcia Athey Fund Residual 1985	6,878.10
Subtotal	$12,212.78
Marcia Athey Fund Grants 1986	6,100.00
Total	$ 6,112.78
Endowment Fund	1,040.00

Following a motion and a second from the floor, the report was approved. The report was audited by Gordon Weddle and Alan Reed and found to be in order.

Committee Reports

1. **COMMITTEE ON PUBLICATION.** Dr. Branson made the report.

The reprinted volume of the *Transactions* Vol. 46(3–4) will be reissued within a few weeks. According to the University of Kentucky Printing Office, Vol. 47(1–2 & 3–4) will be published in early 1987.

Dr. Branson announced that the Executive Committee had decided to return to Allen Press for publication of the *Transactions* starting with Vol. 48(1–2). This will put the publication of the *Transactions* back on schedule.

2. **KENTUCKY JUNIOR ACADEMY OF SCIENCE.** Mr. Pat Stewart made the report.

Last year's operations culminated with the annual symposium held at Warren East High School. Forty-four titles were scheduled of which 39 were read. Our other activities included a tour of the General Motor Corvette plant, Lab-skills, Science-Bowl Competitions and refreshments at the conclusion of our organized activities.

The symposium was once again honored to have as special guests the K.A.S. Executive Committee. This gave us an opportunity to show our "troops in action." We appreciate the fact that this was the second year for review by the K.A.S. Executive Committee. We hope this will become an annual part of the K.J.A.S. symposium.

Scholarships were once again offered by Cumberland College and Western Kentucky University in conjunction with our "Outstanding Science Graduates" program.

This year promises to be another exciting year for K.J.A.S. The data base has been established and we now have the capability to send personalized letters to our clubs. Of the clubs that have joined, enrollment for each club seems to be up. Our annual symposium is scheduled at Eastern Kentucky University on 24–25 April 1987.

3. **MEMBERSHIP COMMITTEE.** The report was made by Dr. Dahlman.

A total of 43 individuals at 33 different colleges, universities and state agencies were contacted to serve as KAS representatives at their respective work places. Each was provided with KAS application blanks, brochures, etc. A list of those individuals is attached and appreciation is expressed to each for their willingness to serve.

At the winter meeting of the KAS Board, approval was given to change the name and definition of the Industrial Affiliate to that of Corporate Affiliate. Having this approved change in hand and through the assistance of Mrs. Jane Dennis, Kentucky Department of Economic Development, we were able to obtain mailing addresses of a large number of Kentucky businesses with science interests. Throughout the summer and early fall a strategy was developed to present these companies with the opportunity to support KAS as Corporate Affiliates and to give KAS an opportunity to interact and serve these same companies. The final product consisting of letters from President Charles Covell on KAS letterhead, a revised brochure describing KAS and an invoice were sent to approximately 250 companies within the state.

As a part of the above described activity, the brochure describing KAS was edited, updated and reprinted. These were placed in each registration packet to be picked up by those attending the combined SSMA-KAS meeting in Lexington. They will also be used for future membership promotion activities.

The committee strongly endorses the establishment of a collegiate level KAS program. A separate committee is working on plans for this program.

During this past year, all individuals who have not paid dues since 1983 were removed from the membership list. The total number of members as of 16 November 1986, that have paid dues at least in 1984 is 782. Of this number, 524 have paid their 1986 dues (including 49 life members). Of the remaining 258, many have paid their 1985 BUT NOT 1986 dues. The net increase of 11 members over 1985 resulted after purging those who had not paid dues since 1983. We have actually had 91 new members added to the roles since the 1985 KAS meeting.

The Membership Committee strongly urges each member to serve as a committee of one in the recruitment of new KAS members.

4. **BOTANICAL GRANTS COMMITTEE.** Dr. Bryant made the report.

During 1986 the Botanical Grants Committee received 3 proposals. Of those 3, 2 were funded. The other proposal was not appropriate and was referred to the Athey Committee. The proposals funded are as follows:

1. Mr. Joseph Abner, $432.00, for a research project on the Vascular Flora of Jackson County, Kentucky. This project is directed by Dr. Ronald Jones, Eastern Kentucky University.
2. Mr. Alan W. Reed, $225.00 for a research proposal concerned with Increased Aluminum Release from Leaf Litter of *Carpinus caroliniana* in Response to Acid Rainfall. This project is being directed by Dr. Joe Winstead, Western Kentucky University.

A preliminary report on the work done on the latter grant was given at the November 1986 KAS Botany and Microbiology Section Meeting.

The Botanical Grants Committee will not receive grant proposals for the 1987 funding period. Guidelines for grants have been published in the *Transactions* and KAS Newsletters.

Members of the Committee are: William S. Bryant, Chairman; Ralph Thompson; and Ronald Jones.

5. **MARCIA ATHEY FUND.** Dr. Freytag made the report.

There were two grants approved and funded for 1986. They were:

1. Dr. Steven I. Usdansky, Department of Geoscience, Murray State University. "Petrologic Characterization of Dike Rocks from the Western Kentucky Fluorspar District." A 1-year study funded for $1,000.00
2. Dr. Joe E. Winstead, Department of Biology, Western Kentucky University. "An Investigation of Sulfur Deposition in the Wood of Shortleaf Pine on the Cumberland Plateau of Kentucky in Relation to Atmospheric Sulfate." A 2-year study funded for $7,500.00

6. **SCIENCE EDUCATION COMMITTEE.** Dr. George made the report.

Awards for Students and Sponsoring Teachers.—At the annual banquet we recognized the student winners of the 5 regional science fairs in Kentucky and the winners of the KJAS Symposium last spring. We honored 10 students and 10 sponsoring teachers. Each honoree was given a plaque recognizing their achievements. They were also the guests of the Academy at the banquet and were given a free membership in the Academy for 1 year. We appreciate all the hard work and initiative shown by these students and their teachers.

The Pre-College Curriculum.—This program was designed by the Council on Higher Education and is set to go into effect by fall, 1987. Students meeting this requirement are eligible for unconditional admission to Kentucky's public universities. These universities may exempt up to 20% of entering freshmen who have not completed the Pre-College Curriculum.

Two units of science are required in this curriculum of which at least one must be from Biology I, Chemistry I or Physics I. CHE published and distributed a brochure which was very misleading. It stated "Science—2 units—Biology I or Chemistry I or Physics I and a science elective." It was not clear to science teachers, principals, and superintendents that the elective could also be chosen from Biology, Chemistry or Physics. This has since been rectified with a more specific recommendation:

Science
A. *Required course*
   1. Biology I (2517) or Chemistry I (2521) or Physics I (2532) or advanced placement courses
B. Elective courses
   1. Biology I (2517) or Chemistry I (2521) or Physics I (2532) could become the elective course after one of the others is taken to meet the required course
   2. Advanced Placement Genera Biology (2513)
   3. Advanced Biology (Biology II) (2516)
   4. Advanced Placement General Chemistry (2522)
   5. Advanced Chemistry (Chemistry II) (2533)
   6. Advanced Placement Physics B (2533)
   7. Advanced Placement Physics C (2534)
   8. Advanced Physics (Physics II) (2538)

However, the flawed brochure will undoubtedly create problems.

Advanced Placement.—Increasing numbers of high schools in Kentucky are beginning to offer courses for Advanced Placement (AP) of the College Entrance Examination Board (CEEB). The reason seems to be the newly instituted Commonwealth Diploma.

The Commonwealth Diploma requires: 22 units of approved credits, successful completion of all minimum requirements of the Pre-College Curriculum required by the Kentucky Council on Higher Education, successful completion of at least 4 AP courses and completion of 3 examinations of the 4 AP courses taken. (NB—it is not required that any of the AP examinations taken be passed.)

It has been reported from several sources that some high schools are simply designating their usual high school science courses as AP. Such practices are a severe distortion of the intentions of AP. Advanced Placement is intended to allow outstanding students that are capable of doing college level work while in high school to do so and get college credit. Standard high school courses would not normally be expected to meet this level of achievement.

Our concerns are that AP courses:

(1) should have adequate lab facilities—by all means should meet and go beyond the requirements of the Minimum Equipment List of the Department of Education;

(2) should have hands-on lab time equivalent to college courses. Demonstrations of experiments do not suffice. The student is expected to have undergone these hands-on experiences in later college courses;

(3) should have college-level textbooks. College level work cannot be done by students using high school texts;

(4) should have adequate budget for supplies and equipment above what is normally expended in secondary science courses;

(5) should be taught by a teacher with a major in the discipline. However, the College Board does not say anything about the qualifications of the teacher; and

(6) that the teacher must go through the training workshop in organizing/teaching AP courses.

This committee proposes that the academy, along with the Kentucky Association for Progress in Science (KAPS) pass a joint resolution expressing our concerns about AP and inform all science teachers, principals, superintendents and the appropriate officials of the Kentucky State Department of Education. This would require an article in both newsletters and mailings to all the above individuals. A resolution to the affect will be offered through the Committee on Resolutions.

Incentive Loan Program.—This program has been successful in attracting new teaching majors in science and mathematics. This committee recommends that we encourage the State Department of Education to continue this program as long as there is a shortage of these teachers. Other science societies have agreed to join with the academy in sponsoring a resolution to this effect. These societies are Kentucky Association for Progress in Science, Kentucky Council of Teachers of Mathematics, Kentucky Chapter of the Wildlife Society and The Kentucky Native Plant Society. A resolution to this effect has been forwarded to the Resolutions Committee.

Science Advisory Council.—This council has previously functioned as an Advisory Council to the Superintendent of Public Instruction. It was a widely-based committee consisting of classroom teachers, science supervisors, superintendents and representatives from government, industry and the science societies. Wide-ranging proposals developed from diverse points of view were able to give input to the Superintendent and his advisors. Some funding is required since classroom teachers (whose presence is vital) must have to pay for a substitute teacher when they attend to meetings and also need travel money. If such a council is in place, we should be able to get our concerns before the Superintendent much more quickly and efficiently.

Those societies are the same ones that joined in the resolution on the Incentive Loan Program. A resolution to this affect has been forwarded to the Resolutions Committee.

7. **COMMITTEE ON RARE AND ENDANGERED SPECIES.** Dr. Branson made the report.

The Rare and Endangered Species list, with modifications and recommendations, is now in press. It will be in Vol. 47(1–2) of the *Transactions*.

8. **AUDIT COMMITTEE.** Mr. Weddle made the report.

Endowment funds of the Kentucky Academy of Science Foundation are being and have been invested to assure continued growth. However, we believe that certain changes in management policy would allow more accurate accounting of these funds. Our concerns are twofold as follows.

Historically, awards have not kept pace with interest income and substantial residual funds have accumulated. Currently, ten per cent of earned incomes generated by the Botany Fund is compounded annually. The remainder is accumulated in other interest-bearing accounts or awarded as grants. Income from the Marcia Athey Fund is significantly larger yet no policy exists for its reinvestment, nor does policy exist to specifically direct the treasurer in managing any residual fund. Reinvestment decisions regarding residuals have been left totally to the discretion of the treasurer. The potential for additional confusion in record keeping and for increased difficulty in maintenance of the integrity of separate funds is of growing concern.

Secondly, financial institutions holding foundation funds provide balance sheets only in July and January. Accordingly, reports of activities in these funds provided to the membership at the annual meeting in November are based on untimely information and are, at best, tentative.

We recommend that the Executive Committee and the Board of Directors consider the following:

1. A detailed and specific policy for reinvestment of a position of the interest accrued from the Athey Fund and for reinvestment of residuals from all KAS Foundation funds should be established. This policy should be sufficiently specific and inclusive to preclude the necessity for decision making, on the part of the treasurer, and should insure the continued integrity of funds.
2. The Annual Audit of KAS Foundation funds should be completed in January after year end bank statements are available. This information could then be disseminated to the membership of publication in the newsletter. A tentative report could be included with the audit report provided the membership in November.
3. Consideration should be given to secure an independent accounting firm to establish a plan for management and reporting of all KAS Endowment Funds.

9. **AD HOC COMMITTEE FOR THE REVISION OF THE CONSTITUTION AND BY-LAWS.** Dr. Rodriguez made the report.

Dr. Rodriguez said that the Committee was studying the constitutions of other Academies and would make a report to the Executive Committee at its January meeting. The committee would try to have a revised copy of the constitution in the spring *Newsletter*.

Dr. Rodriguez made a proposal for increasing the endowment funds. He suggested that when an individual's contributions to the endowment fund reached the amount needed for life membership, that person would then become a life member. No action was taken on the proposal.

10. **LONG RANGE PLANNING COMMITTEE.** Dr. Hettinger made the report.

He reported the committee was continuing its efforts to obtain a central office for the Academy. He said the Kentucky Society of Professional Engineers had their headquarters just outside of Frankfort and had offered to provide telephone answering service and possibly a small room to serve as a repository and office for a KAS representative. This offer would be discussed at the next meeting of the Executive Committee.

In order to get a better understanding of how other Academies handled their administrative details, the committee had obtained copies of constitutions and by-laws of other Academies (1) for review as to how they handle membership, Board of Directors, Executive Secretary, Central Office, etc. This information would also be used by the Ad Hoc Committee on the revision of the Constitution and By-Laws.

Dr. Covell reported that Dr. Rodriguez had agreed to serve as a special assistant to the President for the upcoming year.

11. **RESOLUTIONS AND NOMINATING COMMITTEE.** Dr. Prins submitted the following resolutions which were accepted unanimously.

Resolution 1

Whereas, the science societies of Kentucky, namely the Kentucky Academy of Science, Kentucky Association for Progress in Science, Kentucky Association of Physics Teachers, Kentucky Chapter of the Wild Life Society, and Kentucky Native Plant Society are vitally interested in the future of science in Kentucky, and

Whereas, this future depends upon the education in science in the public schools, and

Whereas, to aid the diffusion of scientific knowledge, these societies wish to take an active interest in, and give all support possible to the Kentucky Department of Education in science education, and

Whereas, science education needs the broad support and insight from many different groups such as classroom teachers, science supervisors, science societies, principals, superintendents, business and lay persons,

Therefore be it Resolved: that these science societies propose that the Superintendent of Public Instruction should appoint a permanent Science Advisory Council to advise the Superintendent on all matters relating to science education in the public schools. Some minor funding will be necessary for travel expenses. Such funding must be set up as a line item in the annual budget of the Kentucky State Department of Education.

Resolution 2

Whereas, the science and mathematics societies of Kentucky, namely the Kentucky Academy of Science, Kentucky Association for Progress in Science, Kentucky Association of Physics Teachers, Kentucky Council of Teachers of Mathematics, Kentucky Chapter of the Wild Life Society, and Kentucky Native Plant Society are vitally interested in the future of science and mathematics in Kentucky, and

Whereas, this future depends upon the education in science and mathematics in the public schools, and

Whereas, for many years, there has been a shortage of qualified teachers of science and mathematics, and

Whereas, the Incentive Loan Program has been in effect for four years which has been highly successful in attracting many fine undergraduates into the teaching fields of science and mathematics.

Therefore be it Resolved: that the Kentucky Department of Education be praised for this excellent program and that the aforementioned science and mathematics societies of Kentucky join together and request that the Incentive Loan Program be continued and regularly budgeted until the shortage of science and mathematics teachers be eliminated.

Resolution 3

Whereas, the Kentucky Academy of Science and the Kentucky Association for Progress in Science are deeply interested in all phases of science education in Kentucky, and

Whereas, we support all efforts directed toward improvement of education in Kentucky, and

Whereas, we support the institution of Advanced Placement courses in the Kentucky curriculum, and

Whereas, it appears that some high schools in the Commonwealth are instituting Advanced Placement without the proper budget, preparation, and facilities for such courses,

Therefore be it Resolved: that the Kentucky Academy of Science and Kentucky Association for Progress in Science join together to inform all parties—teachers, principals, superintendents and pertinent state officials—of the requirements of Advanced Placement courses along with a plea that these requirements should be met.

Resolution 4

Whereas, the School Science and Mathematics Association chose Kentucky as the location for its 1986 national meeting, and

Whereas, the School Science and Mathematics Association has provided the opportunity for this unique joint meeting by inviting the Kentucky Academy of Science, Kentucky Association for Progress in Science, and the Kentucky Council of Teachers of Mathematics to join with it, and

Whereas, the Conference Planning Committee consisting of Bob Creek, Ron Gardella, Frank Howard, Mike Howard, Ron Pelfry, Linda Jensen Sheffield, Sheila Vice and Joe E. Winstead has done an exemplary job of planning the joint meeting,

Therefore be it Resolved: that the Kentucky Academy of Science expresses its sincere appreciation to the School Science and Mathematics Association and the planning committee representing all organizations involved and that the Secretary of the Kentucky Academy of Science be instructed to inform the members of the committee and the Presidents of the organizations.

Resolution 5

Whereas, the State of Kentucky received an EPSCoR grant of $3 million from the National Science Foundation, and with instate matching funds the EPSCoR program provided over $16 million for research in Kentucky,

Whereas, Charles Kupchella and Gary Boggess played key roles in initiating the EPSCoR movement and participated in the grant application process,

Therefore be it Resolved: that the Kentucky Academy of Science expresses its sincere appreciation to Charles Kupchella and Gary Boggess and that the Secretary of the Kentucky Academy of Science be instructed to so do.

Dr. Prins offered the following nominations and moved their acceptance.

Vice President:	Richard Hannan Kentucky Nature Preserves Commission
Secretary:	Robert Creek Eastern Kentucky University
Treasurer:	Morris Taylor Eastern Kentucky University
Board of Directors:	Gordon Weddle (1989) Campbellsville College
	Larry Elliott (1990) Western Kentucky University
	David Legg (1990) Kentucky State University

The motion was seconded and, with no further nominations, was passed.

NEW BUSINESS

Dr. Covell reported that Dr. Winstead, on behalf of Western Kentucky University, had extended to the Academy an invitation to hold its 1987 annual meeting at Western Kentucky University on 6–7 November. Dr. Covell said the Executive Committee had voted to accept the invitation.

President Covell concluded his tenure as President by giving a brief address concerning his past year as president (presented elsewhere in the *Transactions*). He thanked everyone for their help and then presented President-elect Giesmann with the gavel and welcomed him as President of the Kentucky Academy of Science for 1987.

President Giesmann presented Dr. Covell with a plaque for his service as President and contributions to the Academy. President Giesmann gave a short address in which he briefly outlined his goals for the coming year. He said his theme would be "Service to and Through the Academy." His goals were to develop a data base for all members of the Academy, increase membership, develop a local arrangement handbook for putting on annual meetings and to improve public relations. He requested the help of all members of the Academy. Following his remarks he adjourned the meeting at 1040.

Robert Creek, Secretary
Kentucky Academy of Science

Trans. Ky. Acad. Sci., 48(1–2), 1987, 33–35

1986 PRESIDENTIAL ADDRESS TO THE ACADEMY

CHARLES V. COVELL, JR.
Professor of Biology, University of Louisville, Kentucky 40292

What are the goals of the Academy and how are we meeting them?

On 8 May, 1914, 25 scientists met at the "State University" in Lexington to found the Academy. Chemist Joseph H. Kastle, Director of the Kentucky Agricultural Experiment Station, was elected as first President; and 5 papers were delivered on such subjects as bone ossification, theories of thermal and electrical conductivity, and the significance of the work of the Experiment Station to the agricultural prosperity of the state. The Constitution unanimously adopted at that meeting stated the object of the Academy to be: "to encourage scientific research, to promote the diffusion of useful scientific knowledge, and to unify the scientific interests of the state." The first *Transactions* were published in 1924, detailing activities of the first decade of the Academy's existence. By reading this and subsequent volumes of the *Transactions* one can trace the interests and activities of Kentucky's scientific community over the decades. Today, more than 72 years later, the goals of the Academy remain the same. In 1986, how have we adhered to them, and what have we accomplished during the past year?

I cannot imagine any year in which there has been more "encouragement of scientific research" in Kentucky. The successful efforts of the Kentucky EPSCoR Committee in stimulating the writing of 146 grant proposals, many of which have received or will receive funding outside the EPSCoR grant of $15.5 million, is the greatest achievement along these lines in the history of Kentucky science. If you have not done so, please read the "EPSCoR Summary" sent with your latest KAS Newsletter. Along with Chuck Kupchella (the "Father of the Kentucky EPSCoR Project"), Gary Boggess and many other KAS members have worked hard toward the ultimate victory in obtaining the $3 million from NSF, $3 million from state government, $600,000 from industry, and the rest from the institutions involved. This achievement represents not only hard work of high quality by many individuals, but also the fruition of increased cooperation among academia, state government and the private sector during the past 3–4 years—a deliberate focus of the Academy's leadership during this period.

In addition to the direct and indirect encouragement of research through the EPSCoR Program, the Academy itself has been able to provide tangible assistance as never before. Besides recognizing the Scientist, High School Teacher, and College Teacher of the Year, and 10 JKAS student prize winners and their mentors, we have been able to grant $8,500 in research funds under the Marcia Athey Fund to two investigators—the largest dollar amount support ever possible for the Academy to grant. For this we are greatly indebted to Raymond Athey for providing the Fund; and to Paul Freytag and the Marcia Athey Fund Committee members for administering it.

In the area of "promoting the diffusion of useful scientific knowledge" we continue to publish our *Transactions* in 2 annual issues. This year financial and printing-house problems resulted in a double setback: our Volume 46(3/4) was released late and with an unacceptable number of errors; and our Volume 47 has been delayed as well. However, the former is being reprinted, and we hope to get back on schedule in 1987 after returning our printing operation back to Allen Press, a specialized and efficient, although more expensive, company. Our Secretary publishes 2 newsletters a year; and the Junior Academy also diffuses information via its own newsletter.

Press coverage of Academy activities has been poor in the past, but we expect improvement in the future. Also in the area of diffusing scientific information is the creation of a speaker's bureau list, which should be published soon with over 50 of our members listed as available to speak to school and other groups on a wide range of topics. Finally, the record participation by KAS members in this annual meeting, with 252 papers presented (86 more than last year) attests to the strength of this aspect of our mission. Besides quantity, I have noted a steady increase in the quality of papers presented in recent years. Thanks to all of you who have contributed this year; it has been a most stimulating meeting!

The most difficult aspect of the Academy's mission, I feel, is to "unify the scientific interests in the state." To some extent, this is accomplished as members from our various sections agree to serve the Academy in various committees and offices. Yet there are segments of Kentucky's scientific community in the private sector and in some areas of education that we have not yet reached. We hope to make contact with them and feel we have had an excellent chance to do so at this combined meeting. Others have yet to be convinced that membership in the Academy is beneficial to them, and have either dropped their memberships or never have joined. You can help us here by bringing in at least one new or reinstated member in 1987. Selling points can include the fact that communication among scientists in the state is important, and sharing research results by presenting papers and publication in the *Transactions* is worthwhile, and is also a "good place to start" for student scientists trying their wings.

As to affecting the course of science in Kentucky, we seem to be having an increasing effect as our numbers grow, and as we increase the involvement of our colleges and universities and our science-related businesses and industries. Last year's President Joe Winstead began a major effort to enlist these as Institutional and Corporate Affiliates in the Academy, and we have continued that effort this year. Affiliates have provided vital additional income of over $6,000 last year, and $5,550 so far this year from 19 institutions and 2 corporations. The campaign is still underway with our appeal to corporations (and for individual memberships from the private sector as well). Letters are going out to over 300 companies in the Commonwealth, thanks to our Membership Committee, chaired by Doug Dahlman, and President-elect Hettinger.

Some unification of science interests surely accrues from the activity of the Kentucky Tomorrow Commission, led by Lt. Governor Steve Beshear, and the membership of KAS members on the Commission's Science and Technology Committee. And of course the monumental EPSCoR effort cited above has done much toward attaining that objective.

These are some of the ways the Academy is meeting the goals established in 1914. Other aspects of our activity include constitutional revision, which has progressed from initial recommendations presented in September by our *ad hoc* revision committee consisting of Ted George, Gary Boggess, and J. G. Rodriguez (Chairman). Your Executive Committee and Board of Trustees hope to have these revisions ready for your approval in the coming year. A new officer, that of Executive Secretary, may be established through this revision. For now President-elect Giesmann and I have jointly appointed Dr. Rodriguez as a Special Assistant to the President for 1 year. His duties are yet to be fully defined; but he will assist in public relations and other functions to carry out the goals of the Academy. To develop financial recommendations to guide our Treasurer, an *ad hoc* Committee on Financial Policy has just been appointed, made up of Paul Freytag (Chairman), Manuel Schwartz, and Alan Reed. A further activity pertaining to strengthening the Academy is the exploration of a possible "home office" by our *ad hoc* Committee for Long Range Planning (Bill Hettinger, Chair). Such an office will be selected after our constitutional revisions have been completed.

During the past year Academy members participated in the successful drive for improved funding of higher education by the Legislature. Several Academy members formed a small contingent at the "Capital Caravan" rally held in Frankfort on 5 February. We have initiated the development of a Collegiate Academy branch to bring undergraduate college students into Academy activities. Herb Leopold is heading that effort. I explored the possibility of establishing a summer Nature Camp at Pine Mountain Settlement School in conjunction with the Kentucky Federation of Garden Clubs. However, that organization did not elect to pursue this idea, despite the support of its President. In 1986 we signed a document by which we joined 16 other state academies of science and 72 Nobel laureates as *amici curiae* in a brief filed in the case of Edwards *vs.* Aguillard *et al.* pending before the U.S. Supreme Court. This case seeks to overturn a Louisiana law requiring public school teachers to give "balanced treatment" in class to evolution and "creation science."

This has been an exciting and stimulating Annual Meeting, capping an equally exciting and stimulating year. I am deeply grateful for the opportunity to have been your President, and wish to express this gratitude to all of you who have done so much this past year to further the goals of the Academy. I particularly wish to single out Bob Creek and Joe Winstead for their help in many ways as I pursued this job, and also who had the most to do in arranging the Academy's participation in this joint conference. Thanks to all you committee chairs and members for your good service. I want to encourage all of you to continue sharing your scientific interests and achievements with the rest of us through publication and presentation of papers in the years ahead. Also, we want to broaden the participation of our members in the governance of Academy affairs; so let us know your ideas, and indicate your desire to participate.

Now, as is our tradition, I will turn the gavel of the Academy over to your new President, Larry Giesmann of Northern Kentucky University. Good luck to you, Larry, and to all Academy officers, for continuing success in 1987.

Trans. Ky. Acad. Sci., 48(1–2), 1987, 36–46

PROGRAM AND ABSTRACTS, ANNUAL MEETING

KENTUCKY ACADEMY OF SCIENCE
72ND ANNUAL MEETING PROGRAM

MATHEMATICS AND SCIENCE:
BASIC TODAY, CRUCIAL TOMORROW

1986 NATIONAL MEETING

SCHOOL SCIENCE AND MATHEMATICS ASSOCIATION

Co-sponsored By:

Kentucky Academy of Science
Kentucky Association for Progress in Science
Kentucky Council of Teachers of Mathematics

Lexington, Kentucky
20–22 November 1986

KENTUCKY ACADEMY OF SCIENCE

1986 OFFICERS

CONVENTION HIGHLIGHTS

Thursday, 20 November

1300–1600 Preconference Workshops
F.A.S.T.
IBM Math/Science Software
IPS Physical Science
Voyage of the Mimi

1300 Community College Faculty Meeting (Radisson, Lincoln and Davis Rooms)

1500–1700 Task Force on Middle School Science and Mathematics Meeting (open to all interested persons)
1830 KAS Board of Directors Dinner Meeting (Radisson, Breckinridge Room)

Friday, 21 November

0800–1700 Exhibits (including the NASA Aerovan)
0800–0900 Special Lecture: John Saxon
0915–1015 Special Workshop: Dean Vaughn
1230–1730 Tour #1: Buckley Nature Sanctuary and Ancient Age Distillery
1300–1430 General Session I: Judah L. Schwartz
1800–2030 Banquet: F. Story Musgrave and Awards Presentations
2030–2400 Social and Dance

Saturday, 22 November

0800–1700 Exhibits (including the NASA Aerovan)
0915 KAS Business Meeting (Convention Center, Ballroom 1)
0915–1015 Special Lecture: Paul G. Hewitt
0915–1015 Elementary Make-and-Take
0915–1015 "Science Teacher Shop Talks" for Biology and Chemistry Teachers
1030–1200 General Session II: Patrick Suppes
1330–1430 "Science Teacher Shop Talks" for Physics and Earth/Physical Science Teachers
1230–1630 Tour #2: Kentucky Horse Park, Headley-Whitney Museum, and Henry Clay Home

FRIDAY MORNING
21 November 1986

PAPER PRESENTATIONS
0800–1130

ANTHROPOLOGY SECTION

James Murray Walker, Chairperson, Presiding
John Hale, Presiding
Radisson Plaza, Boone A

0800 The Time Required for Bone Repair in Untreated Fractures. Elizabeth Finkenstaedt, University of Kentucky.
0812 Beyond Land Bridges: Exploring the Effects of Changing Sea Levels on Man During the Last Ice Age. Jules De Lambre, Frankfort, Ky.
0824 Two Millennia of Cultural Continuity in a European Farming Commune: Archaeological Discoveries at a Roman Villa in Portugal, and Their Relation to the 20th Century Collective Farm of Torre de Palma. John Hale, University of Louisville.
0836 Break
0848 Archaeological Evidence for the Viking Intrusion into North America. James Murray Walker, Eastern Kentucky University.
0900 Paleo-Nutrition in Central-Eastern United States. Dean Henson, Eastern Kentucky University. (Sponsored by James Murray Walker.)
0912 Excavations at 40-OB6, a Mississippi Mound in Northwest Tennessee. Jack Michael Schock, Western Kentucky University.
0924 A Description of the Adena Tablet from Madison County, Kentucky. Robert C. Moody, Eastern Kentucky University.
0936 Beyond "God's Little Acre": The Journal of a Defunct Anthropologist "Surviving." Earl Robbins, Jr., Irvine, Ky.
0948 Changing Home Health Care Patterns in Kentucky. Thomas L. Bulgrin, Eastern Kentucky University. (Sponsored by James Murray Walker.)
1000 Break
1012 Civil Religious Beliefs among the Baptist Clergy of Kentucky. Robert Moore, Campbellsville College.
1024 Evangelicals Arrive in Latin America: A Challenge to the Catholic Church. Raymond Lewis, Eastern Kentucky University.
1036 Women and What's Happening to Them in the Free Trade Zones in the Third World. K. Ann Stebbins, Eastern Kentucky University.
1048 Group Size and Magical Numbers. Cara E. Richards, Transylvania University.
1100 Business meeting for Anthropology Section.

BOTANY AND MICROBIOLOGY SECTION

Jerry M. Baskin, Chairperson, Presiding
Carol C. Baskin, Secretary
Lexington Convention Center-Ballroom 1

0800 "The Largest Flower of the Tropical World," Studied at the University of Kentucky. Willem Meijer, University of Kentucky.
0900 Decomposition of Oil Waste in a Pond by Enriching for Hydrocarbon-utilizing Microorganisms. J. M. Clauson and L. P. Elliott, Western Kentucky University.
0912 The Presence of Staphylococcus Epidermis Slime Producing Bacteria on Orthopedic Devices. David Overley and Joanne J. Dobbins, Bellarmine College.
0924 Electrophoresis of Plasmids from Coagulase-negative Staphylococci. Pablito Sembillo and Joanne J. Dobbins, Bellarmine College.
0936 Induction of Systematic Protection in Cucumber to Disease Caused by *Colletotrichum lagenarium*. Nancy Doubrava, R. A. Dean, L. Matthews, and J. Kuc', University of Kentucky.
0948 Break
1000 Koch's Postulates: Potato-*Phytophthora infestans* Interaction. Joseph Kuc' and Etta Nuckles, University of Kentucky.
1012 The In Vitro Translation of Glutamine Synthe-

tase. Stanley L. Silver and Valgene Dunham, Western Kentucky University.

1024 Diatoms Associated with Coarse Stream-sediments (Epipsammon) as Influenced by Drainage Basin Physiography. Stephen D. Porter, Kentucky Division of Water, Frankfort.

1036 Control of Flowering in Shoot Tip Cultures of Cucumber. Larry A. Giesmann, Northern Kentucky University.

1048 In Vitro Micropropagation of *Paulownia Tomentosa.* Karen Kaul, Kentucky State University.

1100 Hydrologic Patterns and Phosphorus Dynamics of Forested Wetlands in Western Kentucky. Kimberly Benson, Jefferson Community College.

CHEMISTRY SECTION

Laurence J. Boucher, Chairperson
Vaughn Vandergrift, Secretary

Concurrent Session I

C. H. Henrickson, Presiding
Heritage Hall-Ballroom 3

0800 Chemical Education for the Health Professionals—An ACS Committee Report. C. H. Henrickson, Western Kentucky University.

0812 Software Implementation of the Temporally Optimized Integrating Ratemeter. Steve Engh and F. James Holler, University of Kentucky.

0824 PREP ROOM: A Microcomputer Tutorial in the Preparation of Solutions for the Chemistry Lab. Darnell Salyer, Eastern Kentucky University.

0836 Computer Drills for the First Organic Course. Victor I. Bendall, Eastern Kentucky University.

0848 John William Strutt, The Third Lord Rayleigh. Norman W. Hunter, Western Kentucky University.

0900 Experiences at Argonne National Laboratory in the Student Research Program. Wheeler Conover, Cumberland College. (Sponsored by Ann M. Hoffelder.)

Concurrent Session II

Mustafa I. Selim, Presiding
Heritage Hall-Ballroom 4

0800 Synthesis of -Hydroxyenones. An Approach to the Side Chain of the Cytotoxic Cucurbitacins. Charlene Haertzen, Mark Sabol, and D. S. Watt, University of Kentucky. (Sponsored by Audrey Companion.)

0812 An Approach to the Synthesis of Trichothecenes from Pulegone. Stewart Richardson, A. Jeganathan, and D. S. Watt, University of Kentucky. (Sponsored by Audrey Companion.)

0824 An Approach to the Synthesis of Phyllanthocin from Glucose. R. S. Mani and D. S. Watt, University of Kentucky. (Sponsored by Audrey Companion.)

0836 Polymers of Benzo(b)thiophene. Larry J. Baldwin, Cumberland College.

0848 Analysis of Tree Ring Wood for Determining the Environmental Impact on the Rate of Tree Growth. Keith McClain and Mustafa I. Selim, Murray State University.

0900 Investigation of Groundwater Quality in Western Kentucky. Sandra Dean Grant and Mustafa I. Selim, Murray State University.

Symposium on NMR

J. P. Selegue, Presiding
Heritage Hall-Ballroom 3

0930 Introduction to 2D NMR. Mary Ann Yacko, University of Kentucky. (Sponsored by Audrey Companion.)

1000 2D NMR Applied to Organometallic Complexes. J. P. Selegue and P. N. Nickias, University of Kentucky.

Invited Lecture

1030 NMR Imaging. Stanford Smith, University of Kentucky.

A tour of the University of Kentucky NMR research facilities will be conducted Saturday, 22 November from 1230 to 1330. Attendance will be limited. Sign-up sheets and maps will be provided at the symposium. The tour will originate from the Slone Building, Room 107, Washington Avenue.

1130 Business meeting for Chemistry Section.

GEOGRAPHY SECTION

Gary Cox, Chairperson, Presiding
L. Michael Trapasso, Secretary
Heritage Hall-Room E

0800 Variation in pH of Precipitation in Louisville-Jefferson County, Kentucky. David A. Howarth and Clara A. Leuthart, University of Louisville.

0812 Another Look at Kentucky Tornadoes. Glen Conner, Western Kentucky University.

0824 Agriculture and Wetlands of Clear Creek-Wiers Marsh in the Tradewater River Drainage. Clara A. Leuthart and Hugh T. Spencer, University of Louisville.

0836 Mechanisms Responsible for Summer Precipitation in Kentucky. L. Michael Trapasso, Western Kentucky University.

0848 Regional Semantics of "Barren" and "Desert" in 18th and 19th Century North American Landscape Descriptions. Conrad Moore, Western Kentucky University.

0900 Constructing Topographic Block Diagrams from Projected Profiles. Anthony Clarke, University of Louisville.

0912 Oil Wells in Karst Regions. Ron Dilamarter, Western Kentucky University.

0924 Watershy Geography. Edmund E. Hegen, Western Kentucky University.

0936 Back to the Land Architecture in Cumberland County, Kentucky. Albert Petersen, Western Kentucky University.

0948 Isolationism in Kentucky: Revisited. Wayne L. Hoffman, Western Kentucky University.

1000 The Influence of Transportation on Urban Development: A Case Study. James Davis, Western Kentucky University.

1012 Primate Cities and Vanishing Cities: The Preception of Foreign Urban Areas of Kentucky Students. Edwin T. Weiss, Jr., Northern Kentucky University.

1024 Dhaka: The Metropolis of Bangladesh. Reza Ahsan, Western Kentucky University.

1036 When Silver Threads Turn to Gray: A Spatial Analysis. James M. Bingham, Western Kentucky University.

1048 Geography of Death: Kentucky Farming Fatalities (Report of 1985). Extension of Project to 1986: Review, Comparative Statistics, Outlook and Concluding Comments. Milos Sebor, Eastern Kentucky University.

1100 Delafield: A Neighborhood Analysis in Bowling Green, Kentucky. Hong Liu, Western Kentucky University.

1112 Ecuador's Colorado Indians. Mark Lowry II, Western Kentucky University.

1124 Place Names in Fayette County, Kentucky. William A. Withington, University of Kentucky.

1136 Report from the State Geographer. Neil Weber, Murray State University.

1148 Business meeting for Geography Section.

1200–1300 Discussions concerning geography undergraduate and graduate research. All participants.

GEOLOGY SECTION

Alan D. Smith, Chairperson, Presiding
Charles Mason, Secretary
Lexington Convention Center-Room B

0824 Hydrocarbon Potential of the Ohio Shale (Devonian), Southeast Kentucky. J. R. Moody, J. R. Kemper, I. M. Johnston, and W. T. Frankie, Kentucky Geological Survey. (Sponsored by C. E. Mason.)

0836 Petroleum Exploration & Production. Graham Hunt, University of Louisville.

0848 The Integration of Remotely Sensed Digital Data Into a Computerized Petroleum Exploration Model—The Illinois Basin. Lynn Shelby, Murray State University. (Sponsored by John Philley.)

0900 Structural Controls on Oil Occurrence in South-Central Kentucky. Kenneth W. Kuehn, Western Kentucky University.

0912 Computer Simulation of Thrust-faulted Terrains and Subsurface Geometrics. Scott Wilkerson and Steven I. Usdansky, Murray State University.

0924 Mississippian Reactivation of the Irvine-Paint Creek Fault System, East-Central Kentucky. Garland R. Dever, Jr., Kentucky Geological Survey. (Sponsored by C. E. Mason.)

0936 Reliability of Count Data in Palynology. C. T. Helfrich, Eastern Kentucky University.

0948 Conodont Biostratigraphy of the Duffin Member of the New Albany Shale in East Central Kentucky. Charles C. Mellon, University of Kentucky. (Sponsored by Frank Ettensohn.)

1000 A Biostratigraphic Re-examination of the Basal New Providence Shale Member of the Borden Formation; Jefferson and Bullitt Counties, Kentucky. Charles E. Mason, Morehead State University.

1012 Manifestations of Seafloor Topography During Deposition of the Bedford-Berea Sequence, Northeast Kentucky and South-Central Ohio. Jack Pashion, University of Kentucky. (Sponsored by Frank Ettensohn.)

1024 Tidal Deltaic Deposits in the Lee Formation in Southeastern Kentucky. Bruce C. Amig, University of Kentucky. (Sponsored by Frank Ettensohn.)

1036 Carbonate Paleosols in the Mississippian Carbonates of Northeast Kentucky. Frank R. Ettensohn, University of Kentucky.

1048 Investigation of Mascot Dolomite (Knox Group) Relating to Zinc and Petroleum Resources in South Central Kentucky. Warren H. Anderson, Kentucky Geological Survey. (Sponsored by C. E. Mason.)

1100 Trace Element Variation in Vein Minerals, Central Kentucky Fluorspar District. M. A. Altic and J. R. Monrad, Eastern Kentucky University. (Sponsored by G. L. Kuhnhenn.)

1112 Topological Properties of Petrologic Phase Diagrams. Steven I. Usdansky, Murray State University.

1124 Engineering and Strength Characteristics of Silty-clays Derived from Richmond, Kentucky. Alan D. Smith, Robert Morris College.

1136 Business meeting for Geology Section.

MATHEMATICS AND COMPUTER SCIENCE SECTION

Herbert Berry, Chairman, Presiding
Russell M. Brengelman, Secretary
Radisson Plaza-Boone C

0800 Secondary Computer Science Courses and Certification of Teachers. Don E. Ryoti, Eastern Kentucky University.

0812 Math Achievement: A Statistical Analysis of Eastern Kentucky. John Fox and Mark Sohn, Pikeville College. (Sponsored by Russell Brengelman.)

0824 Twisting and Tying: Mathematical Enrichments for the Classroom. Caroll G. Wells, Western Kentucky University.

0836 Partnership with Industry: Adapting the Traditional Curriculum for Non-traditional On-Site Courses. Carol W. Wilson, Western Kentucky University.

0848 A Pascal Course for Gifted and Talented Middle School Students. Virginia Eaton, Western Kentucky University.

0900 Applications of Graph Theory in Computer Science. John H. Crenshaw, Western Kentucky University.

0912 Applying Software Engineering Principles in Developing CAI Software. Richard A. Rink, Eastern Kentucky University.

0924 Developing Expert Systems for Scientific Use: Some Problems and Possible Solutions. John D. McGregor, Murray State University.

0936 Computer Security Privacy and Ethics: The Law. Marlene Campbell, Murray State University.

1000 The Differential Effect of Computer Programming Languages on Mathematical Problem Solving Abilities. William Blubaugh, University of Texas.

1012 Teachers' Perceptions of Instructional Problems in Teaching Mathematics. Sue Caraway/John Morrow, University of S. Alabama.

1024 A Directed Reading Procedure for Mathematics Word Problems. Charles E. Lamb, The University of Texas at Austin.

1036 Word Processing/Text Editing and the Quality of Student Abstracts. George E. O'Brien/Edward L. Pizzini, Univ. of Pittsburgh/Univ. of Iowa.

1048 Cognitive Preference of Algebra Students Across Grade and Ability Levels. Wm. O'Donnell and Glenn Endsley, Cherry Creek High School, Englewood, Colo.

1100 Effects of Positive/Negative Instances on Learning. Arthur White, Ohio State University.

1112 Teaching Educational Applications with Super PILOT. Donald Pratt, Bloomsburg University, Bloomsburg, Pa.

1145 Business meeting of Mathematics and Computer Science Section.

PSYCHOLOGY SECTION

Barney Beins, Chairperson, Presiding
Bruce A. Mattingly, Secretary
Lexington Convention Center-Room F

0836 The Authoritarian Personality: A Comparison of Students and Police Officers. Edward C. Lovelace, Eastern Kentucky University. (Sponsored by Robert M. Adams.)

0848 Improving Attending Behavior in an Attention Deficit Disordered Boy. M. Shawn Reaves, University of Kentucky. (Sponsored by Arthur J. Nonneman.)

0900 Sex Differences in Tattling Behavior in Kindergarten Students. Susan Burgan, Eastern Kentucky University. (Sponsored by Robert M. Adams.)

0912 The Use of Stress-Challenge Activities to Improve Self-Efficacy. Carol Jean Clevenger, Eastern Kentucky University. (Sponsored by Robert M. Adams.)

0924 Self-touch as an Indicator of Social Anxiety. James C. Burch, Eastern Kentucky University. (Sponsored by Robert M. Adams.)

0936 Accuracy in Students Self-prediction of Academic Performance. Kathy Hamilton, Eastern Kentucky University. (Sponsored by Robert M. Adams.)

0948 Problem-solving Appraisal as it Relates to State-trait Personality Factors and Family Problems. David M. Carscaddon, Pathways, Inc. (Sponsored by Frank H. Osborne.)

1000 The Relationships of Motivational Variables and Achievement in College Science Technologies. R. E. Simpson, L. Greeley, L. P. Elliott, E. T. Park, and D. Thayer, Western Kentucky University.

1012 The Effects of Trait Anxiety on Classroom Achievement of College Freshmen. M. Sohn, Morehead State University. (Sponsored by Frank H. Osborne.)

1024 The Interaction of Orientation and Wing Angle on the Muller-Lyre Illusion. Robert C. Martin, Jr. and Frank H. Osborne, Morehead State University.

1036 Tip Distance in the Muller-Lyre Illusion: Effect or Artifact? Frank H. Osborne and Sandra K. Combs, Morehead State University.

1048 Factors Responsible for Age-related Differences in Incidental Learning. Terry R. Barrett, Murray State University.

1100 Rooster Postures in Males: Are They More Prominent in Solitary Males, Males in All-male Groups, or Males in Mixed-sex Dyads? Kimberly S. Turner, Eastern Kentucky University. (Sponsored by Robert M. Adams.)

1112 Latent Sensitization Effects Following Repeated Administration of Low Doses of Apomorphine. Bruce A. Mattingly, James E. Gotsick, and Dawn Letcher, Morehead State University.

1124 Entorhinal Cortex Lesions Disrupt Spatial Learning and DRL-20 Performance. Michela La Rocca, Arthur J. Nonneman, Teri Landers, and Walter Isaac, University of Kentucky.

1136 Age-dependent Effects of Sulpiride on Punished Key-Peck Responding in the Chick. Karen H. Hagglund, Sanders A. McDougall, and James F. Zolman, University of Kentucky.

SCIENCE EDUCATION SECTION

Kathy Hunt, Chairperson, Presiding
Maurice Esham, Secretary
Lexington Convention Center-Room A

0800 Interhemispheric Communication in Learning Disabled Children—Implications for Mathematics and Science Education. Donna Berlin, The Ohio State University at Newark.

0812 School Science & Mathematics Journal. Gary G. Bitter, Ph.D., Arizona State University.

0824 Using Questions in Science Classes. Patricia Blosser, Ohio State University.

0836 Essential Science Elements—Texas' Key to Scientific Literacy. Jacob Blankenship, University of Houston.

0848 Research on Problem Solving in Middle School Science. Stanley Helgeson, Ohio State University.

0900 A Comparison of the Factors Associated With High School Science Enrollment of Black Students. Joy Lindbeck and Ellen Goggins, University of Akron.

0912 A Report on a Problem-solving Workshop for Middle School Mathematics and Science Teachers. John C. Park, N. Carolina State University.

0924 Developmental Influences of Science Process Skills Instruction. Lawrence Scharmann, Indiana University of PA.

0936 Secondary Science Methods Students Concepts of Teaching at the Beginning of a Methods Course. Lucille Slinger, Indiana University of PA.

0948 Effectiveness of Computer-aided Instruction in a Physical Science Course. John Wernegreen, Eastern Kentucky University.

1012 Examining a General Chemistry Examination. Curtis Wilkins and Norman W. Hunter, Western Kentucky University.

1024 Data Handling With the Microcomputer in General Chemistry Laboratory. Experiences and Student Response. C. H. Henrickson, Western Kentucky University.

1036 Aspects of 1986 NSF Workshop Held at MSU for High School Chemistry and Physical Science Teachers. Vaughn Vandegrift, Murray State University.

1048 The Perils of Textbook Publishing. William R. Falls, Morehead State University.

1100 The Scientist at Work as Perceived by Pre-service Elementary Teachers. Betty Stoess, Eastern Kentucky University.

1112 The Construction and Use of Economical Electrophoresis Apparatus. David R. Hartman, Western Kentucky University.

1124 Computer Prediction of Grades Using Pattern Recognition. Earl Pearson and Larry Wood, Western Kentucky University.

1136 Early Kentucky Naturalists: A Small Museum's Educational Approach. Lorna P. Harrell, Behringer-Crawford Museum.

1148 Business meeting of Science Education Section.

ZOOLOGY AND ENTOMOLOGY SECTION

W. Blaine Early III, Chairperson, Presiding
Blaine R. Ferrell, Secretary
Lexington Convention Center-Ballroom 2

0800 Sensitivity of the Alfalfa Weevil Stem-count Technique to Several Environmental Parameters. Robert J. Barney and D. E. Legg, Kentucky State University.

0812 Factors Influencing the Distribution of Maize Weevil (Coleoptera: Curculionidae) Eggs on Maize. D. E. Legg, R. J. Barney, P. W. Tipping, and J. G. Rodriguez, Kentucky State University.

0824 Life History Studies on the Green Stink Bug, *Acrosternum* Hilare (Hemiptera: Pentatomidae). Alvin Simmons and K. V. Yeargan, University of Kentucky.

0836 Ecology and Predatory Behavior of Three Coexisting Damsel Bug Species. Susan Kristine Braman and K. V. Yeargan, University of Kentucky.

0848 The Effects of Parasitization by *Microplitis croceipes* on *Heliothis Virescens*. Danise L. Coar and Douglas Dahlman, University of Kentucky.

0900 The Influence of Mating on Longevity in Male Treehole Mosquitos, *Aedes triseriatus*. Richard B. Buchanan and Blaine R. Ferrell, Western Kentucky University.

0912 Natural History of a Bolas Spider, *Mastophora hutchinsoni* Gertsch, in Kentucky: When Sex Calls, Death Answers. Kenneth V. Yeargan, University of Kentucky.

0924 Biologies of *Euschistus servus* and *E. variolarius*. Dwinardi Apriyanto, J. D. Sedlacek, and L. H. Townsend, University of Kentucky.

0936 Life History of *Madeophylax* sp. (Trichoptera: Limnephilidae). Guenter Schuster, Eastern Kentucky University.

0948 Food Utilization and Development of Corn Earworm *Heliothis zea* (Boddie), on Different Soybean Foliages. Raden Saleh and D. L. Dahlman, University of Kentucky.

1000 Pollen Dietary of Some Predator Mites. A. M. Afifi, M. F. Potts, C. G. Patterson, and J. G. Rodriguez, University of Kentucky.

1012 The Effect of Habitat and Hosts on the Abundance of Lonestar Ticks and American Dog Ticks. Robert H. Zimmerman, T.V.A. Land Between the Lakes.

1024 Lyme Disease: The Unknown Arthropod-borne Spirochete. Allen N. Hunt, Elizabethtown Community College.

1036 The Distribution and Abundance of Kentucky's Cave Bats. John R. MacGregor, Nongame Wildlife Program.

1048 The Foraging Behavior of Male and Female American Kestrels. Christopher J. Kellner and Gary Ritchison, Eastern Kentucky University.

1100 Home Range Size of Bobcats in The Land Between the Lakes. Linda Beth Penry and Robert B. Frederick, Eastern Kentucky University.

1112 Competition for Nest Sites: Do Starlings Inhibit Bluebird Production? Wayne H. Davis and William C. McComb, University of Kentucky.

1124 Animal Life in Abandoned Coal Mines in Eastern Kentucky. John R. MacGregor and Hal Bryan, Nongame Wildlife Program.

1136 Ohio River Fish Population Studies at Thomas More College Aquatic Biology Station, Campbell County Kentucky. John W. Ferner, Thomas More College.

1148 Osmoregulation by Amphibian Larvae. Janis Lynn Goldsmith and J. J. Just, University of Kentucky.

1200 Business meeting of Zoology Section.

FRIDAY AFTERNOON
21 November 1986

PAPER PRESENTATIONS
1445–1700

BOTANY AND MICROBIOLOGY SECTION

Jerry M. Baskin, Chairperson, Presiding
Carol C. Baskin, Secretary
Lexington Convention Center-Ballroom 1

1500 On the Occurrence of *Quercus montana* Willd. the Mountain Chestnut Oak, Along the Bluegrass Palisades. Ronald E. Houp, Kentucky Division of Water, Frankfort.

1512 The Stemless Blue Violets of Kentucky: A Year Later. Landon E. McKinney, Vanderbilt University.

1524 The Role of *Carpinus caroliniana* in Release of Aluminum in Response to Acid Rain. Alan W. Reed and Joe E. Winstead, Lindsey Wilson College and Western Kentucky University.

1536 Patch Dynamics and Community Development on Roadside Embankments. James O. Luken, Northern Kentucky University.

1548 Hydrologic Patterns and Phosphorus Dynamics in Forested Wetlands of Western Kentucky. Kimberly Benson, Jefferson Community College, SW.

1600 Vascular Flora of Rock Creek Research Natural Area and Environs, Kentucky. R. L. Thompson and R. L. Jones, Berea College and Eastern Kentucky University.

1612 Notes on Kentucky Vascular Plants Currently Listed or Under Petition for Listing as Federally Endangered or Threatened. Hal D. Bryan, Max E. Medley, and Jerry M. Baskin, Department of Transportation, Frankfort, University of Louisville and University of Kentucky.

1624 Business meeting for Botany and Microbiology Section.

CHEMISTRY SECTION

Laurence J. Boucher, Chairperson
Vaughn Vandergrift, Secretary

Concurrent Session I

Audrey L. Companion, Presiding
Lexington Convention Center-Ballroom 3

1448 Math-Pack—An Apple IIe Numerical Package for Chemists. Audrey L. Companion, University of Kentucky.

1500 Syntheses of Metallacumulenes of Ruthenium. Ramnath S. Iver and John P. Selegue, University of Kentucky.

1512 Reactions of Zwitterionic (Fe(CO)(PPH2)2CH) E (n-C5H5) with Electrophiles. John P. Selegue and James Goodrich, University of Kentucky.

1524 A Redox Study of the Reaction Between Iodine and CoTSPC4- in Various Solvents. Byung-Soo Yu and Robert D. Farina, Western Kentucky University.

1536 Temperature Dependence of Formation Constants of EDTA Complexes. Vickie Triantafyllakis and Harry M. Smiley, Eastern Kentucky University.

1548 Excess Volumes of Mixing of Benzene and Isomers of Octane. Michelle Drewes, Steve House, Kevin Briney, and Joan Reeder, Eastern Kentucky University.

1600 Synthesis, Structure, and Reactivity of Compounds with Bonds Between Early and Late Transition Metals. William J. Sartain and John P. Selegue, University of Kentucky.

1612 Synthesis and Reactivity of Ruthenium Alkynyl and Vinylidene Complexes. John P. Selegue and Bruce A. Young, University of Kentucky.

1624 Mechanisms and Stoichiometries. P. L. Corio, University of Kentucky.

1636 Synthesis and Reactivity of Electron Rich Iron Phosphine Complexes. Kevin Frank and John Selegue, University of Kentucky.

1648 Synthesis and Reactivity of Early-Late Transition Metal Hetero-bimetallic Complexes. Stanley L. Latesky and John P. Selegue, University of Kentucky.

1700 Simultaneous Determination of Nitrogen and Phosphorus in Biological Tissues by 14 MeV INAA. YiXian Mao, W. D. Ehmann, and W. R. Markesbery, University of Kentucky.

Concurrent Session II

Vaughn Vandegrift, Presiding
Lexington Convention Center-Ballroom 4

1436 Studies of Antibiotic Resistance-containing Plasmids Isolated from Pathogenic Bacteria. V. Vandegrift and T. Maudru, Murray State University.

1448 Detection of Chloroalkane Metabolites by Derivatization and High Performance Liquid Chromatograph. M. A. Toon and R. F. Volph, Murray State University.

1500 Fugitive Emissions from Packaging of Household Organo Phosphate Products. Michael W. Nold and William D. Schulz, Eastern Kentucky University.

1512 Separation and Identification of an Unknown Estrogenic Compound from Various Feedstuffs in Western Kentucky. Mustafa I. Selim and Karola Doak, Murray State University.

1524 Influence of Sialic Acid on the Motion of Terminal Galactose Residues on Human Erythrocyte Glycoconjugates. D. Allan Butterfield, Joseph W. Wyse, and J. Dwayne Jarrell, University of Kentucky.

1536 Electron Spin Resonance of Human Erythrocyte Membranes: Investigations of the Membrane Skeletal Network and Interactions of Potential Neurotoxins. D. Allan Butterfield, University of Kentucky.

1548 Membrane Alterations in Erythrocytes from Zinc-deficient Rats. Donna Palmieri, Michael Jay, and D. Allan Butterfield, University of Kentucky.

1600 Electron Spin Resonance Studies of Membrane Alteration: Implications to Biochemical Studies. Joseph W. Wyse and D. Allan Butterfield, University of Kentucky.

1612 Hydrogenation of Nitrogen Containing Heterocycles with Pd(II) Anchored Anthranilic Acid Polymer Catalysts. Laurence J. Boucher and Thomas M. Pope, Arkansas State University and Western Kentucky University.

1624 Attempted Syntheses of Ruthenium-Butatrienylidene Complexes. John Davis and J. P. Selegue, University of Kentucky.

1636 Elemental Concentrations at the Cellular Level in Alzheimer's Disease by INAA. D. E. Wenstrup, W. D. Ehmann, and W. R. Markesbery, University of Kentucky.

1648 Decarboxylation of I-Aminocyclopropanecarboxylic Acid and its Derivatives. Ganesan Vaidyanathan and Joseph W. Wilson, University of Kentucky. (Sponsored by Audrey Companion.)

SCIENCE EDUCATION SECTION

Kathy Hunt, Chairperson, Presiding
Maurice Esham, Secretary
Lexington Convention Center-Room A

1445 Student Water Quality Monitoring Network. Jane Sisk-Calloway County High School, Murray.

1500–1600 Aerial Photographs and Remote Sensing Products in the Classroom. David Hylbert, John Philley, and Maurice Esham, Morehead State University.

ZOOLOGY AND ENTOMOLOGY SECTION

Symposium: Plant/Arthropod Interaction
W. Blaine Early III, Moderator
Lexington Convention Center-Ballroom 2

1448 Visual Patterns and Flower Visitation by *Phyciodes tharos*. W. Blaine Early III, Cumberland College.

1500 Factors Involved in the Utilization of UV Patterns in Flowers by Bees. Rozenna Blandford Carr, University of Louisville.

1512 Strawberry Foliage: Seasonal Biochemical Changes and Mite Interaction. J. G. Rodriguez, T. R. Hamilton-Kemp, R. A. Anderson, C. G. Patterson, and J. M. Loughrin, University of Kentucky.

1524 Biochemical Changes in Soybeans in Response to Mite Feeding. D. F. Hildebrand, J. G. Rodriguez, G. C. Brown, and C. S. Legg, University of Kentucky.

1536 Physiological Impact of a Scale Insect on its Woody Plant Host. Stephen D. Cockfield and D. A. Potter, University of Kentucky.

1548 Naturally Occurring Insecticides—Effect of Endophyte-infected Tall Fescue Extracts. Douglas L. Dahlman, L. P. Bush, and M. R. Siegel, University of Kentucky.

1600 Prickles, Poisons and Leathery Leaves: Leafminer Interactions on American Holly. Daniel A. Potter and T. W. Kimmerer, University of Kentucky.

1612 Interactions Between Tree Stress and Attraction of the Two-lined Chestnut Borer to White Oak. James P. Dunn and D. A. Potter, University of Kentucky.

SATURDAY MORNING
22 November 1986

PAPER PRESENTATIONS
0800–0900

BOTANY AND MICROBIOLOGY SECTION

Symposium: The Vegetation and Flora of Kentucky
Carol C. Baskin, Presiding
Lexington Convention Center-Ballroom 1

0800 Introduction. Carol C. Baskin, University of Kentucky.

0810 Late Glacial and Holocene Vegetation of Kentucky: A General Overview. Jerry M. Baskin and Carol C. Baskin, University of Kentucky.

0830 The Mixed Mesophytic Forest Region: Diversity and Change After Chestnut and E. Lucy Braun. William H. Martin III, Eastern Kentucky University.

CHEMISTRY SECTION

Laurence J. Boucher, Chairperson
Vaughn Vandergrift, Secretary
Audrey L. Companion, Presiding
Lexington Convention Center-Ballroom 4

0800 Why is the Bond Energy of FeO^+ Less Than That of FeO, While That of FeO^- is Larger? Audrey L. Companion, University of Kentucky.

0812 Construction of an Inexpensive, Versatile Laboratory Interface. Earl Pearson and James Howze, Jr., Western Kentucky University.

0824 Interaction of Hydrogen With Defects in Aluminum Metal. H. F. Ades, University of Kentucky.

0836 The Effect of Kel-F and Graphite Particle Sizes in Kel-F Graphite Electrodes. J. E. Anderson, C. L. Hughes, and R. J. Tompkins, Murray State University.

0915 Annual Business Meeting.

1230–1530 Tour of NMR Research Facilities, Slone Building. See NMR Symposium (Friday) for Details.

PHYSIOLOGY, BIOPHYSICS, BIOCHEMISTRY AND PHARMACOLOGY SECTION

David L. Wiegman, Chairman, Presiding
Nancy L. Alsip, Secretary
Lexington Convention Center-Room D

0800 "New" Diseases in Kentucky: A Study of Origins. Elizabeth Finkenstaedt, University of Kentucky.

0812 The Osmoregulatory Role of a Functional Asymmetry in Homologous, Bilaterally Symmetrical Neurons. R. Scot Payne, University of Kentucky.

0824 Neural Control of Microvessels in the Rat Cremaster. Jeffery Brock, Irving Joshua, and Andrew Roberts, University of Louisville.

0836 Oxygen Control of Small Blood Vessels. Andreas S. Luebbe, Nancy L. Alsip, and Patrick D. Harris, University of Louisville.

0848 Reflex Effects of Left Atrial Distension. Michael Kurz, W. B. Wead, and A. M. Roberts, University of Louisville.

0900 Protein Synthesis in Alzheimer's Disease. Janice A. Cole, University of Kentucky.

ZOOLOGY AND ENTOMOLOGY SECTION

W. Blaine Early III, Chairperson
Blaine R. Ferrell, Secretary

Concurrent Session I

Blaine R. Ferrell, Presiding
Lexington Convention Center-Ballroom 2

0800 Tenacity of the Marine Gastropods, *Nerita peloronta* and *N. versicolor* on San Salvador Island, Bahamas. Mark Domalewski and Thomas E. Bennett, Bellarmine College.

0812 North and South American Freshwater Isopods: Anatomical Comparisons of Copulatory Appendages. Rudolph Prins and Rodney McCurry, Western Kentucky University.

0824 Morphological Differences Between Light and Dark Adapted Ommatidia in the Cockroach, *Leucophaea maderae*. Patrick K. Alexander and Blaine R. Ferrell, Western Kentucky University.

0836 Altered Integumental Pigmentation of *Lirceus lineatus*. David F. Oetinger, Kentucky Wesleyan College.

0848 Mollusca From a Mammoth-Excavation Site (Wisconsin) in Dewey County, Oklahoma. Branley Allan Branson, Eastern Kentucky University.

Concurrent Session II

W. Blaine Early III, Presiding
Lexington Convention Center-Ballroom 3

0800 Effects of 4-nitrophenol (PNP) and Low pH on Hatchability and Survival Rates of Fathead Minnow (*Pimephales promelas*) Embryos and Larvae. Lee Colten and Barbara A. Ramey, Eastern Kentucky University.

0812 Avoidance Responses of Juvenile Fathead Minnows to Acid pH. Barbara A. Ramey and Lee Colten, Eastern Kentucky University.

0824 Hemolymph Proteins of *Heliothis virescens*. Billy R. Thomas and D. L. Dahlman, University of Kentucky.

0836 Biochemical Strategies of Overwintering in *Achaeta domesticus*. John C. Mobley, Cumberland College.

0848 Zoology and Entomology. Catherine Hunter and K. V. Yeargan, University of Kentucky.

0900 Food Quality and Growth in Garter Snakes. Roy M. Scudder-Davis and Gordon M. Burghardt, Berea College.

SATURDAY AFTERNOON
22 November 1986

PAPER PRESENTATIONS
1330–1700

BOTANY AND MICROBIOLOGY SECTION

Symposium: The Vegetation and Flora of Kentucky
Carol C. Baskin, Presiding
Lexington Convention Center-Ballroom 1

1330 Forest Vegetation of the Knobs Region. Robert N. Muller, University of Kentucky.

1350 Presettlement Vegetation of the Bluegrass Region, a Eutrophic Island Within the Primeval Landscape. Julian Campbell, University of Kentucky.

1410 Actual and Potential Vegetation of the Bluegrass Region. William S. Bryant, Thomas More College.

1430 Actual and Potential Vegetation of the Pennyroyal Plateau. Joe E. Winstead, Western Kentucky University.

1450 An Overview of the Vegetation of the Shawnee Hills of Kentucky. Marc Evans, Kentucky Nature Preserves Commission.

1510 Some Aspects of the Vegetation of the Jackson Purchase Region of Western Kentucky. Max E. Medley, University of Louisville.

1530 Planted and Volunteer Vegetation on Surface-Mines in the Eastern Kentucky Coal Field Region. William G. Vogel and Ralph L. Thompson, U.S.D.A., Forest Service and Ber College.

1550 The Native Flora of Kentucky and its Geographical Relationships. Willem Meijer, University of Kentucky.

1610 The Weed Flora of Kentucky and its Geographical Relationships. Patricia Dalton, University of Kentucky.

1630 The Bryoflora of Kentucky and its Geographical Relationships. Susan Moyle Studlar and Jerry Snider, Centre College and University of Cincinnati.

CHEMISTRY SECTION

Laurence J. Boucher, Chairperson
Vaughn Vandergrift, Secretary

Coal & Petroleum Pitch Symposium

John T. Riley, Presiding
Lexington Convention Center-Ballroom 4

1324 Mineral Matter Segregation in Particle Size Fractions of Pulverized and Attritor-Milled Coal. John T. Riley and Fred Hayes, Western Kentucky University.

1336 The Role of Coal's Soluble Fraction in Coal Plasticity—One View. John W. Reasoner, Jana Whitt, and Mark McElroy, Western Kentucky University.

1348 Measurement of Micron-Range Size Distributions in Ultrafine Milled Coals. Leonor M. Lopez-Froedge and William G. Lloyd, Western Kentucky University.

1400 Components of Fresh vs. Aged Coal Extracts. David Igo, William D. Schulz, and Joan Reeder, Eastern Kentucky University.

1412 The Nature of Volatile Matter in Coal. Dallas Mellon and John T. Riley, Western Kentucky University.

1424 Thermodynamics of Coal-solvent Interactions. Thomas K. Green, George Ransdell, and Doug Kimbler, Western Kentucky University.

1436 Analysis of Petroleum Pitch by Pyrolysis Gas Chromatography. M. D. Kiser and W. L. Budden, Ashland Petroleum Co.

1448 Determination of Carbon Fiber Length Using a Coulter Particle Counter. W. L. Budden and M. D. Kiser, Ashland Petroleum Co.

1500 A Study of the Effect of Gauge Length on the Tensile Strength and Modulus of Carbon Fibers. E. E. Perdue, Ashland Petroleum Co.

Chemistry Paper Presentations

Oliver J. Muscio, Jr., Presiding

1524 Hydrolysis of Fluoro-N-Heteroarenes in Buffer Solutions: Nucleophilic or General Base Catalysis? Oliver J. Muscio, Jr. and Kelly A. Marlow, Murray State University.

1536 A Kinetic Study of the Reduction of Anthraquinone. Rita K. Hessley and Duane L. Osborne, Western Kentucky University.

1548 Binuclear Copper Complexes as Models of the Active Site in Tyrosinase. Robert M. Buchanan and Cheryl W. Blumenberg, University of Louisville.

1600 Magnetic Exchange Interactions in Binuclear Copper(II) Complexes. Robert M. Buchanan, Thomas Doman, and J. Frederick Banks, University of Louisville.

1612 Synthesis and Characterization of Binuclear Schiff Base Macrocycles and Their Transition Metal Complexes. Robert M. Buchanan, Mark S. Mashuta, and Thomas Doman, University of Louisville.

1624 Preparation and Characterization of Binuclear Manganese Complexes. Models of the Photosynthetic Water Oxidation Apparatus. Robert M. Buchanan and Rajesh Desai, University of Louisville.

PHYSICS SECTION

Doug Humphrey, Chairperson
Jack Wells, Secretary
Lexington Convention Center-Ballroom 3

1336 Halley's Comet—A Stimulus of Science. Joel Gwinn, University of Louisville.

1348 A Multi-photogate Timer System. W. F. Huang, University of Louisville.

1400 A Computer Description of the Atom, Based on the Independent Particle Model. John Morrison, University of Louisville.

1412 A Physics and Astronomy Update at J.C.C. Les Burton, Jefferson Community College.

1424 A Computerized Free-fall, Inclined Plane Apparatus. Terry Flesch, Thomas More College.

1436 New Experimental Data on the Structure of the Glass—As2Se3. Jack Wells, Thomas More College.

1448 The Nucleus of Quarks and Gluons. Christopher Davis, University of Louisville.

1500 A Large Portable Telescope for Teaching, Research, and Community Service. Raymond C. McNeil, Northern Kentucky University.

PHYSIOLOGY, BIOPHYSICS, BIOCHEMISTRY AND PHARMACOLOGY SECTION

David L. Wiegman, Chairman, Presiding
Nancy L. Alsip, Secretary
Lexington Convention Center-Room D

1324 Physiology of the Developing Urinary Bladder in Amphibians. Theresa L. Powell and John J. Just, University of Kentucky.

1336 The Wavelength Dependence of Avoidance Behavior in the Green Algae Volvox. Mary Blakefield and John Calkins, University of Kentucky.

1348 Properties of Photomutagens in Synthetic Fuels. Christopher P. Selby, John Calkins, and Harry Enoch, University of Kentucky.

1400 Evidence Suggesting an Inducible DNA Repair System in the Eukaryote, *Tetrahymena pyriformis*. John Wheeler and John Calkins, University of Kentucky.

1412 The Effects of Inducible Repair on UV-B-UV-C Action Spectra Shape in *Tetrahymena pyriformis*. John Calkins and John Wheeler, University of Kentucky.

1424 Effects on Division Time of *Paramecium aurelia* and *Tetrahymena pyriformis* by the Timed Addition of Caffeine. Melinda K. Eades and John Calkins, University of Kentucky.

1436 Effect of Fescue Endophyte on Reproductive Hormones in Rats. Dan R. Varney, Loretta Carrico, and Sanford L. Jones, Eastern Kentucky University.

1448 Examination of Potyviral Proteins in Infected Tobacco Protoplasts. Gary M. Hellmann, University of Kentucky.

1500 Protein-DNA Interactions Regulate Gene Activity. Robert C. Dickson, Michael Whitte, Lewis Wray, Jr., and Michael Riley, University of Kentucky.

1512 Comparison of Two Molecular Weight Forms of an Enzyme by Fluorescence. David Robbins, University of Kentucky.

1524 Molecular Cloning of Ca2+ AtPase. Paul Brandt, Mauri Zurini, Robert E. Rhoads, and Thomas C. Varaman, University of Kentucky.

1536 Business meeting for Physiology, Biophysics, Biochemistry, and Pharmacology.

Workshop

1548–1700 Integrative Study in Physiology and Medicine. This workshop will be devoted to integrative approaches to the study of the human organism. A medical case history (Case 26-1969, New England Journal of Medicine 280:1466–1473, 1969) will provide the framework for discussion. The case involves consequences of a partial, congenital obstruction of the aorta, and involves cardiovascular, respiratory, acid-base, and electrolyte problems. Providing an opportunity for discussions which transcend specific scientific problems, organ systems, or areas of specialization, this session will focus on the elucidation of physiologic events which generate disease processes. Physiologic interrelationships which shed a light on differences between health, illness, dying, and death will also be examined. Joseph Engelberg, University of Kentucky.

PSYCHOLOGY SECTION

Barney Beins, Chairperson, Presiding
Bruce Mattingly, Secretary
Lexington Convention Center-Room F

1336 The Role of Postural Cues in Nonverbal Communication. Jack Thompson, Tammy Day, and Debbie Finkel, Centre College.

1348 Postural Correlates of Affect. Jane Kelly and Jack Thompson, Centre College.

1400 The Relationships between Health, Mood and Psychological Stress. Linda Young and Jack Thompson, Centre College.

1412 Beauty is Best: An Investigation of the Effects of Physical Attractiveness on Performance Evaluation. Kevin Patrick Bucknam, Eastern Kentucky University. (Sponsored by Robert M. Adams.)

1424 Effects of Viewing Graphic Portrayals of the Consequences of Violence on Aggressive Behavior. Krister Martin Harnack, Eastern Kentucky University. (Sponsored by Robert M. Adams.)

1436 Effects of Pornography on Sexual Behavior in Erotopholer and Erotophiler. Dana Cooper, Eastern Kentucky University. (Sponsored by Robert M. Adams.)

1448 Altruistic Behavior: When Do People Stop Helping? Dean Henson, Eastern Kentucky University. (Sponsored by Steve Falkenberg.)

1500 The Effect of Physical Attractiveness on Children's Altruistic Behavior. Constance L. Mason, Eastern Kentucky University. (Sponsored by Robert M. Adams.)

1512 Business meeting for Psychology Section and Presentation of Griffith Awards.

Trans. Ky. Acad. Sci., 48(1–2), 1987, 47–50

Abstracts of Some Papers Presented at the Annual Meeting, 1986

BOTANY & MICROBIOLOGY

Patch dynamics and community development on roadside embankments. JAMES O. LUKEN, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41076.

Differences in amount and vertical distribution of aboveground biomass were measured between patches of crownvetch (*Coronilla varia*) and Kentucky-31 tall fescue (*Festuca arundinacea*) on a revegetated roadside embankment in Northern Kentucky. Growth of tall fescue was stimulated when growing in crownvetch patches (field) and when growing in soils collected from crownvetch patches (greenhouse). In comparison, growth of crownvetch was inhibited when growing in tall-fescue patches (field) and when growing in soils collected from tall-fescue patches (greenhouse). These data coupled with a measured growth response of tall fescue to nitrogen fertilization suggest that tall fescue will eventually invade and dominate crownvetch patches.

The role of *Carpinus caroliniana* in release of aluminum in response to acid rain. ALAN W. REED* and JOE E. WINSTEAD, Departments of Biology, Lindsey Wilson College, Columbia, KY 42728, and Western Kentucky University, Bowling Green, KY 42101.

To test *Carpinus caroliniana* Walt. (ironwood) as an aluminum contributor in acidic aquatic systems, we placed leaf samples in solution buffered to pH 3.5, 4.4, and 7.0 and one of 4.4 inoculated with 10 g of limestone. After 75 days, microbial activity altered solution pH as follows: 3.5 to 4.7; 4.4 to 5.0; 7.0 to 4.8; and 4.4 to 6.1. Aluminum assay of leachate was by atomic absorption techniques. More acidic leachates contained higher aluminum levels with 1 g leaf samples contributing 0.341 mg/liter under initial pH of 3.5 compared to 0.153 mg/liter in pH solution with limestone.

CHEMISTRY

Detection of chloroalkane metabolites by derivatization and high-performance liquid chromatography. MARK A. TOON* and ROBERT F. VOLP, Department of Chemistry, Murray State University, Murray, KY 42071.

2-Chloropropane is metabolized to acetone. Our goal was to obtain an analytical method of detecting the acetone produced by liver microsomes. By reacting acetone with dansyl hydrazine, we were able to form a fluorescent hydrozone derivative, which could then be analyzed using reversed-phase HPLC and a fluorescence detector. The derivatization procedure was optimized with respect to reagent concentration, pH, and water content and gave reproducible, quantitative results. After 60 minutes incubation of 5.0 mM 2-chloropropane (5 mg protein/ml), 117 μM acetone was present in the mixture. By varying the incubation time, this method can be used to determine the rate of 2-chloropropane metabolism.

Components of fresh vs. aged coal extracts. DAVID IGO*, WILLIAM D. SCHULZ, and JOAN REEDER, Department of Chemistry, Eastern Kentucky University, Richmond, KY 40475.

Authorities believe soluble portions of coals reflect structure of insoluble portions and that loss of thermoplasticity upon heating or aging are mechanistically similar. To study these phenomena, Kentucky coal KCER 9091 was crushed, "artificially aged" by stirring under oxygen for 7, 21 and 24 days. Control and "aged" samples were soxhlet extracted, concentrated and analyzed by capillary gas chromatography/mass spectrometry. Chief differences in extracts were lower boiling alkenes, dienes and aromatics present in control samples, and not in aged samples. We believe that these compounds are oxidatively incorporated into cross-linked coal structure during aging.

Fugitive emissions from packaging of household organophosphate products. MICHAEL W. NOLD and WILLIAM D. SCHULZ*, Department of Chemistry, Eastern Kentucky University, Richmond, KY 40475.

Several samples of "controlled-release" household pesticide products containing organic phosphate ester (cholinesterase inhibitor) active ingredients were examined for fugative toxic emissions. Products included "flea collars" and "pest strips" of various brands. These products are sealed in polymer-foil or treated paper packages. Sealed packages were washed with methylene chloride, concentrated, and analyzed by capillary gas chromatography/mass spectrometry. All products had traces of active ingredient on outsides of sealed packages. Concentrations ranged from 15 mg to traces of hydrolyzed ingredient. We have yet to determine if these results are due to diffusion through the package or deposition during packaging.

GEOGRAPHY

Regional semantics of "barren" and "desert" in 18th and 19th century North American landscape descriptions. CONRAD MOORE, Department of Geography and Geology, Western Kentucky University, Bowling Green, KY 42101.

Previous interpretations of the meaning of "barren" and "desert" in historic North American landscape descriptions have emphasized the importance of an absence of trees. An examination of 371 travel accounts written during 1774–1880, revealed that the primary indicators of "barren" landscapes were the presence of shrubs and small trees in the humid East, a lack of grass in the subhumid-semiarid

Central Plains, and the presence of sand hills or plains and xerophytes in the semiarid-arid Far West. Dominant "desert" criteria were a lack of settlement in the East and the presence of unconsolidated sand in the Central Plains and Far West.

Place names of Fayette County, Kentucky. WILLIAM A. WITHINGTON, Department of Geography, University of Kentucky, Lexington, KY 40506-0027.

Place name studies or gazetteers, frequent at national and state or provincial levels, are few for the U.S. county level. This place-name study focusing on Fayette County in east-central Kentucky adds to those few. The purpose is to identify place names of sufficient prominence for inclusion in a county gazetteer. Fayette County place names and their numbers, classifications, and sources are reviewed. Onomastic questions of name sources and questions of inclusion of historic but non-current or detailed feature names are examined, indicating several possible approaches to place-name studies in such localized areas as Fayette County.

GEOLOGY

Carbonate paleosols in the Mississippian carbonates of northeastern Kentucky. FRANK R. ETTENSOHN, Department of Geology, University of Kentucky, Lexington, KY 40506.

Subaerial exposure crusts are common atop disconformities separating Meramecian and early Chesterian (Mississippian) members of the Slade Formation in northeastern Kentucky. Although the crusts commonly attributed to diagenetic processes, the widespread presence of soil features suggests a pedogenic origin. Significant pedogenic features include root traces, soil structure, and soil horizons. Evidence for rooting includes root molds, root tubules, and alveolar texture. Soil structures most commonly occur as megascopic peds. Most soil profiles are immature or truncated, and only the C horizon remains; locally relict A and B horizons are present. The crusts themselves represent carbonate illuviated in the C horizon during dry, evaporative periods.

Petroleum exploration and production in the U.S.A. GRAHAM HUNT*, Department of Geology, University of Louisville, Louisville, KY 40292.

With the collapse of oil prices there are many and widely various projections and predictions for the years ahead in this historically cyclical business. For this country recent data indicate: (1) a rise in petroleum demand (3% annually); (2) a decline in oil production (2% from 8.9 million barrels per day, 1985, to 8.5 million barrels per day); (3) a decline in development drilling (62%, the lowest level in the last 40 years, 954 rigs operating in 1986 compared with 1962 rigs operating a year ago); and (4) a highly fluctuating oil price (prices with lows of $7/barrel to highs near $18/barrel).

The demand for energy alternatives in the U.S.A., such as natural gas and coal, may start to increase sharply (1990 to 2000) in reply to the rising oil prices and declining production and increased imports. As the oil begins to become more scarce there will be more drilling for natural gas at depths near 15,000 feet in host sedimentary rocks.

MATHEMATICS & COMPUTER SCIENCE ENGINEERING

Applications of graph theory in computer science. JOHN H. CRENSHAW, Department of Computer Science, Western Kentucky University, Bowling Green, KY 42101.

Deadlock detection is a practical application that can be used as an example in teaching graph theory. In graph-theoretical terms, a deadlock occurs when the adjacency matrix describing the physical system possesses a cycle. If there are M processes in a system, then the adjacency matrix $\mathbf{A}$ is an $M \times M$ matrix where $\mathbf{A}(I, J) = 1$ if process I is waiting for a resource possessed by process J and 0 otherwise. The classical technique is to compute $\mathbf{A}^M$. If $\mathbf{A}^M$ is non-zero then $\mathbf{A}$ possesses a cycle. However, the time constraints of a practical system make this approach inefficient and impractical; faster techniques must be devised.

A Pascal course for gifted and talented middle-school students. VIRGINIA EATON, Department of Computer Science, Western Kentucky University, Bowling Green, KY 42101.

During summers 1984, 1985, and 1986 Western Kentucky University offered a Pascal course for middle school students. The course is offered as part of WKU's Summer Program for Verbally and Mathematically Precocious Youth, which is a cooperative effort with the Duke University Talent Identification Program. Students alternate between attending lectures and doing lab work. They are in class for 6 hours per day for 3 weeks. The material covered is the same material taught in WKU's introductory Pascal course. The students learn TURBO Pascal on microcomputers and VAX Pascal on a VAX 11/785.

Expected utility and decision making. WALTER FEIBES, Department of Business Administration, Bellarmine College, Louisville, KY 40205.

When one or more of the outcomes of a decision problem results in either an extraordinary large monetary or utility loss, the expected monetary value criterion for obtaining an optimal decision is replaced by Von Neumann's expected utility criterion. Criticism of the classical utility assumptions are discussed and illustrated with the Allais paradox and Raiffa's "money pump" problem. Specifically, the assumptions of transitivity and the existence of a unique utility function are questioned and possible alternative assumptions are proposed.

Partnership with industry: adapting the traditional curriculum for non-traditional on-site courses. CAROL W. WILSON, Department of Computer Science, Western Kentucky University, Bowling Green, KY 42101.

Teaching at an industrial site can be challenging and rewarding. During academic year 1985–1986, I taught Introduction to Programming and Programming I (BASIC) at the Logan Aluminum plant in Russellville, KY. Class examples and programming assignments were chosen carefully to relate to the adult experience or the industrial environment. Students were delighted when they realized that they were capable of generating the production reports that they used in their daily work. Reaction was so positive to these first courses that three additional university courses hav been offered at the Logan site and more courses are planned for the future.

Classroom enrichments from topology. CARROLL G. WELLS*, Department of Mathematics, Western Kentucky University, Bowling Green, KY 42101.

Topology is the geometry which studies what happens when objects are twisted, stretched, bent, cut, glued, etc. Using a strip of paper, form the following objects: (1) strip; (2) band—bend the strip without twisting and tape the seam; (3) band with full twist—bend and put a full twist in the strip and tape the seam; (4) Mobius strip—bend and put a half twist in the strip and tape the seam. Now determine how many sides each has and what happens when each is cut lengthwise.

PHYSIOLOGY, BIOPHYSICS & PHARMACOLOGY

Reflex cardiac effects of left atrial distension. MICHAEL A. KURZ*, WILLIAM B. WEAD, and ANDREW M. ROBERTS, Department of Physiology and Biophysics, University of Louisville, Louisville, KY 40292.

To determine the effects of left atrial distension on myocardial contractility, a balloon-tipped catheter was placed in the left atrial appendage of anesthetized dogs. Left ventricular pressure was recorded for determination of Vmax. Inflation of the balloon with warm saline increased Vmax and heart rate. External pacing of the ventricles did not eliminate the inotropic effect. Following bilateral cervical vagotomy, distension had no effect on heart rate but caused an increase in Vmax. Sympathectomy eliminated all reflex cardiac effects. We conclude that left atrial distension causes a vagally mediated increase in heart rate and a sympathetically mediated increase in contractility.

Physiology of the developing urinary bladder in the amphibian *Rana catesbiana*. THERESA L. POWELL* and JOHN J. JUST, Thomas Hunt Morgan School of Biological Sciences, University of Kentucky, Lexington, KY 40506.

Transition of fully aquatic larval amphibians to semiterrestrial adults involves osmoregulatory alterations. We are interested in how the developing urinary bladder, which serves as a water storage organ in adults, contributes to this process. Isolated bladders transport water at a rate of 32 $\mu l/cm^2/min$ in vitro. In 2-week-old froglet bladders arginine vasotocin (AVT), 10^{-6} M, increased the rate of water loss to 1.25 $\mu l/cm^2/min$. However, preliminary experiments on stages XXII–XXV (Taylor-Kollros) show no significant response to AVT over control rates. These data along with electron microscopy suggest that completion of metamorphosis results in a fully developed and functional bladder.

PSYCHOLOGY

Entorhinal cortex lesions disrupt spatial learning and DRL-20 performance. M. LAROCCA*, A. NONNEMAN, T. LANDERS, and W. ISAAC, Department of Psychology, University of Kentucky, Lexington, KY 40506-0044.

The hippocampus seems to be critical for working memory (comparison of current situation with results of variable preceding events) but not reference memory (situation is stable/predictable). Lesions of the entorhinal cortex eliminate the major sensory input to the hippocampus. The consequences of such lesions in rats were studied with respect to retention of a preoperatively learned, spatial orientation, reference memory task and a postoperatively learned, DRL-20, working memory task. The lesions caused a transient retention deficit on the spatial task but totally prevented learning of DRL-20. The entorhinal cortex apparently provides information to the hippocampus critical for efficient working memory.

SCIENCE EDUCATION

The construction and use of economical electrophoresis apparatus. DAVID R. HARTMAN, Department of Chemistry, Western Kentucky University, Bowling Green, KY 42101.

Plans and a materials list were presented for the construction of an electrophoresis chamber to use paper, cellulose acetate, or thin layer strips. Amino acids, blood proteins, and enzymes can be separated in the economical clear plastic chamber. Designs for an economical power supply and uses for the equipment were discussed.

ZOOLOGY & ENTOMOLOGY

Ohio River fish population studies at the Thomas More College Aquatic Biology Station, Campbell County, KY. JOHN W. FERNER* and STEVEN C. ROSCHKE, Department of Biology, Thomas More College, Crestview Hills, KY 41017.

The Thomas More College Aquatic Biology Station is located at mile 450.5 of the Ohio River near California, KY. Fish populations have been monitored since 1974 at this location and nearby power plants during the summer months. While most sampling has been done with electroshocking, some collections by hoop nets, seines, and gill nets and on power-plant intake-screens have also been made. A total of 11,064 fishes representing 49 species has been captured over this 13-year period, the majority in the past 3 years. The most abundant species were *Doro-*

soma cepedianum, Notropis atherinoides, Lepisosteus osseus, Lepomis macrochirus, and *Carpiodes carpio.*

Osmoregulation by the bullfrog tadpole, *Rana catesbeiana.* JANIS L. GOLDSMITH* and JOHN J. JUST, Thomas Hunt Morgan School of Biological Sciences, University of Kentucky, Lexington, KY 40506.

Osmoregulatory capacity of tadpoles and froglets was studied using osmotic saline stress. All stages were osmoregulators in solutions between 8 and 200 mOsm/liter; above these concentrations, all were osmoconformers. In an attempt to determine onset of adult urinary bladder function, time-course studies were performed in a 250 mOsm/liter medium. Urine could be isolated only from bladders of newly metamorphosed froglets. In 1-week-old froglets, urine osmolarity increased from 30 to 100 mOsm/liter during short-term osmotic stress while the plasma osmolarity temporarily decreased. Thus, although the bladder develops early (state XII, Taylor-Kollros), it does not appear to be used as an osmoregulatory organ until after metamorphosis.

Altered integumental pigmentation of *Lirceus lineatus.* DAVID F. OETINGER, Department of Biology, Kentucky Wesleyan College, Owensboro, KY 42302.

Lirceus lineatus (Say 1818) (Isopoda, Asellidae) were collected from tributaries of Panther Creek (Daviess County, KY) during the winter months, 1985 and 1986. There were high levels of infection (11–42%) of isopods with acanthocephalans, *Acanthocephalus dirus* (Van Cleave 1931). Ninety-six per cent of the infected isopods had altered integumental pigmentation: 10 were more lightly pigmented (as has been described for North American asellids infected with acanthocephalans); 37 were more darkly pigmented (as has been described for European asellids infected with acanthocephalans). This is the first report of acanthocephalan-infected isopods, from the same populations, exhibiting both lighter and darker extremes of altered integumental pigmentation. Examination of infected isopods failed to relate altered pigmentation to size or sex of isopods, different strains of isopods, or size and sex of parasites.

Trans. Ky. Acad. Sci., 48(1–2), 1987, 50

NEWS AND COMMENTS

Printer Change

The membership of the Academy of Science will be happy to learn that the Board of Directors voted at the November meeting in Lexington to return to Allen Press for the production of the *Transactions.* This change will not only insure high quality of the journal, but it will also make life for the editor more pleasant.

Annual Meeting

The next annual meeting of the Kentucky Academy of Science is scheduled for 6–7 November 1987 at Western Kentucky University, Bowling Green. Watch for additional information in the Newsletter.

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 48
Numbers 3–4
October 1987

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.

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 $15.00 for Active Members; $7.00 for Student Members; $20.00 for Family; $250.00 for Life Members.

Subscription rates for nonmembers are: domestic, $30.00; foreign, $30.00; 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.

EDUCATIONAL AFFILIATES

Sustaining Members

University of Kentucky

Member

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

Associate Member

Alice Lloyd College
Bellarmine College
Brescia College
Campbellsville College
Centre College
Cumberland College
Georgetown College
Kentucky State University
Kentucky Wesleyan College
Lees College
Lindsey Wilson College
Spalding College
St. Catherine's College
Thomas More College

CORPORATE AFFILIATES

Alltech, Inc.
Ashland Oil
IBM

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

October 1987
Volume 48
Numbers 3–4

Trans. Ky. Acad. Sci., 48(3–4), 1987, 51–54

Sumac-directed Patch Succession on Northern Kentucky Roadside Embankments

JAMES O. LUKEN AND JOHN W. THIERET

Department of Biological Sciences, Northern Kentucky University, Highland Heights, Kentucky 41076

ABSTRACT

There was little evidence that staghorn sumac (*Rhus typhina* L.) colonies growing on revegetated roadside embankments in Northern Kentucky were facilitating tree invasion. Rather, the primary effect appeared to be inhibition of crownvetch (*Coronilla varia* L.) and Kentucky-31 tall fescue (*Festuca arundinacea* Schreb.), which in turn allowed other herbaceous and shrub species to invade the colonies. Amur honeysuckle (*Lonicera maackii* (Rupr.) Maxim.) was an important bird-dispersed invader, but wind-dispersed herbaceous species were also present in the seedbank and vegetation. Unique patches of vegetation are generated by staghorn sumac, but the background of introduced species and the landscape position of these colonies will likely preclude tree invasion for many years.

INTRODUCTION

Two previous studies documented indirect facilitation of tree seedling establishment by sumac (*Rhus*) species (1, 2). Colonies of sumac apparently attracted seed-carrying animals and also eliminated dense stands of perennial herbs and grasses that were inhibiting colonization by trees. This role of sumac species in patch succession, however, may not be universal. Even when sumacs are present, rates of tree invasion might be modified by the severity of initial disturbance, the availability of seeds and seed dispersers, and the background of introduced plant species.

The purpose of our study was to determine from seed banks and vegetation analyses whether staghorn sumac (*Rhus typhina* L.) was modifying colonization of revegetated roadside embankments in Northern Kentucky. Because our research sites were revegetated with highly competitive perennial grasses and herbs, and also because the staghorn sumac colonies were isolated from natural seed sources, we hypothesized that staghorn sumac growing on these road embankments may not be an important successional link in the development of a deciduous forest. Such data are clearly needed as ecologists experiment with techniques to restore natural plant communities following severe disturbance (3, 4).

METHODS

Staghorn sumac colonies we sampled were located on roadside embankments within 3 miles of the Northern Kentucky University (NKU) campus, Highland Heights, Campbell County, Kentucky. Maximum colony ages, as indicated by increment borings of the largest ramets, indicated all were 8–10 years old. Vegetation around the colonies and records of the district road engineer (Ralph Dietz, pers. comm.), indicated that the sites were revegetated with either crownvetch (*Coronilla varia* L.) or Kentucky-31 tall fescue (*Festuca arundinacea* Schreb.). Scarification of these sites during road construction was severe; but we

TABLE 1. Mean prominence values for plant species found inside and outside staghorn sumac colonies. Means are derived from 16 sites inside the colonies and from 14 sites outside the colonies.

	Inside	Outside
Herbs and grasses		
Coronilla varia L.	437	766
Festuca arundinacea Schreb.	79	107
Poa sp.	40	6
Alliaria petiolata (Bieb.) Cavara & Grande	30	—
Aster cordifolius (typical)	26	—
Ambrosia artemisiifolia L.	17	<1
Solidago sp.	15	4
Cirsium vulgare (Savi) Tenore	11	2
Impatiens capensis Meerb.	3	—
Ambrosia trifida L.	<1	4
Allium vineale L.	1	—
Rumex crispus L.	<1	<1
Linaria vulgaris Hill	—	<1
Lactuca serriola L.	<1	—
Trifolium repens L.	<1	—
Chenopodium album L.	<1	—
Shrubs and trees		
Rhus typhina L.	71	18
Lonicera maackii (Rupr.) Maxim	35	<1
Rubus occidentalis L.	5	—
Rosa setigera Michx.	1	—
Carya sp.	<1	<1
Number of resident species	3	3
Number of alien species	17	9
Total number of species	20	12

TABLE 2. Seedlings of plant species emerging from soils collected inside and outside staghorn sumac colonies. Values indicate the cumulative number of seedlings that emerged during 1 year.

	Inside	Outside
Herbs and grasses		
Coronilla varia L.	71	384
Festuca arundinacea Schreb.	27	12
Lamium purpureum L.	24	5
Solanum ptycanthum Dun. ex DC.	24	10
Verbascum thapsus L.	7	4
Trifolium repens L.	6	8
Aster sp.	4	6
Galium aparine L.	3	16
Polymnia canadensis L.	3	0
Stellaria media L.	2	0
Chenopodium album L.	1	0
Solidago sp.	1	0
Typha latifolia L.	1	0
Rumex crispus	0	2
Lepidium campestre L.	0	1
Dipsacus sylvestris Huds.	0	1
Shrubs and trees		
Rhus typhina L.	47	5
Rubus occidentalis L.	1	0
Number of resident seedlings	145	401
Number of alien seedlings	77	53
Total number of seedlings	222	454
Number of resident species	3	3
Number of alien species	12	9
Total number of species	15	12

do not know whether sumac colonies originated from seed or from buried roots and rhizomes.

During July 1986, per cent cover and frequency of plant species growing inside and outside staghorn sumac colonies were measured. Sixteen colonies and 14 adjacent areas outside the colonies were sampled. At each site, seven 1-m^2 plots were systematically arranged and visually analyzed.

Prominence values (% coverage × square root of frequency) were calculated for each species at each site. Then the positions of the 30 sites on a multidimensional polar ordination were calculated using the prominence values. Calculations followed Mueller-Dombois and Ellenberg (5).

Soil samples for seedbank analyses were collected during November 1985 at the centers of 7 different colonies and outside these same colonies (3 m downslope). The techniques used for estimating seedbanks provided an estimate of readily germinable seeds but did not record those seeds that did not break dormancy. In each area, 10 randomly distributed soil samples were removed with a soil core (21.2 cm^2 at the top; 84.9 cm^3 in volume), composited, and then taken to the greenhouse (mean temperature 20°C). Fourteen flats (1,300 cm^2) were prepared with 3 cm of moistened potting soil (Metro-mix®). The soils were spread on the flats and mixed with another 0.5 cm of soil. Photoperiod was extended to 16 hours with fluorescent lights, soils were kept moist with tap water, and they were stirred once every month. During the next 12 months, seedlings emerging from the soils were counted, removed, transplanted, and identified.

RESULTS

Areas inside and outside staghorn sumac colonies were still dominated by *Coronilla varia* L. and *Festuca arundinacea* Schreb., the 2 species introduced during revegetation (Table 1). But, inside the colonies there was decreased prominence of these 2 species and greater prominence of alien herbs and shrubs (Table 1). Specifically, vegetation inside was characterized by *Poa* sp., *Alliaria petiolata* (Bieb.) Cavara and Grande, *Aster cordifolius* (typical), *Ambrosia artemisiifolia* L., *Solidago* sp., and *Lonicera maackii* (Rupr.) Maxim. Inside the colonies there was little evidence to indicate tree invasion except for a few *Carya* seedlings; some *Carya* seedlings also occurred outside the colonies. Separation and clustering of the 30 different sites were most evident when sites were positioned along X and Y axes of the ordination (Fig. 1).

Inside and outside the colonies, the seedbank was dominated by seeds of *Coronilla varia* L., although many more seedlings of this species emerged from soils collected outside the colonies (Table 2). More seedlings of *Festuca arundinacea* Schreb., *Lamium purpureum* L., and *Solanum ptycanthum* Dun. ex DC. emerged from soils collected inside the colonies as compared to soils collected outside the colonies. As might be expected, the dominant woody species in the seedbank was staghorn sumac. Various species were represented in the seedbank that were not present in the midsummer vegetation (Tables 1, 2). In general, no seedlings of alien, bird-dispersed, woody species emerged from the soils.

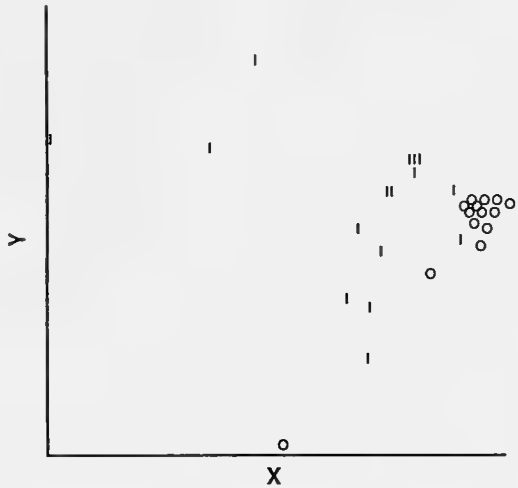


FIG. 1. Positions of 30 research sites on a two-dimensional polar ordination. The X axis is 100 units; the Y axis is 97 units. Sites inside staghorn sumac colonies are represented by I's; sites outside staghorn sumac colonies are represented by O's.

DISCUSSION

There was little evidence of tree invasion in the staghorn sumac colonies. It is possible that enough time has not passed for such invasion to occur. However, this is not likely since maximum colony age was 8–10 years and these ages are conservative estimates of site age. Werner and Harbeck (2) noted that trees began invading under staghorn sumac in Michigan old fields 5–8 years after field abandonment. Thus, on roadside embankments in our area, it appears that tree invasion under staghorn sumac is either much slower than reported in previous studies or is not occurring.

It is also possible that the landscape position of the colonies affected arrival rates of seeds. Because the colonies are isolated from forest edges and have little surrounding woody vegetation, birds may be reluctant to use them. This would not agree with a study in New Jersey old fields where seed deposition was greatest beneath tree stems that projected farthest above the surrounding vegetation (6).

Even if seeds arrive in the colonies, seedling establishment might be modified by interactions with *Coronilla varia* L. and *Festuca arundinacea* Schreb. (7). Both of these species are aggressive competitors that produce high amounts of aboveground biomass and detritus (8); *Festuca arundinacea* Schreb. also produces allelopathic chemicals (9). The decreased prominence of these 2 species inside the colonies probably explains why more alien herbs and grasses were found here. However, *Coronilla varia* L. and *Festuca arundinacea* Schreb. still dominate the vegetation inside and this could be a major factor controlling the establishment of invaders. The elimination of perennial grasses and herbs under staghorn sumac by shading or by the excretion of allelopathic chemicals is considered critical for tree invasion (1, 2).

One woody plant species, Amur honeysuckle (*Lonicera maackii* (Rupr.) Maxim.), successfully invades staghorn sumac colonies. This Eurasian native is a fast-growing shrub with bird-dispersed seeds. Throughout Northern Kentucky and elsewhere it has become well naturalized, occupying both forests and open sites (10). Since shrubs can successfully compete with tree seedlings (11), it is possible that staghorn sumac colonies growing on roadside embankments will be replaced by relatively homogeneous stands of Amur honeysuckle.

Estimated seedbank sizes of 1,500–3,067 seeds m^{-2} were similar to seedbanks measured in other successional sites (12, 13, 14). The make-up of the seedbank was indicative of the relative dominance of *Coronilla varia* L. and *Festuca arundinacea* Schreb. inside and outside the colonies. Slightly more alien seedlings emerged from soils collected inside the colonies (77 inside vs. 53 outside), but most of the alien species found in the seedbank were small-seeded annual or perennial herbs that lack fleshy fruits, the exceptions being *Solanum ptycanthum* Dun. ex DC. and *Rubus occidentalis* L. Although it is possible that seeds of woody species were present in the seedbank but did not break dormancy in our experiment, it is clear that resident and wind-disseminated species are important in seedbank and subsequent vegetation development.

From a synthesis of vegetation and seedbank data, we conclude that staghorn sumac colonies depress the growth of *Coronilla varia* L. and *Festuca arundinacea* Schreb. This in turn allows both wind and animal-dispersed species to grow beneath the canopy. Although there is no evidence of tree invasion, *Lonicera maackii* (Rupr.) Maxim. is a prominent bird-dispersed component of the colonies. This introduced shrub emerges from competition with perennial herbs and grasses that persist inside the colonies.

Our study indicates that successional trends observed in old fields may not be valid in severely man-disturbed sites such as highway corridors. This is especially true if there is a large background of aggressive introduced species, if the seedbank has been destroyed by soil scarification, and if the sites are isolated from natural seed sources.

ACKNOWLEDGMENTS

Funds for this research were supplied by an NKU Faculty Project Grant. We thank the Kentucky Department of Transportation for granting permission to sample the right-of-way.

LITERATURE CITED

1. Petranka, J. W. and J. K. McPherson. 1979. The role of *Rhus copallina* in the dynamics of the forest-prairie ecotone in north-central Oklahoma. Ecology 60:956–965.

2. Werner, P. A. and A. L. Harbeck. 1982. The pattern of tree seedling establishment relative to staghorn sumac cover in Michigan old fields. Am. Midl. Nat. 108:124–132.

3. Bradshaw, A. D. and M. J. Chadwick. 1980. The ecology and reclamation of derelict and degraded land. University of California Press, Berkeley, California.

4. DePuit, E. J. and J. G. Coenenberg. 1980. Establishment of diverse native plant communities on coal surface-mined lands in Montana as influenced by seeding methods, mixture and rate. Montana Ag. Exp. Station Res. Rept. #163, Montana State University, Bozeman, Montana.

5. Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York.

6. McDonnell, M. J. 1986. Old field vegetation height and the dispersal pattern of bird-disseminated woody plants. Bull. Torrey Bot. Club 113:6–11.

7. Vogel, W. G. and W. A. Berg. 1973. Fertilizer and herbaceous cover influence establishment of direct-seeded black locust on coal-mine spoils. Pp. 190–197. In R. J. Hutnik and G. Davis (eds.) Ecology and reclamation of devastated land. Gordon and Breach Inc., New York.

8. Luken, J. O. 1987. Potential patch dynamics on a roadside embankment: interactions between crownvetch (*Coronilla varia* L.) and Kentucky-31 tall fescue (*Festuca arundinacea* Schreb.). Reclam. Reveg. Res. (in press).

9. Creek, R. and G. L. Wade. 1985. Excretion of phenolic compounds from the roots of *Festuca arundinacea*, *Eragrostis curvula*, and *Lespedeza striata*. Trans. Kentucky Acad. Sci. 46:51–55.

10. Pringle, J. S. 1973. *Lonicera maackii* (Caprifoliaceae) adventive in Ontario. Can. Field Nat. 87:54–55.

11. Huenneke, L. F. 1983. Understory response to gaps caused by the death of *Ulmus americana* in central New York. Bull. Torrey Bot. Club 110:170–175.

12. Johnson, R. G. and R. C. Anderson. 1986. The seed bank of a tallgrass prairie in Illinois. Am. Midl. Nat. 115:123–130.

13. Lippert, R. D. and H. H. Hopkins. 1950. Study of viable seeds in various habitats in mixed prairies. Trans. Kansas Acad. Sci. 53:355–364.

14. Livingston, R. B. and M. L. Allessio. 1968. Buried viable seed in successional field and forest stands, Harvard Forest, Massachusetts. Bull. Torrey Bot. Club 95:58–69.

Trans. Ky. Acad. Sci., 48(3–4), 1987, 55–61

Development of a Multinomial Based Attributes Control Chart and OC Surface

WILLIAM J. KOLARIK
Assistant Professor of Industrial Engineering, Texas Tech University, Lubbock, Texas 79409

AND

LLOYD R. JAISINGH
Assistant Professor of Mathematics, Morehead State University, Morehead, Kentucky 40351

ABSTRACT

This paper develops families of general case attributes control charts applicable to sorting operations. The charts are based on the multinomial distribution. Formulas and computer programs for the operating characteristics associated with the chart families are also developed. Possible applications are demonstrated through the use of an example.

INTRODUCTION

Control charts are fundamental and useful tools in the field of quality assurance. The statistical development of variables and attributes control charts, as well as applications of these charts, can be found in most statistical quality control books (1, 2). Ghare and Torgersen (3) discussed multicharacteristic control charts related to the multivariate normal distribution. Only limited attention has been devoted to multicharacteristic attributes control charts.

In the case of p and np control charts, provisions are made for only 2 classifications. Items either conform to specifications or they do not conform to specifications. No provisions are made for items which might be classified or sorted in more than 2 ways. For example, an item might be classified in 3 ways, acceptable, reworkable, or scrap. It has been suggested that multiple binomial based p charts are applicable to sorting operations (2). However, such a classification system is technically beyond the scope of binomial based control charts.

Sorting into 3 or more classifications occurs frequently in practice in both industrial and agricultural fields as well as in service industries. Blank (4) briefly discussed a multinomial inspection example, but did not consider multinomial control charts. It is worthwhile to investigate appropriate control charting techniques which apply specifically to sorting operations.

OBJECTIVE

The objective of this paper is to develop the mathematical basis for general purpose attributes control charts for sorting operations and to demonstrate the technique through a simple example. The multinomial distribution is the basis for this development.

The following notation is used:

n = sample size
i = a variable index, $i = 1, 2, \ldots, r$

where $r \geq 2$

X_i = random variable i
n_i = positive integer value i

where $\sum_{i=1}^{r} n_i = n$

p_i = proportion i

where $p_i > 0$ and $\sum_{i=1}^{r} p_i = 1$

$\bar{p}_i$ = stabilized or process proportion i

where $\bar{p}_i > 0$ and $\sum_{i=1}^{r} \bar{p}_i = 1$

ASSUMPTIONS

In order to utilize the multinomial distribution the following assumptions must be met:

1. Successive units inspected must be independent of each other.
2. Each unit must be classified into only one of r categories.
3. A continuous production process is being sampled.

DEVELOPMENT

The multinomial distribution can be expressed as:

$$P(X_1 = n_1, X_2 = n_2, \ldots, X_r = n_r) = \frac{n!}{n_1!\, n_2! \ldots n_r!} p_1^{n_1} p_2^{n_2} \ldots p_r^{n_r} \quad [1]$$

In the special case where $r = 2$, equation [1] reduces to the binomial distribution which provides the basis for the usual development of the p and np charts (4). However, if the general case is maintained, it is possible to develop np_i chart families.

The mean of the ith variable in the multinomial distribution is

$$\mu_i = np_i \quad [2]$$

and the variance is

$$\sigma_i^2 = np_i(1 - p_i) \quad [3]$$

Making use of equations [2] and [3] and sigma limits, families or sets of $r - 1$ np_i control charts can be developed. The ith mean corresponds to the center line for the np_i chart. Sigma limits for the np_i charts can be set at multiples of σ_i or probability limits may be used. The latter technique is used in this paper since computer programs were developed to perform the many calculations involved in obtaining exact probability limits. Operating characteristics for a chart family for a given set of p_i's are calculated by the following relationship:

$$\beta = \Sigma' \frac{n!}{n_1!\, n_2! \ldots n_r!} p_1^{n_1} p_2^{n_2} \ldots p_r^{n_r} \quad [4]$$

where Σ' in [4] represents a sum over all feasible combinations of n_i values subject to:

$$LCL_i \le n_i \le UCL_i \qquad i = 1, 2, \ldots, r$$

$$\sum_{i=1}^{r} n_i = n$$

The calculation for α, the probability of a Type I error, is shown below.

$$\alpha = 1 - \Sigma' \frac{n!}{n_1!\, n_2! \ldots n_r!} \bar{p}_1^{n_1} \bar{p}_2^{n_2} \ldots \bar{p}_r^{n_r} \quad [5]$$

ILLUSTRATIONS

Case I: r = 2

In this case equation [1] reduces to the binomial distribution. The result is a typical np chart as described in statistical quality control texts (1).

Case II: r = 3

This case establishes a 3-dimensional control concept. In practice, one might develop a family of r (3) charts with control limits set at some specified number of items as shown in Figure 1. For example, items produced by a certain process might be of 3 different classifications: acceptable, reworkable, or scrap. A sample of size n would be drawn. The sample would be inspected and each item classified into one of the 3 classes. Then, the number of reworkable items and the number of scrap items would be plotted. The family of np_i charts (Fig. 1) would be set up and interpreted for control.

In this case, for a process to be considered in control, three conditions must hold:

$$LCL_1 \le x_1 \le UCL_1 \quad [6]$$

and

$$LCL_2 \le x_2 < UCL_2 \quad [7]$$

and

$$LCL_3 \le x_3 \le UCL_3 \quad [8]$$

The last condition can be expressed in terms of LCL_3, UCL_3 and $x_1 + x_2$.

Since

$$x_3 = n - x_1 - x_2$$

then

$$LCL_3 \le n - x_1 - x_2 \le UCL_3$$

and

$$n - UCL_3 \le x_1 + x_2 \le n - LCL_3 \quad [9]$$

Therefore, the third condition above can be stated as

$$n - UCL_3 \le x_1 + x_2 \le n - LCL_3 \quad [10]$$

The result is that a non-rectangular acceptance

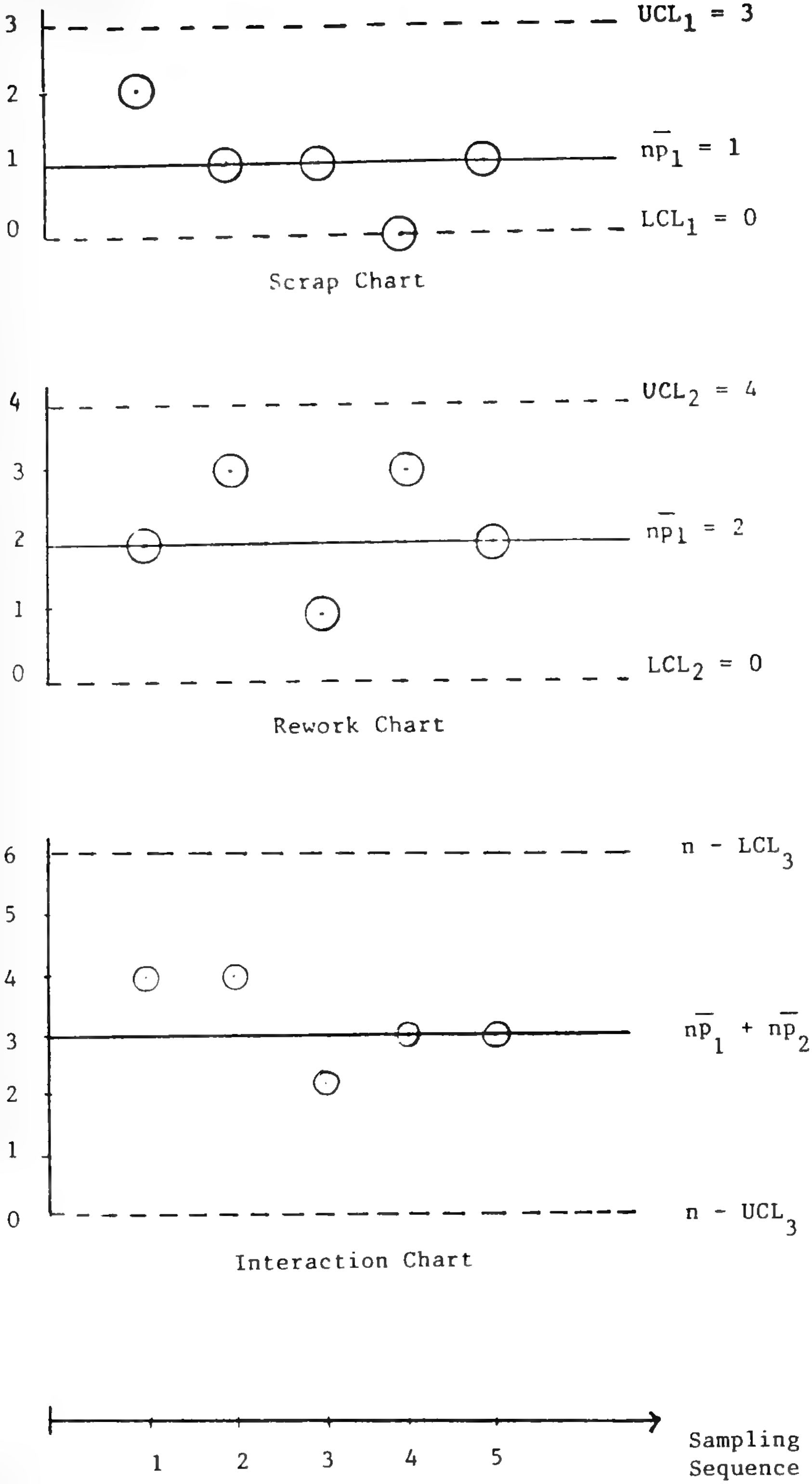


FIG. 1. Conceptual np_i chart family for $r = 3$.

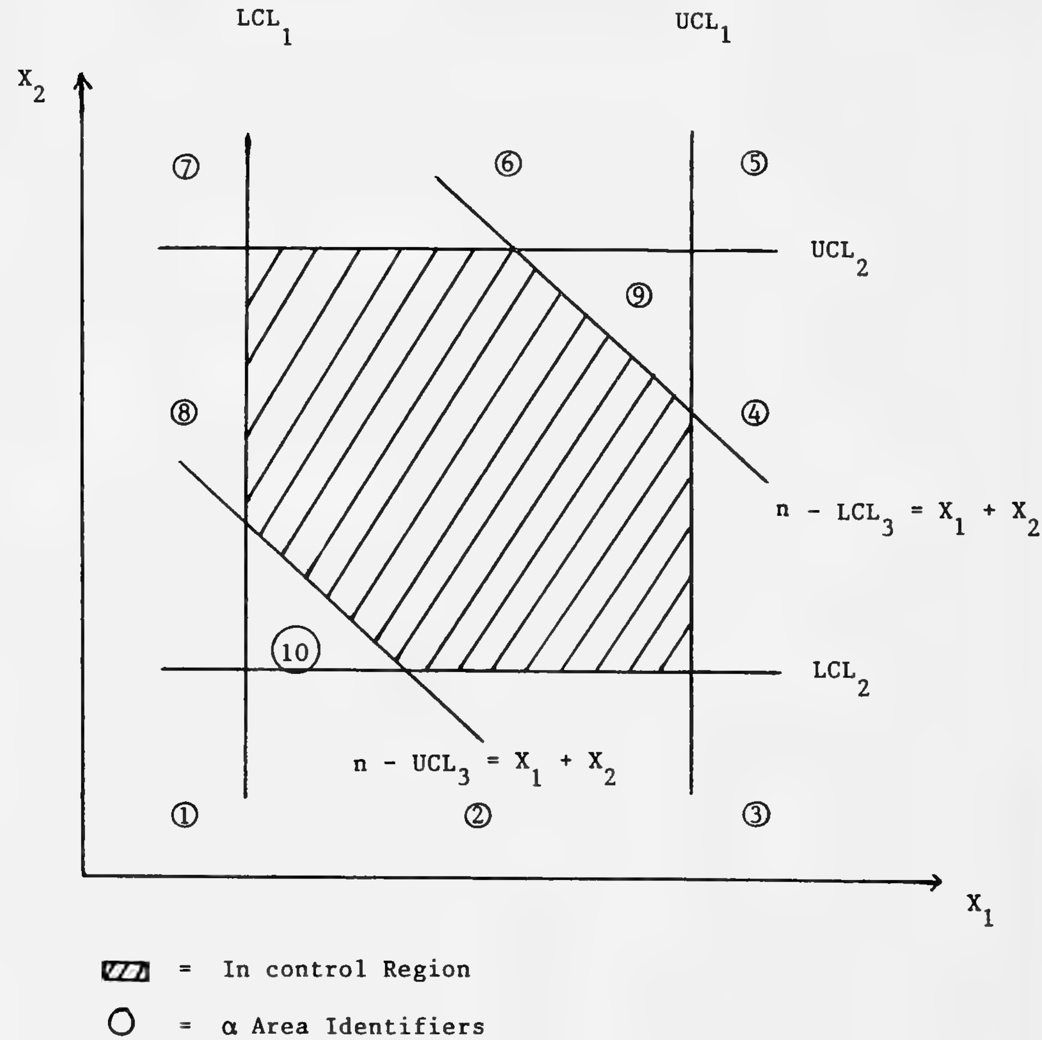


FIG. 2. In control region for np_i chart for r = 3.

or in control region may be encountered. In the most general case, it would be a hexagonal region, when plotted on x_1, x_2 axes (Fig. 2).

Conceptually, the operating characteristics for this family of np_i charts would be an OC surface, rather than an OC curve as in the binomial case. The calculations for the OC surface would be made using equation [4] and considering the 3 conditions stated above in equations [6], [7] and [10]. The number of calculations needed to completely develop the OC surface would be much higher than the number required to develop a typical OC curve.

Example.—Assume one is interested in control charting an operation where items produced are classified into 1 of 3 categories: scrap, reworkable, or acceptable. Further, assume that the process has been running at a 10% scrap rate, a 20% rework rate and an acceptable rate of 70%. For simplicity of calculations, a sample size n = 10 will be used.

Making use of equations [2] and [3], the mean and variance associated with scrap and rework are:

$$\mu_1 = 10(0.1) = 1$$
$$\mu_2 = 10(0.2) = 2$$
$$\mu_3 = 10(0.7) = 7$$

x_2 \ x_1	0	1	2	3	4	5	6	7	8	9	10
10	.000										
9	.000	.000									
8	.006	.002	.000								
7	.047	.034	.005	.000							
6	.166	.143	.064	.007	.000						
5	.377	.349	.226	.079	.008	.000					
4	.633	.608	.468	.249	.075	.007	.000				
3	.850	.830	.698	.453	.207	.055	.004	.000			
2	.967	.952	.835	.596	.327	.127	.029	.002	.000		
1	.998	.985	.876	.646	.377	.167	.051	.009	.000	.000	
0	1.00	.987	.879	.650	.382	.172	.055	.011	.001	.000	.000

FIG. 3. OC surface "β" probabilities for the example problem ($n\bar{p}_1 = 1$, $LCL_1 = 0$, $UCL_1 = 3$, $n\bar{p}_2 = 2$, $LCL_2 = 0$, $UCL_2 = 4$, $n\bar{p}_3 = 7$, $LCL_3 = 4$, $UCL_3 = 10$).

$$\sigma_1^2 = 10(0.1)(0.9) = 0.9 \text{ and } \sigma_1 = 0.949$$
$$\sigma_2^2 = 10(0.2)(0.8) = 1.6 \text{ and } \sigma_2 = 1.265$$
$$\sigma_3^2 = 10(0.7)(0.3) = 2.1 \text{ and } \sigma_3 = 1.449$$

where $i = 1$ represents scrap, $i = 2$ represents rework and $i = 3$ represents acceptable product.

Considering an np_i chart, assume the control limits are set as follows:

$$np_1 = 1 \quad LCL_1 = 0 \quad UCL_1 = 3$$
$$np_2 = 2 \quad LCL_2 = 0 \quad UCL_2 = 4$$
$$np_3 = 7 \quad LCL_3 = 4 \quad UCL_3 = 10$$

These settings would represent about a 2 sigma setting for the scrap parameter, and about a 1.6 sigma setting for the rework parameter and about a 2 sigma setting for the acceptable parameter products when calculated in a fashion similar to that used for a conventional np chart. Using a probability limit approach and a FORTRAN computer program, developed by the authors, Type I and Type II error probabilities can be calculated. The program was written in MICROSOFT FORTRAN77 v3.2 and runs on an IBM PC with an 8087 co-processor. One program, called BETA, calculates one minus the Type I error probability ($1 - \alpha$) when the process is centered at np_1 and np_2. This program will calculate a single "β" value or the user may specify the option of having the program generate an entire OC surface such as the one shown in Figure 3. When utilized on a microcomputer the program will interact with the user so that the user may develop a single point on the OC surface or an entire OC surface. The program utilizes equation [4] recursively and the 3 previously discussed control conditions. It checks to see that only feasible combinations of n_1, n_2, and n_3 are considered, when the distribution is centered at x_1 and x_2 combinations.

This example demonstrates the case where $r = 3$. The idea of an α error or "false alarm" when the process is centered at $n\bar{p}_1$ and $n\bar{p}_2$ is more complex than the usual np chart case ($r = 2$). Figure 2 shows a conceptual picture of the general situation, where the α "area" is the non-dotted region. The non-dotted area can be divided into 10 subareas, numbered 1–10 as shown in Figure 2.

Note that subareas 2, 4, 6, and 8 represent cases where one parameter (scrap or rework) is still within control limits but the other is outside control limits. Subareas 9 and 10 rep-

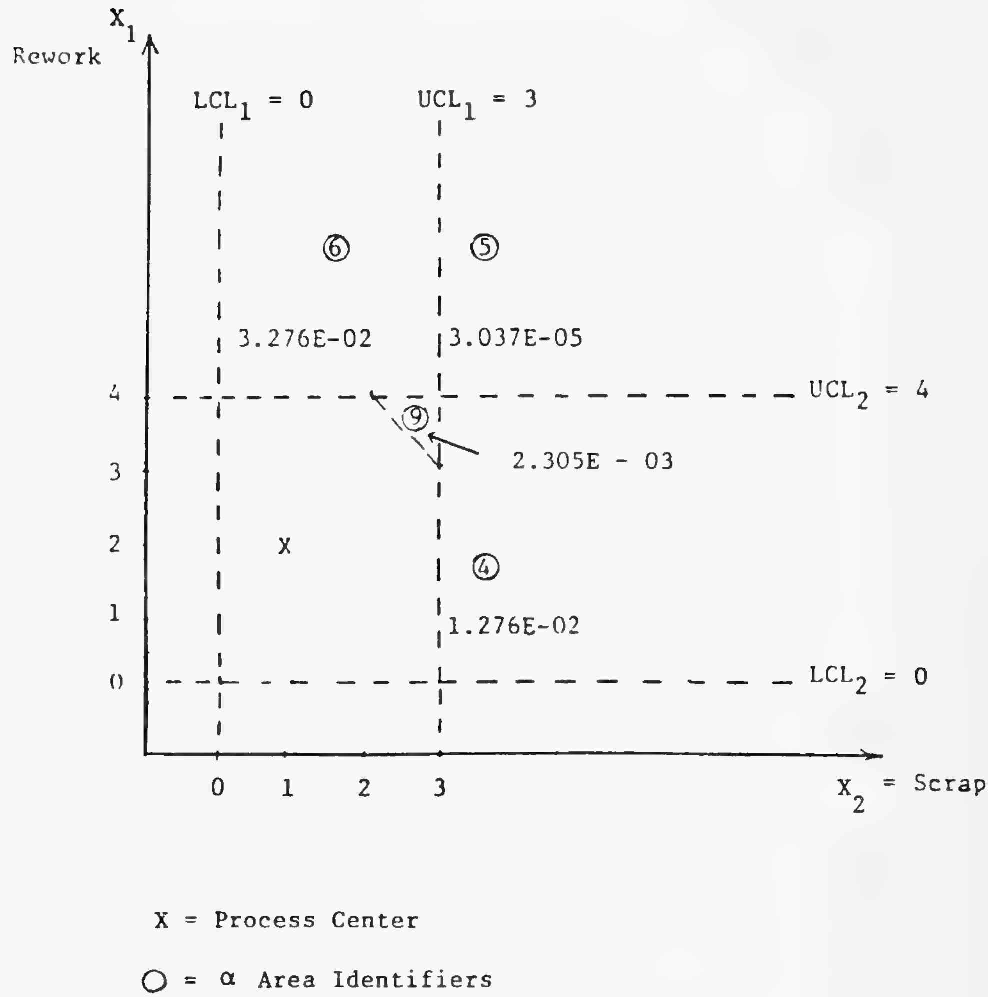


FIG. 4. Graphical results of the ALPHA (α) sub-areas for example ($n\bar{p}_1 = 1$, $n\bar{p}_2 = 2$).

resent out of control cases, even though both scrap and rework are within this control limits, due to the combined effect of scrap and rework. In order to assess the portion of α which lies in each of these 10 regions, another FORTRAN computer program was developed. This program is named ALPHA. It was developed to run interactively under MICROSOFT FORTRAN77 v3.2 on the IBM PC microcomputer. Results for the example problem are shown in Figure 4. Figure 4 shows the results in a graphical format for each of the 10 subareas, as previously discussed. It should be noted that since the control limits for both scrap and rework were set at 0, ALPHA1, ALPHA2, ALPHA3, ALPHA7, and ALPHA8 are zero. In addition, ALPHA5 is very small thus indicating a very low probability of an α error or "false alarm" outside both upper control limits simultaneously. The ALPHA10 region is equal to 0 because the $UCL_3 = 0$. The ALPHA9 region is present since the LCL_3 was set greater than 0. The second computer program utilizes equation [4] in a manner similar to that of the first computer program, however, the second program must calculate the probabilities outside the control limits in each of the 10 areas, shown in Figure 2. Both programs are available from the authors.

Case III: $r \geq 4$

The development of this case is analogous to that of Case II. As r increases, the number of np_i charts increase and the effort in establishing and maintaining them increases. The conceptual operating characteristics surpass a surface and become abstract in shape. The operating characteristics of Case III np_i chart families are similar to those of Case II, but the number of calculations involved becomes extremely large.

Conclusions

The preceding sections of this paper have expanded the scope of attributes control charts. The expansion from a binomial to a multinomial basis allows one to address situations with 3 or more item classifications. Such situations are common in many sorting operations involving manufactured items. In addition, services are sometimes rated by classifications such as good, fair, and poor. The np_i chart families previously developed are applicable to these situations, provided the assumptions listed previously are valid.

The mathematics involved with the np_i chart families is relatively simple. Charts can be readily set up and maintained. However, the number of calculations involved with operating characteristics become extremely large as the number of classifications and the sample size n increase. The example and computer programs provided develop the case where three classifications occur and demonstrate the procedure for a small sample size.

Literature Cited

1. Duncan A. J. 1974. Quality control and industrial statistics. D. Irwin, Inc., Homewood, Illinois.

2. Grant, E. L. and R. S. Leavenworth. 1980. Statistical quality control. McGraw-Hill, New York.

3. Ghare, P. M. and P. E. Torgersen. 1968. The multicharacteristic control chart. Journal of Industrial Engineering 19:269–272.

4. Blank, L. 1980. Statistical procedures for engineering, management, and science. McGraw-Hill, New York.

Trans. Ky. Acad. Sci., 48(3–4), 1987, 62–70

Distribution of Aquatic Snails (Mollusca: Gastropoda) in Kentucky with Notes on Fingernail Clams (Mollusca: Sphaeriidae: Corbiculidae)

BRANLEY ALAN BRANSON AND DONALD L. BATCH
Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

AND

SAMUEL M. CALL
Kentucky Natural Resources and Environmental Protection Cabinet,
Division of Environmental Services, Frankfort, Kentucky 40601

ABSTRACT

Data are presented for 6 families, 16 genera and 29 species of aquatic gastropods, 4 of which are in the threatened category. *Cipangopaludina chinensis malleata* (Reeve, 1862) and *Gyraulus deflectus* (Say, 1824) are reported for the first time from Kentucky. Subfossil specimens of *Io* from Pulaski County, Kentucky are discussed. Data and notes on 2 families, 3 genera and 7 species of sphaeriacean clams are presented. *Pisidium casertaneum* (Poli, 1791) is reported from Kentucky.

INTRODUCTION

In view of the ongoing attempts to unscramble the problem of endangered species in Kentucky (1), it seems appropriate to present data on groups of organisms for which the published records are sparse or old. In the case of the Mollusca of Kentucky, information on the Unionidae ("mussels") has far outstripped that on the Gastropoda, particularly in the aquatic species. In recent years, a few authors (2, 3, 4, 5, 6, 7, 8, 9, 10) have attempted to provide additional ecological and distributional information on aquatic snails, including species newly reported from Kentucky (11). This contribution provides new distributional data for 6 families, 16 genera and 29 species of aquatic gastropods. Four of the species were previously unreported from Kentucky, and 2 of them are under consideration for federal listing (1). Data are presented also for 2 genera and 6 species of fingernail clams.

COLLECTING SITES

1. Pond at Ballard County Wildlife Management Area, Ballard Co.; 6 May 1982.
2. Clear Pond, 4.8 km NW of County Road (CR) 1105 Bridge on Hazel Creek, Ballard Co.; 18 May 1982.
3. Pond at Cave Hill Cemetery, Louisville, Jefferson Co.; 30 March 1984.
4. Bert T. Combs Pond, Pineville, Bell Co.; 14 September 1980.
5. Little South Fork of the Cumberland River, Ritner Ford, McCreary Co.; 14 September 1980.
6. Slate Creek at U.S. 60, Bath Co.; 23 February 1980.
7. North Fork of Elkhorn Creek at Galloway Road Bridge, Scott Co.; 28 March 1986.
8. Salt River at U.S. 31E, Bullitt Co.; 7 October 1980.
9. Ohio River, 8.1 km north of Louisville at I-65, Jefferson Co.; 25 September 1982.
10. Licking River at Cynthiana, Harrison Co.; 8 September 1984.
11. Spring seep, 9.3 km north of Richmond, KRS 288, Madison Co.; 13 November 1979.
12. Muddy Banks of Kentucky River below main cemetery, Frankfort, Franklin Co.; 6 November 1980.
13. Spring seep, S-Tree Recreation Area, Jackson Co.; 23 July 1982.
14. Muddy hillside, 1.6 km west of KSR 111 on CR 1940, Montgomery Co.; 25 February 1984.
15. Licking River at I-64, Bath Co.; 25 February 1984.
16. Townsend Creek at U.S. 27 at Bourbon-Harrison co. line in Bourbon Co.; 15 March 1986.
17. Bullskin Creek at junction of Antioch and Garrington roads (Salt River Drainage), Shelby Co.; 16 October 1981.
18. Marrowbone Creek at KSR 100, Cumberland Co.; 14 April 1981.
19. Boone Creek at Grimes Mill Road, Clark Co.; 7 September 1982.
20. North Fork of Kentucky River, 1.2 km east of Banks, CR 1103, Letcher Co.; 13 April 1984.
21. Bear Creek at junction of U.S. 461 and KSR 90, Cumberland Co.; 11 April 1981.
22. Buck Creek at KSR 192, Pulaski Co.; 31 August 1981.
23. Licking River at Butler, Pendelton Co.; 23 June 1981.

24. Donaldson Creek at Skinner Road, 1.65 km east of KSR 807, Donaldson-Trigg County line; 6 July 1981.
25. Laurel River, 0.84 km south of junction of CR 1189 with KSR 830 on KSR 830, Laurel Co.; 3 July 1979.
26. West Fork of Skeggs Creek at CR 1152, Rockcastle Co.; 30 July 1979.
27. Meshack Creek at Vernon, Monroe Co.; 18 September 1979.
28. Little South Fork of Cumberland River, 4.2 km east of junction of KSR 167 with Mt. Pisgah Road, Wayne Co.; 2 June 1978; 10 July 1979.
29. Greasy Creek, 2.4 km above Chappell, Leslie Co.; 3 July 1978.
30. Mud Lick Creek at Lipps, Clay Co.; 4 May 1978.
31. Buckhorn Creek at KSR 28, Breathitt Co.; 19 June 1978.
32. Rock Creek at mouth of Puncheon Creek, McCreary Co.; 3 October 1979.
33. Big South Fork of Cumberland River at mouth of Troublesome Creek, McCreary Co.; 24 October 1979.
34. North Fork of Elkhorn Creek at Galloway Road Bridge, Scott Co.; 28 May 1986.
35. Rockcastle River at KSR 490, Rockcastle Co.; 13 October 1983.
36. Fishing Creek, 10.3 km south of confluence with Lick Creek, Pulaski Co.; 31 July 1978.
37. Clear Fork at first bridge east on KSR 217 from its junction with KSR 988, Bell Co.; 4 July 1979.
38. Bunches Creek, 3.2 km above mouth, Whitley Co.; 22 August 1979.
39. Brush Creek at KSR 328, Rockcastle Co.; 1 July 1979.
40. Roundstone Creek, 1.8 km northeast of Wildie, on CR 1786, Rockcastle Co.; 5 August 1978.
41. Marsh Creek above mouth of Brushy Creek, McCreary Co.; 12 November 1979.
42. Rockcastle River at mouth of Eagle Creek, Rockcastle Co.; 12 December 1979.
43. Kennedy Creek at confluence with Little South Fork of Cumberland River, Wayne Co.; 4 August 1979.
44. Licking River at Claysville, Robertson Co.; 23 June 1984.
45. Smith Creek, 3.8 km southeast of Albany, KSR 696, Clinton Co.; 20 September 1978.
46. Middle Fork of Rockcastle River at Lick Road Ford, near Parrot, Jackson Co.; 23 August 1979.
47. Mud River at Gus, Butler Co.; 6 July 1984.
48. Pitman Creek at U.S. 210, Taylor Co.; 19 April 1975.
49. Red River at KSR 591 ("Price's Mill"), Simpson Co.; 13 July 1982.
50. West Fork of Red River at Barker's Mill, Christian Co.; 7 July 1982.
51. Whippoorwill Creek at James Road, Logan Co.; 8 July 1982.
52. Kentucky River at Ann Street, Frankfort, Franklin Co.; 12 August 1984.
53. Gasper River at KSR 626, Warren Co.; 9 July 1982.
54. Kentucky Lake at end of KSR 732, Calloway Co.; 21 August 1983.
55. Ohio River at river mile 243.7, Hancock Co.; 27 July 1982.
56. East Fork of Clarks River at Bryantford Road, McCracken Co.; 22 September 1984.
57. Wolf Lick Creek at KSR 107 near Lewisburg, Logan Co.; 20 July 1984.
58. Eagle Creek, 1.6 km northwest of Wheatley, Owen Co.; 19 October 1982.
59. Green River at mouth, Henderson Co.; 16 August 1981.
60. Red River at KSR 765, Logan Co.; 13 July 1982.
61. Red River at KSR 848, Todd Co.; 8 July 1982.
62. Montgomery Creek at Pruitt Road, Christian Co.; 18 August 1979.
63. Mossy, dripping cliffs (shale) overlooking Marrowbone Creek at KSR 691, 0.8 km west of junction with KSR 90, Cumberland Co.; 13 April 1986.
64. Roundabout Swamp, 1.4 km southwest of confluence of Biggerstaff Creek and Mud River, Butler Co.; 26 April 1982.
65. West Fork of Otter Creek, 9.3 km north of Richmond on KSR 60, Madison Co.; 13 November 1979.
66. Kentucky River at Clay's Ferry Bridge, Madison Co.; 26 June 1968.
67. Spring flowing into Donaldson Creek, 1.85 km east of KSR 807-Old Dover Road junction, Trigg Co.; 6 July 1982.
68. East Fork of Clarks River, 3.0 km northwest of the junction of KSR 348 with KSR 641, Marshall Co.; 28 April 1982.
69. Crane Pond Slough, 0.3 km west of Daviess-Ohio county line, 3.4 km northeast of Pleasant Ridge, Daviess Co.; 22 July 1980.
70. Owsley Fork Lake at Owsley Fork Church, Jackson Co.; 9 December 1982.
71. Pond at Central Kentucky Wildlife Management Area, Madison Co.; 14 March 1984.
72. Pond, 2.0 km northeast of Sassafras Ridge Church (Fish Creek Road), Fulton Co.; 26 April 1982.
73. Muddy Creek at KSR 231, Ohio Co.; 30 September 1980.
74. Spring seep near base of Black Mountain, KSR 100, Harlan Co.; 13 September 1980.
74. Salt River at KSR 52, Mercer Co.; 9 October 1980.

RESULTS

In the discussion that follows, species are correlated with collecting sites by station numbers, and the figures in parentheses represent the number of specimens collected.

VIVIPARIDAE

Three native genera of this family are known in Kentucky, *Campeloma* Rafinesque 1819, *Lioplax* Troschel 1856, and *Viviparus* Montfort 1810. This report adds a fourth genus for Kentucky, *Cipangopaludina* Hannibal 1912.

Cipangopaludina chinensis malleata (Reeve 1862)

Collecting Sites.—1 (4), 2 (1), 3 (4).

This Asian species was introduced into California prior to 1900 and in the interim became dispersed to many other sections of the country (12). This large (39 mm or more), live-bearing snail prefers habitats in permanent ponds and lakes or sluggish portions of rivers with mud bottoms that have a minimal calcium concentration of 5.0 ppm (13). The food is bottom detritus and associated algae. Because of the environmental conditions observed at the collecting sites in Ballard and Jefferson counties, we may safely assume that the species is a permanent addition to the gastropod fauna of Kentucky.

Campeloma decisum (Say 1817)

Collecting Sites.—4 (2), 5 (5), 6 (2), 7 (3).

Campeloma decisum, another live-bearing species, ranges through much of the eastern United States and adjacent Canada (12). The range in Kentucky based upon the older literature is misleading but has been clarified recently by Burch (14). *Campeloma integrum* (Say 1821) and *C. obesum* Lewis 1865 are 2 synonyms applicable to the Kentucky fauna.

Campeloma crassula Rafinesque 1819

Collecting Sites.—7 (1), 8 (1), 9 (1).

Previously reported as *C. ponderosa* (Say 1821) (15), *C. crassula* is considered to be an Ohio River derivative in the fauna rather than a Cumberland or Tennessee river mollusk, although the species occurs marginally in the Cumberland (4, 16).

Lioplax subcarinata occidentalis Pilsbry 1935

Collecting Sites.—10 (1).

This relatively thin, small (25 mm or less in length), usually pale-green snail is not very abundant in Kentucky, although it is relatively abundant in the lower Licking River though uncommon elsewhere. Clench (12, 17) and Clench and Turner (18) considered this subspecies to be a synonym of *L. sulcosa* Menke 1828, mostly because typical *L. subcarinata* is smaller (around 20–21 mm in length). This snail bears watching by concerned scientists since its populations appear to be dwindling in waters where it was once common, often in association with unionid beds, especially in the lower Kentucky River.

POMATIOPSIDAE

Although these small, elongated and operculated snails are considered by certain authors (19) to be terrestrial, their habits indicate an amphibious life style. Until very recently, *Pomatiopsis* was included in the family Hydrobiidae. Burch (14, 20) and Hubricht (19) resurrected the Pomatiopsidae Stimpson 1865.

Pomatiopsis lapidaria (Say 1817)

Collecting Sites.—11 (2), 12 (3), 13 (1), 14 (1), 15 (2).

This amphibious, calciphilic species (19) is often found varying distances away from bodies of water, usually on a mud substrate. In addition to the localities cited above, Hubricht (19) recently included Carter, Edmonson, Jefferson, Rockcastle and Pike counties in the known Kentucky distribution.

PLEUROCERIDAE

The Pleuroceridae is one of the most pervasive groups of aquatic gastropods in the Mississippi River drainage, and systematically the family is almost an enigma. Literally hundreds of nominal species have been described; hence, the list of synonyms for any currently recognized species is usually long. The center of distribution and speciation appears to be the Alabama-Coosa River system and, secondarily, the Tennessee and middle Cumberland river systems (21), with depauperacy becoming more noticeable northward. Because pleurocerids have used various Kentucky streams as migration routes in pre- and post-Pleistocene times and as refugia (Green River, Licking River) at various times (21), the state has a fairly large representation of these snails.

There is considerable debate over generic designations (and recognition of species) in the family. In his massive presentation, Burch (14) resurrected a number of generic names that have not been used for many years; recent authors are divided on the use of resurrected names. Because of the more familiar designations of Calvin Goodrich (22 and afterward), we have elected to follow that author's logic. In the text that follows, however, we have included in parentheses Burch's (14) generic designations of the various species discussed.

Goniobasis (=*Elimia*) *semicarinata* (Say 1929)

Collecting Sites.—5 (24), 16 (1), 17 (13), 18 (21), 19 (11), 20 (4), 21 (43), 22 (13), 23 (9), 24 (5), 25 (59), 26 (8), 27 (5), 28 (86), 29 (3), 30 (2), 31 (2), 32 (1), 33 (3), 43 (2).

This is the most abundant *Goniobasis* of the whole Kentucky River basin (3, 5, 6), the Salt River (15), and "tributaries of Ohio River, Scioto River, Ohio, to Big Blue River, Indiana; Licking River to Salt River in Kentucky; two creeks of Green River of Kentucky" (22). The latter distribution, written by Goodrich, has been cited by practically every paper dealing with aquatic gastropods from Kentucky, and it has greatly biased the opinions of collectors in other drainages within the state. For example, Krieger and Burbank (24) designated specimens from Prior Creek in Trigg County as this species, but Blair and Sickel (2) referred carinate specimens from the same general area as deviate specimens of *Goniobasis laqueata* (see below). In some previous work (4), abundant specimens from various Cumberland River streams were found to be indistinguishable from typical Kentucky River specimens and ones from the Blue River and the East Fork of the White River in Indiana (26).

Thus, the specimens we have designated as *G. semicarinata* from Donaldson Creek, a tributary of Lake Barkley in Trigg County, tend to substantiate the previous report of the species from that environs (24). *Goniobasis semicarinata* has a much wider distribution in the Ohio River basin than previously discerned and research needs to be accomplished to clarify the recognition of the various forms of the species.

Goniobasis (=*Elimia*) *ebenum* (Lea 1841)

Collecting Sites.—35 (3), 36 (4), 37 (2), 38 (2), 39 (20), 40 (2), 42 (109), 43 (75).

This weakly differentiated but common species is known from the Cumberland River above the falls through Pulaski County, Kentucky and in springs and tributaries of the Cumberland River to Dickson County, Tennessee (23). The records presented here add to the distributional knowledge of the species and indicate that its populations appear to be stable.

Goniobasis (=*Elimia*) *costifera* (Haldeman 1841)

Collecting Site.—44 (1).

Goniobasis costifera has been considered as a more or less typical pleurocerid of Ohio River tributaries in Kentucky and Illinois (23). However, the species does not seem to be abundant in Kentucky streams. The populational status of the species needs to be determined before any conservation recommendations can be suggested. We have a few specimens from the upper Kentucky River, where the species is rare.

Goniobasis (=*Elimia*) *laqueata* (Say 1829)

Collecting Sites.—24 (1), 27 (5), 28 (2), 43 (6), 45 (36), 46 (5), 47 (15), 48 (75), 49 (4), 50 (62), 51 (2).

Some of us (4) previously reported specimens of *G. laqueata* from segments of the Cumberland River drainage, the eastern-most distribution of the species. This distinctive snail ranges west to Trace Creek (Tennessee River) in Humphreys County, and in the Duck and Elk rivers, Tennessee (27). In the upper Cumberland River drainage, the species is fairly widespread but of sporadic occurrence. In western Kentucky (Green including Mud River, Cumberland including Red River, and Tennessee River) it is the most common species of *Goniobasis* encountered.

Io fluvialis (Say 1825)

Collecting Sites.—None.

A relatively large collection of mollusks from prehistoric Indian middens located near old Burnside, Pulaski County, Kentucky, removed before impoundment of Cumberland Lake, contain a number of large specimens of this peculiar species. This raises an interesting question. The modern distribution of *Io* lies in the Tennessee River of western Virginia and eastern Tennessee, including the main tributaries Clinch, French Broad, Holston, Nolichucky and Powell rivers (28). The nearest straight-line locality in which *Io* can be found lies in the Powell River of Tennessee. The question is, did the Indians transport the specimens of *Io* all the way from the Powell River or elsewhere to the Burnside area as food items—operculated snails such as this can live for hours or even days in cool weather out of water—or for other uses? Or, was there at one time a population of *Io* in the Cumberland River that has become extinct in the interim? The question is, of course, partially rhetorical. However, the presence of the *Io* in the middens suggests that surveys of bank and/or old flood deposits should be undertaken to help answer this perplexing question.

Anculosa (=Leptoxis) praerosa (Say 1824)

Collecting Site.—50 (41).

Although this species has been reported from various sites in the Tennessee section of the Cumberland River, the record presented here from the Red River in Christian County is the farthest west it has been found in Kentucky. The most recent list of Kentucky endangered plants and animals (1) lists *A. praerosa* in Category 2, i.e., species up for possible status review by the U.S. Fish and Wildlife Service because their information "indicates that proposing to list as endangered or threatened is possibly appropriate, but for which conclusive data on biological vulnerability and threat are not currently available to support proposed rules." Because our sample from Red River contains both young and reproductive adults, it seems probable that C2 is the appropriate category for the species in this very important population.

Lithasia obovata (Say 1829)

Collecting Sites.—51 (18), 52 (5).

Lithasia obovata is the most widespread member of the genus in Kentucky. Six of the specimens from site 51 are morphologically similar to that termed forma *sorida* by Goodrich (22). Most populations of the snail in Kentucky appear to be healthy. Prehistoric Indians apparently used the species for food, along with *Goniobasis curreyana* and *Pleurocera canaliculatum* (29).

Pleurocera acuta Rafinesque 1831

Collecting Sites.—57 (3), 58 (1).

An attempt should be made to determine population sizes of this species. It probably deserves a place on the Kentucky list as of special concern, at least at the C2 level on the federal list.

Pleurocera alveare (Conrad 1834)

Collecting Site.—59 (1).

Pleurocera alveare is not at the present time under consideration for inclusion on the national list of endangered species. However, the snail is very rare in Kentucky, and Sinclair (30) listed it as extirpated from the Tennessee River in Tennessee. The species should be listed as threatened in Kentucky waters.

Pleurocera canaliculatum (Say 1821)

Collecting Sites.—44 (2), 47 (9), 52 (1), 56 (7).

Most populations of this large river snail appear to be healthy. The snail is known to be resistant to several types of pollution, including moderate siltation (30).

Pleurocera canaliculatum undulatum (Say 1829)

Collecting Sites.—23 (88), 54 (2), 55 (1).

Of the 88 specimens from Station 23, 50 were banded. This dimorphism has sometimes led to misidentifications but, as Goodrich (31) pointed out, banding is common in this variety in various streams, particularly in the Kentucky and Green rivers.

Pleurocera curtum (Haldeman 1841)

Collecting Sites.—60 (1), 61 (1).

A highly variable species (32) known from headwater tributaries of the Tennessee and the main stream near Knoxville to Muscle Shoals, Alabama, and the Cumberland River above Burnside, Kentucky to the vicinity of Davidson County, Tennessee (also, the Caney Fork River, Tennessee) (23), *P. curtum* is not abundant in Kentucky. Some of us (4) reported small populations in the Rockcastle River in Laurel County and the Cumberland River in McCreary County. Population assessments should be undertaken to determine the conservation status.

Pleurocera cf. *walkeri* Goodrich 1928

Collecting Site.—62 (4).

The characteristics of these 4 specimens fit the description of *P. walkeri* (32) better than those for any other described species. This species is known from the Cumberland River at Granville, Jackson County, Tennessee, the Little Sequatchie River near Marian, Tennessee, and from the Tennessee River at Muscle Shoals and Shoals Creek, Lauderdale County, Alabama. However, in the opinion of the first author, *P. walkeri* is probably conspecific with the variable *P. curtum*.

LYMNAEIDAE

There is divergence of opinion regarding generic designations in this family. Burch (14), for example, resurrected many of the genera of F. C. Baker (34), whereas Hubendick (33) considered these as subgenera. We follow the latter author.

Lymnaea (*Fossaria*) *humilis* (Say 1822)

Collecting Sites.—16 (2).

Although there are few published records for this species in Kentucky (11 scattered records in the same number of counties) (16), it probably occurs throughout the state.

Lymnaea (*Pseudosuccinea*) *columella* (Say 1817)

Collecting Sites.—4 (5), 6 (1), 15 (1), 64 (1), 65 (5).

This snail prefers quiet, vegetated backwaters over mud bottoms, where it sometimes produces prodigious populations. Statements of distribution within Kentucky are similar to those made for *L. humilis*.

PHYSIDAE

The Physidae is doubtless one of the most confusing taxa in North America, in spite of Te's (35) valiant effort to bring order to the family. One of the reasons for confusion is the extreme variability within a nominal "species," variability that reflects ecological plasticity. Te (35) recognized 4 genera: *Physa* Draparnaud 1801 with 2 northern species (*P. jennessi* Dall 1919 and *P. skinneri* Taylor 1954); *Physella* Haldeman 1843 (most species in the family, including all those known from Kentucky); the monotypic *Aplexa* Fleming 1830 (*A. elongata* (Say 1821)—outside our area); and *Stenophysa* Martens 1898 (2 species from northern South America, Central America, and Mexico, and introduced into Texas). These "genera" are most easily distinguished by features of the mantle.

Physa (=*Physella*) *gyrina* (Say 1821)

Collecting Sites.—1 (3), 67 (10), 68 (34), and 10 from Reelfoot Lake, Reelfoot National Wildlife Refuge, Tennessee.

Several of the specimens from Station 1 approach the morphology of *P. gyrina ampullacea* Gould 1855. This is a common species in western Kentucky, becoming progressively less common eastward.

Physa (=*Physella*) *heterostropha* (Say 1817)

Collecting Sites.—4 (3), 16 (2), 21 (4), 65 (8).

Except in sections of the Purchase Area, *P. heterostropha* is the most widespread and common physid in Kentucky, occurring in virtually every kind of water, often to the exclusion of other species.

ANCYLOPLANORBIDAE

Although Burch (14) retained the Planorbidae and the Ancylidae as separate families, Hubendick (36) and Stardbogatov (37) provided compelling reasons why the 2 families should be combined, and we follow the latter authors. Their subfamily Rhodacmeinae includes the genus *Rhodacmaea* Walker 1917 which occurs in Kentucky. *Laevapex* Walker 1903 and *Ferrissia* Walker 1903, both with Kentucky representatives, are placed in the subfamily Bulininae, which also includes *Helisoma* Swainson 1840. The subfamily Planorbinae includes *Planorbula* Haldeman 1840 (including *Menetus* H. and A. Adams 1855 and *Promenetus* F. C. Baker 1935) and *Gyraulus* Charpentier 1837 (includes *Armiger* Hartmann 1840). In Burch's (14) treatment, *Promenetus* and *Menetus* are retained as separate genera and *Helisoma* is divided into *Helisoma* and *Planorbella* Haldeman 1842.

Gyraulus parvus (Say 1817)

Collecting Site.—4 (5).

There are very few records for this (and similar species) small (3–4 mm diameter) snail in Kentucky. Specimens are easily missed in general collecting. Fine-mesh dip nets and sieves should be used in searching aquatic vegetation and bottom debris.

Gyraulus deflectus (Say 1824)

Collecting Site.—16 (2).

Previously unreported from Kentucky, this species is slightly larger than *G. parvus*. It tends to have an asymmetrical aperture, although it is not loop-shaped as in the last species. Likewise, the body whorl is not evenly rounded or carinate. Our specimens were both 4.3 mm in diameter.

Helisoma (Helisoma) anceps (Menke 1840)

Collecting Sites.—16 (2). Also, 3 from Laurel Lake, Breaks Interstate Park, Virginia.

Helisoma anceps frequents streams and running water as well as lakes, and it is much more common in such habitats than the next species, which prefers backwaters and lowland ponds, lakes, and sluggish streams.

Helisoma (Planorbella) trivolvis (Say 1817)

Collecting Sites.—1 (10), 16 (3), 64 (5), 68 (2), 69 (5), 70 (4), 71 (9), 72 (3).

Menetus dilatatus (Gould 1841)

Collecting Sites.—16 (2), 73 (1).

Although widespread east of the Mississippi River (38), there are few published records for this species in Kentucky. The preferred habitat is in quiet, vegetated backwaters.

Planorbula armigera (Say 1821)

Collecting Site.—69 (4).

This very distinctive little aquatic snail, recently reported from western Kentucky (11), is often mistaken for other small members of this family. There are white, tooth-like barriers a short distance within the aperture. *Planorbula jenksi* (H. F. Carpenter), reported from Crane Pond Slough in Henderson County (10), is a synonym (14).

Ferrissia fragilis (Tryon 1863)

Collecting Sites.—74 (1), 75 (3).

This small lentic snail has been reported from two Kentucky counties only (Jefferson, Madison) (16). The small size, cryptic coloration, and fragility are all factors causing it to be overlooked in general collecting. The species is doubtless of state-wide distribution.

SPHAERIACEA

This superfamily contains the familiar bivalves generally called "fingernail" and "pea" clams (Sphaeriidae) and the introduced Asian clam of the Afro-Asian family Corbiculidae. Since Kentucky records for the sphaeriids are scanty, the following data are of interest.

SPHAERIIDAE

Pisidium casertanum (Poli 1791)

Collecting Site.—16 (2).

This small bivalve has not been previously reported from Kentucky (39).

Sphaerium (Musculium) transversum (Say 1829)

Collecting Sites.—4 (2), 64 (2), 68 (2).

In spite of the relatively few records for Kentucky, this is a very common lentic species.

Sphaerium simile (Say 1816)

Collecting Site.—16 (2).

Also with paltry Kentucky records, *S. simile* prefers sluggish streams and backwaters and ponds and lakes with abundant vegetation.

Sphaerium striatinum (Lamarck 1818)

Collecting Site.—65 (1).

This is one of the most common lotic sphaeriids in the state, particularly in small- to medium-sized creeks and in shallow riffles of large rivers.

Sphaerium rhomboideum (Say 1822)

Collecting Site.—16 (2).

This distinctive bivalve prefers sheltered, sluggish waters with vegetation (39).

Sphaerium partumeium (Say 1822)

Collecting Site.—1 (1).

This species is retained in *Musculium* by Burch (38). It is common throughout the United States.

CORBICULIDAE

Corbicula manilensis (Philippi 1844)

Collecting Sites.—47 (3), 61 (12).

Records from these sites have not been published previously, but this obnoxious clam is now very widespread in Kentucky waters. In many places it occurs to the exclusion of native sphaeriids. Whether there is a correlation remains to be determined. There are many unpublished records for this species in the files of the Kentucky Nature Preserves Commission.

ACKNOWLEDGMENTS

We greatly appreciate the assistance of various students and associates in making collections, including J. R. Omer, Tim Towles, Yvonne Thompson, Mark Vogel, D. E. van Norman, K. E. Camburn, R. R. Cicerello, B. Kuhajda, Glenn Fallo, John MacGregor, and Hal Bryan. Special thanks to Melvin Warren, Department of Zoology, Southern Illinois University, for contributing important specimens and for reviewing the manuscript.

LITERATURE CITED

1. 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. 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.

2. Blair, L. and J. B. Sickel. 1986. A survey of freshwater gastropods in selected habitats of Land Between the Lakes, Kentucky and Tennessee. Trans. Ky. Acad. Sci. 47: 6–12.

3. Branson, B. A. and D. L. Batch. 1982. The Gastropoda and sphaeriacean clams of Red River, Kentucky. Veliger 24:200–204.

4. Branson, B. A. and D. L. Batch. 1982. Molluscan distributional records from the Cumberland River, Kentucky. Veliger 24:351–354.

5. Branson, B. A. and D. L. Batch. 1981. The gastropods and sphaeriacean clams of the Dix River system, Kentucky. Trans. Ky. Acad. Sci. 42:54–61.

6. Branson, B. A. and D. L. Batch. 1981. Distributional records for gastropods and sphaeriid clams of the Kentucky and Licking rivers and Tygarts Creek drainages, Kentucky. Brimleyana 7:137–144.

7. Branson, B. A., J. B. Sickel, and B. M. Bauer. 1983. Notes on rare and endangered or threatened pleurocerid snails from the Cumberland River, Kentucky. Nautilus 97: 58–60.

8. Hannan, R. R., R. R. Cicerello, E. D. Keithan, M. L. Giovannini, and L. J. Andrews. 1984. Aquatic biota and water quality survey of the Kentucky oil shale region. Ky. Nat. Pres. Comm. Tech. Rept. 1984. 2 vols.

9. Hannan, R. R., M. L. Warren, Jr., K. E. Camburn, and R. R. Cicerello. 1982. Recommendations for Kentucky's outstanding resource water classifications with water quality criteria for protection. Ky. Nat. Pres. Comm. Tech. Rept. 1982.

10. Harker, D. F., M. L. Warren, Jr., K. E. Camburn, and R. R. Cicerello. 1981. Aquatic biota and water quality survey of the Western Kentucky Coal Field. Ky. Nat. Pres. Comm. Tech. Rept. 1981. 2 vols.

11. Branson, B. A. and S. Rice. 1981. *Planorbula armigera* (Say) in Kentucky. Trans. Ky. Acad. Sci. 42:134.

12. Clench, W. J. 1962. A catalogue of the Viviparidae of North America with notes on the distribution of *Viviparus georgianus* Lea. Occ. Pap. Moll. Mus. Comp. Zool. Harvard Univ. 2:261–287.

13. Jokinen, E. H. 1982. *Cipangopaludina chinensis* (Gastropoda: Viviparidae) in North America, review and update. Nautilus 96:89–95.

14. Burch, J. B. 1982. Freshwater snails (Mollusca: Gastropoda) of North America. EPA-600/3-82-026:1–293.

15. Rosewater, J. 1959. Mollusks of the Salt River, Kentucky. Nautilus 73:57–63.

16. Branson, B. A. 1972. Checklist and distribution of Kentucky aquatic gastropods. Ky. Fish. Bull. 54:1–20; 45 maps.

17. Clench, W. J. 1962. New records for the genus *Lioplax*. Occ. Pap. Moll. Mus. Comp. Zool. Harvard Univ. 2:288.

18. Clench, W. J. and R. D. Turner. 1955. The North American genus *Lioplax* in the family Viviparidae. Occ. Pap. Moll. Mus. Comp. Zool. Harvard Univ. 2:1–20.

19. Hubricht, L. 1984. The distributions of the native land mollusks of the eastern United States. Fieldiana n.s. 24:1–191.

20. Burch, J. B. 1978. An outline classification of the Recent freshwater gastropods of North America (north of Mexico). J. Conchyliologie 65:4–9.

21. Branson, B. A. 1985. Aquatic distribution patterns in the Interior Low Plateaus. Brimleyana 11:169–189.

22. Goodrich, C. 1934. Studies of the gastropod family Pleuroceridae—I. Occ. Pap. Mus. Zool. Univ. Michigan 286:1–17.

23. Goodrich, C. 1940. The Pleuroceridae of the Ohio River drainage system. Occ. Pap. Mus. Zool. Univ. Michigan 417:1–21.

24. Krieger, K. A. and W. D. Burbank. 1977. Morphological and electrophoretic evidence of population relationships in stream snails of the family Pleuroceridae (Prosobranchia). Ph.D. Dissertation. Emory University, Atlanta.

25. Kuehne, R. A. and R. M. Bailey. 1961. Stream capture and the distribution of the percid fish, *Etheostoma sagitta*, with geologic and taxonomic considerations. Copeia 1961:1–8.

26. Bickel, D. 1968. *Goniobasis semicarinata* and *G. indianensis* in Blue River, Indiana. Nautilus 81:133–138.

27. Goodrich, C. 1930. *Goniobasis* of the vicinity of Muscle Shoals. Occ. Pap. Mus. Zool. Univ. Michigan 209: 1–358.

28. Adams, C. C. 1915. The variations and ecological distribution of the snails of the genus *Io*. Mem. Nat. Acad. Sci. 12:1–185.

29. Taylor, R. W. 1982. Mollusk shells associated with evidence of habitation by prehistoric native Americans in a Hardin County, Kentucky cave. Trans. Ky. Acad. Sci. 43:155–157.

30. Sinclair, R. M. 1969. The pleurocerid fauna of the Tennessee River, Gastropoda: Prosobranchia. Ann. Rept. Amer. Malacol. Union 35:45–47.

31. Goodrich, C. 1938. Studies of the gastropod family Pleuroceridae—VII. Occ. Pap. Mus. Zool. Univ. Michigan 376:1–12.

32. Goodrich, C. 1928. *Strephobasis*: a section of *Pleurocera*. Occ. Pap. Mus. Zool. Univ. Michigan 192:1–19.

33. Hubendick, B. 1951. Recent Lymnaeidae, their variation, morphology, taxonomy, nomenclature, and distribution. Kungl. Svenska Vet. Handl. 3:223; 5 pl.

34. Baker, F. C. 1928. The fresh water Mollusca of Wisconsin. Wisc. Geol. Nat. Hist. Surv. Bull. 70:i–xx, 1–507; 28 pl.

35. Te, G. A. 1978. The systematics of the family Physidae (Basommatophora: Pulmonata). Ph.D. Dissertation. University of Michigan, Ann Arbor.

36. Hubendick, B. 1978. Systematics and comparative morphology of the Basommatophora. Pp. 1–45. In V. Fretter and J. Peake. Systematics, evolution and ecology. Vol. 2A. Pulmonates. Academic Press, London.

37. Stardbogatov, Y. I. 1970. Mollusk fauna and the zoogeographic partitioning of continental water bodies of the globe. NaukLeningrad Br. Akad. Sci. USSR.

38. Burch, J. B. and J. L. Tottenham. 1980. North American freshwater snails: species list, ranges, and illustrations. Trans. Poets Soc. 3:1–215.

39. Burch, J. B. 1975. Freshwater sphaeriacean clams (Mollusca: Pelecypoda) of North America. U.S. Env. Prot. Agency Ident. Manual 3:1–96.

Trans. Ky. Acad. Sci., 48(3–4), 1987, 71–75

In Vitro Micropropagation of *Paulownia tomentosa* Steud.[1]

KARAN KAUL

KSUCRS Plant and Soil Science Research, Kentucky State University, Frankfort, Kentucky 40601

ABSTRACT

In vitro micropropagation of *Paulownia tomentosa* Steud. was achieved on a modified Murashige and Skoog's medium. Nodal segments from mature (35–40-year-old) trees were used as explants to obtain shoots from axillary buds. Repeated multiplication from nodal segments of such shoots could be achieved. Rooted plantlets could be produced in about 6 weeks. These plants could be grown outside the culture tubes. The procedure described can be used for mass propagation of superior trees of *P. tomentosa*.

INTRODUCTION

The increasing demand for forest products makes sound management of forest resources a necessity. Such management practices include reforestation to renew both timber as well as biomass resources. In many instances it is desirable to use propagules vegetatively derived from proven stock in order to ensure continued superior quality of forest resources (1, 2, 3). Vegetative propagation of mature forest trees from cuttings has not been possible for most species (1, 2, 4). Plant tissue culture technique has been suggested as a possible method for mass propagation of both coniferous and hardwood tree species (1, 5, 6, 7). Many taxa of hardwood trees have been propagated in vitro with varying degrees of success (2). However, in most cases the starting explants were derived from juvenile material (2). Only in a few instances have explants from mature trees been successfully used for plantlet regeneration in vitro (2, 8, 9, 10). The present work describes a tissue-culture procedure for micropropagation of *Paulownia tomentosa* Steud. (empress tree) from shoot segments of mature trees. *P. tomentosa* grows as a naturalized tree in many parts of the eastern and southeastern United States including Kentucky; it is valuable as a source of biomass and for reclamation of strip-mined land (11, 12, 13). Trees with superior form are a source of exportable timber to Japan. The procedure described in this paper can be used for mass propagation of *P. tomentosa* trees with superior growth characteristics.

MATERIALS AND METHODS

The experimental material was collected during the spring and summer of 1984 and 1985 from 35- to 40-year-old trees of *P. tomentosa* growing in central Kentucky. The experimental material consisted of the top 15 to 20 cm segments from young (4 to 12 weeks after bud break) shoots of such trees. The shoot segments were wrapped in wet paper towels and brought to the laboratory. Within 1 hour of collection, shoots were cut into approximately 3-cm-long pieces which were surface sterilized by treating them with a 2.265% sodium hypochlorite (50% clorox) solution for 10 min followed by a 70% ethanol treatment for 2 min. Shoot segments were washed 4× with sterilized double distilled water. About 1-cm-long segments of stem containing 1 node, pieces of petiole, and leaves were put on medium C—a modified (14) Murashige and Skoog's basal medium (MS) supplemented with 0.2 mg/liter α-naphthaleneacetic acid (NAA) and 2.0 mg/liter benzyladenine (BA). For the study of the effects of auxin and cytokinin concentration on organogenesis, nodal segments of stems of 5- to 6-week-old plantlets which had developed on medium C were inoculated on MS supplemented with 0, 0.02, 0.05, 0.1, 0.2, 0.5, 1.0, and 2.0 mg/liter NAA in combination with 0, 0.1, 0.2, 0.5, 1.0, 2.0, and 5.0 mg/liter BA.

All media used in the present study were prepared with analytical grade reagents, contained 2% sucrose, 0.7% Difco bacto-agar and were sterilized by autoclaving at 1 kg/cm^2 pressure at 121°C for 15 min. The pH of all

[1] Any opinions, findings, conclusions, and/or recommendations expressed in this publication are those of the author and do not necessarily reflect the view of the United States Department of Agriculture, Cooperative State Research Service (USDA/CSRS). Mention of a trade name does not constitute a guarantee or warranty of the product by USDA/CSRS and does not imply their approval to the exclusion of other products that may also be suitable.

TABLE 1. Effects of BA and NAA concentration in the medium on shoot regeneration from axillary buds of *Paulownia tomentosa* Steud.

BA and NAA concentration in medium	Effects on shoot development			
	% Cultures with shoots after 1 wk	% Cultures with shoots after 8 wk	Approx. height of ax. shoots after 8 wk	Secondary & tertiary branches after 8 wk
0–1 mg/liter BA + 0–0.1 mg/liter NAA	100	100	5–10 cm	absent
2 or 5 mg/liter BA + 0–0.2 mg/liter NAA	100	100	1–3 cm	present
0–1 mg/liter BA + 0.2–2 mg/liter NAA	10–50	20–100	0.5–3 cm	absent
2 or 5 mg/liter BA + 0.5–2 mg/liter NAA	0–30	10–80	0.5–2 cm	absent or present

media was adjusted to 5.8 before sterilization. All cultures were grown on 10 ml medium in 25- × 150-mm culture tubes and were incubated at 25 ± 1°C under continuous cool white fluorescent illumination of 450–500 $\mu W/cm^2$. Ten to 20 cultures were grown on each medium. Weekly observations were made on the development of shoots from axillary buds, callusing, and root differentiation for a period of 8 weeks after inoculation. Each experiment was repeated twice.

RESULTS

Response of Explants on Medium C

Within 7 days after inoculation small shoots developed in both leaf axils and callus proliferation occurred at the cut basal end of stem axis. The 2 shoots which developed from the axillary buds grew equally well for some time, but in most instances 1 of the shoots became dominant 4–5 weeks after inoculation. Basal portions of the axillary shoots formed green, compact callus which differentiated into many shoots. Four to 6 weeks after inoculation root differentiation also occurred from the callus as well as the basal end of the original explant. Nodal explants from such plantlets were used for further experiments to study the effects of auxin and cytokinin concentration on organogenesis.

Effects of Auxin and Cytokinin Concentration

Shoot Development.—The effects of auxin and cytokinin concentration in the culture medium on shoot development have been summarized in Table 1. Shoot initiation from axillary buds and their subsequent growth was influenced by the BA and NAA concentrations in the media. On media containing 0.2 mg/liter or more of NAA, shoot initiation was delayed by 2 to 3 weeks. This effect could be partially overcome by the presence of 2 or 5 mg/liter BA.

On media containing 1 or 2 mg/liter NAA only 10 to 40% of the cultures produced shoots which were poorly developed. Media containing 1 mg/liter or higher concentration of BA and up to 0.2 mg/liter NAA induced growth of secondary branches which gave a bushy appearance to the shoots. Secondary branching was inhibited by the presence of NAA in the medium. Frequently on media with 2 or 5 mg/liter BA, shoot development also occurred from the callus produced from the basal part of newly developed shoots.

Root Development.—Root development occurred either from the explant axis close to the developing axillary shoot or from the callus formed at the basal cut end of the explant axis. Root development occurred within 2 weeks

TABLE 2. Effects of BA and NAA concentration in the medium on root regeneration from *Paulownia tomentosa* Steud. cultures.

BA and NAA concentration in medium	Effects on root development		
	Time taken for root development (wk after inoculation)	% Cultures with roots after 2 wk	% Cultures with roots after 8 wk
0–0.5 mg/liter NAA + 0 mg/liter BA	2	10–50	70–100
1 or 2 mg/liter NAA + 0 mg/liter BA	3	0	100
0–2 mg/liter NAA + 0.1 to 2 mg/liter BA	3–5	0	30–100
0–2 mg/liter NAA + 5 mg/liter BA	≥6	0	0–100

FIG. 1. Rooted plantlet derived from nodal stem segment of *P. tomentosa* on MS + 0.2 mg/liter BA + 0.02 mg/liter NAA 45 days after inoculation. Notice the well-developed root system.

FIG. 2. In vitro-derived plantlet of *P. tomentosa* growing in vermiculite/peat moss/potting soil (1/1/1).

after inoculation on media containing 0–0.5 mg/liter NAA and no BA. Higher concentration of NAA in absence of BA, and all concentrations of BA in presence or absence of NAA delayed initiation of root development for up to 6 weeks after inoculation. Very high amounts of BA (2 or 5 mg/liter) in absence of NAA or in presence of 0.02 mg/liter NAA caused total inhibition of root formation. Data on root regeneration have been summarized in Table 2. Roots in cultures on media containing 1 mg/liter or higher amounts of BA were very thin, few in number, and often grew out of the culture medium.

Callus Proliferation.—Callus proliferation occurred on all media except those containing 0–0.1 mg/liter NAA and no BA. All concentrations of BA used, alone or in presence of NAA, induced callus proliferation. In most instances callus proliferated from the basal cut end of the explant axis but in presence of 1 mg/liter or higher amounts of BA callusing also occurred from the base of newly formed shoots. High concentrations (2 or 5 mg/liter) of BA also induced shoot differentiation from the callus tissue. Similarly high concentrations (1 or 2 mg/liter) of NAA caused root differentiation from callus in the absence of any shoot differentiation.

Growth of Plantlets Outside the Culture Tube

Plantlets produced on media containing 0.1, 0.2, or 0.5 mg/liter BA in combination with 0.02 or 0.05 mg/liter NAA were about 10 cm tall and had a well-developed root system about 6 weeks after inoculation (Fig. 1). These plantlets were transplanted to a 1/1/1 vermiculite/peat moss/potting soil mixture under high humidity under a glass bell jar. Gradually the humidity was decreased until the plants could grow outside the bell jar (Fig. 2).

DISCUSSION

Thus far only a few in vitro studies on *Paulownia tomentosa* have been published (2, 10, 15, 16). In all instances except 1 (10) juvenile plants were used as explant source. While the present study was in progress, Burger et al. (10) published their studies on micropropagation of *Paulownia*. These authors used nodal segments collected either from flowering trees or from greenhouse-grown trees derived from cuttings of mature trees as explants. The development of axillary buds into shoots was achieved on a MS + BA + NAA medium. The elongated shoots were rooted on MS supplemented with indolebutyric acid (IBA). The induction and development of axillary buds was easier on explants derived from greenhouse-grown trees compared to field-grown trees. In the present study the explants were derived from 35- to 40-year-old trees. The development of axillary buds into shoots occurred in only 10 to 15% of the cultures if the explants were taken directly from the mature field-grown trees. However, shoot development occurred in 100% of the cultures if explants were taken from plantlets developed on medium C. It seems that growth in vitro rejuvenates the explants from the mature trees. The present study, unlike that of Burger et al., describes a 1-step procedure for mass clonal propagation of *Paulownia tomentosa* where development of axillary shoots and rooting of these shoots can be achieved on the same medium. On MS + 0–0.05 mg/liter NAA + 0–0.5 mg/liter BA transplantable plantlets were obtained in 40–45 days after inoculation. Assuming 1 plantlet developing from each of the 5 nodal segments (number of nodes varies between 5 and 7) in 45 days, 78,125 transplantable plantlets can be obtained from a single nodal segment after 1 year of multiplication in vitro.

Doubts have been raised about the uniformity of tissue culture-derived plants because of the possibility of somaclonal variations within such plant populations (17). The procedure described in the present study minimizes the chances of somaclonal variations because of the absence of a dedifferentiation phase before the plantlet development. However, on certain media (for example medium C), the possibility of somaclonal variation does exist. On this medium, not only does the plantlet development take place from axillary buds on the explant but the callus formed from the cut end of explant also differentiates to give rise to a number of plantlets. It seems possible that this phenomenon can be used to obtain plantlets from genetically engineered callus tissue. Once such plantlets with desirable characteristics have been obtained, their clonal mass propagation can be achieved by the procedure described in this paper.

ACKNOWLEDGMENTS

This research was supported by USDA/CSRS grant No. KYX10-85-P3. I thank Ms. Linda Winkle for technical assistance. I thank Mr. Keith Bennett and Dr. Jeff Rush for the experimental material. Continuous support of Dr. Harold Benson, Director of Land-Grant Programs and his staff is gratefully acknowledged.

LITERATURE CITED

1. Bonga, J. M. 1974. Vegetative propagation: tissue and organ culture as an alternative to rooting cuttings. NZJ For. Sci. 4:253–260.

2. Sommer, H. E. and H. Y. Wezstein. 1985. Hardwoods. Pp. 511–540. In P. V. Ammirato, D. A. Evans, W. R. Sharp, and Y. Yamada (eds.) Handbook of plant cell culture. Vol. 3. Crop species. Macmillan Pub. Co., New York.

3. Thorpe, T. A. and S. Biondi. 1984. Conifers. Pp. 435–470. In W. R. Sharp, D. A. Evans, P. A. Ammirato, and Y. Yamada (eds.) Handbook of plant cell culture. Vol. 2. Crop species. Macmillan Pub. Co., New York.

4. Brown, C. L. and H. E. Sommer. 1982. Vegetative propagation of dicotyledonous trees. Pp. 109–149. In J. M. Bonga and D. J. Durzan (eds.) Tissue culture in forestry. Dr. W. Junk Publishers, Boston.

5. Durzan, D. J. and R. A. Campbell. 1974. Prospects for the mass production of improved stock of forest trees by cell and tissue culture. Can. J. For. Res. 4:151–174.

6. Karnosky, D. F. 1981. Potential for forest tree improvement via tissue culture. BioScience 31:114–120.

7. Konar, R. N. and R. Nagmani. 1974. Tissue culture as a method for vegetative propagation of forest trees. NZJ For. Sci. 4:279–290.

8. Jaiswal, V. S. and P. Narayan. 1985. Regeneration of plantlets from the callus of stem segments of adult plants of *Ficus religiosa* L. Plant Cell Reports 4:256–258.

9. Gupta, P. K., A. L. Nadgir, A. F. Mascarenhas, and V. Jagannathan. 1980. Tissue culture of forest trees: clonal multiplication of *Tectona grandis* L. (teak) by tissue culture. Plant Sci. Lett. 17:259–268.

10. Burger, D. W., L. Liu, and L. Wu. 1985. Rapid micropropagation of *Paulownia tomentosa*. Hortscience 20:760–761.

11. Tang, R. C., S. B. Carpenter, R. F. Wittwer, and D. H. Graves. 1980. *Paulownia*—crop tree for wood products and reclamation of surface-mined land. Southern J. Appl. For. 4:19–24.

12. Stearns, J. L. 1944. *Paulownia* as a tree of commerce. Am. For. 52:60–61, 95–96.

13. Preston, D. J. 1983. *Paulownia*—miracle tree or passing fancy? Am. For. 89:10–15, 47.

14. Kasperbauer, M. J. and R. A. Reinert. 1965. Photometrically assayable phytochrome in vivo in callus tissue cultures from *Nicotiana tabacum*. Physiol. Plant. 20:977–981.

15. Marcotrigiano, M. and D. P. Stimart. 1983. In vitro organogenesis and shoot proliferation of *Paulownia tomentosa* Steud. (Empress tree). Plant Sci. Lett. 31:303–310.

16. Radojevic, L. 1979. Somatic embryos and plantlets from callus cultures of *Paulownia tomentosa* Steud. Z. Pflanzenphysiol. 91:57–62.

17. Larkin, P. J. and W. R. Scowcraft. 1981. Somaclonal variation—a novel source of variability from cell cultures for plant improvement. Theor. Appl. Genet. 60: 197–214.

Trans. Ky. Acad. Sci., 48(3–4), 1987, 76–83

Hydrocarbon Degradation in a Waste-Water Pond by Enriched Indigenous Microorganisms

JOHN M. CLAUSON AND LARRY P. ELLIOTT[1]

Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

ABSTRACT

Indigenous microorganisms were stimulated to degrade hydrocarbon waste oils in a waste-water pond. The dominant organism isolated and identified from the pond was *Acinetobacter calcoaceticus* subsp. *anitratus.* Laboratory and field experiments on aeration and fertilization with 10 ppm garden fertilizer (10-10-10) were conducted and the results evaluated by quantitative gravimetric analyses and gas chromatographic techniques to determine if oil degradation occurred. The biodegradation of this waste oil was considerably enhanced by the combination of forced aeration and fertilization as compared to controls. Gravimetric analyses of oil from laboratory ecosystems incubated 42 days at 25°C indicated that 38.2% more oil was degraded in the aerated and fertilized system than in the control system. Gas chromatographic analyses of oil from laboratory and field ecosystems showed quantitative decreases in individual hydrocarbon compounds associated with aeration and fertilization.

INTRODUCTION

In the early 1970s an aluminum die cast industry in southcentral Kentucky began disposing toxic waste products into a 1.0-acre, aboveground lagoon that was constructed on site. The waste products included chromium hydroxide, polychlorinated biphenols (PCB) and petroleum from in-plant processes. The lagoon is no longer receiving wastes but the Environmental Protection Agency and the Kentucky Department of Natural Protection are now requiring this facility to be reconditioned. The petroleum wastes were quite noticeable, and their removal could be monitored visibly by the disappearance of the abundant oily film. Since petroleum wastes have been in the lagoon for years, the probability is high that the indigenous flora has been enriched to utilize hydrocarbons because of its long exposure to them. Numerous reports in the literature suggest that microorganisms metabolize petroleum (1, 2, 3). Several studies have been concerned with the biodegradation of hydrocarbons by microorganisms in marine and estuarine waters (4, 5, 6, 7). Studies conducted on freshwater systems, however, are more limited (8, 9, 10).

Petroleum in freshwater seems to be degraded mainly aerobically (1) and is temperature affected. Also, growth of the microorganisms may be limited by the amount of available nitrogen and/or phosphorus present in the aquatic habitat (1).

This study was conducted to determine which petroleum-degrading microorganisms were in the petroleum-containing waste lagoon and if aeration and/or fertilization would enhance their activity.

MATERIALS AND METHODS

Preliminary studies on the microbial community of the lagoon were initiated 30 October 1985. Water samples were collected monthly in sterile dilution bottles from the same sample sites (Fig. 1) and their heterotrophic microorganisms were enumerated on plates of Bushnell-Haas medium containing 0.5% SAE 30 motor oil and Nobel agar (1.5% wt/vol) as the solidifying agent. The medium was sterilized by autoclaving for 15 min at 121°C, 1 atm. In order to assure adequate dispersal of the oil, the medium was prepared in small volumes (200 ml), tempered and swirled just before pouring it into plates. Control and oil agar plates were incubated in separate incubators at 25°C for 14 d (7). Triplicate plates were prepared for each enumeration. Counts on control plates were subtracted from counts on the oil agar plates, and the plate count estimates of hydrocarbon-degrading microorganisms were recorded as colony-forming units (CFU) per ml of water.

A preliminary study was conducted to determine if hydrocarbon-degrading microorganisms were present in this pond. Represen-

[1] To whom correspondence should be addressed.

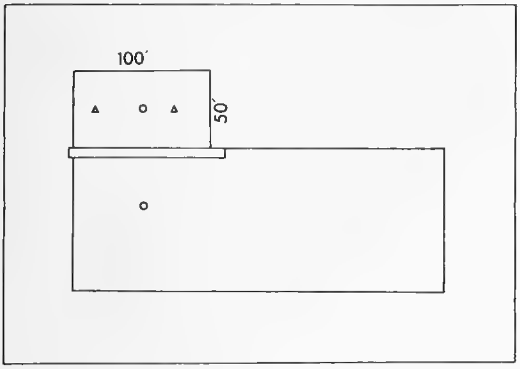


FIG. 1. Diagram of waste pond. Symbols: ○ sample sites, △ aeration sites.

tative colonies were picked from each of the triplicate oil agar plates, purified and tested for their ability to decompose oil. Each pure culture was inoculated into 3 flasks of Bushnell-Haas broth containing 0.5% SAE 30 motor oil, incubated at 25°C along with 3 uninoculated controls for 14 d, then observed for oil degradation.

The waste lagoon was separated into 2 parts by building an earthen dam. This provided a 50- × 100-ft section to use as an experimental pond and the remainder as a control. The experimental site, estimated to contain 700 kl of waste water and oil, was fertilized with 3.3, 50-lb bags of 10-10-10 garden fertilizer to obtain a 10-ppm nitrogen and phosphorus supplement. The fertilizer was broadcast over the entire surface of the experimental side (Fig. 2). Additional fertilizer was added as needed to maintain stable nitrogen and phosphorus levels. Aeration was provided with 2, 2-hp air pumps delivering 16 psi through a 3-inch pipe (Fig. 3). Water samples were collected periodically and analyzed by the Water Quality Laboratory of Western Kentucky University to monitor the levels of nitrogen and phosphorus in the pond.

Laboratory ecosystems were prepared by mixing a known amount of purified lagoon oil and 100 ml of lagoon water in each of 32, 250-ml sterile, cotton-plugged erlenmeyer flasks. The lagoon water was obtained from the control portion of the lagoon and refrigerated until used. The purified lagoon oil was prepared

FIG. 2. Broadcasting the fertilizer over the surface of the experimental pond.

FIG. 3. Aeration of experimental pond.

from oil obtained from the control portion of the lagoon by dissolving it in hexane, suction-filtering the solution through Whatman 541 paper, distilling the hexane from the solution, then oven-drying (2 h at 110°C) the residue. The amount of purified lagoon oil in each ecosystem was determined by adding approximately 0.5 g oil to an oven-dried (2 h at 110°C), weighed flask, weighing the flask plus oil, then subtracting the weight of the flask from the weight of the flask plus oil. Eight of the flask ecosystems were used in testing each of 4 parameters: no treatment, aeration by 200 rpm on a rotary shaker (New Brunswick Model V.5), fertilization with 10 ppm of 10-10-10 garden fertilizer, and aeration plus fertilization. Four of the flasks of each parameter were steam sterilized and used as controls. Our unpublished data indicate no loss of hydrocarbons occurred during drying or autoclaving. These data agree with Walker and Colwell (12). The flasks were incubated at 25°C for 28 and 42 d after which the oil was extracted and subjected to gravimetric and gas chromatographic analyses. Ten ml of hexane were introduced into duplicate flasks of each parameter and mixed at 200 rpm on a rotary shaker (New Brunswick Model V.5) for 2 h. The hexane layer was separated in a 250-ml separatory funnel and collected into appropriately numbered glass petri dishes that had been dried and weighed. The hexane was allowed to evaporate under a hood, the oil dried and weighed, and the percentage of decomposed hydrocarbons calculated.

After the gravimetric calculations were completed, the oil from the laboratory ecosystem was analyzed by gas-liquid chromatography. A 20-mg sample of oil was collected from each petri dish and diluted with 0.1 ml hexane. A 10-μl GC syringe was used to remove 2 μl of the hexane extract which was then resolved on a glass column (6 feet by ¼ inch by 2 mm) packed with 3% OV-1 on 80/100 Supelcoport from Supelco Laboratories. Gas chromatograms were obtained using a Varian Model 3700 gas chromatograph with an ion-flame detector and a Hewlett-Packard 3390A integrator. Parameters on the integrator were as follows: attenuation, 0; chart speed, 0.5; peak width, 0.4; threshold, 0; and area rejection, 0.

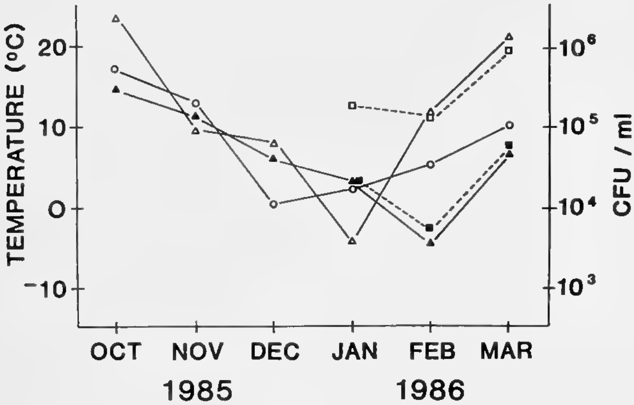


FIG. 4. Enumeration of microbial populations from the pond with average monthly temperature. Symbols: O average monthly temperature, ▲ oil plate counts from control side of pond, △ nonoil plate counts from control side of pond, ■ oil plate counts from experimental side of pond, □ nonoil plate counts from experimental side of pond.

Injections of 0.4 μl of hexane extract were made into the injection port set at 300°C and the ion-flame detector was set at 270°C. The chromatograph was programmed for 160°C for 1 min, 8°C/min to 335°C, and 15 min isothermal at 335°C. Compounds in the eluted fractions were compared with gas chromatographic retention times of known alkanes and compared with the peak height response of these individual components. Gas chromatograph analyses were also performed on the oils obtained from the water from the control and experimental portions of the waste lagoons.

RESULTS

Since Roubal and Atlas (7) were able to plate count oil decomposers in a marine ecosystem, it was hypothesized that this technique would estimate hydrocarbon-utilizing microorganisms in limnetic ecosystems. Unfortunately, most of the counts on Bushnell-Haas agar were higher than counts on the Bushnell-Haas agar with oil. This indicated the oil was toxic to the microbial flora and an oligotrophic microbial population existed (13).

Figure 4 depicts the waste lagoon plate counts and temperature over time. Plates counts were started on the waste lagoon before the dam was constructed. Counts on Bushnell-Haas agar without oil were highest in October (3.6×10^6) before declining to 43×10^3 in January. On only 2 occasions were counts on the Bushnell-Haas oil agar higher than counts obtained on Bushnell-Haas agar without oil which is needed to give a correct estimate of petroleum-degrading, aerobic, heterotrophic bacteria. After the dam was constructed, counts from the experimental side of the pond gave higher counts on the non-oil agar, thus no meaningful estimate of petroleum-degraders could be made.

It was demonstrated, however, that this autochthonous population could be stimulated to degrade the petroleum pollutants by aeration and fertilization and oil decomposition determined by gas chromatographic techniques. Observation of the changes in surface oil indicated changes in viscosity and brown zones of decomposed oil occurred in the experimental portion as compared to little change in the control portion of the waste lagoon. Only 1 bacterial colony type was dominant in the oil agar plates and exhibited oil degradation in Bushnell-Haas broth with 0.5% SAE 30 motor oil present. These isolates produced zones of degradation after 14 d incubation at 25°C (Fig. 5). Characterization of these isolates was performed with the API 20E (Analytab products, Plainview, New York) and gave a profile number of 000500203, which was a very good identification for *Acinetobacter calcoaceticus* subsp. *anitratus*. This organism gave a typical distinct colonial growth on eosin-methylene blue agar as described by Spino and Geldreich (14).

Quantitative gravimetric analysis on laboratory ecosystems also demonstrated that the microbial population may be stimulated to increase the amount of petroleum degradation

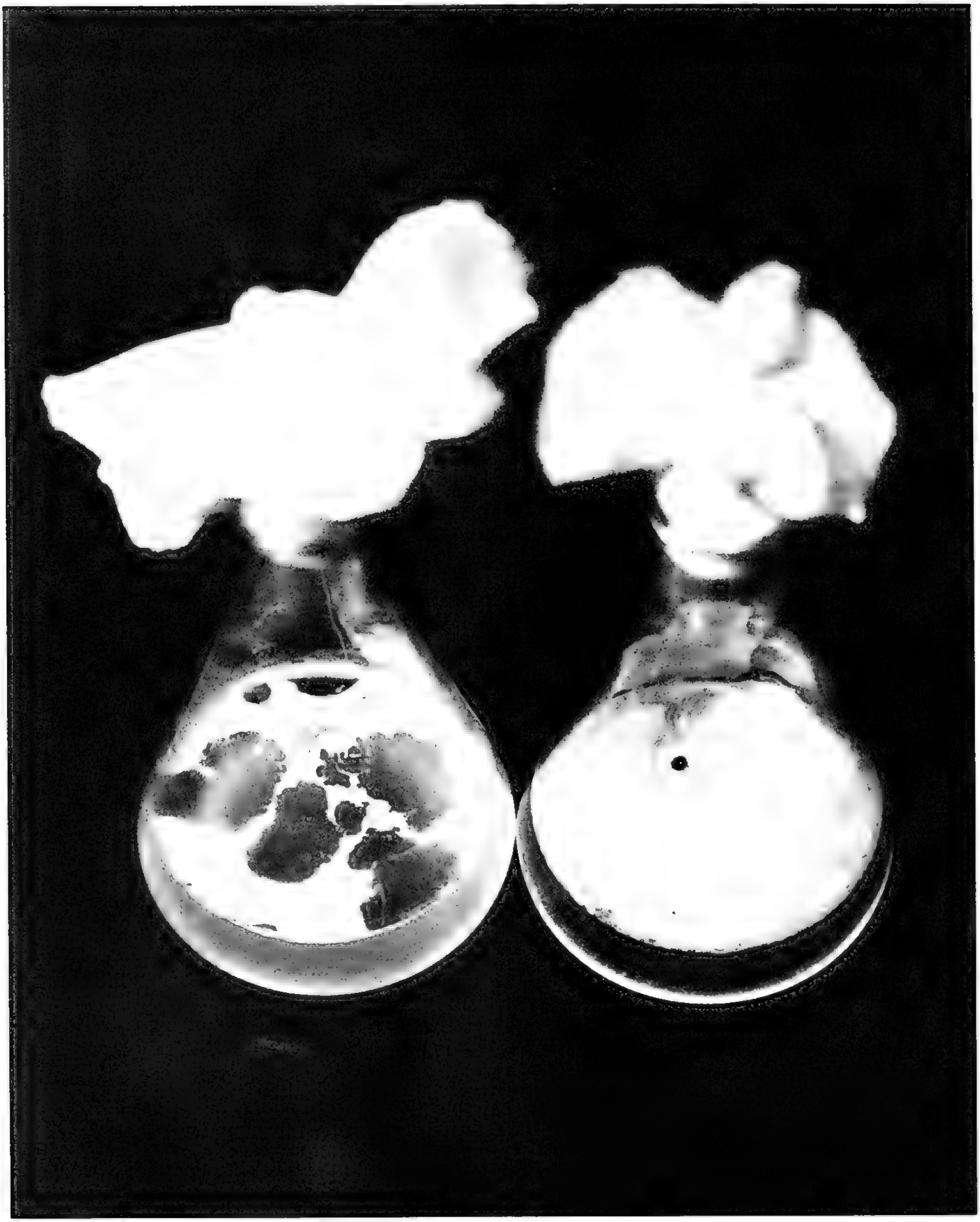


FIG. 5. Preliminary experiments showing zones of degradation occurring after 14 days of incubation at 25°C. Left: Flask inoculated with *Acinetobacter calcoaceticus*. Right: Uninoculated control flask.

(Table 1). Results obtained from both trials 1 and 2 indicate that biodegradation increased approximately equally upon fertilization or aeration. An even greater increase in biodegradation occurred when both aeration and fertilization of the systems was done. Water samples used in trial 1 ecosystems, which were collected 9 January 1986, had more oil-decom-

TABLE 1. Gravimetric analysis of oil in laboratory ecosystems.

Treatment	% Degradation experimental[a] 4 wk	% Degradation experimental[a] 6 wk	% Degradation control[a] 4 wk	% Degradation control[a] 6 wk
Trial #1				
None	25.5	27.8	2.5	0.9
Fertilizer	27.5	30.6	3.0	1.1
Aeration	24.0	31.8	0.02	0.6
Fertilizer and aeration	28.0	39.3	0.04	1.1
Trial #2[b]				
None	22.8	23.3	1.9	0.02
Fertilizer	24.2	24.1	0.8	0.03
Aeration	24.3	26.0	0.4	0.01
Fertilizer and aeration	29.8	33.2	1.7	0.01

[a]Average of duplicate flasks, 32 flasks per trial
[b]Water samples for trial #2 were affected by EPA-enforced water clean up procedures

posing microorganisms than did water samples used in trial 2 ecosystems. Water samples that were collected for trial 2 analysis were exposed to commercial treatment procedures, which were ordered by the Kentucky Department of Natural Protection, and contained large quantities of pond sediment. Sludge and water removal possibly caused less oil degradation obtained in trial 2 (33.2%). Because the pond ecosystem was completely disturbed, the field study was terminated in March 1986.

Gas chromatographic analysis of oil recovered from the laboratory ecosystems also indicated that experimental flasks given aeration and fertilization showed a greater decrease in individual hydrocarbon components than did their sterile controls (Fig. 6). Gas chromatographic analyses of oils recovered from the waste lagoon (Fig. 7), showed that the oil was degraded more in the experimental portion than in the untreated portion of the lagoon.

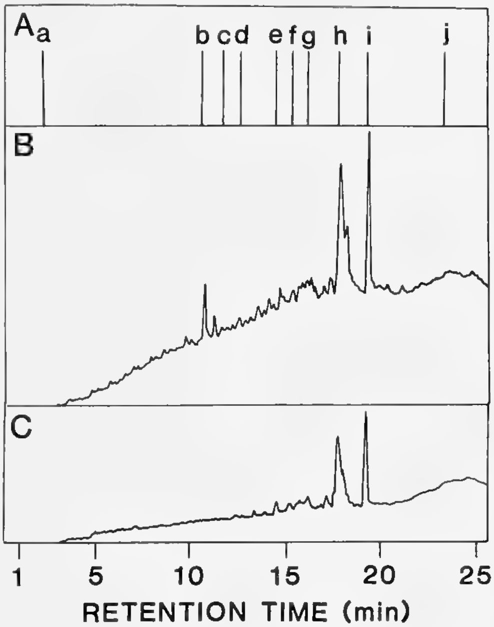


FIG. 6. Gas chromatographic analyses of oils recovered from laboratory ecosystems. (A) Known model compounds. (B) Control flask receiving aeration and fertilization. (C) Experimental flask receiving aeration and fertilization. (a) Retention time for standard n-hexadecane. (b) Retention time for standard n-tetracosane. (c) Retention time for standard n-pentacosane. (d) Retention time for standard n-hexacosane. (e) Retention time for standard n-octacosane. (f) Retention time for standard n-nonacosane. (g) Retention time for standard n-triacontane. (h) Retention time for standard n-dotriacontane. (i) Retention time for standard n-tetratriacontane. (j) Retention time for standard n-tetracontane.

DISCUSSION

Our results agreed with Roubal and Atlas (7) who found that the use of purified agar did not eliminate the problem of some organisms growing on control plates with no added carbon sources. Possibly GELRITE could be used as an agar substitute to alleviate this problem (15). Plate-count procedures for enumerating hydrocarbon-utilizing microorganisms have been criticized because trace amounts of organic contaminants in the media may support the growth of microorganisms other than hydrocarbon utilizers. Atlas (16) described a technique that uses radiolabeled hexadecane-spiked crude oil to specifically enumerate petroleum-degrading microorganisms. This procedure is problematic since handling and disposing of radiolabeled compounds are problems and many laboratories could not be properly equipped to carry out such analyses. Only 1 colony type, which was always in dominant numbers on the oil agar plates, was isolated from the pond water and was able to biodegrade the waste oil. This suggests that this pond bacterium was indigenous. More oil degradation occurred during warmer months but degradation also occurred at low temperatures which agrees with Lock et al. (9) who found

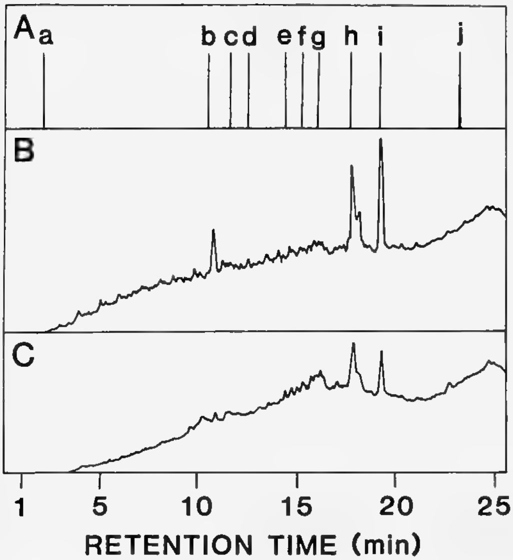


FIG. 7. Gas chromatographic analyses of oils recovered from the field study. (A) Known model compounds (see Fig. 6). (B) Control side of pond. (C) Experimental side of pond.

river bacteria which degraded oil quite rapidly at 4°C.

There have been other reports that *Acinetobacter* can degrade petroleum. Walker and Colwell (12) reported that *A. lwoffi* degrades petroleum and produced long-chained n-alkanes which was a waxy residue. Hauxhurst et al. (17) performed numerical taxonomic analyses on bacteria strains isolated from the Gulf of Alaska and 9 of them met the characteristics of the genus *Acinetobacter* and 6 decomposed pristane. A study by VanAken et al. (18) of the carbon sources that support bacterial growth in metal-working fluids used in large-scale industrial operations demonstrated that 7 strains of *Acinetobacter* reached high densities with oleic acid as sole carbon source. The *Acinetobacter* strains also grew in liquid culture on hexadecane, and naphthenic petroleum oils. *Acinetobacter calcoaceticus* RAG-1 (ATCC 31012) was found by Pines and Gutnick (19) to produce an emulsifying agent termed emulsan which allows the bacterium to grow in a petroleum-abundant environment.

Chromatographic analyses of the field control ecosystem revealed that weathering did not have much effect in reducing the concentration of hydrocarbons. Pond controls were not available to test the effect of aeration or fertilization on decomposition of the oil. Gas chromatographic analyses of oil from the experimental portion of the waste lagoon demonstrated that the indigenous flora almost completely decomposed the waste oil in the probable range of n-alkanes C_{15}–C_{27} and to a lesser extent degraded the waste oil in the probable range of n-alkanes C_{28}–C_{40}. Similar results were obtained by chromatographic analyses of the oil in laboratory ecosystems. One noted difference was that the field ecosystem (Fig. 7) flora decomposed the waste oil more uniformly as indicated by the 2 large peaks (retention times 17.59 and 19.03) as compared to data obtained in the laboratory ecosystem analyses. The laboratory ecosystems were incubated without controlled lighting in contrast to the field ecosystem which had natural lighting. This would possibly stimulate algae to grow which did not grow in the laboratory ecosystems. Such algae may be involved in petroleum degradation. As the water temperature increased in the field ecosystem, algae (*Oscillatoria* and euglenoids) increased in numbers enough to be detectable by microscopic observation. Atlas (2) reviewed the action of microorganisms on petroleum hydrocarbons and recognized that cyanobacteria such as *Oscillatoria* spp. and algae were capable of hydrocarbon degradation.

When conducting gravimetric analyses it was found, in order to get 100% recovery of the oil, the flasks containing the ecosystems should be washed with hexane twice when transferring the oil to drying dishes. Drying the pond-recovered oil at 110°C did not cause volatilization of the hydrocarbons, as determined by gas chromatographic analysis. These analyses indicated that the initial peaks of this oil recovered from the column were hydrocarbons in the probable range of n-alkanes C_{15}–C_{16} which have boiling points greater than 270°C.

Gravimetric and gas chromatographic analyses of waste oil from field and laboratory ecosystems have shown that aeration and fertilization can stimulate indigenous microbial communities to degrade contaminating hydrocarbons. The combination of aeration and fertilization may be the logical and least expensive method for removing contaminating hydrocarbons after oil spills in freshwater systems.

ACKNOWLEDGMENTS

This study was supported by a grant from the Faculty Research Committee of Western Kentucky University.

LITERATURE CITED

1. Hambrick, G. A., III, R. D. DeLaune, and W. H. Patrick. 1980. Effect of estuarine sediment pH and oxidation-reduction potential on microbial hydrocarbon degradation. Appl. Envir. Microbiol. 40:365–369.

2. Atlas, R. M. 1981. Microbial degradation of petroleum hydrocarbons: an environmental perspective. Microbiol. Rev. 45:73–86.

3. Walker, J. D. 1984. Chemical fate of toxic substances: biodegradation of petroleum. Mar. Tech. Soc. J. 18:73–86.

4. Atlas, R. M. 1975. Effects of temperature and crude oil composition on petroleum biodegradation. Appl. Envir. Microbiol. 30:396–403.

5. Davis, S. J. and C. F. Gibbs. 1975. The effect of weathering on a crude oil residue exposed at sea. Water Res. 9:275–285.

6. Walker, J. D. and R. R. Colwell. 1976. Long chain n-alkanes occurring during microbiol degradation of petroleum. Can. J. Microbiol. 22:886–891.

7. Roubal, G. and R. M. Atlas. 1978. Distribution of hydrocarbon-utilizing microorganisms and hydrocarbon biodegradation potentials in Alaskan continental shelf areas. Appl. Envir. Microbiol. 35:897–905.

8. Horowitz, A. and R. M. Atlas. 1977. Response of microorganisms to an accidental gasoline spillage in an Arctic freshwater ecosystem. Appl. Envir. Microbiol. 33: 1252–1258.

9. Lock, M. A., R. R. Wallace, and D. W. S. Westlake. 1982. Biodegradation of synthetic crude oil in two rivers of northern Alberta, Canada. Water Res. 16:497–500.

10. Sayler, C. S., R. E. Perkins, T. W. Sherrill, B. K. Perkins, M. C. Reid, H. L. Kong, and J. W. Davis. 1983. Microcosm and experimental pond evaluation of microbial community response to synthetic oil contamination in fresh water sediments. Appl. Envir. Microbiol. 46:840–845.

11. Olivieri, B., P. Bacchin, A. Fobertiello, N. Oddo, L. Degen, and A. Tonolo. 1976. Microbial degradation of oil spills enhanced by slow-released fertilizer. Appl. Envir. Microbiol. 31:629–634.

12. Walker, J. D. and R. R. Colwell. 1976. Enumeration of petroleum-degrading microorganisms. Appl. Envir. Microbiol. 31:198–207.

13. Horowitz, A., M. I. Kricheusky, and R. M. Atlas. 1983. Characteristics and diversity of subarctic marine oligotrophic, stenoheterotrophic and euryheterotrophic bacterial populations. Can. J. Microbiol. 9:527–535.

14. Spino, D. F. and E. E. Geldreich. 1981. *Acinetobacter* spp.: distinct morphology on eosin methylene blue agar as an aid to identification in drinking water. Appl. Envir. Microbiol. 41:1063–1064.

15. Shungu, D. M., V. Valiant, E. Tuthane, E. Weinkerg, B. Weissherger, L. Koupal, H. Gadebush, and E. Stapley. 1983. Gelrite as an agar substitute in bacteriological media. Appl. Envir. Microbiol. 46:840–845.

16. Atlas, R. M. 1975. Effects of temperature and crude oil composition on petroleum biodegradation. Appl. Envir. Microbiol. 30:396–403.

17. Hauxhurst, J. D., M. I. Kricheusky, and R. M. Atlas. 1980. Numerical taxonomy of bacteria from the Gulf of Alaska. J. Gen. Microbiol. 120:1160–1169.

18. VanAken, F., J. A. Brown, W. Young, I. Salmern, T. McClur, S. Napier, and R. H. Olsen. 1986. Common components of industrial metal-working fluids as sources of carbon for bacterial growth. Appl. Envir. Microbiol. 51: 1160–1169.

19. Pines, O. and D. Gutnick. 1986. Role for emulsan in growth of *Acinetobacter calcoaceticus* RAG-1 on crude oil. Appl. Envir. Microbiol. 51:661–663.

Trans. Ky. Acad. Sci., 48(3–4), 1987, 84–87

Index Herbariorum Kentuckiensis II

RONALD L. JONES

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

A survey conducted during the academic year 1986–1987 provides information on herbarium collections in 19 herbaria in Kentucky. A total of about 212,000 vascular plant specimens and 5,400 nonvascular plant specimens is reported for the state.

INTRODUCTION

This survey is an update of the one published by Lassetter in 1978 (1), in which a total of 119,000 vascular plant specimens were reported from 12 herbaria. For the present study, a questionnaire was sent to all colleges, universities, agencies, and individuals known to have herbaria in the state. The following data were requested: name and address of collection, phone number, date of establishment, number of specimens, emphasis and special collections, names of curator and other staff, exchange policies, and loan policies. The objective of the survey is to determine the current status of herbarium collections in Kentucky. The cooperation of all who responded to the survey is appreciated.

RESULTS

This survey provides information on 19 herbaria in the state. Fifteen are institutional, 3 are private individual collections, and 1 is a state government collection. The total number of mounted vascular plant specimens in these Kentucky herbaria is roughly 212,000. Collections at the University of Kentucky (2 herbaria) and the University of Louisville account for about 96,000, while the number of specimens at the 5 regional universities is about 82,000. Collections at private colleges total about 10,000 with the great majority at Berea College. The total number of nonvascular plant specimens is about 5,400 with the largest collections at Centre College and the University of Kentucky.

The information obtained in this survey is listed below. The acronyms (given in parentheses after the institution) and general format of the data are based on *Index Herbariorum* (2). Proposed but unpublished acronyms are indicated by an asterisk.

BEREA: Herbarium, Department of Biology, Berea College (BEREA), Hall Science Building Rm 212B, Berea, KY 40404. 606-986-9341, ext. 6320. Established about 1961. 8,000 vascular plants, and 4,700 being processed. Label information now being entered into computer data files. 200 fruits for teaching use only. Flora of south-central and eastern Kentucky, especially surface-mine flora and the floras of Madison, Rockcastle, and Laurel counties. Complete sets of specimens from floristic studies of Berea College Forest and Rock Creek Research Natural Area. Special collections of the Fabaceae of Kentucky. Exchange for eastern Kentucky plants, especially legumes. Loans to acronymed herbaria for a 4-month period, subject to renewal. Ralph L. Thompson, Curator.

BLEDSOE: Elwood J. Carr Plant Collection, Pine Mountain Settlement School, Bledsoe, KY 40810. 606-558-3571. Dates and numbers not given. A collection of edible and medicinal plants, containing specimens, slides, and books. Available for students of plant life. No exchange or loans. Mary Rogers, Curator.

BOWLING GREEN: Herbarium, Biology Department, Western Kentucky University (WKU*), Thompson Science Complex, North Wing Rm 218, Bowling Green, KY 42101. 502-745-3696. Established in 1967. 13,538 vascular plants; 500–700 fungi. Flora of central and western Kentucky. Collections of E. Beal from the Carolinas, R. Athey from western Kentucky, and G. Johnson from Barren County. Limited exchange and standard loan policy. Kenneth A. Nicely, Curator; Jeff Jenkins, Mycologist.

CAMPBELLSVILLE: Biological Collection,

Campbellsville College, Science Building Rm 101, Campbellsville, KY 42718. 502-465-8158, ext. 263. Established in 1965. About 1,000 vascular plants. Flora of Taylor County and surrounding counties. Exchanges and loans available. G. Weddle and M. Rogers, Staff.

COLUMBIA: Herbarium, Lindsey Wilson College, Science Building Rm 210, Columbia, KY 42728. 502-384-2126, ext. 231. Established in 1986. 300 vascular plants, about 1,700 unmounted. Collections are currently being entered into a computer database. Flora of south-central Kentucky; economic botany collections. Special collections of *Castanea*. Exchanges and loans available. George P. Johnson, Curator.

CYNTHIANA: Varner Herbarium, Rt. 3, Cynthiana, KY 41031. Established in 1965. 18,945 vascular plants; 217 fruit specimens. Kentucky woody plants, southern Appalachian collections. Special collections of *Crataegus*. No exchanges, no loans, no visitation. Johnnie B. Varner, Curator.

DANVILLE: Bryophyte Herbarium, Division of Science and Math, Centre College (KBRYO), Danville, KY 40422. Established in 1974. 2,600 mosses and hepatics. Collections from Red River Gorge, Central Kentucky Wildlife Refuge, and Mountain Lake, Virginia. Exchange only with research associates. Susan Moyle Studlar, Curator.

FRANKFORT: Rare Plant Reference Collection, Kentucky Nature Preserves Commission, 407 Broadway, Frankfort, KY 40601. 502-564-2886. Established in 1985. About 1,000 vascular plants. Collection of rare plant species being monitored by KNPC. No exchange or loans; visitors welcome. Richard Hannan, Director; Marc Evans, Curator.

GEORGETOWN: Herbarium, Biology Department, Georgetown College, Georgetown, KY 40324. 606-863-8085. Established in 1945. 275 vascular plants and 42 nonvascular. Herbarium used for teaching purposes only. No exchange or loans. Johnnie B. Varner, Curator.

HIGHLAND HEIGHTS: Herbarium, Biological Sciences, Northern Kentucky University (KNK), NS 501, Highland Heights, KY 41076. 606-572-6390. Established in 1973. 18,560 vascular plants; 129 nonvascular plants; 230 cones and fruits. Flora of Northern Kentucky. Special collections of gymnosperms and Poaceae. Usual policies for loaning and borrowing. John W. Thieret, Director; George F. Buddell II, Research Associate.

LEXINGTON: Herbarium, College of Agriculture, Department of Agronomy, University of Kentucky, Agricultural Science Building North Rm A-4, Lexington, KY 40546-0091. 606-257-3587. Established about 1887. About 21,000 vascular plants. Emphasis on weedy plants and agricultural weeds of Kentucky. Many old specimens, mostly collected by Harrison Garman and Mary Didlake from 1896 to 1930. A public service collection, providing identifications of specimens sent to the College. No exchange or loans; visitors welcome. Patricia Dalton Haragan, Curator.

LEXINGTON: Herbarium of the Thomas Hunt Morgan School of Biological Sciences, University of Kentucky (KY), Funkhouser Building Rms 207, 213, 216, Lexington, KY 40506. 606-257-3240. Reestablished in 1948 after fire destroyed the previous collection. About 50,000 vascular plants; about 1,500 nonvascular, mostly bryophytes. Flora of the Bluegrass; swamp forests around the Bluegrass; Berea Forest; Mary Wharton collections; various Kentucky county floras. Special collections of the Tiliaceae—Flora Neotropica; economic plants of Indonesia. Standard exchange and loan policies. Willem Meijer, Curator; Julian Campbell, Research Associate.

LOUISVILLE: Davies Herbarium, Department of Biology, University of Louisville (DHL), Life Sciences Rm 214, Louisville, KY 40292. 502-588-6771. Established in 1953. 25,000 vascular plants. Flora of Carroll County, Bernheim Forest, Kleeber Bird Sanctuary, Horner Wildlife Sanctuary. Research collections of *Malacothrix* (Asteraceae). Exchange of vascular plants from Kentucky and southeastern states. Loans for a 12-month period. W. S. Davis, Curator.

MOREHEAD: Herbarium, Department of Biological and Environmental Sciences, Morehead State University (MOKY*), Lappin Hall Rm 306, Morehead, KY 40351. 606-784-2947. Established in 1930s, reestablished in 1970 after long period of inactivity. 10,000 vascular plants; 200 fruits and seeds. Flora of eastern Kentucky, especially Cave Run area (Rowan, Morgan, Bath, and Menifee counties); duplicates of some of McCoy's Kentucky ferns. Exchanges available. Loans to established herbaria. Howard L. Setser, Curator.

MURRAY: Herbarium, Department of Biological Sciences, Murray State University (MUR), Blackburn Science Building, 5th Floor, Murray, KY 42071. 502-462-2687. Established in 1967. Over 24,000 vascular plants; 600 nonvascular plants. Floras of Calloway, Fulton, Hickman counties; Loess bluffs of Carlisle County. Exchanges on a one-for-one basis. Loans for a 6-month period. Marian J. Fuller, Curator.

PADUCAH: Athey Herbarium, 2723 Tennessee St., Paducah, KY 42001. Established in 1967. 5,069 unmounted vascular plant specimens. Flora of western Kentucky, especially of swamps and prairie sites. Duplicates at Memphis State University Herbarium. No exchange or loans. Raymond Athey, Curator.

RICHMOND: Herbarium, Department of Biological Sciences, Eastern Kentucky University (EKY), Moore Building Rm 109, Richmond, KY 40475. 606-622-1531. Established in 1974. 15,000 vascular plants, and about 2,000 being processed. Specimens now being mapped on Kentucky county maps and preparations underway for entering data in computer files. About 150 fruit and seed collections for teaching use only. Flora of eastern Kentucky, especially woody plants and aquatics. Collections from Lilly Cornett Woods, Maywoods, Brodhead Swamp, Kentucky River Palisades, Oil Shale areas of Bath and Montgomery counties, and Rock Creek Research Natural Area. Special collections in the Asteraceae, Poaceae, and Fabaceae. Interested in exchanges for vascular plants of Kentucky and southeastern U.S., especially woody plants, composites, aquatics, and grasses. Loans for a 6-month period, subject to renewal. Ronald L. Jones, Curator; William H. Martin, Associate Curator.

WILLIAMSBURG: Herbarium, Biology Department, Cumberland College, Science Building Rm 120, Williamsburg, KY 40769. 606-549-2200. Established in 1984. About 650 vascular plants. Herbarium currently under development, with primary purpose as a teaching collection and depository of local county floras; interest in McCreary, Whitley, Knox, Bell, Laurel, and Pulaski counties, Kentucky, and Campbell County, Tennessee. Special collections from Berea College Forest and of the Vitaceae of southeastern U.S. Limited exchange and loans. David D. Taylor, Curator.

WILMORE: Herbarium, Department of Biology, Asbury College, Wilmore, KY 40390. Established in 1967. 120 vascular plants; 20 nonvascular. Mostly student collections. No exchange or loans. John Brushaber, Curator.

DISCUSSION

A number of Kentucky plant specimens are housed in herbaria outside of the state. In addition to those listed by Lassetter (1), the following herbaria also have considerable numbers of Kentucky specimens: Austin Peay State University (APSC), Gray Herbarium of Harvard University (GH), Missouri Botanical Garden (MO), New York Botanical Garden (NY), University of North Carolina (NCU), and Vanderbilt University (VDB).

The total of 212,000 Kentucky herbarium specimens is an increase of 93,000 over the total of 119,000 in 1977 (the actual date of the survey). Because the UK College of Agriculture Herbarium was not listed in this previous survey, the actual increase in new collections is about 75,000 over the last decade, or about 7,500 specimens a year. Most surrounding states have collections that number several times these Kentucky totals. For example, in 1981, there were over 600,000 specimens in Tennessee herbaria, and over 1 million specimens were housed in Ohio herbaria (2). With the initiation of several new herbaria (Lindsey Wilson College and Cumberland College) and the increased activity at several others, these Kentucky numbers should rise sharply over the next few years. A number of county floras are currently in progress in the state, and this is very encouraging. Only 32 Kentucky counties have published floras, with 12 of these being done prior to the turn of the century, and only 9 completed since 1950 (3). The completion of additional county floras, especially from the neglected eastern and western regions of the state, is one of the best ways to increase our knowledge of the flora and vegetation of Kentucky.

LITERATURE CITED

1. Lassetter, S. 1978. Index herbariorum kentuckiensis. Trans. Ky. Acad. Sci. 39:147–149.

2. Holmgren, P., W. Keuken, and E. Schofield. 1981. Index herbariorum. Part I. The herbaria of the world, 7th ed. Bohn, Scheltema & Holkema, Utrecht, Netherlands. 452 pp.

3. Jones, R. 1986. The need for county floras. The Kentucky Native Plant Society Newsletter 1(3):1.

Trans. Ky. Acad. Sci., 48(3–4), 1987, 88

NEWS

Annual Meeting

The next annual meeting of the Kentucky Academy of Science is scheduled for 6–7 November 1987 at Western Kentucky University, Bowling Green.

Trans. Ky. Acad. Sci., 48(3–4), 1987, 89–95

ACADEMY BUSINESS

Committees of the Kentucky Academy of Science: 1986–1987

On behalf of the membership of the Academy, President Giesmann expresses the sincere appreciation for the commitment and dedication shown by the individuals serving in the many important leadership roles listed below.

Executive Committee

President
Larry A. Giesmann
Dept. of Biological Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5304 or 572-5110
home: (606) 635-5322

President-Elect
William P. Hettinger, Jr.
Carbon Fibers Division
Ashland Petroleum Co., Box 391
Ashland, KY 41101-4114
(606) 329-3333, ext. 4650

Vice-President
Richard Hannan
Director
Ky. Nature Preserves Commission
407 Broadway
Frankfort, KY 40601
(502) 564-2886

Past-President
Charles V. Covell, Jr.
Dept. of Biology
University of Louisville
Louisville, KY 40292
(502) 588-5942 or 588-6771

Secretary
Robert O. Creek
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1539

Treasurer
Morris D. Taylor
Dept. of Chemistry
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1465

Editor
Branley A. Branson
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1537

AAAS/NAAS Rep.
William P. Hettinger, Jr.
Carbon Fibers Division
Ashland Petroleum Co., Box 391
Ashland, KY 41001-4114
(606) 329-3333, ext. 4650

Director, KJAS
Joseph P. "Pat" Stewart
Warren East High School
6867 Louisville Rd.
Bowling Green, KY 42101
(502) 781-1277

Chair, Board of Directors
Douglas L. Dahlman
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4962

Special Asst. to President
J. G. Rodriguez
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4902

KAS FOUNDATION MARCIA ATHEY FUND COMMITTEE

Chair
Ray K. Hammond (1987)
Division of Science
Centre College
Danville, KY 40422
(606) 236-5211

William S. Davis (1988)
Dept. of Biology
University of Louisville
Louisville, KY 40292
(502) 588-5937

James L. Lee (1987)
Dept. of Psychology
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1115

Paul H. Freytag (1989)
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-7452

William Wagner (1989)
Dept. of Physical Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5414

KAS FOUNDATION BOTANY FUND COMMITTEE

Chair
William S. Bryant (1988)
Dept. of Biology
Thomas More College
Ft. Mitchell, KY 41017
(606) 341-5800

Ralph Thompson (1988)
Dept. of Biology
Berea College
Berea, KY 40403
(606) 986-9341

Ronald Jones (1987)
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1539

COMMITTEE ON LEGISLATION

Chair
Gary W. Boggess (1988)
College of Science
Murray State University
Murray, KY 42071
(502) 762-2886

Joe Musacchia (1987)
Graduate School
University of Louisville
Louisville, KY 40292
(502) 588-6495

Ex Officio
Larry A. Giesmann (President)
Dept. of Biological Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5304 or 572-5110

Joe Winstead (1989)
Dept. of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6004

William P. Hettinger, Jr. (Pres-Elec)
Carbon Fibers Division
Ashland Petroleum Co., Box 391
Ashland, KY 41101-4114
(606) 329-3333, ext. 4650

Charles V. Covell, Jr. (Past-Pres)
Dept. of Biology
University of Louisville
Louisville, KY 40292
(502) 588-5942

SCIENCE EDUCATION COMMITTEE

Chair
Ron Gardella (1988)
Dept. of Education
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5237 or 572-5229

Blaine Early (1989)
Dept. of Biology
Cumberland College
Williamsburg, KY 40769
(606) 549-2200, ext 382

Mike Howard (1987)
Fayette County Schools
701 E. Main St.
Lexington, KY 40502
(606) 259-1411, ext 325

Ted M. George (1989)
Dept. of Physics
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1521

Patricia Pearson (1987)
Dept. of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6009

Manuel Schwartz (1988)
Dept. of Physics
University of Louisville
Louisville, KY 40292
(502) 588-6787

Ex Officio
Richard Hannan (Vice-President)
Ky. Nature Preserves Comm.
407 Broadway
Frankfort, KY 40601
(502) 564-2886

MEMBERSHIP COMMITTEE

Chair
Douglas L. Dahlman
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4962

Thomas C. Rambo (1987)
Dept. of Biological Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5305

Randy Falls (1989)
Dept. of Physical Sciences
Morehead State University
Morehead, KY 40351
(606) 783-2913

James Murray Walker (1988)
Dept. of Anthropology
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1648 or 622-1644

Committee on Rare and Endangered Species

Chair
John MacGregor
Ky. Fish and Wildlife Resources
Arnold L. Mitchell Building
#1 Game Farm Road
Frankfort, KY 40601
(502) 564-5448

Jerry Baskin
Dept. of Biological Sciences
University of Kentucky
Lexington, KY 40406-0225
(606) 257-8770

Donald Batch
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1818

Branley A. Branson
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1537

Wayne Davis
Dept. of Biological Sciences
University of Kentucky
Lexington, KY 40406-0225
(606) 257-1828

Paul H. Freytag
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-7452

Richard Hannan, Director
Ky. Nature Preserves Commission
407 Broadway
Frankfort, KY 40601
(502) 564-2886

Max Medley
1386 S. 3rd St
Louisville, KY 40208
(502) 588-6771

Melvin Warren, Jr.
Dept. of Zoology
Southern Illinois University
Carbondale, IL 62901
(618) 536-2314

NOMINATING AND RESOLUTIONS COMMITTEE (1987)

Chair
Gerrit Kloek
Dept. of Biology
Kentucky State University
Frankfort, KY 40601
(502) 227-6066

Charles V. Covell, Jr.
Dept. of Biology
University of Louisville
Louisville, KY 40292
(502) 588-5942

John C. Philley
College of Arts and Sciences
211 Rader Hall
Morehead State University
Morehead, KY 43501
(606) 783-2650

AUDIT COMMITTEE (1987)

Chair
Alan W. Reed
Dept. of Biology
Lindsey-Wilson College
Columbia, KY 42728
(502) 384-2126, ext 231

Modesto del Castillo
Dept. of Science
Elizabethtown Comm. College
Elizabethtown, KY 42701
(502) 769-2371

Gordon Weddle
Dept. of Biology
Campbellsville College
Campbellsville, KY 42718
(502) 465-8158

ad hoc COMMITTEE ON REVISION OF THE CONSTITUTION

Chair
J. G. Rodriguez
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4902

Gary W. Boggess
College of Science
Murray State University
Murray, KY 42071
(502) 762-2886

Ted M. George
Dept. of Physics
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1521

ad hoc COMMITTEE ON FINANCIAL POLICY

Chair
Paul H. Freytag
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-7452

Alan W. Reed
Dept. of Biology
Lindsey-Wilson College
Columbia, KY 42728
(502) 384-2126, ext 231

Manuel Schwartz
Dept. of Physics
University of Louisville
Louisville, KY 40292
(502) 588-6787

ad hoc COMMITTEE ON SITE SELECTION FOR ANNUAL FALL MEETING

Chair
Debra Pearce
Dept. of Biological Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5362

Frank Howard
Kentucky Dept. of Education
1829 Capital Plaza Tower
Frankfort, KY 40601
(502) 564-2672

Joe Winstead
Dept. of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6004

Gerrit Kloek
Dept. of Biology
Kentucky State University
Frankfort, KY 40601
(502) 227-6066

INDEX TO VOLUME 48

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 49
Numbers 1–2
March 1988

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.

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 $15.00 for Active Members; $7.00 for Student Members; $20.00 for Family; $250.00 for Life Members.

Subscription rates for nonmembers are: domestic, $30.00; foreign, $30.00; 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.

EDUCATIONAL AFFILIATES

Sustaining Members

University of Kentucky

Member

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

Associate Member

Alice Lloyd College
Bellarmine College
Berea College
Brescia College
Campbellsville College
Centre College
Cumberland College
Georgetown College
Kentucky State University
Kentucky Wesleyan College
Saint Catharine College

CORPORATE AFFILIATES

All-Rite Pest Control
Alltech, Inc.
International Business Machines
United Catalysts, Inc.

SUSTAINING CORPORATE AFFILIATES

Ashland Oil, Inc.

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

March 1988
Volume 49
Numbers 1–2

Trans. Ky. Acad. Sci., 49(1–2), 1988, 1–7

Silicon Content in Wood and Bark of Baldcypress Compared to Loblolly Pine and Southern Red Oak

Lynne Jordan Bowers

Christian Brothers College,
4920 Cole Road, Memphis, Tennessee 38117

AND

John H. Melhuish, Jr.

U.S. Department of Agriculture, Forest Service,
Northeastern Forest Experiment Station, Berea, Kentucky 40403

Abstract

The durability and resistance to decay of baldcypress wood have been attributed to the quantity and type of extractives in the wood. Studies of agricultural plants have linked variations in silicon content with the degree of resistance to herbivory and fungal attack. The data presented here show that baldcypress bark and wood contain higher concentrations of silicon than pine and oak. The durability of baldcypress wood as well as the ability of this tree to tolerate long periods of flooded soil may be related to this higher silicon content.

Introduction

Baldcypress (*Taxodium distichum* L. Rich.)—Taxodiaceae—wood is known for its durability and resistance to decay (1). This durability has been disputed and reported to be highly variable but has been historically attributed to the quantity and type of extractives in the wood (2). The durability of coastal redwood (*Sequoia sempervirens* (D. Don) Endl), a member of the Taxodiaceae, has also been attributed to the type and quantity of extractives (3).

It has been suggested and debated that some tropical woods which exhibit resistance to marine borers contain considerable quantities of silica (4, 5). Studies of agricultural plants have linked variations in silicon content with the degree of resistance to herbivory and fungal attack (6, 7, 8, 9). If the content of silicon in baldcypress wood is significantly higher than other tree species, it is logical to assume that variation in the silicon content as well as the extractives contribute to the natural resistance to decay and the variation in the durability reported for baldcypress wood. In addition, if the content of silicon is greater in baldcypress tissues, it may suggest that silicon accumulation is a mechanism related to the species survival in its natural habitat. The most obvious difference in the natural habitat of baldcypress when compared with southern red oak and loblolly pine is that baldcypress is most commonly found growing in flooded soils. Silicon accumulation by another wetland species, rice (*Oryza sativa* L.)—Poaceae—has been documented (9).

Wetland plants are adapted to flooded soils and the concomitant low oxygen conditions.

Anaerobic conditions affect the bioavailability of nutrients and potentially toxic substances. Complexities exist but the net result of soil submergence is that it often enhances the availability of manganese and iron to plants. As shown by Patrick and Delaune (10), the oxidized and reduced layers in a flooded soil can be characterized by a vertical distribution of the redox potential and concentrations of oxygen, nitrate, manganous manganese, ferrous iron, and sulfide depending on the degree of reduction. The findings of Okuda and Takahashi (11) suggest that the amount of silicon accumulation in rice plants promotes the oxidation power of rice roots resulting in the deposition of iron and manganese oxides on the root surface. Thus, silicon uptake by rice can reduce the probability of iron and manganese toxicity by decreasing the uptake of iron and manganese. Analysis of the leaves of baldcypress and another wetland species, tupelo (*Nyssa* sp.), by Dickson (12) indicates that tupelo rapidly absorbs and tolerates high internal manganese concentrations while baldcypress apparently excludes manganese.

Flooded soil conditions also increase the amount of silica in the soil solution and the uptake of silica by rice increases with increasing water content of the soil. Ponnamperuma (13) suggested that silica improves the oxygen supply to rice roots by increasing the volume and rigidity of the gas channels to the shoot and root.

Elemental analysis was conducted on wood and bark samples from southern red oak (*Quercus falcata* Michx.)—Fagaceae, loblolly pine (*Pinus taeda* L.), and baldcypress as part of a pilot study for an air pollution study (14). The silicon content of the wood and bark of the 3 species is compared here. The trees sampled are growing adjacent to an abandoned smelter.

Study Area.—Chrome Mining and Smelting Corporation (Chromasco) is located north of Memphis near Millington, Tennessee in the Illinois Central Woodstock Industrial Park (Fig. 1). The location of the oak, pine, and baldcypress sampled with respect to the smelter is shown. Although the baldcypress trees are located upwind from the smelter it is assumed that they received smelter impact comparable to that of the oak and pine because of air inversion within the proximity to the smelter. Silicon dioxide was one of the documented emissions from the smelter (14).

METHODS

Sample Collection and Processing

Two cores were chemically analyzed from each of 5 red oak trees, 7 loblolly pine trees, and 1 core from 4 baldcypress trees growing approximately 1.2 km from the abandoned smelter. Two bark samples were analyzed from each of 5 red oak trees, 7 loblolly pine trees, and 5 baldcypress trees.

A teflon-coated Swedish increment borer was used to remove two 5-mm cores from each tree. The borer and extractor were rinsed with a 10% solution of quaternary ammonium chloride in 2-heptanone and rinsed with acetone before insertion into the tree. This procedure removes any surface lead contamination (15). The cores were taken approximately 1.4 m from the ground on opposite sides of the tree. Studies of lead movement within xylem tissues suggest metal gradients may occur within the xylem making the standardization of sampling height advisable in comparative studies (16). Wooden plugs were inserted into the core holes to reduce the risk of fungal invasion (17). The cores were inserted into plastic straws, labeled and placed in plastic bags to prevent contamination in transport to the laboratory. Bark samples were removed with a stainless steel knife from the 2 core sites, placed in Ziploc plastic bags, and labeled. Field notes included date, tree species, tree location, tree diameter, and core location.

Samples were processed immediately or frozen until surfaced to eliminate microbial growth and/or contamination as described by McLaughlin et al. (18) and Baes (19). Surfacing consisted of "peeling" the samples to reduce contamination and to reveal ring detail. Each specimen was examined under 10× magnification and the skeleton-plot technique of cross-dating was used to accurately date each growth ring as described by Stokes and Smiley (20). After the rings were measured the ring widths for each sample were plotted and checked for errors. The listing and plotting procedures of the Statistical Package for the Social Sciences (SPSS) were used.

Ring widths are not usually directly comparable between trees, e.g., the ring width for

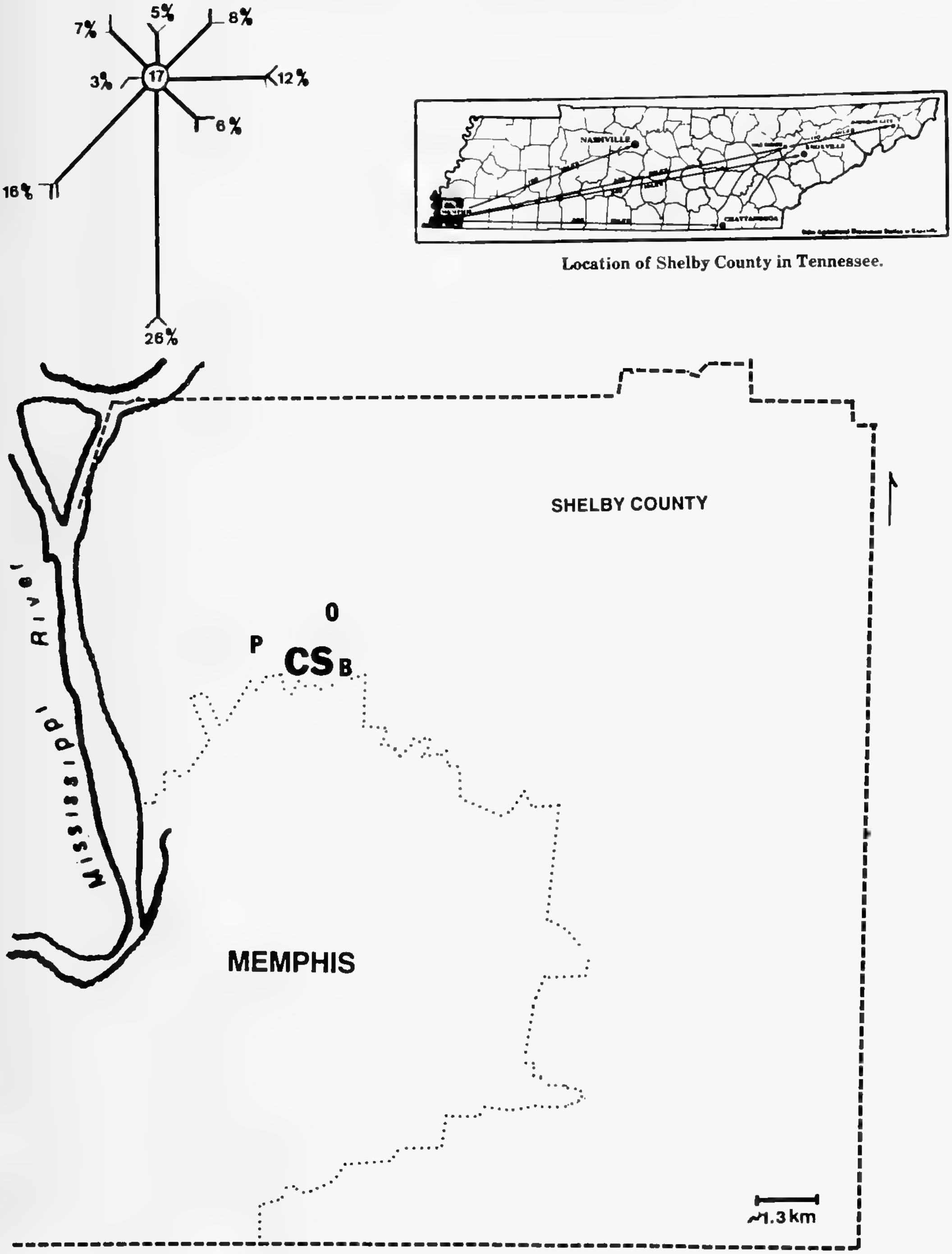


FIG. 1. Location of study area, smelter (CS) and pine (P), oak (O), and baldcypress (B) trees. The 1984 wind rose (Feb.–Dec.) in the upper left-hand corner indicates the wind was from the south 48% of the time in the Memphis, Tennessee area (21).

TABLE 1. Mean silicon concentration (microgram Si/gram of wood, dry weight).*

Time period	Species		
	Baldcypress	Loblolly Pine	Southern Red Oak
Pre-smelter years (1942–1952)	286.38 (10) non-sign.	217.60 (5)	249.80 (5)
Smelter years (1953–1970)	540.55 (8) $P < 0.04$	139.11 (18)	123.60 (10)
Smelter-with-scrubber years (1971–1980)	429.94 (4) $P = 0.01$	172.15 (14)	176.20 (10)
Post-smelter years (1981–1984)	758.79 (4) non-sign.	474.54 (13)	297.10 (10)
All wood samples	459.35 (26) $P < 0.05$	243.42	206.23
Bark/cambium	5,349.75 (10) $P < 0.0000$	669.50 (14)	758.00 (10)

* The sample size is shown in parentheses next to the mean. The statistical significance of the difference measured among species is shown under the baldcypress mean

1960 may be much smaller on tree A than on tree B due to the advanced age of tree A. A trend line or growth curve was fitted to each ring-width graph so that the value for each year can be interpreted as percentage of growth. The percentages of growth derived by fitting the growth curve or indices have a mean approximating 1 for each sample. Indices are comparable among trees. If both trees A and B show reduced growth in a particular year, they both have an index value less than 1. The data are normalized by this curve fitting procedure and are suited to analysis of variance (ANOVA) (22).

The INDXA computer program, developed at the Laboratory of Tree-Ring Research, University of Arizona, was used to convert the values into indices, to average the indices for each year of each sample to yield a site chronology, and to calculate the statistical parameters of the site chronologies. Output from this program was checked with SPSS procedures.

Each increment core was sectioned for chemical analysis into 5 segments: 1. pre-smelter years (1942–1952); 2. smelter years (1953–1970); 3. smelter-with-scrubber years (1971–1980); 4. post-smelter years (1981–1984); 5. cambium/bark.

Chemical Analysis

The samples were analyzed for 25 elements, including silicon, at the Northeastern Forest Experiment Station Research Laboratory in Berea, Kentucky. The wood samples were placed in a drying oven for 48 hours prior to grinding. Then a dried sample of 0.2 g was weighed, and heated for 1 hour at 200°C and at 600°C for 7 hours. The resulting ash was dissolved in 25 ml of 50% HCl. The HCl mixture was diluted to 50 ml with distilled water.

The samples were analyzed with a Beckman Spectra Span 3B direct current plasma (DCP) emission spectrometer. Quality control samples (EPA and National Bureau of Standards) were used to check the standards of all elements before and after the wood samples were analyzed.

RESULTS

The mean concentration of silicon detected for the samples of all 3 species is shown in Table 1. The mean silicon concentration of the baldcypress samples was significantly higher than the mean for the loblolly pine and red oak samples for the smelter years, smelter-with-scrubber years, and for the bark samples.

The ring-width indices chronology constructed for each species of this study as well as an unimpacted upland loblolly pine and red oak site located approximately 125 miles southeast of the smelter is shown in Figure 2. All chronologies show a growth decline in 1968–1969, 1977, and the drought of 1980 (Fig. 2). The most obvious difference in the chronologies is the sharp increase in growth which occurs on the smelter-impacted loblolly pine site between 1981–1983. Further perusal of the chronologies in Figure 2 reveals the years in each time period which are below the 30-year (1953–1982) growth mean for the unimpacted

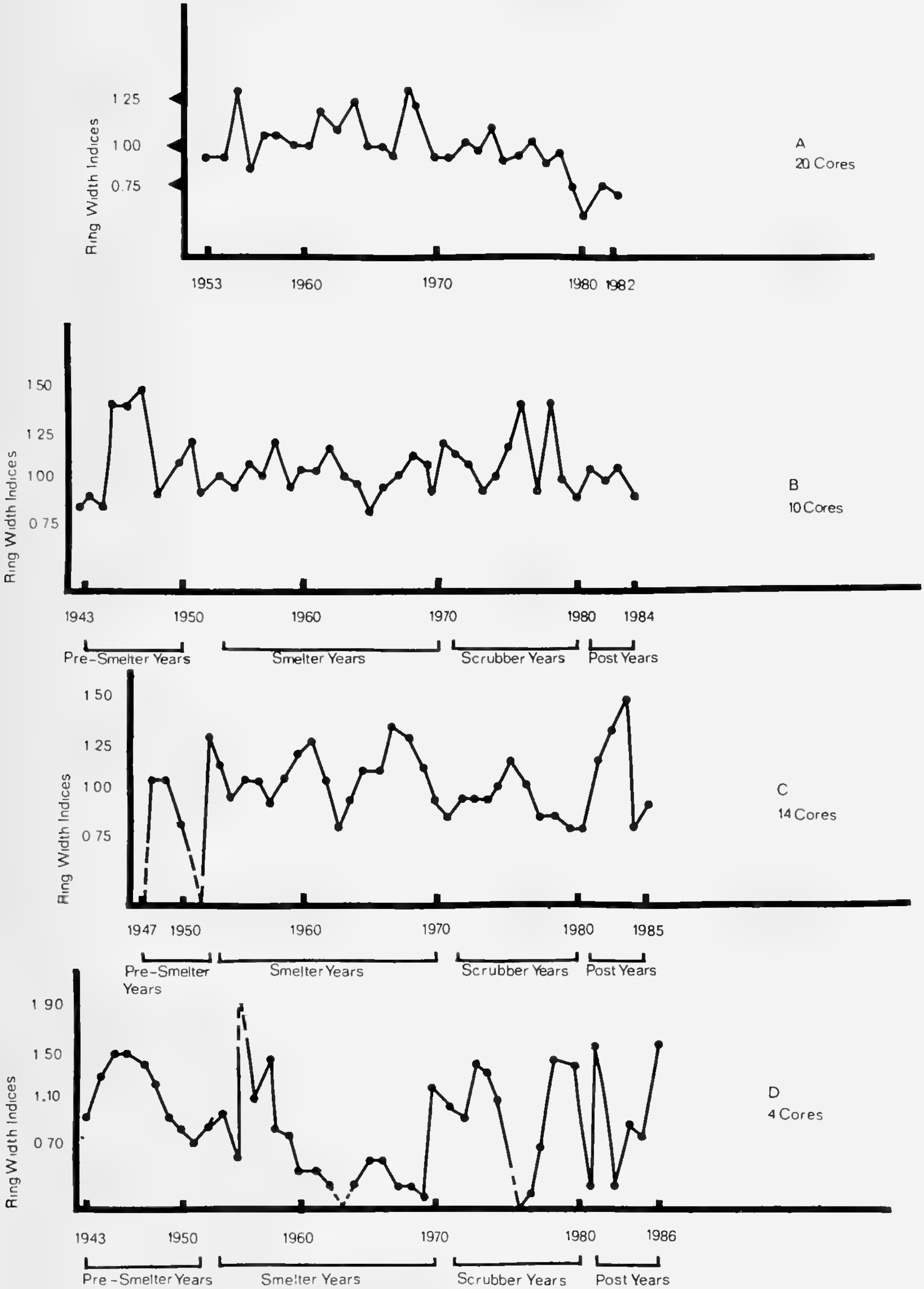


FIG. 2. Ring-width chronologies for A. the unimpacted pine-oak site showing regional growth trends (taken from 23), B. the smelter-impacted oak site, C. the smelter-impacted pine site, and D. the smelter-impacted baldcypress site.

and impacted sites. All years of the post-smelter period were below the mean except on the impacted pine site.

DISCUSSION

The silicon content of the baldcypress samples was significantly higher than for the red oak and loblolly pine samples for 3 of the 5 time periods analyzed. The time periods in which no significant difference was found were the pre-smelter and the post-smelter periods (Table 1). The silicon content of the baldcypress samples was not significantly greater for the post-smelter samples because of the high concentration for the loblolly pine samples. The loblolly pine samples of the post-smelter period contained a significantly higher silicon concentration than any of the other loblolly pine wood samples ($P = 0.01$).

The significantly higher concentration of silicon for the loblolly pine wood samples of the post-smelter period may be explained by the growth anomaly which occurred during this time period in the pine trees. Figure 2 shows the site chronologies for the smelter-impacted loblolly pine, red oak, and baldcypress sites of this study. Also shown in Figure 2 is an unimpacted oak-pine site chronology which can be used for a comparison of regional growth trends. The trees for this latter chronology are located approximately 125 miles southeast of the smelter. All the chronologies in Figure 2 show a growth decline in 1968–1969, 1977, and the drought of 1980. The most obvious difference in the chronologies is the sharp increase in growth which occurs on the loblolly pine site between 1981–1983. This growth increase corresponds exactly with the post-smelter period but it is not believed to be attributable to the cessation of smelter activity. A holding pond was installed on the loblolly pine site in 1981 which had an irrigating effect on these trees during a period of regional drought causing increased silicon uptake. Tree-ring studies have shown that common growth trends occur throughout the eastern United States because of regional climate and that a reduction in tree growth is evident throughout the southeastern U.S. from 1977 through the 1980s (24, 25). All years of the chronologies showed growth below the 30-year growth mean (1953–1982) for the post-smelter period except on the impacted pine site.

Although studies of agricultural plants have not shown that silicon affects growth rate (9), it is possible that growth rate affects the accumulation rate of silicon. Therefore, silicon concentrations may not suppress or enhance growth, but rather growth rate affects accumulation of silicon. It is obvious that significantly greater concentrations of silicon were accumulated in the loblolly pine wood samples during a period of released growth (Table 1 and Fig. 2). Mariaux (26) suggests that the formation of silica grains in the wood of Gaboon mahogany (*Aucoumea klaineana* Pierre)—Burseraceae of western Africa—is related to growth rate.

The other time period which did not reveal significantly higher concentrations of silicon for the baldcypress samples was the pre-smelter period. The younger age of the trees during this time period may partially explain the lack of difference between the species. According to Lewin and Reimann (9), studies have shown that silica content varies with age in some plants. Mature plants and older leaves have a higher silicon content. The loblolly pine and red oak samples did not show any trend which could be attributed to aging but the baldcypress samples did show an increase in silicon concentration with time (Table 1).

When the concentrations measured for all the wood samples, that is, pre-smelter, smelter, smelter-with-scrubber, and post-smelter are averaged together, the differences in elemental concentration due to differences in smelter activity and growth rates are pooled together. A significant difference was still obvious among species (Table 1).

Although limited, the data reveal that baldcypress bark and wood contain higher concentrations of silicon than loblolly pine and red oak. The durability of baldcypress wood as well as the ability of this tree to tolerate long periods of flooded soil conditions may be related to this higher silicon content.

LITERATURE CITED

1. U.S. Department of Agriculture. 1955. Agric. Handb. 72. U.S. Department of Agriculture, Washington, D.C.

2. Campbell, R. N. and J. W. Clark. 1960. Decay resistance of baldcypress heartwood. Forest Prod. J. 10: 250–253.

3. Anderson, A. B. 1961. The influence of extractives on tree properties. J. Inst. Wood Sci. 8:14–34.

4. Panshin, A. J. and C. de Zeeuw. 1970. Textbook of wood technology, Vol. 1. Structure, identification, uses, and properties of the commercial woods of the United States and Canada. McGraw-Hill Book Co., New York.

5. De Silva, D. and W. E. Hillis. 1980. The contribution of silica to the resistance of wood to marine borers (*Bankia* spp.). Holzforschung, Berlin, Herbert Cram 34: 95–97.

6. Ponnaiya, B. W. X. 1951. Studies in the genus *Sorghum*. The cause of resistance in *Sorghum* to the insect pest *Antherigona indica* M. Madras U. J. B 21:203–217.

7. Gallum, R. L., R. Ruppel, and E. H. Everson. 1966. Resistance of small grains to the cereal leaf beetle. J. Econ. Entomol. 59:827–829.

8. Jones, L. H. P. and K. A. Handreck. 1967. Silica in soils, plants, and animals. Pp. 107–149. In A. G. Norman (ed.) Advances in agronomy, Vol. 19. Academic Press, New York.

9. Lewin, J. and B. E. F. Reimann. 1969. Silicon and plant growth. Ann. Rev. Plant Phys. 20:289–304.

10. Patrick, W. H., Jr. and R. D. Delaune. 1972. Characterization of the oxidized and reduced zones in flooded soil. Soil Science Soc. America Proc. 36:573–576.

11. Okuda, A. and E. Takahashi. 1965. The role of silicon. Pp. 123–146. In The mineral nutrition of the rice plant. Proc. Symp. Intern. Rice Res. Inst.; 1964 February; Los Banos, Laguna, Philippines. Johns Hopkins Press, Baltimore, Maryland.

12. Dickson, R. E. 1987. Personal communication. Letter dated June 18, 1987, North Central Forest Experiment Station, Rhinelander, Wisconsin.

13. Ponnamperuma, F. N. 1965. Dynamic aspects of flooded soils and the nutrition of the rice plant. Pp. 295–328. In The mineral nutrition of the rice plant. Proc. Symp. Intern. Rice Res. Inst.; 1964 February; Los Banos, Laguna, Philippines. Johns Hopkins Press, Baltimore, Maryland.

14. Bowers, L. J. and J. H. Melhuish, Jr. 1987. Elemental analysis of red oak and loblolly pine growing near an inactive chromium smelter. Pp. 231–245. In Sixth central hardwood conference; 1987 February 24–26; Knoxville, Tennessee.

15. Baes, C. F., III and H. L. Ragsdale. 1981. Age-specific lead distribution in xylem rings of three tree genera in Atlanta, Georgia. Environ. Pollut. Ser. B 2:21–35.

16. Lepp, N. W. 1975. The potential of tree-ring analysis for monitoring heavy metal pollution patterns. Environ. Pollut. 9:49–61.

17. Maeglin, R. R. 1979. Increment cores—how to collect, handle, and use them. U.S. Department of Agriculture, Forest Service, Madison, Wisconsin, Res. Paper FPL 25, pp. 1–19.

18. McLaughlin, S. D., C. F. Baes, III, R. K. McConathy, L. L. Sigal, and R. F. Walker. 1983. Interactive effects of acid rain and gaseous air pollutants on natural terrestrial vegetation. National acid precipitation assessment program effects research review February 21–25, 1983:1–18.

19. Baes, C. F., III. 1984. Personal communication. Letter dated October 11. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

20. Stokes, M. A. and T. L. Smiley. 1968. An introduction to tree-ring dating. The University of Chicago Press, Chicago.

21. Sobel, J. A. 1984. Wind rose data. Dept. Geogr., Memphis St. Univ., Memphis, Tennessee.

22. Matalas, N. C. 1962. Statistical properties of tree ring dating. Publ. Intern. Assn. of Sci. Hydrol. 7:39–47.

23. Bowers, L. J. and W. H. Patrick, Jr. 1983. Tree ring study. Pp. v-1–v-16. In Evaluation of the effects of Corps projects on the East Fork floodplain, Tombigbee River. W. H. Patrick, Inc. contract DACW01-82-C-0149. Mobile District, U.S. Army Corps of Engineers.

24. Fritts, H. C., G. R. Lofgren, and G. A. Gordon. 1979. Variations in climate since 1602 as reconstructed from tree rings. Quat. Res. 12:18–46.

25. Bowers, L. J., J. G. Gosselink, W. H. Patrick, Jr., and E. T. Choong. 1985. Influence of climatic trends on wetland studies in the eastern United States which utilize tree ring data. Wetlands 5:191–199.

26. Mariaux, A. 1980. Formation of silica grains in wood as a function of growth rate (*Aucoumea klaineane*, tree structure). Intern. Assoc. of Wood Anatom., Leiden, Netherlands 1:140–142.

Trans. Ky. Acad. Sci., 49(1–2), 1988, 8–14

The Sphaeriacean Clams (Mollusca: Bivalvia) of Kentucky

Branley Allan Branson

Department of Biological Sciences, Eastern Kentucky University,
Richmond, Kentucky 40475

Abstract

Keys to the 13 species of sphaeriacean clams known from Kentucky are presented; most species are illustrated by photographs. Comments on habitat requirements and distribution are included, and search recommendations for 6 species not yet reported from Kentucky are presented.

Introduction

One of the most neglected segments of the Kentucky aquatic fauna is the sphaeriacean mollusks. Most generally, surveys of aquatic faunas either completely ignore these small clams or mention them by genus only. This hiatus is an unfortunate commentary on the status of our knowledge in the Commonwealth. Because of their well-developed mechanisms for passive dispersal and excellent adaptive features, sphaeriid clams are nearly cosmopolitan in distribution (1). In spite of that, the distribution patterns of these mollusks in Kentucky remain poorly understood, and some species—*Pisidium dubium*, for example (2)—have not been reported since early in the 1900s. Some species that almost certainly occur in Kentucky waters have not been reported at all. This dearth of information is entirely the result of inadequate collecting and/or proper identification and reporting.

Most of the information on sphaeriaceans in Kentucky has been reported in a few publications. Bickel (3) summarized the literature through 1967, although Heard (4) implied the occurrence of several species that were not included in Bickel's list, as did Herrington (5) and Burch (6). Since publication of the Bickel (3) checklist, several papers have discussed the distribution of various sphaeriacean clams in Kentucky, including the introduced Asian clam *Corbicula* (7, 8, 9, 10, 11, 12, 13, 14). Two families (Sphaeriidae and Corbiculidae), 3 genera (*Sphaerium, Pisidium* and *Corbicula*) and 13 species are presently known from the state.

Another reason for the lack of published records for the Commonwealth is the dearth of easily accessible literature with special emphasis on the Kentucky fauna. Thus, this paper presents a key, augmented by photographs of most species, in an attempt to stimulate more interest in this important segment of our aquatic fauna.

Key to Kentucky Sphaeriacean Clams
(modified from Burch 1975)

1a. Valves very coarsely sculptured; lateral teeth of hinges serrated .... Family Corbiculidae . . . *Corbicula fluminea* (Mueller 1744) (Figs. 1, 2)

b. Valves not so heavily sculptured; lateral teeth of hinges smooth .... Family Sphaeriidae . . . 2

2a. Beaks (umbos) of shell closer to anterior end than posterior (sometimes nearly central); shells not seed-like 3

b. Beaks (umbos) of shell closer to posterior end than anterior (sometimes nearly central); shells often seed-like 14

3a. Shell usually distinctly mottled with black; each valve with only 1 cardinal tooth (see notes at end of article) .... *Eupera cubensis* (Prime 1865) (Fig. 3)

b. Shell usually not mottled; 2 cardinal teeth in 1 valve, 1 in the other 4

4a. Adult shell relatively coarsely striate (8–9 striae per linear mm) 5

b. Adult shell relatively smoothly striate (12 or more striae per linear mm) 7

5a. Adult shell with nearly evenly dispersed striae .... *Sphaerium simile* (Say 1816)

b. Adult shell with irregularly dispersed striae 6

6a. Shell somewhat inflated; surface (excluding striae) even; striae nearly as strong on beaks as rest of shell .... *Sphaerium striatinum* (Lamarck 1818) (Fig. 4)

b. Shell compressed; surface rather uneven;

striae much weaker on beaks than rest of shell ....
.... *Sphaerium fabale* (Prime 1852) (Fig. 5)

7a. Shells relatively large (more than 8 mm in length) 8

b. Shells smaller (less than 8 mm in length) 12

8a. Shells with prominent beaks (often cap-like), more or less distinctly raised above the dorsal surface 9

b. Shell beaks neither prominent nor raised above the dorsal surface 11

9a. Height of shell three-fourths or less the length ....
..... *Sphaerium* (*Musculium*) *transversum* (Say 1829) (Fig. 6)

b. Height of shell nearly equal to length ...10

10a. Shell more or less oval in outline, its dorsal margin nearly straight; posterior margin meets dorsal one at nearly a 90° angle; striae very fine ....
..... *Sphaerium* (*Musculium*) *partumeium* (Say 1822) (Fig. 7)

b. Shell more or less elongate in outline, its dorsal margin more rounded; posterior margin meets dorsal one at an angle greater than 90°; striae relatively coarse
.... *Sphaerium* (*Musculium*) *lacustre* (Mueller 1774) (Fig. 8)

11a. Shell nearly rectangular in outline ....
...... *Sphaerium rhomboideum* (Say 1822) (Fig. 9)

b. Shell rounded in outline ....
...... *Sphaerium corneum* (Linnaeus 1758) (Fig. 10)

12a. Posterior end of shell forms virtually a 90° angle with dorsal margin ....
.... *Sphaerium partumeium*

b. Posterior end of shell forms an obtuse angle with dorsal margin 13

13a. Beaks of shell very prominent and raised above the dorsal surface ....
.... *Sphaerium lacustre*

b. Beaks of shell not prominent, only slightly raised above the dorsal surface ....
.... *Sphaerium corneum*

14a. Shell relatively large, 6 mm or more in greatest length ....
.... *Pisidium dubium* (Say 1816)

b. Shell smaller, less than 6 mm in greatest length 15

15a. Cardinal teeth centrally located; shell somewhat inflated; beaks moderately prominent 16

b. Cardinal teeth more anteriorly placed (near anterior cusps); shell not inflated; beaks not prominent ....
..*Pisidium casertanum* (Poli 1791) (Fig. 11)

16a. Surface of shell more or less glossy, finely striate (30 or more striae per linear mm), without strongly developed ridges on the beaks ....
.... *Pisidium variable* Prime 1852 (Fig. 12)

b. Surface of shell dull with coarser striae (less than 30 striae per linear mm), with well-developed ridges on beaks ....
.... *Pisidium compressum* Prime 1852 (Fig. 13)

ANNOTATIONS

Corbicula fluminea, since it was first reported from Kentucky (15, 16, 17, 18), has rapidly invaded many Commonwealth drainages, including the Ohio, Kentucky, Licking, Green, and Cumberland rivers. Populations of this noxious clam are sometimes enormous.

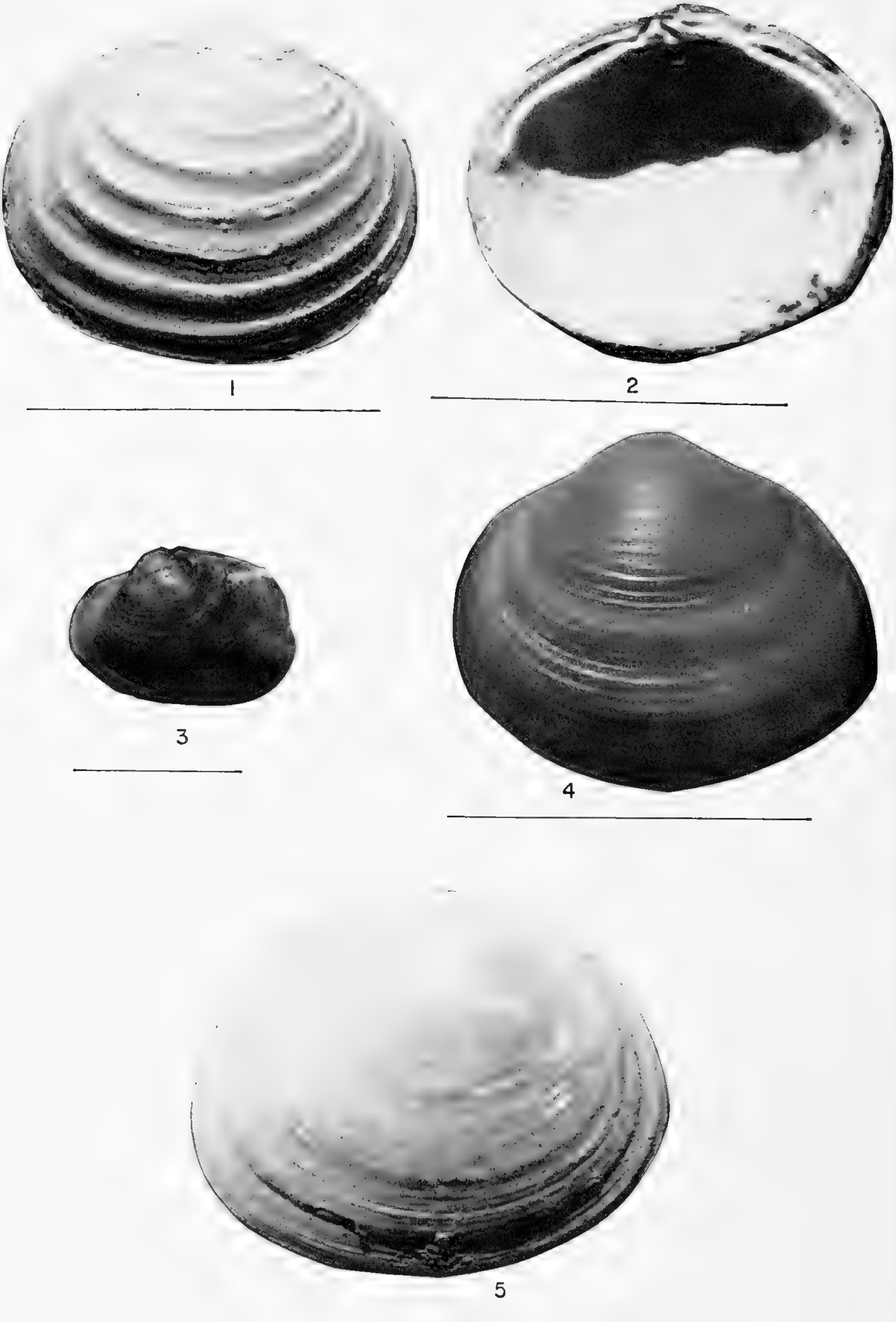
Eupera cubensis is a coastal plains species that favors sluggish streams and ponds. This small, distinctive clam is often attached to moss, rootlets, and twigs in the water by means of byssal threads. It has not been reported from Kentucky but should be sought in Ballard, Hickman, Carlisle, Fulton, and adjacent counties. *Eupera singleyi* Pilsbry 1889 is a synonym (5, 6).

Sphaerium simile has been reported from Kentucky as *S. sulcatum* (Lamarck 1818) (3, 8), a synonym according to Burch (6). It was first reported from the Cumberland River drainage (2) in Kentucky but has in the interim been reported from the Tygarts Creek (7), Cumberland (8), Kentucky (9), Dix (10), Rough (13), and Licking (14) river drainages. The habitat is small lakes and backwaters of creeks and rivers with sand bottoms.

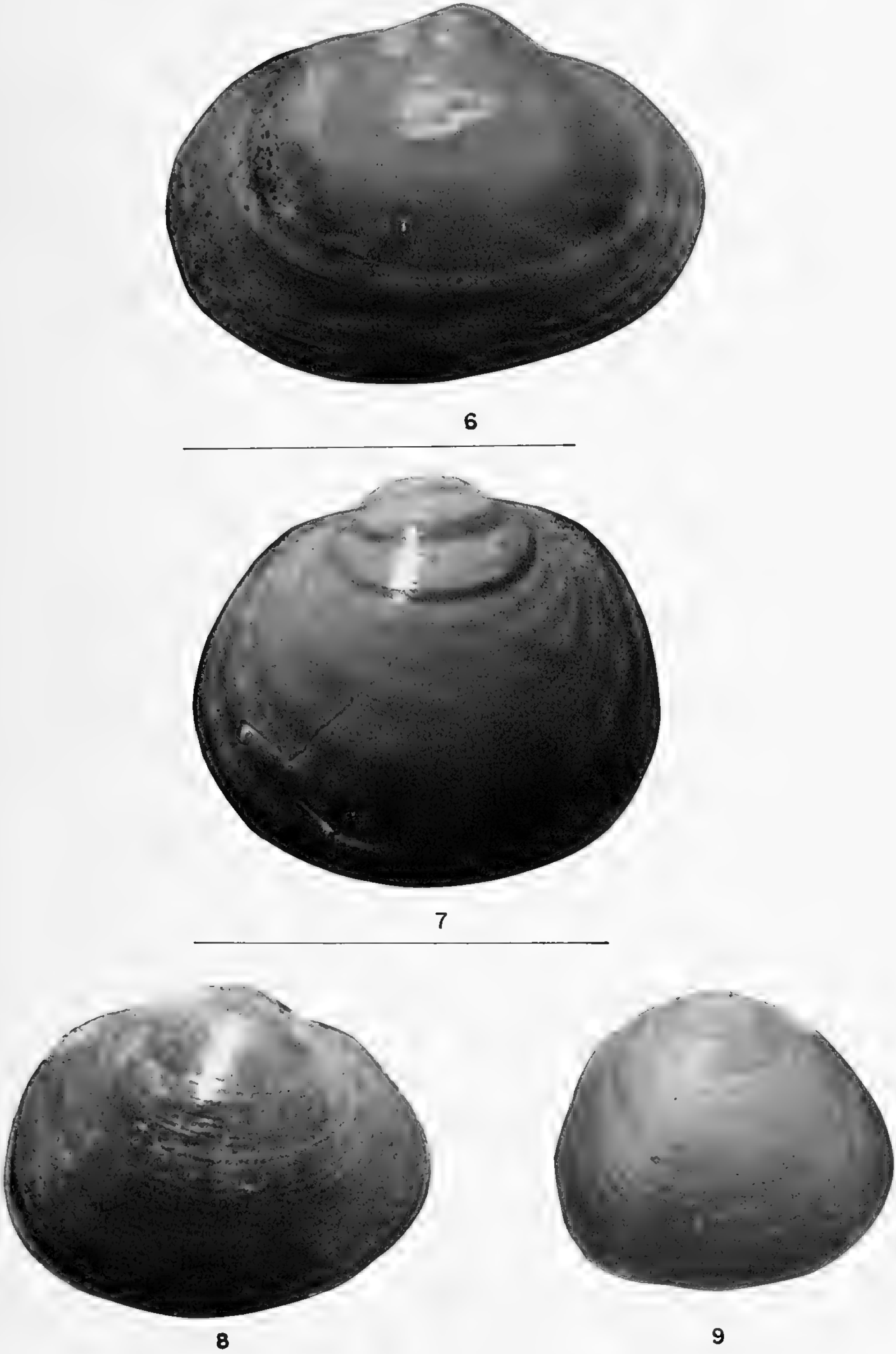
Sphaerium striatinum is the most widespread fingernail clam in the state, from the westernmost streams (8, 13) to the easternmost (9). This is a stream species that occupies sandy to rocky riffles. It is the most abundant sphaeriid species in Salt River (19).

Sphaerium fabale, only recently reported from Kentucky (9), enjoys a relatively wide distribution in the state (9, 10, 11, 13). The habitat is stream gravel, never fine sand or backwaters.

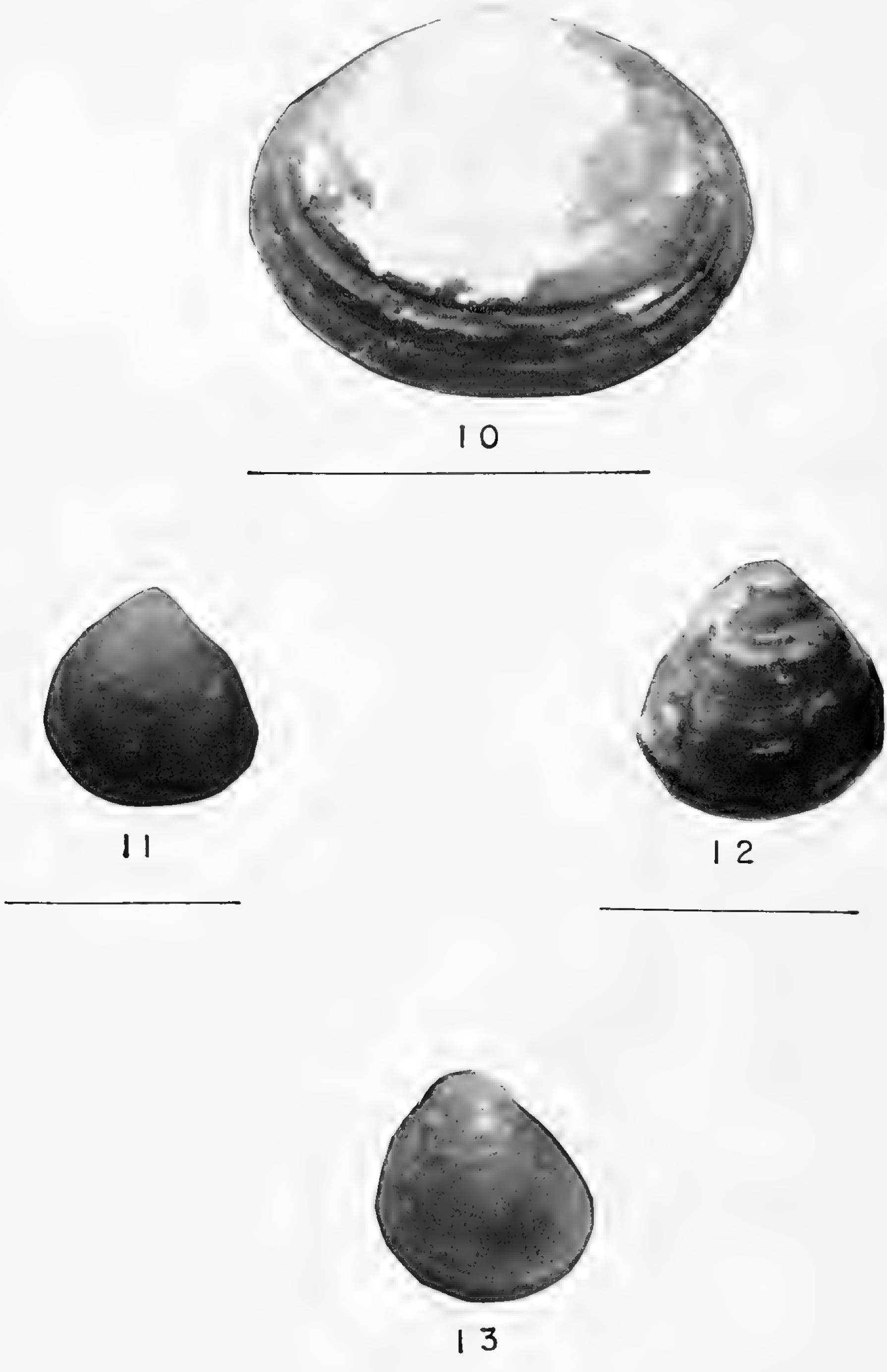
Sphaerium transversum, one of the largest sphaeriids (up to 15 mm in length), is mostly a lowlands species in lakes, ponds, swamps, and backwaters of streams. Although widespread in the state, after being first reported in 1900



FIGS. 1–5. 1. *Corbicula fluminea*. Scale = 8.5 mm. 2. *Corbicula fluminea*, internal, showing serrated lateral teeth. Scale = 8.5 mm. 3. *Eupera cubensis*. Note mottling. Scale = 3.5 mm. 4. *Sphaerium striatinum*. Scale = 10 mm. 5. *Sphaerium fabale*. Scale = 9.5 mm.



FIGS. 6–9. 6. *Sphaerium transversum*. Scale = 9.5 mm. 7. *Sphaerium partumeium*. Scale = 8 mm. 8. *Sphaerium lacustre*. Scale = 7.5 mm. 9. *Sphaerium rhomboideum*. Scale = 8 mm.



FIGS. 10–13. 10. *Sphaerium corneum*. Scale = 6.5 mm. 11. *Pisidium casertanum*. Scale = 3.5 mm. 12. *Pisidium variable*. Scale = 4.5 mm. 13. *Pisidium compressum*. Scale = 3.5 mm.

(2) there were no additional reports until 1962 (5), and that by range implication. We (8, 9, 14) have found it common in the western half of Kentucky, less common in the east (9, 10, 11, 12, 13, 14), although Taylor (7) reported a thriving population in Tygart's Creek. The preferred habitat is mud.

Sphaerium partumeium has not been reported from Kentucky since 1900 (2). Thus, our record from Ballard County (14) was of interest. The habitat is nearly entirely in mud-bottomed lakes, ponds, and backwaters of streams.

Sphaerium lacustre was implied by range in Kentucky (4), but the only record with exact locality data is from a small, heavily vegetated lake in Madison County (9). The preferred habitat is in the mud of ponds and lakes and, occasionally, in the backwaters of large streams (5).

Sphaerium rhomboideum, another species preferring the mud of ponds and lakes and backwaters of streams (5), was reported from the Dix River drainage in 1981 (10), later (14) from a muddy backwater of Townsend Creek in Bourbon County (14).

Sphaerium corneum, at present known only from Slate Creek in Bath County (9), is a European exotic of sporadic occurrence in the United States (5). It prefers soft, sandy mud in the backwaters of streams and ponds and lakes (5).

Pisidium dubium has not been reported from Kentucky since 1900 (2), doubtless because of inadequate collecting. This is a very small (maximum length about 9.0 mm) species, although large for the genus. The habitat is mud in large, sluggish creeks.

Pisidium casertanum was reported from the Ohio River at Louisville (18), and this remained the only record from the state until our recent report from Townsend Creek, Bourbon County (14). The shell seldom measures larger than 4.0 mm in length and 3.3 mm in height, usually smaller. The species is adaptable to many kinds of habitats (5), although it prefers mud-bottomed ponds and lakes.

Pisidium variable is known from Buck Creek in Pulaski County (8), the only record for Kentucky. The preferred habitat is soft, silt mud in still water (5).

Pisidium compression is known only from some mud-bottomed ponds in Madison County (9), although it doubtless is widely distributed in such environments elsewhere. An abundance of aquatic vegetation appears to be a habitat requirement.

DISCUSSION AND SUGGESTIONS FOR FURTHER WORK

The relationships of the Kentucky sphaeriid fauna are mixed. *Eupera* (when found), of course, is a representative of the coastal plains fauna, being distributed from southern Texas to central North Carolina and Florida (4, 5, 6) and Oklahoma (20). The clam should be sought in waters of the Purchase Area. *Pisidium* is principally a northern complex of species; *Sphaerium* (ss) is most abundant in the Great Lakes region; the subgenus *Musculium* is principally southern (4). Thus, Kentucky must be thought of as an intergradation zone between 2 areas of speciation, and its fauna is a reflection of that position, modified, perhaps, by various phases of migration during Pleistocene times.

At least 3 additional species ought to be sought in Kentucky waters. One is *Sphaerium occidentale* (Prime 1856). This species has been reported from all the states surrounding Kentucky (6); it lives in silt and mud in swamps, roadside ditches, and ponds with an abundance of decaying vegetation (5). Another species that should be sought is *Sphaerium securis* (Prime 1852), since it, too, has been reported from all surrounding states (6). The habitat is fine sand of ponds, lakes and rivers (5). Finally, *Pisidium adamsi* (Prime 1851), a rather large species (7 mm or more) that lives in muck and decaying vegetation of lakes, ponds, and the backwaters of rivers (5), has been reported from all the states surrounding Kentucky. Two additional species that may be in Kentucky are *Pisidium nitidum* Jenyns 1832 (practically transcontinental) and *P. punctatum* Sterki 1895, known from Ohio, Pennsylvania, Virginia and Tennessee (6).

ACKNOWLEDGMENT

I greatly appreciate the criticisms and suggestions of Dr. Guenter Schuster, Eastern Kentucky University, during preparation of this article.

LITERATURE CITED

1. Mackie, G. L. 1979. Dispersal mechanisms in Sphaeriidae (Mollusca: Bivalvia). Bull. Amer. Malacol. Union 45:17–21.

2. Price, S. F. 1900. Mollusca of southern Kentucky. Nautilus 14:75–79.

3. Bickel, D. 1967. Preliminary checklist of Recent and Pleistocene Mollusca of Kentucky. Sterkiana 28:7–20.

4. Heard, W. H. 1963. Survey of the Sphaeriidae (Mollusca: Pelecypoda) of the southern United States. Proc. Louisiana Acad. Sci. 26:102–120.

5. Herrington, H. B. 1962. A revision of the Sphaeriidae of North America (Mollusca: Pelecypoda). Misc. Pub. Mus. Zool. Univ. Michigan 118:1–74, 7 pl.

6. Burch, J. B. 1975. Freshwater sphaeriacean clams (Mollusca: Pelecypoda) of North America. Malacol. Pub., Hamburg, Michigan.

7. Taylor, R. W. 1980. Freshwater bivalves of Tygart Creek, northeastern Kentucky. Nautilus 94:89–91.

8. Branson, B. A. and D. L. Batch. 1971. Annotated distribution records for Kentucky Mollusca. Sterkiana 43: 1–9.

9. Branson, B. A. and D. L. Batch. 1981. Distributional records for gastropods and sphaeriid clams of the Kentucky and Licking river and Tygart Creek drainages. Brimleyana 7:137–144.

10. Branson, B. A. and D. L. Batch. 1981. The gastropods and sphaeriacean clams of the Dix River system, Kentucky. Trans. Kentucky Acad. Sci. 42:54–61.

11. Branson, B. A. and D. L. Batch. 1982. The Gastropoda and sphaeriacean clams of Red River, Kentucky. Veliger 24:200–204.

12. Branson, B. A. and D. L. Batch. 1982. Molluscan distribution records from the Cumberland River, Kentucky. Veliger 24:351–354.

13. Branson, B. A. and D. L. Batch. 1983. Gastropod and sphaeriacean clam records for streams west of the Kentucky River drainage, Kentucky. Trans. Kentucky Acad. Sci. 44:8–12.

14. Branson, B. A., D. L. Batch, and S. M. Call. In press. Distribution of aquatic snails (Mollusca: Gastropoda) in Kentucky with notes on fingernail clams (Mollusca: Sphaeriidae;Corbiculidae). Trans. Kentucky Acad. Sci. 48: 62–70.

15. Sinclair, R. M. and B. G. Isom. 1961. A preliminary report on the Asiatic clam *Corbicula* in Tennessee. Stream Poll. Cont. Bd. Tennessee. Dept. Publ. Health 1961: 1–31.

16. Bates, J. M. 1962. Extension of the range of *Corbicula fluminea* within the Ohio drainage. Nautilus 76: 35–36.

17. Keup, L. W., B. Horning, and W. M. Ingram. 1963. Extension of range of Asiatic clam to Cincinnati reach of the Ohio River. Nautilus 77:18–21.

18. Bickel, D. 1966. Ecology of *Corbicula manilensis* Philippi in the Ohio River at Louisville, Kentucky. Sterkiana 23:19–24.

19. Rosewater, J. 1959. Mollusks of the Salt River, Kentucky. Nautilus 73:57–63.

20. Branson, B. A. 1981. The sphaeriacean pelecypods of Oklahoma. Proc. Oklahoma Acad. Sci. 61:1–7.

Trans. Ky. Acad. Sci., 49(1–2), 1988, 15–20

Identification of Eggs, Larvae, and Early Juveniles of the Slabrock Darter, *Etheostoma smithi*, from the Cumberland River Drainage, Kentucky

THOMAS P. SIMON

Large Rivers Larval Research Station, P.O. Box 727, Grayslake, Illinois 60030

ABSTRACT

Specimens of larval to early juvenile *Etheostoma smithi* from Ferguson Creek, Kentucky, are described with emphasis on meristic, morphometric, and pigment characteristics. Adhesive eggs are attached to the underside of slab rocks in shallow upstream pools which are guarded by an attendant male. Egg diameters of *E. smithi* ranged from 1.9 mm to 2.4 mm. Larva hatched at 6.1 mm TL and possessed 15 preanal myomeres and between 19 and 21 postanal myomeres. Pigmentation of newly hatched larvae is limited to the mid-ventral yolk sac and mid-ventral postanal myosepta. Larvae have a large, spherical yolk sac, precocious fin-ray development, and yolk sac absorption after first fin-ray development similar to other larval *Catonotus*.

INTRODUCTION

The slabrock darter, *Etheostoma smithi*, is found sporadically in tributaries of the lower Cumberland River basin from the mouth of the river in Kentucky upstream to Caney Fork, Tennessee. It also occurs in the lower Tennessee River below the Duck River (1, 2, 3).

Information on larval fishes is limited within the tribe Etheostomatini. Larval and early juvenile characteristics have been described for several species of the subgenus *Catonotus*, including *E. flabellare*, *E. kennicotti*, and *E. squamiceps* (4, 5, 6, 7); however, no meristic or morphometric information is available for larvae and early juveniles of *E. smithi*. Page and Burr (8), within the context of a life history study, provided information on early life history stages, including egg incubation, larval development, and illustrations of a newly hatched larva, a 3-day-old larva, and an 8-day-old juvenile. The present paper describes larval and early juvenile characteristics with emphasis on meristic, morphometric, and pigmentation features. Diagnostic characters will be evaluated for separation from sympatric species of *Catonotus*.

METHODS AND MATERIALS

Material Examined.—Etheostoma smithi: Kentucky: Livingston County: Ferguson Creek, INHS 88476 (13), INHS 62624 (4), INHS 68351 (70), INHS 68354 (2), INHS 68352 (2), INHS 58353 (2), LRRC 00344 (5). Tennessee: Wilson County: unnamed creek 1–½ mi N Martha, INHS 84181 (12).

The reference collection of larvae was raised from aquarium-spawned adults from Ferguson Creek, Livingston County, Kentucky (Cumberland River drainage). Adults were collected, acclimated, and induced to spawn, and eggs were incubated in enamel pans (9) at temperatures of 13°C and 21°C by the Illinois Natural History Survey.

A total of 45 eggs and 105 larval and early juvenile slabrock darters were examined after preservation in 10% formalin. Preanal myomeres included those anterior to a vertical line drawn from the posterior portion of the anus, while postanal myomere counts included a urostylar element. All myomeres were counted utilizing polarized light. After formation, fin rays were enumerated following methods in Hubbs and Lagler (10); methods of counting head canal pores followed Hubbs and Cannon (11).

Morphometric characteristics were expressed as per cent total length (TL) unless otherwise noted, and methods of measuring follow Simon (7). Specimens used for vertebral counts were initially preserved in 10% formalin then transferred to isopropyl alcohol, cleared and stained using the method of Fritzsche and Johnson (12), and stored in glycerine. Illustrations were delineated following guidelines outlined in Faber and Gadd (13). For brevity, this description is presented in telegraphic style.

TABLE 1. Morphometry of *Etheostoma smithi* larvae and early juveniles grouped by selected intervals of total length (N = sample size). Characters expressed as per cent total length with a single standard deviation.

Length interval TL	N	Length (% TL)					Depth (% TL)			
		Standard	Preanal	Snout[a]	Eye[a]	Head	Head	Body	Greatest	Caudal peduncle
6.1–7.4	3	92.1 ± 3.5	50.4 ± 1.9	12.6 ± 1.3	39.0 ± 4.2	19.8 ± 0.9	16.0 ± 1.1	10.2 ± 1.3	17.5 ± 4.6	4.4 ± 0.6
7.6–12.6	10	84.2 ± 2.1	50.0 ± 2.5	18.5 ± 2.0	30.3 ± 2.6	25.4 ± 2.0	15.1 ± 0.5	11.9 ± 0.9	16.8 ± 1.1	6.8 ± 0.8
13.0–16.0	34	86.0 ± 2.1	50.9 ± 2.8	19.5 ± 1.5	27.9 ± 1.3	25.7 ± 1.5	15.0 ± 0.8	12.4 ± 1.1	17.4 ± 1.0	7.2 ± 0.5
16.1–19.8	28	84.6 ± 1.6	49.7 ± 2.6	19.9 ± 2.1	27.9 ± 1.1	25.0 ± 1.3	14.2 ± 0.8	12.9 ± 0.7	17.1 ± 0.8	7.4 ± 0.4
20.0–25.5	26	83.3 ± 1.4	49.2 ± 1.7	19.6 ± 2.0	26.2 ± 1.6	25.8 ± 1.1	13.8 ± 1.1	13.2 ± 0.9	17.0 ± 0.9	7.8 ± 0.5
25.9–26.4	3	84.6 ± 1.6	48.7 ± 0.8	20.2 ± 2.0	26.5 ± 0.8	24.8 ± 0.7	13.7 ± 0.2	12.5 ± 0.2	15.9 ± 0.3	7.1 ± 0.5

[a] Proportion expressed as per cent head length

TABLE 2. Selected meristic values and size (mm total length) at the apparent onset of development for *Etheostoma smithi*.

Attribute/event	*Etheostoma smithi*
Dorsal fin spines/rays	VIII–X/12–15
First rays formed	7.0 mm
Adult complement formed	7.6 mm
Anal fin spines/rays	II/8–11
First rays formed	7.0 mm
Adult complement formed	7.4 mm
Pelvic fin spines/rays	I/5
First rays formed	7.6 mm
Adult complement formed	<9.0 mm
Pectoral fin rays	11–13
First rays formed	6.1 mm
Adult complement formed	7.6 mm
Caudal fin rays[a]	viii–xiii, 7–8 + 6–7, viii–xii
First rays formed	6.1 mm
Adult complement formed	9.0 mm
Lateral series—scales	42–55
Myomere/vertebrae	34–36/34–35
Preanal myomeres	15
Postanal myomeres	19–21

[a] Secondary rays expressed in roman numerals

RESULTS

Eggs

Eggs were spherical, translucent, adhesive, and averaged 2.2 mm in diameter (8). In the present study, eggs from Ferguson Creek, Livingston County, Kentucky, ranged from 1.9 mm to 2.4 mm (N = 45, $\bar{x}$ = 2.2 mm). Mature eggs of the slabrock darter were spherical, demersal, and adhesive. Eggs contained translucent yolk, a single oil globule, a narrow perivitelline space, an unsculptured chorion, and were unpigmented. Eggs were attached to the underside of slab rocks in shallow upstream pools (1, 8, 14, 15, 16).

Larvae

Morphology.—Characteristics of length and depth of slabrock darter larvae and early juveniles are presented in Table 1. The lengths at initial formation of selected structures are summarized. At 6.1 mm TL (newly hatched): well-developed pectoral fins with 9 incipient rays; yolk sac large, spherical (ca. 31.4% SL; 33.5% TL); yolk amber, with a single anterior oil globule, and distinct vitelline vein network; head not deflected over yolk sac; eyes oval. First fin rays formed pectoral and caudal simultaneously (6.1 mm). Notochord flexion, oc-

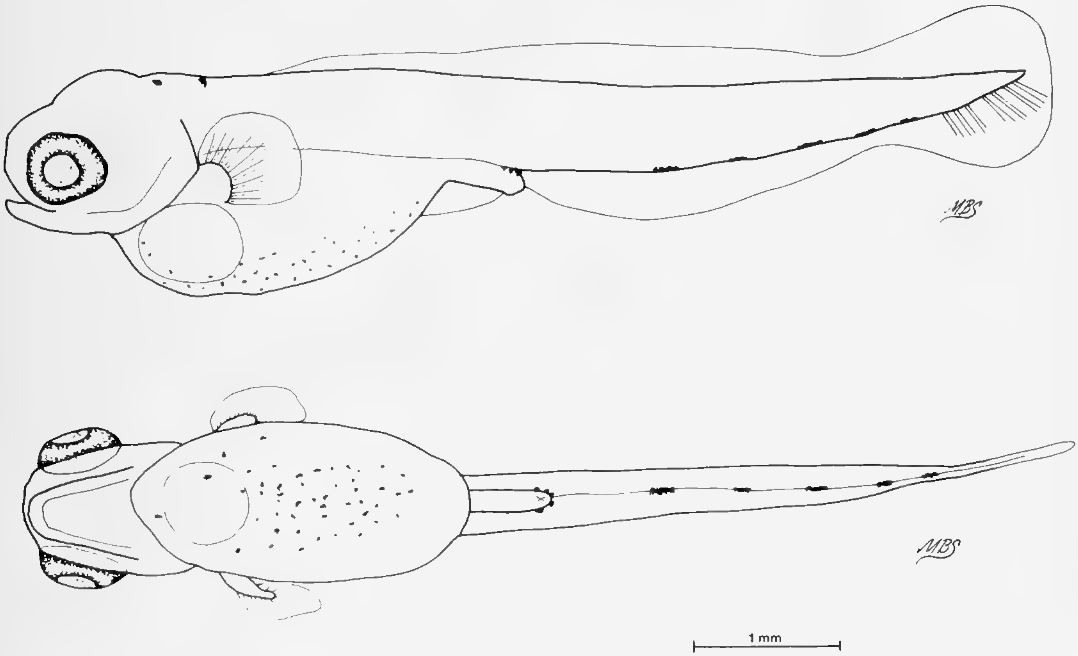


FIG. 1. *Etheostoma smithi,* slabrock darter (newly hatched larva) 6.1 mm TL, Ferguson Creek, Kentucky. a. lateral; b. ventral.

curring after first caudal fin ray formation; spinous and soft dorsal, and anal fin rays forming; incipient dorsal and anal fin margin partially differentiated; and pelvic buds formed anterior to dorsal fin origin preceding complete yolk absorption (7.0 mm). Anal fin margin completely differentiated; yolk absorbed (7.4 mm). Spinous dorsal fin origin situated over preanal myomere 4, soft dorsal origin over preanal myomere 15 (7.0–7.6 mm). Dorsal fin completely differentiated; average predorsal length 36.0% SL (range: 29.5–45.0% SL); first pelvic fin rays formed; entire finfold absorbed (7.6 mm). No swim bladder formed; gut straight; caudal fin truncate (11.6 mm). Infraorbital, and lateral head canals forming (11.9 mm). Scales present in posterior half of caudal peduncle at 12.1–13.3 mm. Supraorbital, supratemporal, and preoperculomandibular head canals formed (14.5 mm). Nape, prepectoral, cheek, opercle, and breast unscaled; belly scaled (14.7 mm). Infraorbital canal complete with 10 pores extending to mid-orbit; squamation complete (15.6 mm). Preoperculomandibular canal completely formed, pores 10 (15.8 mm). Lateral line began forming (ca. 16.8 mm). Infraorbital completely formed with retrogression to interrupted conditions of 1 pore posterior and 3 pores anterior (26.4 mm).

Meristics.—Preanal myomeres 15, postanal myomeres 19–21 (N = 11, $\bar{x}$ = 19.6), total myomeres 34–36. Total vertebrae 33–34 (N = 5, $\bar{x}$ = 33.6), including one urostylar element. Scales in lateral series 42–55 (N = 40, $\bar{x}$ = 48.1). Fin-ray counts and length at appearance are presented in Table 2.

Pigmentation.—Newly hatched larva sparsely pigmented; eyes pigmented; melanophores limited to posterior cerebellum; midventral yolk sac, anus, and postanal myomeres 5, 9, 12, 15, and 17 (6.1 mm; Fig. 1). Throat pigmentation evident extending into isthmus (7.0 mm). Cranial melanophore intensity increasing with stellate melanophores outlining optic lobe and operculum (7.4 mm); additional pigmentation at postanal myomeres 5 alternating every second or third myosepta posteriorly mid-ventrad, and at base of caudal peduncle (7.4 mm; Fig. 2a). Melanophores on nape, and beneath spinous dorsal and soft dorsal incipient finfolds (7.6 mm). Future preorbital and postorbital bars forming; breast me-

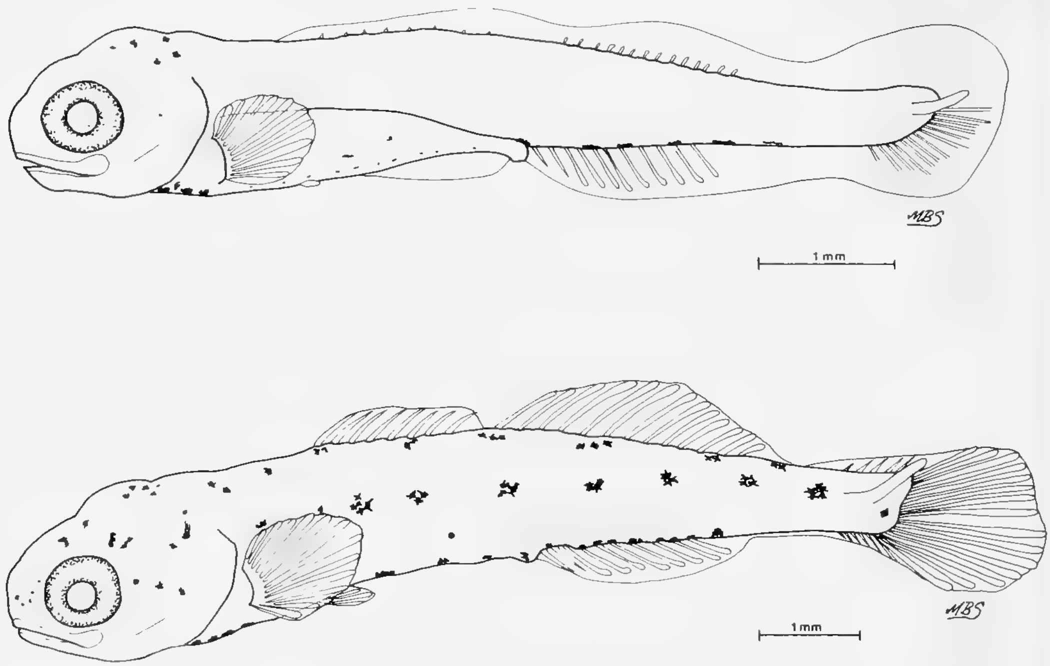


FIG. 2. *Etheostoma smithi*, slabrock darter larva, Ferguson Creek, Kentucky. a. 7.4 mm TL; b. 10.3 mm TL.

lanophores becoming subdermal; ventral pigmentation near throat and lepidotrichia of anal fin; 7 areas of dorsal melanophores and 11 lateral blotches forming (7.7–10.3 mm; Fig. 2b). Cranial pigment on snout, ventral operculum, anterior optic lobe and cerebellum; melanophores on prepectoral and base of caudal peduncle; 8 dorsal saddles formed; 11 distinct lateral blotches; 2 ventral saddles; melanophores on spinous dorsal fin forming mid-stripe; soft dorsal, anal, and caudal fin pigmentation restricted to proximal third of fins (10.5–12.0 mm; Fig. 3a). A single line of pigment extending between orbit from anterior optic lobe to mid-nares; melanophores distributed in epaxial operculum, scattered hypaxially on postanal area and entire postcaudal base; 13 elliptical to oval lateral blotches; 8 dorsal saddles; melanophores at distal end of soft dorsal and also concentrated at anterior base of soft dorsal; 3 diagonal stripes in caudal fin (12.2–14.9 mm). Juvenile pigmentation consists of a preorbital and postorbital bar, suborbital tear drop may only be weakly formed; melanophores concentrated on cerebellum, optic lobe, and ventral mandible. A series of 10–13 mid-lateral elongate, elliptical blotches, and 6 or 8 dorsal saddles; 3 or 4 mid-ventral saddles connect with mid-lateral blotches in area of caudal peduncle; spinous dorsal with scattered melanophores; soft dorsal fin with melanophores at distal end; caudal fin with 3 distinct diagonal stripes. Scattered melanophores sometimes in pectoral fins, no pigmentation in pelvic or anal fins (15.0–18.8 mm). Distinct humeral spot, and melanophores present at base of lepidotrichia interdigitation with pterigiophores of anal fin; spinous dorsal with melanophores concentrated into an anterior basal blotch at completion of interval (18.9–26.4 mm; Fig. 3b).

DISCUSSION

The habitat of *E. smithi* includes small creeks with bedrock slab pools in Ferguson Creek (8), gravel bottom pools in the Duck River, and variable habitat, usually pools with either sand, gravel, or bedrock substrate in the lower Cumberland River (3). Reproductive behavior was previously studied in Ferguson Creek, Kentucky (8). Spawning occurs from late April to mid-June (3, 8), with greatest activity during May, when water temperatures ranged from 15 to 20°C (8). Adhesive eggs are attached to the underside of slab rocks, guarded by atten-

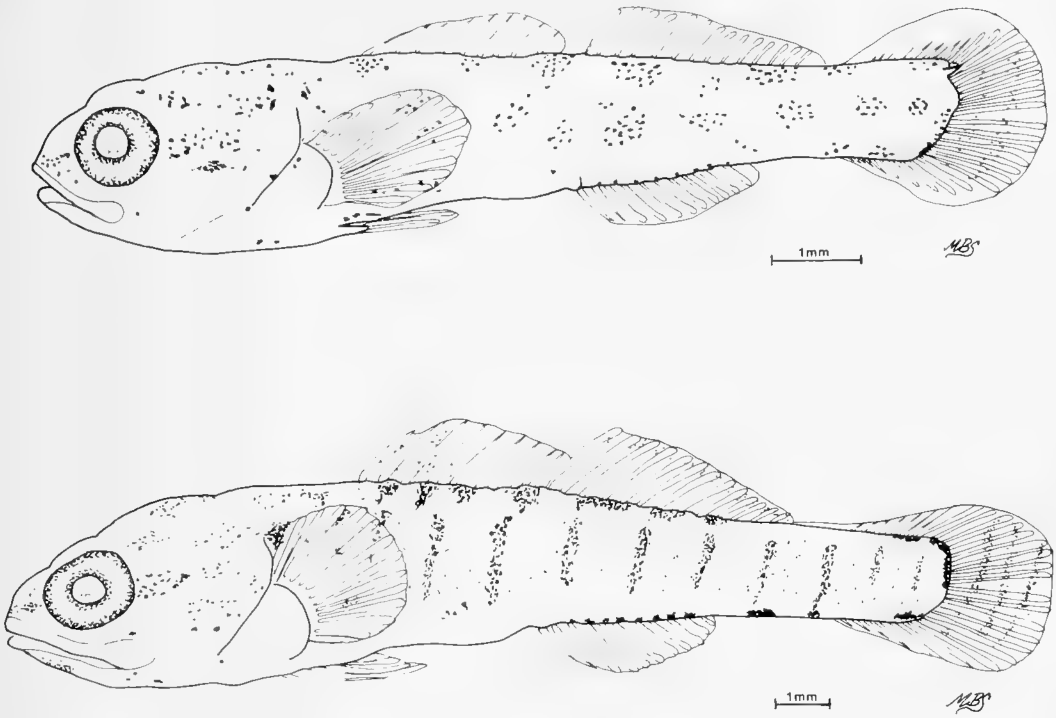


FIG. 3. *Etheostoma smithi,* slabrock darter, Ferguson Creek, Kentucky. a. 11.9 mm TL larva; b. 18.9 mm TL early juvenile.

dant male, in groups of only 1 or 2 eggs. Balon (17) classified fishes in this reproductive guild as speleophils (B.2.5), while Page (18) grouped known species of *Catonotus* as clusterers. Balon's classification is based on adult spawning behavior, site of egg placement, and larval respiratory structures. Page based his classification on adult egg spawning site selection. Eggs incubated at 13°C hatched in 29.5–30.5 days, while eggs at 21°C hatched in 12.5–13.5 days (8). Larval and early juvenile food sources included chironomids and ephemeropterans, copepods, trichopterans, cladocerans, ostracods, and amphipods (8). Larvae are demersal, usually remaining in close association with the substrate. Page and Burr (8) found age-0 *E. smithi* to occupy slab pools; however, many still were found in non-slab pools and slab riffles.

Etheostoma smithi is sympatric with *E. kennicotti* and *E. squamiceps* throughout its range (15). Previous descriptions of larval and early juvenile *E. kennicotti* and *E. squamiceps* were available from Illinois tributaries of the Ohio River (6, 7). The separation of larval *E. smithi* from other sympatric *Catonotus* was facilitated since it possesses 15 preanal myomeres, while *E. kennicotti* and *E. squamiceps* have 16 preanal myomeres. Postanal myomere counts in *E. smithi* were also higher ranging from 19 to 21 while *E. kennicotti* and *E. squamiceps* range between 18 and 19. Newly hatched *E. smithi* were more sparsely pigmented with melanophores limited to the mid-ventral yolk sac and mid-ventral postanal myosepta. Larvae of *E. kennicotti* can be differentiated by the more spherical, larger yolk sac and smaller head length/TL from *E. squamiceps*. *Etheostoma squamiceps* has melanophores distributed postanally, while *E. kennicotti* has melanophores limited primarily to the yolk sac (7).

Larval characteristics of the subgenus *Catonotus,* previously diagnosed by Simon (6, 7), were shared by *E. smithi*. Larvae possessed large, spherical yolk sacs (yolk sac length/SL = 0.32–0.42); well-developed pectoral fins; precocious fin-ray development; and yolk sac absorption after initial fin-ray development. *Catonotus* larvae also have either 15 or 16 preanal myomeres; a complex vitelline vein network on the ventral yolk sac; and a complete supraorbital canal retrogressing to adult interrupted conditions during juvenile development.

Acknowledgments

Special thanks to Lawrence M. Page, Illinois Natural History Survey, for providing specimens and for his encouragement and professional guidance in my studies of the tribe Etheostomatini. I would also like to thank my wife Beth Simon for preparation of all figures and for her support and encouragement. Manuscript format has been clarified through discussions with Lee A. Fuiman, Dunstaffnage Marine Research Laboratory, Oban, Scotland; and Daniel J. Faber, National Museum of Canada. Collection designation refers to the Illinois Natural History Survey (INHS) and Large Rivers Research Collection (LRRC), respectively.

Literature Cited

1. Page, L. M. and M. E. Braasch. 1976. Systematic studies of darters of the subgenus *Catonotus* (Percidae), with the description of a new species from the lower Cumberland and Tennessee River systems. Occas. Pap. Mus. Nat. Hist. Univ. Kansas 60:1–18.

2. Page, L. M. 1980. *Etheostoma smithi* Page and Braasch, slabrock darter. P. 694. In D. S. Lee et al. (eds.) Atlas of North American freshwater fishes. North Carolina State Mus. Nat. Hist., Raleigh.

3. Braasch, M. E. and R. L. Mayden. 1985. Review of the subgenus *Catonotus* (Percidae) with descriptions of two new darters of the *Etheostoma squamiceps* group. Occas. Pap. Mus. Nat. Hist. Univ. Kansas 119:1–83.

4. Cooper, J. E. 1979. Descriptions of eggs and larvae of fantail (*Etheostoma flabellare*) and rainbow (*E. caeruleum*) darters from Lake Erie tributaries. Trans. Am. Fish. Soc. 108:46–56.

5. Auer, N. A. 1982. Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. Great Lakes Fishery Commission, Ann Arbor, Michigan 48105. Special Pub. 82–83:1–744.

6. Simon, T. P. 1985. Descriptions of larval Percidae inhabiting the Upper Mississippi River basin (Osteichthyes: Etheostomatini). M.S. Thesis. Univ. Wisconsin-La-Crosse. 117 pp.

7. Simon, T. P. 1987. Descriptions of eggs, larvae, and early juveniles of the stripetail darter, *Etheostoma kennicotti* (Putnam) and spottail darter, *E. squamiceps* Jordan (Percidae: Etheostomatini) from tributaries of the Ohio River. Copeia 1987:433–442.

8. Page, L. M. and B. M. Burr. 1976. The life history of the slabrock darter, *Etheostoma smithi*, in Ferguson Creek, Kentucky. Illinois Nat. Hist. Surv. Biol. Notes 99: 1–12.

9. Strawn, K. 1956. A method of breeding and raising three Texas darters. Part II. Aquarium Journal 27:11, 13–14, 17, 32.

10. Hubbs, C. L. and K. F. Lagler. 1958. Fishes of the Great Lakes region. The Univ. Michigan Press, Ann Arbor.

11. Hubbs, C. L. and M. D. Cannon. 1935. The darters of the genera *Hololepis* and *Villora*. Misc. Publ. Mus. Zool. Univ. Michigan 30:1–93.

12. Fritzsche, R. A. and G. D. Johnson. 1979. Striped bass vs. white perch; application of a new morphological approach to ichthyoplankton taxonomy. Pp. 19–29. In R. Wallus and C. W. Voightlander (eds.) Proc. Workshop Freshwater Larval Fish. Tennessee Vall. Author., Norris.

13. Faber, D. J. and S. Gadd. 1983. Several drawing techniques to illustrate larval fishes. Trans. Am. Fish. Soc. 112:349–353.

14. Page, L. M. and D. W. Schemske. 1978. The effect of interspecific competition on the distribution and size of darters of the subgenus *Catonotus* (Percidae: *Etheostoma*). Copeia 1978:406–412.

15. Page, L. M. 1983. Handbook of darters. T.F.H. Publications, Neptune, New Jersey.

16. Kuehne, R. A. and R. W. Barbour. 1983. The American darters. The Univ. Press of Kentucky, Lexington.

17. Balon, E. K. 1975. Reproductive guilds of fishes: a proposal and definition. J. Fish. Res. Board Can. 32:821–864.

18. Page, L. M. 1985. Evolution of reproductive behaviors in percid fishes. Illinois Nat. Hist. Surv. Bull. 33: 275–295.

Trans. Ky. Acad. Sci., 49(1–2), 1988, 21–25

Fishes of Murphy's Pond, a Cypress Swamp in Western Kentucky

Tom J. Timmons
Hancock Biological Station, Department of Biological Sciences,
Murray State University, Murray, Kentucky 42071

Abstract

Twenty-seven species of fishes were collected from Murphy's Pond from 1984 to 1986. Seven additional species have been reported from previous collections. The Kentucky distribution of 4 (*Esox niger, Fundulus dispar, Lepomis marginatus, L. symmetricus*) is restricted to extreme western Kentucky, and 1 (*Ictalurus nebulosus*) is poorly represented in state collections. Three species from Murphy's Pond have been listed as threatened (*Erimyzon sucetta*) or endangered in Kentucky (*Fundulus dispar, Lepomis marginatus*). The greatest percentage of fish biomass in Murphy's Pond consisted of predators such as *Amia calva, Esox niger, Micropterus salmoides,* and catfishes (*Ictalurus melas, I. natalis, I. nebulosus*). *Amia calva* stomachs contained mostly crayfish, but also fish and amphibians, while those of *Esox niger* and *Micropterus salmoides* contained only fishes.

Introduction

Murphy's Pond is a natural cypress swamp in western Kentucky that may have a species composition of fishes similar to that which it had when it was formed. Cypress swamps, like other wetlands, have disappeared in many areas in the past century. Despite their value as wildlife habitat and ability to retain flood waters and thus prevent downstream flooding, they have been drained and cleared for farmland. Even wetland areas designated as nature preserves, such as Murphy's Pond, may be threatened by lowered water tables caused by channelization projects outside the preserve.

The objectives of this study were to determine the species of fishes present in Murphy's Pond and their relative abundance. This is the first intensive survey of the fishes of Murphy's Pond. Past fish collections were made in Murphy's Pond by Smith (1) as part of his survey of Obion Creek, and fishes were collected in 1980 by the Kentucky Department of Fish and Wildlife Resources with the fish toxicant rotenone (2). Two recent additions to the fish fauna of Kentucky were first found in Murphy's Pond: *Fundulus dispar*, formerly considered a subspecies of *F. notti* (3), and *Lepomis marginatus* (4).

Study Area

Murphy's Pond is located adjacent to Obion Creek near the northeast corner of Hickman County in western Kentucky (Fig. 1). The pond and surrounding land was deeded to Murray State University by the Nature Conservancy in 1975. A large area south and southwest of Murphy's Pond along Obion Creek is also swamp and was sampled during this study. Fish were collected in the adjacent beaver pond and Obion Creek since during floods they may be a source of fishes for Murphy's Pond. Stream fishes may not stay or survive long in Murphy's Pond, but their presence in adjacent waters explains their occasional presence. The area sampled most frequently outside of Murphy's Pond is referred to as the beaver pond, since beavers are active in the swamp and maintain a long dam. The beaver pond floods the region of the old Obion Creek channel. The beaver pond has a firm bottom that allows wading and seining, whereas Murphy's Pond has a soft bottom that prevents effective seining. The channelized section of Obion Creek west and southwest of Murphy's Pond was occasionally sampled. The channelized section is shallow (<1 m and often <0.3 m), narrow (4–5 m wide), with no riffles, few pools, and has a sand substrate.

Methods

Fishes were collected from June 1984 to August 1986 using gill nets, seines, hoop nets, trotlines, and with the fish toxicant rotenone. Experimental gill nets with many different mesh sizes were used to sample as wide a variety of species and sizes as possible. Rotenone was used in 2 small areas (<0.01 hectare) of shallow water. Rotenone was difficult to use

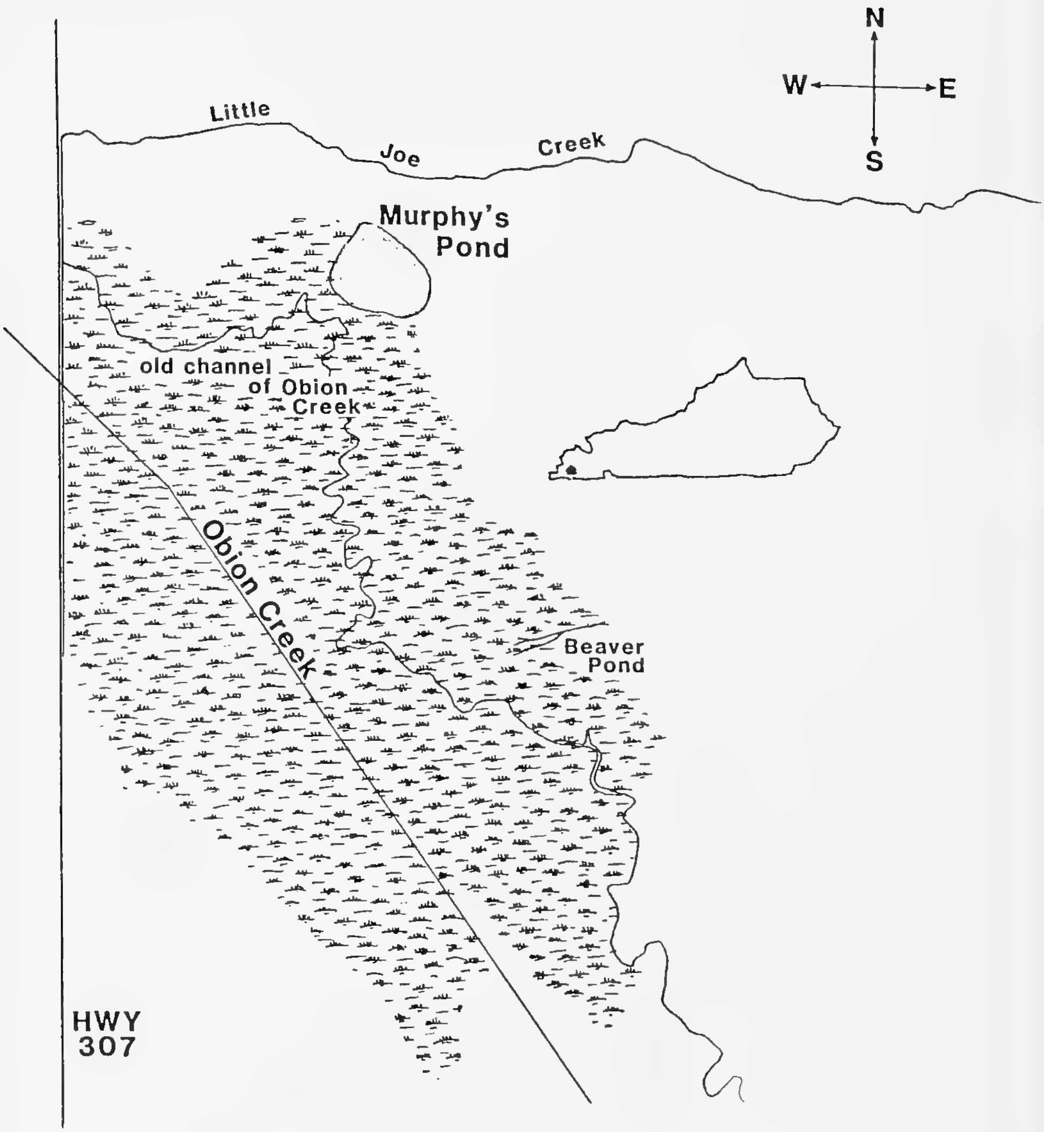


FIG. 1. Map of Murphy's Pond and surrounding drainage.

effectively because there were no areas where a block net could be placed to keep fish within the sampled area. Only small samples were desired from the pond in order to minimize the impact on the ecosystem. Hoop nets and trotlines were occasionally fished. Stomachs from piscivorous fishes were examined to detect prey species that were missed in other collections. Fishes were collected in Obion Creek by seining and in the beaver pond with the same methods described for Murphy's Pond. Fishes from all 3 areas were preserved and placed in the Murray State University Ichthyological Collection at the Hancock Biological Station. Dissolved oxygen was measured monthly by Dr. C. D. Wilder, Director of Research in Murphy's Pond.

RESULTS AND DISCUSSION

The fish species composition of Murphy's Pond appeared to be typical of cypress swamps as described by Pflieger (5) for fishes in the

Lowland faunal region of the Mississippi River drainage. Twenty-seven species of fishes were collected in Murphy's Pond from 1984 to 1986 (Table 1). Seven additional species have been reported from previous collections (1, 2, 3). Four of the species (*Esox niger, Fundulus dispar, Lepomis marginatus,* and *Lepomis symmetricus*) are restricted to extreme western Kentucky, and one (*Ictalurus nebulosus*) is poorly represented in collections in Kentucky (5). The most common fishes in Murphy's Pond were: *Amia calva, Esox americanus, E. niger, Notemigonus crysoleucas, Ictalurus melas, Aphredoderus sayanus, Fundulus olivaceus, Gambusia affinis, Centrarchus macropterus, Elassoma zonatum, Lepomis gulosus, L. macrochirus,* and *L. symmetricus*. The above list is not in order of relative abundance. Species diversity was lower than in a river drainage system because the pond is small, and the diversity of habitats is low. Murphy's Pond was difficult to sample because the bottom in the shallow areas was extremely soft and made wading difficult and seining ineffective. The abundance of vegetation, including cypress trees and roots, provided cover for fishes when seining was attempted, and only allowed short seine hauls that were easily avoided by the fish. Gill nets and traps could be set in a few large, open pools, but much of the swamp was too thickly vegetated to set nets. Some pools filled with filamentous algae or macrophytes that impeded sampling during the summer.

The greatest percentage of biomass of fishes in Murphy's Pond was of predators such as *Amia calva, Esox niger, Micropterus salmoides,* and catfishes (*Ictalurus melas, I. natalis, I. nebulosus*). Stomachs from 15 *Amia calva*, which ranged in length and weight from 36 cm (0.4 kg) total length to 74 cm (3.6 kg), were examined for food items. Seventy-five per cent of the stomachs with food had crayfish, 2 fish had *Siren* sp., and 3 had fish (*Centrarchus macropterus* and *Ictalurus* sp.) Stomachs from 16 *Esox niger*, from 26 cm (0.2 kg) to 53 cm (1.2 kg), were examined. One-half the stomachs were empty, and the remainder had fishes (*Erimyzon* sp., *Aphredoderus sayanus, Lepomis* sp., *L. gulosus,* and *Pomoxis* sp.). Five examined largemouth bass stomachs contained crayfish, *Aphredoderus sayanus, L. macrochirus,* and *L. symmetricus*.

Many species of fishes were less common than those listed above, but are probably permanent residents of Murphy's Pond. These include: *Lepisosteus oculatus, Cyprinus carpio, Erimyzon sucetta, Ictalurus natalis, I. nebulosus, Noturus gyrinus, Lepomis marginatus, Micropterus salmoides, Pomoxis annularis, P. nigromaculatus,* and *Etheostoma gracile*. A few species were represented by the collection of a single fish in Murphy's Pond: *Ictiobus cyprinellus, Minytrema melanops,* and *Lepomis cyanellus*.

TABLE 1. Occurrence of fish species at Murphy's pond and adjacent areas.

Species	Murphy's Pond	Beaver pond	Obion Creek by Murphy's Pond
Amia calva	X	X	
Lepisosteus oculatus	X	X	
Dorosoma cepedianum	A		
Esox americanus	X	X	X
Esox niger	X	X	
Ctenopharyngodon idella	A		
Cyprinus carpio	X	X	
Notemigonus crysoleucas	X	X	
Notropis lutrensis	A		X
Pimephales vigilax			X
Semotilus atromaculatus			X
Erimyzon oblongus	A		
Erimyzon sucetta	X	X	
Ictiobus cyprinellus	X	X	
Ictiobus niger	A		
Minytrema melanops	X		
Ictalurus melas	X		
Ictalurus natalis	X	X	X
Ictalurus nebulosus	X		
Noturus gyrinus	X	X	
Aphredoderus sayanus	X	X	
Fundulus dispar	C		
Fundulus olivaceus	X	X	X
Gambusia affinis	X	X	X
Centrarchus macropterus	X	X	
Elassoma zonatum	X	X	
Lepomis cyanellus	X	X	X
Lepomis gulosus	X	X	
Lepomis humilis	B		
Lepomis macrochirus	X	X	X
Lepomis marginatus	X	X	
Lepomis megalotis	A		X
Lepomis symmetricus	X	X	
Micropterus punctulatus	A		
Micropterus salmoides	X	X	X
Pomoxis annularis	X		
Pomoxis nigromaculatus	X	X	
Etheostoma gracile	X	X	X

A = collected with the fish toxicant rotenone by the Kentucky Department of Fish and Wildlife Resources in 1980 (2)
B = Smith (1)
C = Branson (3)

By late summer, some areas of Murphy's Pond had a dense covering of floating algae and oxygen was low (C. D. Wilder, pers. comm.). In August, *Cyprinus carpio* collected in nets were in extremely poor condition with frayed fins. Poor water quality may limit the suitability of Murphy's Pond as habitat for some species abundant in Obion Creek.

Several species collected from Murphy's Pond by earlier investigators were not found in this study. *Fundulus dispar* was collected in 1972 in a channel draining into Murphy's Pond (3), but has not been collected again in Kentucky except near Reelfoot Lake (6). Smith (1) collected *Dorosoma cepedianum* and *Lepomis humilis* in Murphy's Pond in 1968. McLemore (2) collected the grass carp (*Ctenopharyngodon idella*), *Notropis lutrensis*, *Ictiobus niger*, and *Micropterus punctulatus* in 1980. The grass carp has been widely introduced in the southeastern United States to eliminate aquatic plants in farm ponds. *Notropis lutrensis* and *Micropterus punctulatus* probably gained access from Obion Creek during high water and are not permanent residents of Murphy's Pond. McLemore also reported *Erimyzon oblongus* and *Lepomis megalotis*. *Erimyzon oblongus* may have been based on misidentified *E. sucetta*. I found *E. sucetta* in Murphy's Pond. The *Lepomis megalotis* were either strays from Obion Creek, where they are common, or they were *L. marginatus*, which is sometimes confused with *L. megalotis*.

The species composition of the beaver pond was basically similar to that in Murphy's Pond (Table 1). However, 4 species (*Minytrema melanops, Ictalurus melas, I. nebulosus, Pomoxis annularis*) were absent in collections from the beaver pond, but continued sampling probably would have yielded these species. None of the species taken by earlier collectors (absent in my collections from Murphy's Pond) were present in the beaver pond. Fishes listed as the most common in Murphy's Pond were also representative of the most common species in the beaver pond.

Fishes collected in Obion Creek adjacent to Murphy's Pond and the beaver pond are listed in Table 1. Most species were common to abundant in collections except for *Micropterus salmoides* and *Etheostoma gracile*. The most abundant species was *Notropis lutrensis*.

Three species from Murphy's Pond have been listed as threatened or endangered species (7). Warren et al. (7) consider *Fundulus dispar* and *Lepomis marginatus* as endangered; *Erimyzon sucetta* as threatened. *Fundulus dispar* was absent in my collections and has not been collected anywhere in Kentucky except Reelfoot Lake and one collection in Murphy's Pond in 1972. *Lepomis marginatus* and *Erimyzon sucetta* were common in the beaver pond, but difficult to collect in Murphy's Pond because seining was ineffective. Branson et al. (8) in 1981 considered *Lepisosteus oculatus* and *Lepomis marginatus* as threatened species; *Fundulus dispar, Elassoma zonatum*, and *Lepomis symmetricus* as species of special concern; and *Erimyzon sucetta* as undetermined. After a period of more thorough fish collecting in Kentucky, *Lepisosteus oculatus, Elassoma zonatum*, and *Lepomis symmetricus* were delisted by Warren et al. (7). *Elassoma zonatum* and *Lepomis symmetricus* were abundant in the beaver pond and Murphy's Pond. Three *Lepisosteus oculatus* were collected in the beaver pond and Murphy's Pond.

Murphy's Pond is managed by Murray State University and the fish fauna receives little direct disturbance or perturbation. The greatest probable dangers to Murphy's Pond are siltation and further channelization of Obion Creek. If Obion Creek is channelized deeper, the lower water table could lower significantly the level of Murphy's Pond. Much of the pond is already shallow and a lowered water level would greatly reduce the surface area.

Acknowledgments

Funding for this study was provided by the Department of Biological Sciences and the Murray State University Committee on Institutional Studies and Research. Laboratory space was provided at the Hancock Biological Station.

Literature Cited

1. Smith, P. L. 1968. A survey of the fishes of the Obion Creek drainage system in West Kentucky. M.S. Thesis. Murray State University, Murray, Kentucky. 19 pp.

2. McLemore, W. 1980. Murphy's Pond population study. Kentucky Department of Fish and Wildlife Resources. Unpublished report.

3. Branson, B. A. 1972. *Fundulus notti* in Kentucky. Trans. Kentucky Acad. Sci. 32:76.

4. Burr, B. M. and R. L. Mayden. 1979. Records of fishes in western Kentucky with additions to the known fauna. Trans. Kentucky Acad. Sci. 40:58–67.

5. Pflieger, W. L. 1975. The fishes of Missouri. Missouri Dept. Conservation.

6. Burr, B. M. and M. L. Warren, Jr. 1986. A distributional atlas of Kentucky fishes. Kentucky Nature Preserves Comm. Sci. and Tech. Series No. 4:1–398.

7. 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 in Kentucky. Trans. Kentucky Acad. Sci. 47:83–98.

8. Branson, B. A., D. F. Harker, Jr., J. M. Baskin, M. E. Medley, D. L. Batch, M. L. Warren, Jr., W. H. Davis, W. C. Houtcopper, B. Monroe, Jr., L. R. Phillippe, and P. Cupp. 1981. Endangered, threatened, and rare animals and plants of Kentucky. Trans. Kentucky Acad. Sci. 42: 77–89.

Trans. Ky. Acad. Sci., 49(1–2), 1988, 26–28

Intersampler Variability and Scouting for Larvae of the Alfalfa Weevil (Coleoptera: Curculionidae)

ROBERT J. BARNEY AND DAVID E. LEGG
Community Research Service, Kentucky State University, Frankfort, Kentucky 40601

AND

CHRISTIAN M. CHRISTENSEN
Department of Entomology, University of Kentucky, Lexington, Kentucky 40546

ABSTRACT

Comparisons were made among 8 samplers belonging to 4 experience groups to determine if shake-bucket estimates of larvae of the alfalfa weevil, *Hypera postica* (Gyllenhal), were influenced by intersampler variation. Although no significant difference was found in alfalfa stem lengths selected by the groups, inexperienced samplers selected stems with greater numbers of larvae. Overestimation of pest-population densities could result in management decision errors.

INTRODUCTION

After the realization in the 1950s that sole reliance on insecticides was not a viable insect-control strategy because of many unanticipated problems, e.g., insect resistance, outbreaks of secondary pests, and pesticide residues, a push was made in the late 1960s for insect control via integrated pest management (IPM) (1). The development of sampling plans which provide accurate estimates of pest-population densities is a crucial step in the development of a successful IPM program. Although considerable research has been directed toward the construction of management-decision models, little attention has been focused on the problem of intersampler variability, which may lead to imprecise density estimates and decision errors.

An IPM program developed for the alfalfa weevil (AW), *Hypera postica* (Gyllenhal), is based upon the number of AW larvae per alfalfa stem found in samples taken by the shake-bucket technique (2). This technique consists of a sampler randomly selecting and removing stems while walking through the field and placing them in a plastic bucket. When the appropriate number of stems have been collected, they are shaken vigorously against the inside of the bucket and the dislodged larvae are counted. Although this technique is used primarily by inexperienced scouts to make management decisions as part of the alfalfa IPM program of many states, including Kentucky, little attention has been focused on the influence of intersampler variability on AW population density estimates.

The objective of this study was to determine if intersampler variability existed in AW population estimates based on shake-bucket samples taken by samplers with varying levels of AW sampling experience.

MATERIALS AND METHODS

Sampling was conducted on 13 May 1987 at a degree-day accumulation since 1 January 1987 of 620 (base 48°F [8.9°C]). A 6-yr-old, 8-ha field of 'Arc' alfalfa was chosen for the experiment. The field was located in Anderson County, Kentucky, and had never been sprayed with an insecticide.

Intersampler comparisons were made among 8 samplers belonging to 4 experience groups: 2 alfalfa growers with no scouting experience, 2 county extension agents with ca. 15 hours of in-field AW scouting experience, 1 recent graduate with a Ph.D. in entomology but no AW experience, and 3 professional entomologists with extensive (4–12 yr) scouting experience. Prior to sampling each grower completed a questionnaire to document their experience scouting for AW larvae in alfalfa.

Each sampler was given 5 large paper bags and instructed to walk through the field and randomly select a 6-stem sample from 5 different 100-m^2 areas. The correct method of randomly selecting and picking a stem was

TABLE 1. Intersampler comparison of the number of larvae per 6-stem sample selected in the same field by groups with different levels of experience scouting for alfalfa weevil larvae, Anderson County, Kentucky, 1987.[a]

Experience	Samplers	Samples	$\bar{x} \pm$ SE
Professionals	3	15	6.9 ± 1.4a
County agents	2	10	6.0 ± 1.4a
Alfalfa growers	2	10	12.1 ± 2.0b
Recent graduate	1	5	19.4 ± 3.2c

[a] Experience group means followed by the same letter are not significantly different, planned nonorthogonal comparisons ($F = 6.06$; df = 7, 32; $P < 0.0001$)

TABLE 3. Intersampler comparison of ability to identify and count alfalfa weevil larvae in buckets by individuals with different levels of experience scouting for alfalfa weevil larvae to a professional (R.J.B.), Anderson County, Kentucky, 1987.

Comparison	t	df	*P*
R.J.B. × County agent #1	0.28	5	0.7926
× Professional #1	−0.42	5	0.6952
× Graduate	0.54	5	0.6109
× Alfalfa grower #1	1.19	5	0.2892
× County agent #2	1.32	5	0.2431
× Alfalfa grower #2	1.35	5	0.2354
× Professional #2	1.75	5	0.1398

demonstrated before the experiment began. The bags were labelled by sampler, stapled, and returned to the laboratory for processing. This experiment was designed to evaluate intersampler variation in the stem picking process. The number of AW per 6-stem sample was determined and the length of 10 stems per sampler was measured.

The second part of the experiment was designed to evaluate each sampler's ability to recognize and count AW larvae in buckets after a 6-stem sample had been taken. Six 6-stem samples were taken by one professional (R.J.B.) and the samples placed in numbered buckets. All samplers were shown how to identify AW larvae and distinguish them from spittlebug nymphs which were also very abundant at this time. Each sampler was then provided with a numbered score sheet and asked to examine each bucket independently and record their estimates of weevil numbers.

The data from the pick-and-stem comparisons were analyzed by one-way analysis of variance and the experience groupings were compared with planned nonorthogonal comparisons. The data from the count test were analyzed by comparing each sampler to a designated professional (R.J.B.) with a paired t-test.

TABLE 2. Intersampler comparison of alfalfa stem lengths selected in the same field by groups with different levels of experience scouting for alfalfa weevil larvae, Anderson County, Kentucky, 1987.

Experience	Samplers	Samples	$\bar{x} \pm$ SE
Professionals	3	30	23.5 ± 0.6
County agents	2	20	24.2 ± 0.6
Alfalfa growers	2	20	23.4 ± 0.8
Recent graduate	1	10	22.7 ± 1.0

RESULTS AND DISCUSSION

The analysis of the stem picking data was highly significant ($F = 6.06$; df = 7, 32; $P < 0.0001$) indicating that intersampler variation existed in the number of larvae resulting from stem selection. Planned nonorthogonal comparisons between experience group means showed that as the level of scouting experience increased the number of larvae per sample decreased (Table 1). Shufran (3) found that an inexperienced scout reported ca. twice as many AW larvae from shake-bucket samples as an experienced graduate student. This may indicate that inexperienced samplers tend to select stems with more apparent feeding damage even though they were instructed to select stems randomly.

The intersampler variation found in the picking test was not caused by a nonrandom selection of stems based on stem length. There was no significant difference ($F = 1.61$; df = 7, 72; $P = 0.1444$) in stem length measurements between samplers (Table 2). Shufran (3) also found no significant difference in stem lengths collected by 2 scouts.

The results of the larval counting test showed that none of the samplers, regardless of their level of scouting experience, identified and counted AW larvae in buckets at a significantly different rate than the professional (Table 3). However, it must be pointed out that the average number of larvae per bucket was less than 4 and that the larvae were mostly large fourth instars. A comparison of counts made earlier in the season when a greater number of larvae are smaller may reveal greater differences in count numbers between experience groups. Also, we believe that the 'testing' atmosphere of this experiment would tend to make the samplers take more time and be more conscientious in their counting than a scout would be in an unsupervised situation.

Assuming that the AW-density estimates made by the professionals and county agents were correct, the inexperienced samplers overestimated the pest population density by a factor of 2–3 times (Table 1). Significant overestimations such as these can cause incorrect management decisions which result in unnecessary applications of insecticides (4). This study illustrates the importance of intersampler variation and the need for uniformity in sampling techniques.

ACKNOWLEDGMENT

This investigation was supported in part by a USDA/CSRS grant to Kentucky State University under Agreement KYX-10-85-04P.

LITERATURE CITED

1. Metcalf, R. L. and W. L. Luckmann. 1975. Introduction to insect pest management. Wiley, New York.

2. Wedberg, J. L., W. G. Ruesink, E. J. Armbrust, and D. P. Bartell. 1977. Alfalfa weevil pest management program. Illinois Coop. Ext. Serv. Circ. 1136.

3. Shufran, K. A. 1986. The accuracy of integrated pest management scouting observations and factors affecting the performance of scouts employed in Kentucky. M.S. Thesis. University of Kentucky, Lexington.

4. Barney, R. J. and D. E. Legg. 1987. Accuracy of a single 30-stem sample for detecting alfalfa weevil larvae (Coleoptera: Curculionidae) and making management decisions. J. Econ. Entomol. 80:512–516.

Trans. Ky. Acad. Sci., 49(1-2), 1988, 29-31

Response of *Xanthium strumarium* L. to Simulated Acid Rain

JOE E. WINSTEAD AND LISA SIMPSON STRANGE[1]

Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

ABSTRACT

Foliage of the common cocklebur treated with simulated precipitation of pH 4.5, 3.5 and 2.5 compared with controls subject to artificial rain of pH 5.6 showed a reduction of dry-weight biomass between 21.8 and 27.5%. While no indication of reduced caloric content was found, significant declines in total chlorophyll levels were detected in plants treated with regulated artificial rain of pH 3.5 and 2.5 under controlled laboratory conditions.

INTRODUCTION

Acid-rain formation from atmospheric pollutants, primarily particulate sulfates and nitrates, has been shown to have a significant role in decline of productivity in numerous types of regional flora (1, 2). The relationship between specific compounds (SO_x, NO_x) released due to anthropogenic activities and acid rain has been continually under debate (3) but it is evident that the phenomenon is not unique to the western hemisphere (4) and patterns of decreasing pH in the eastern United States have been well documented (5, 6). Notable studies on ecosystem response to acid rain have been done by Schofield (7), Tamm (8) and Knabe (9). Many species of plants, including *Betula alleghaniensis* Britt., *Populus* spp., *Phaseolus vulgaris* L., and *Helianthus annuus* L., have been subjected to acid-rain tests (10, 11, 12) since the potential for vegetation damage by acidic deposition (both wet and dry) was recognized in the late 1960s.

This study was designed to provide baseline data on the effect of acid rain on a geographically widespread weedy species common to a variety of habitats. *Xanthium strumarium* L. (cocklebur) is a species that exploits disturbed habitats. A population from east central Texas was chosen to provide genomes that have had little exposure to acid rain conditions in recent years. Previous work (13) in our laboratory has shown that this species is a good laboratory tool particularly in regard to studies of chlorophyll levels.

[1] Permanent home address: 117 Pine Village, Bardstown, Kentucky 40004.

MATERIALS AND METHODS

Fruits of cocklebur were collected in December from Fannin County, Texas and germinated under constant light and alternating temperatures of 29–18°C (12 hr each temp.). Seedlings were transplanted to 10- × 10- × 9-cm plastic pots using a 3:1 peat perlite mixture and placed in growth chambers under the temperature regime mentioned above. Three different experiments were conducted using 2 different photoperiods: 16-hr light and 8-hr dark and 12-hr light and 12-hr dark period. Growth-chamber light intensity during the light periods was maintained at ca. 11,000 lux. The 12-hr temperature of 29°C in each 24-hr cycle was set to match or fit evenly within the light period of each experiment. Since this species is known to induce flowering under long dark periods, it was decided to expose plants under the longer dark cycles of 12 hr to the lower pH of 2.5 to determine if earlier stimulation of the flowering cycle would alter any response in chlorophyll and biomass development to the acidic treatment.

The 3 different experiments involved spraying the foliage of 12 to 15 plants with solutions of pH values of 2.5, 3.5 and 4.5 using a mechanical mister. The control of each experiment was of simulated rain of pH 5.6. Simulated rain solutions were prepared by standard titration with 18 M sulfuric acid to desired pH levels utilizing a Corning Model 21 pH meter. The misting applications were applied on an average of every third day providing total simulated rainfall of between 123 and 175 mm but within each specific experiment all test and control plants received the same misting exposure within the limits of timing the misting applications. The total applications were de-

TABLE 1. Effect of acid-rain applications on biomass of *Xanthium strumarium*.

Acid rain application (pH)	No. of applications	Growth chamber conditions	Duration of growth period[1]	No. of plants	Avg. g fresh wt
Control of 5.6	10	16/8 light/dark	37 days	15	14.42
Test of 4.5	10	16/8 light/dark	37 days	15	10.44**
Control of 5.6	9	16/8 light/dark	33 days	15	8.70
Test of 3.5	9	16/8 light/dark	33 days	15	6.51**
Control of 5.6	9	12/12 light/dark	29 days	15	11.18
Test of 2.5	9	12/12 light/dark	29 days	12	8.74**

[1] Growth periods were staggered between tests due to different planting times
** Difference between control and test significant at 0.1 level

signed to correspond closely with anticipated natural rainfall in Warren County, Kentucky during the months of June, July and August (range 4.88–6.88 inches). Hoagland's solution was applied in equal amounts (ca. 50 ml) at regular intervals to each plant during the course of the growing period.

To insure consistency in measuring chlorophylls and to avoid possible chlorophyll deterioration from floral induction (and subsequent flower development) in the group of plants grown under the longer dark cycle of 12 hr, all 3 experiments were terminated at the same time. Previous experience in our laboratory had determined that actual floral bud development would be initiated in the Texas population after 30 days of the 12-hr dark cycle. All plants were cropped at the cotyledon level for biomass measurements (g fresh wt.). Chlorophyll determinations used 5-g composite samples (in triplicate) from 3 plants in each test and control. Chlorophyll extraction, analysis and calculations followed that outlined by Abdulrahman and Winstead (13).

Six plants from the control set and group treated with simulated acid rain of pH 3.5 were analyzed for caloric content at the end of the growth and test period. The leaves of each of the plants after being air dried were ground in a Wiley Mill and 1 g samples combusted in a Parr bomb calorimeter to determine energy levels.

RESULTS

Pronounced effects on both biomass and chlorophyll levels were found in plants exposed to simulated acid rain applications. Plants exposed to simulated acid rains of pH 4.5, 3.5 and 2.5 had weight reductions of 27.6%, 25.2% and 21.8%, respectively, when compared to controls. Statistical analysis (Student's t-test) showed all the reductions highly significant at the 0.1 level.

Chlorophyll determinations from representative plants of the experiments outlined in Table 1 showed similar patterns of chlorophyll reductions (Table 2). The pH treatments resulted in reduction of chlorophyll in all 3 experiments with statistically significant (at or near the 0.05 level) differences in plants treated with simulated rainfall of pH 2.5 and 3.5. Percentage decreases of chlorophylls under the treatments of pH 4.5, 3.5 and 2.5 were 7.3, 8.7 and 8.7, respectively. The longer dark period of 12 hr did not seem to alter chlorophyll levels.

TABLE 2. Effect of acid-rain treatments on chlorophyll levels of *Xanthium strumarium*.

Values in mg/g dry wt		
Experiment 1 (10 applications of simulated rain of pH 4.5 and control of pH 5.6)	pH 5.6	pH 4.5
Sample 1	22.74	20.84
Sample 2	20.93	19.03
Sample 3	18.95	18.16
Avg.	20.87	19.34[ns]
Experiment 2 (9 applications of simulated rain of pH 3.5 and control of pH 5.6)	pH 5.6	pH 3.5
Sample 1	17.19	16.46
Sample 2	17.06	15.13
Sample 3	17.62	15.79
Avg.	17.29	15.79*[a]
Experiment 3 (9 applications of simulated rain of pH 2.5 and control of pH 5.6)	pH 5.6	pH 2.5
Sample 1	18.95	17.00
Sample 2	17.76	16.21
Sample 3	17.26	16.06
Avg.	17.99	16.42*[b]

[ns] Difference between control and test not significantly different
*[a] Difference between control and test significant at 0.024 level
*[b] Difference between control and test significant at 0.054 level

The reduction in chlorophyll found in the plants exposed to pH 4.5 was not statistically significant from the control set. Caloric values of leaves were highly variable and there was no statistically significant difference seen when comparing the pH 3.5 test with the control. The control group had a range of 3.5 to 4.7 kcal/g/dry wt. and the test plants were determined to have a range of 3.2 to 4.7 kcal/g/dry wt., and no further caloric measurements were made.

DISCUSSION

The effects of simulated acid rain, at least on this species being investigated, indicates the potential for reduction of biomass by influencing the photosynthetic process. Primary productivity declines of 10% in natural ecosystems have been previously suggested to be the result of acidic precipitation (14) and in this study consistent reductions of biomass exceeded 20% in the tests under 3 different experimental acidic rain exposures. Accentuated differences between the control and experimental might be expected since the growth conditions were controlled providing the best possible habitat. In natural systems, maximum potential biomass production may be somewhat reduced due to the fluctuations of limiting factors as water, temperature and light quality. The demonstrated reduction in chlorophyll levels under the 2 more acidic treatments indicates a possible mechanism of lowered carbon fixation and indicates the need for further research to determine the actual physiological effects of acidic moisture on leaf tissue. Reductions in cuticular deposits on leaf surfaces by acidic solutions could result in decreased chlorophyll production in nature since high light intensity will interfere with chlorophyll synthesis. Cytological investigations will be required to determine the actual mechanism(s) involved in reduction of photosynthetic pigments.

The lack of statistically significant reductions in caloric values of leaves was not unexpected since plant leaf material is comprised mostly of carbohydrate. The significant reductions in total biomass (if mostly carbohydrate) would not show a caloric difference on a per-gram basis but a 20% reduction of total leaf biomass obviously would contribute to a significant reduction in total energy available when considering net productivity in a population of primary producers.

There has been significant public discussion about the effects of acidic deposition (both dry and wet) on biota in the eastern United States. Most of the Commonwealth of Kentucky now shows an annual average rainfall of pH of 4.2 or less (6). Power generating utilities and public officials have made numerous calls for more research prior to legislative controls on anthropogenic activities that contribute to reductions in the pH of precipitation. It is hoped that the current study provides a contribution that documents a measure of the potential damage to biomass production resulting from exposure to precipitation acidic below the norm.

LITERATURE CITED

1. Kozlowski, T. T. 1980. Impacts of air pollution on forest ecosystems. Bioscience 30:88–93.
2. Bach, W. 1985. Forest dieback; extent of damages and control strategies. Experientia 41:1095–1104.
3. Abelson, P. H. 1985. Air pollution and acid rain. Science 230:617.
4. Galloway, J. N., Z. Dianwu, X. Jiling, and G. E. Likens. 1987. Acid rain: China, United States, and a remote area. Science 236:1559–1562.
5. Likens, G. 1975. Acidity in rainwater: has an explanation been given? Science 188:957–958.
6. Kupchella, C. E. and M. C. Hyland. 1986. Environmental science. Allyn and Bacon, Newton, Massachusetts
7. Schofield, C. L. 1976. Acid precipitation: effects on fish. Ambio 5:228–230.
8. Tamm, C. 1976. Acid precipitation: biological effects in soil and forest vegetation. Ambio 5:235–238.
9. Knabe, W. 1976. Effects of sulfur dioxide on terrestrial vegetation. Ambio 5:213–218.
10. Wood, T. and F. H. Bormann. 1974. The effects of an artificial acid mist upon the growth of *Betula alleghaniensis* Britt. Env. Pollut. 6:259–267.
11. Evans, L. S., N. F. Gmur, and F. Delosta. 1977. Leaf surface and histological perturbations of leaves of *Phaseolus vulgaris* and *Helianthus annuus* after exposure to simulated acid rain. Amer. J. Bot. 64:903–913.
12. Evans, L. S. and T. M. Curry. 1979. Differential responses of plant foliage to simulated acid rain. Amer. J. Bot. 66:953–962.
13. Abdulraham, F. S. and J. E. Winstead. 1977. Chlorophyll levels and leaf ultrastructure as ecotypic characters in *Xanthium strumarium* L. Amer. J. Bot. 64:1177–1181.
14. Whittaker, R. H., F. H. Bormann, G. E. Likens, and T. G. Siccama. 1974. The Hubbard Brook ecosystem study: forest biomass and production. Ecol. Monog. 44:233–254.

Trans. Ky. Acad. Sci., 49(1–2), 1988, 32–34

Isolation and Identification of Non-*Salmonella* Bacteria from Egg and Milk Products Screened for *Salmonella* spp.

Bobby L. Bowles, Martin R. Houston,
and Larry P. Elliott

Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

and

Alan R. Coates

Country Oven Bakery, Bowling Green, Kentucky 42101

Abstract

Egg and milk products (26 egg and 6 milk) from various food processing companies were routinely screened for *Salmonella* spp. by FDA-recommended procedures. All 32 samples were determined to be negative for *Salmonella* but contained gram-negative, non-*Salmonella* bacteria which produced typical *Salmonella* reactions on selective differential agars. These bacteria were isolated and identified by morphological and biochemical characteristics as *Enterobacter cloacae*, *Citrobacter diversus-livenea* (*C. koseri*) and *Klebsiella pneumoniae*.

Introduction

Food substances provide environments which are rich in nutrients and under proper conditions are suitable for microbial growth (1, 2). Consequently, food substances contaminated with pathogenic microorganisms are a serious concern for disease control and prevention (3, 4). In view of the federal regulations prohibiting the occurrence of pathogenic organisms such as *Salmonella* in foods, the isolation of these organisms presents a difficult problem for the food scientist, since a high ratio of other bacteria compared to *Salmonella* spp. exists (5, 6). The Food and Drug Administration (FDA) has developed protocols for isolating and identifying *Salmonella* spp. These methods generally include a pre-enrichment step that provides damaged organisms the opportunity to repair physiological lesions and a selective enrichment step that allows the *Salmonella* spp. to achieve numbers comparable to closely related non-pathogenic bacteria. Selective differential agars are used to determine biochemical and colony-form characteristics of *Salmonella* (5).

In this laboratory, egg and milk samples routinely tested for *Salmonella* were found to contain gram-negative, non-*Salmonella* bacteria which produced typical *Salmonella* reactions on media recommended by the FDA. Employing biochemical and morphological tests, the characteristics and subsequent identification of these bacteria were determined.

Materials and Methods

Materials.—Media employed for pre-enrichment, selective enrichment, selective plating and biochemical screening were purchased from DIFCO Laboratories (Detroit, MI). The API 20 Enterobacteriaceae Identification System (API 20E: Analytab Products, Plainview, NY) was employed for identification of the isolates.

Samples.—A total of 32 samples (26 egg and 6 milk) obtained by the Country Oven Bakery (Bowling Green, KY) from various food processing companies was employed in this investigation. The samples were screened for *Salmonella* spp. according to FDA-approved procedures (5).

Media and Biochemical Tests.—Lactose broth was used for pre-enrichment, and tetrathionate and selenite broths were used for selective enrichment. Bismuth sulfite (BS), hektoen enteric (HE) and xylose lysine desoxycholate (XLD) agars were used for selective plating. Triple sugar iron (TSI) and lysine iron (LIA) agars were used for biochem-

TABLE 1. Bacteriological screening of food products for typical *Salmonella* reaction on selective differential media.

Food products	Number of samples	Typical reactions				
		BS[1]	HE[2]	XLD[3]	TSI[4]	LIA[5]
Dried whole eggs	11	4	0	0	0	0
Egg white	1	1	0	0	0	0
Whole eggs	1	1	0	0	0	0
Fortified whole eggs	1	1	0	0	0	0
Frozen eggs	5	2	0	0	1	0
Dried egg whites	5	1	0	0	1	0
Egg white solids	2	0	0	0	NA	NA
Dairy whey	2	1	0	0	0	0
Sweet dairy whey	1	0	0	0	NA[6]	NA
Non-fat dried milk	3	1	0	0	0	0

[1] Bismuth sulfite
[2] Hektoen enteric
[3] Xylose lysine desoxycholate
[4] Triple sugar iron
[5] Lysine iron agar
[6] Not applicable; screening of sample ended with negative growth or no growth on BS, HE and XLD

ical screening. Samples were then evaluated as either negative or typical on BS, HE, XLD, TSI or LIA media.

Isolation and Identification of Non-Salmonella Species.—Typical salmonella-like colonies from selective differential media were transferred to the medium upon which the positive reaction was produced to reproduce the original results. The resulting growth was streaked for isolation on nutrient agar (NA) plates and incubated at 37°C for 24 ± 2 hr. These isolates were identified by their cellular morphology, gram reaction, and biochemical characteristics using the API 20E system.

RESULTS

The 32 egg and milk samples were negative for *Salmonella* organisms. Typical *Salmonella* reactions were produced by non-*Salmonella* bacteria in 12 of the 32 samples (Table 1). Egg products (10 samples) were found to contain 83.3% of the non-*Salmonella* bacteria isolated and identified compared to the milk products tested; 38.5% of the egg samples contained bacteria which expressed *Salmonella*-like characteristics when cultured on bismuth sulfite agar. No apparent differences in the occurrence of non-salmonella bacteria were found in the food products obtained from the different companies.

All typical *Salmonella* reactions were observed on BS agar. The selective enrichment broths tetrathionate and selenite did not inhibit the growth of these non-*Salmonella* organisms. Seven of the 12 typical reactions were attributed to bacteria subcultured from selenite broth to BS agar, and 5 were subcultured from tetrathionate broth to BS agar plates.

Bacterial cultures exhibiting typical *Salmonella* reactions were identified as *Enterobacter cloacae*, *Citrobacter diversus-levinea* (*C. koseri*) (7), and *Klebsiella pneumoniae* (Table 2). Of the 12 samples producing typical *Salmonella* reactions, 92% were identified as *E. cloacae*.

DISCUSSION

The results of this investigation indicate that during various phases of processing, egg and milk products receive and/or retain gram-negative, non-*Salmonella* bacteria which produce typical reactions on selective differential media during routine screening for *Salmonella* organisms. These findings are significant in that typical *Salmonella* reactions by non-*Salmonella* organisms in various food products can increase the time required for screening. If the same types of egg and milk products from all commercial food suppliers harbor a similar percentage (37.5%) of bacteria capable of eliciting a false-positive *Salmonella* reaction on BS agar, a significant waste of analytical time and supplies becomes a reasonable assumption. Furthermore, analysis of large numbers of food samples or samples requiring rapid-screening results can become cumbersome and difficult for food scientists.

According to Sinell (8), microbial populations found in food products are dependent upon the product composition and environ-

TABLE 2. Identification of non-*Salmonella* bacteria in egg and milk food products screened for *Salmonella*.

Sample number	Food product	API 20E System: Reference number	API 20E System: Identification
2	Dried whole eggs	3 105 773	*Enterobacter cloacae*
3	Dried whole eggs	3 105 773	*Enterobacter cloacae*
7	Egg whites	3 144 733	*Citrobacter diversus-levinea**
8	Dried whites	3 105 773	*Enterobacter cloacae*
9	Whole eggs	3 105 573	*Enterobacter cloacae*
10	Fortified whole eggs	3 105 573	*Enterobacter cloacae*
11	Frozen eggs	3 105 773	*Enterobacter cloacae*
13	Frozen eggs	3 105 773	*Enterobacter cloacae*
22	Dried whole eggs	3 305 573	*Enterobacter cloacae*
24	Dried whole eggs	3 305 773	*Enterobacter cloacae*
29	Non-fat dried milk	3 305 573	*Enterobacter cloacae*
32	Dairy whey	5 215 773	*Klebsiella pneumoniae*

* Currently recognized as *C. koseri* in *Bergey's Manual of Systematic Bacteriology*.

mental conditions. Tetrathionate and selenite broths as selective enrichment media are efficient in growth enhancement of *Salmonella*. The results of this investigation indicate that these broths do not sufficiently inhibit non-*Salmonella* bacteria in the mixed microbial populations of the food products tested. Rhodes et al. (9) investigated the effect of incubation temperature on the growth kinetics and of selective enrichment broths for *Salmonella* enrichment. The selectivity of tetrathionate, selenite and Muller-Kauffman tetrathionate broths was increased at elevated temperatures (42°C). In recent years, many rapid microbial tests for *Salmonella* detection have been developed; however, the conventional method having FDA approval, used in this study, is widely employed. To decrease the time required for *Salmonella* detection (4–7 days) in the presence of bacteria such as those isolated in this study, the modification of existing tests (2) or development of more sensitive techniques (1, 10, 11, 12, 13) would be economically advantageous for food processing laboratories.

LITERATURE CITED

1. Ibrahim, G. F., M. J. Lyons, R. A. Walker, and G. H. Fleet. 1986. Rapid detection of *Salmonella* in foods using immunoassay systems. J. Food Prot. 49:92–98.

2. Walker, A. P. 1981. A note on the inhibition of *Pseudomonas aeruginosa* by a modification of brilliant green agar for improved *Salmonella* isolation. J. Appl. Bacteriol. 51:405–408.

3. Anonymous. 1986. Food and Drug Administration, Department of Health and Human Services. Code of Federal Regulations No. 21, U.S. Government Printing Office, Washington, D.C.

4. Anonymous. 1986. Animal and plant health and inspection service, Department of Agriculture. Code of Federal Regulations No. 9, U.S. Government Printing Office, Washington, D.C.

5. Andrews, W. H., P. L. Poelma, and C. R. Wilson. 1984. Isolation and identification of *Salmonella* species. Pp. 7.01–7.18. In Bacteriological analytical manual, 6th ed. Association of Analytical Chemists, Arlington, Virginia.

6. Silliker, J. H. and D. A. Gabis. 1973. ICMSF methods studies. I. Comparison of analytical schemes for detection of *Salmonella* in dried foods. Can. J. Microbiol. 19:475–479.

7. Krieg, N. R. (ed.) 1984. Bergey's manual of systematic bacteriology, Vol. 1. Williams & Wilkins, Baltimore.

8. Sinell, H. J. 1980. Interacting factors affecting mixed populations. Pp. 215–221. In Ed. committee, Microbial ecology of foods, Vol. 1. Factors affecting life and death of microorganisms, ICMSF. Academic Press, New York.

9. Rhodes, P., L. B. Quesnel, and P. Collard. 1985. Growth kinetics of mixed culture in *Salmonella* enrichment media. J. Appl. Bacteriol. 59:231–237.

10. Cerqueira-Campos, M., P. I. Peterkin, and A. N. Sharpe. 1986. Improved immunological membrane filter method for detection of food-borne *Salmonella* strains. Appl. Environ. Microbiol. 52:124–127.

11. Ibrahim, G. F. 1986. A review of immunoassays and their application to Salmonellae detection in foods. J. Food Prot. 49:299–310.

12. LaRoche, R. N., V. Desai, B. Friedman, and B. Swaminathan. 1981. Field evaluation of the membrane filter-disc immuno-immobilization technique in the detection of *Salmonella* in egg products. Poultry Sci. 60: 2265–2269.

13. Richter, E. R. and G. J. Banwart. 1982. Evaluation of an x-ray microprobe technique as a possible aid to detect salmonellae. Can. J. Microbiol. 28:650–653.

Trans. Ky. Acad. Sci., 49(1–2), 1988, 35–36

A Counterexample in Difference Ring Ideal Theory

CHARLES H. FRANKE

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

ABSTRACT

An example is given of a principal, prime, difference ideal which has no m-basis.

INTRODUCTION

The notation and terminology are as in (1, pp. 82–94). In particular, if R is a difference ring then R{x} is the difference ring generated by R and x, and if F is a difference field then F⟨x⟩ is the difference field generated by F and x. If S is a subset of the difference ring R then [S] is the difference ideal generated by S and {S} is the perfect difference ideal generated by S. If T is a subset of R then T′ is the set of all elements products of powers of transforms of which are in T. If we define T(0) = T and T(n) = [T(n − 1)]′ then {T} is the union of the ascending chain T(n). A basis for a set S in a difference ring R is a finite subset T of S such that {T} = {S}. T is an m-basis for S if T(m) = {S}.

The purpose of this paper is to exhibit a perfect difference ideal which has a basis but does not have an m-basis. This answers a question posed in (1, p. 94). It is shown that in this example the ring R is not a Ritt difference ring, i.e., R does not satisfy the ascending chain condition on perfect difference ideals. Therefore, it is still possible that every ideal in a Ritt difference ring has an m-basis.

RESULTS

Assume that C is a difference field with the identity transform. Define sequences $x^{(i)}$, $R^{(i)}$, and $F^{(i)}$ as follows. Choose $x^{(0)}$ and $x_1^{(0)}$ algebraically independent over C with $x_2^{(0)} = x$. Define $R^{(0)} = C\{x^{(0)}\}$, and $F^{(0)} = C\langle x^{(0)}\rangle$. For $i > 0$, choose $x^{(i)}$ transcendental over $F^{(i-1)}$ and define $x_1^{(i)} = (x^{(i-1)} + x_1^{(i-1)})/x^{(i)}$. Define $R^{(i)} = R^{(i-1)}\{x^{(i)}\}$, $F^{(i)} = F^{(i-1)}\langle x^{(i)}\rangle$ and R as the union of the $R^{(i)}$. Since each $x^{(i)}$ satisfies the difference equation $y_2 = y$, each element of R satisfies that equation. Therefore, $R^{(i)}$ is the ring obtained from C by the oridinary algebraic ring adjunction of the $x^{(j)}$ and $x_1^{(j)}$ for $0 < j \leq i$. We note further that $R^{(i)}$ is a subring of the quotient ring of $R^{(i-1)}[x^{(i)}]$ with respect to the powers of $x^{(i)}$.

We show that the ideal $\{x^{(0)}\}$ has no m-basis. It is clearly sufficient to show that some basis is not an m-basis. Define $S^{(0)} = [x^{(0)}]$ and $S^{(i+1)} = [S^{(i)\prime}]$. (The notation here differs from that in (1).) Define $T^{(i)} = [x^{(0)}, \ldots, x^{(i)}]$. The proof is completed by showing by induction that $S^{(i)} = T^{(i)}$. This is true by definition, for $i = 0$.

If $j > 0$ and $S^{(j-1)} = T^{(j-1)}$ then $x^{(j-1)} \in S^{(j-1)}$. Therefore, $x^{(j)}x_1^{(j)} \in S^{(j-1)}$, $x^{(j)} \in S^{(j)}$ and $T^{(j)} \leq S^{(j)}$. The proof of the converse inclusion uses a representation of the elements of R in a canonical form.

Define $\bar{R} = C[X^{(i)}, Y^{(i)}]$ to be the polynomial ring over C in a double sequence of algebraically independent elements. Define R* to be the set of all $Q \in \bar{R}$ with the following property. If $i > 0$ and M is a monomial of Q then M does not contain both $X^{(i)}$ and $Y^{(i)}$. If $a \in R$, $Q \in R^*$ and $a = Q(x^{(i)}, x_1^{(i)})$ then Q is called a canonical expression of a. By repeated use of the relations $x^{(i)}x_1^{(i)} = (x^{(i-1)} + x_1^{(i-1)})$, one may obtain a canonical expression for each element of R. Since $x^{(i)}$ is transcendental over $F^{(i-1)}$, it is easy to see that the expression is unique.

If $S^{(j)} \not\subseteq T^{(j)}$ then $S^{(j-1)\prime} \not\subseteq T^{(j)}$ so there is an $a \notin T^{(j)}$ with $a \in S^{(j-1)\prime}$. Thus there are integers p and q so that $a^p a_1^q \in S^{(j-1)}$. Choose the largest integer t with $X^{(t)}$ or $Y^{(t)}$ appearing effectively in the canonical expression of a. Consider the mapping σ of $R^{(t)}$ into $F^{(t)}$ defined by

$$\sigma(x^{(i)}) = \sigma(x_1^{(i)}) = 0 \text{ if } i < j,$$
$$\sigma(x^{(j)}) = x^{(j)},\ \sigma(x_1^{(j)}) = 0,$$
$$\sigma(x^{(i)}) = x^{(i)},\ \sigma(x_1^{(i)}) = [x^{(i-1)} + \sigma(x^{(i-1)})] \div x^{(i-1)}, \text{ if } j < i \leq t.$$

We show that σ is an algebraic specialization of $R^{(t)}$ by proving that the restriction of σ to $R^{(i)}$ is a specialization of $R^{(i)}$ for $0 \leq i \leq t$. This is clear for $i = 0$. If it is true for $i - 1$ then, since $x^{(i)}$ is transcendental over $F^{(i-1)}$, σ induces a specialization of $I = R^{(i-1)}[x^{(i)}]$.

For $i < j$, to extend σ from I to $R^{(i)}$ it is sufficient to show that if $P \in C[X^{(k)}, Y^{(k)}]$, $0 \leq k \leq i$, and $P(x^{(k)}, y^{(k)}) = 0$ then P vanishes when each $x^{(k)}$ and $y^{(k)}$ is replaced by zero. If this were not the case, then some such P would have a non-zero constant term and $\{x^{(0)}\}$ would contain an element of C and be equal to R.

For $i \geq j$, since σ can be extended uniquely to the quotient ring of I with respect to the powers of $x^{(i)}$, σ can be extended to its subring R(i).

Since $\sigma(a^a)\sigma(a_1{}^q) = 0$, and the range of σ is contained in F(t), either $\sigma(a) = 0$ or $\sigma(a_1) = 0$. Since $(a^p a_1{}^q)_1 = a^q a_1{}^p$ is also in $S^{(j-1)}$ and not in T(j), we can assume $\sigma(a^p) = 0$. Assume that Q is the canonical expression for a. Define $\bar{Q}$ to be the polynomial obtained from Q by substituting 0 for each $X^{(i)}$, $0 \leq i < j$, and each $Y^{(i)}$, $0 \leq i \leq j$. From $Q(x^{(i)}, x_1{}^{(i)}) = a$ we obtain $Q[x^{(i)}, \sigma(x^{(i)})] = \sigma(a) = 0$. Next we see that Q is identically zero.

If Q is written as a polynomial in $X^{(t)}$ and $Y^{(t)}$ we obtain a relation $0 = \Sigma\, A^{(k)}(x^{(i)}, \sigma(x_1{}^{(i)})x^{(t)k} + B^{(k)}(x^{(i)}, \sigma(x_1{}^{(i)}))(x^{(t-1)} + x_1{}^{(t-1)})^k(x^{(t)-k})$. Since $x^{(t)}$ is transcendental over $F^{(t-1)}$, each coefficient vanishes and $\bar{Q}(x^{(j)}, \ldots, \sigma(x_1{}^{(t-1)}), X^{(t)}, Y^{(t)}) = 0$. Each $A^{(k)}$ and $B^{(k)}$ can be written as polynomials in $X^{(t-1)}$ and $Y^{(t-1)}$. Continuing in this way, we conclude that $\bar{Q}$ is identically zero, $Q \in C[X^{(0)}, Y^{(0)}, \ldots, X^{(j)}, Y^{(j)}]$ and $a \in T^{(j)}$. This completes the proof.

We show that R is not a Ritt difference ring in the case where C is the complex numbers with the identity transform. The necessary modifications of the proof for other cases are discussed at the end.

Define $S = C(j)$ where j is transcendental over C and $j_1 = -j$.

For each $n \geq 0$ define $\partial^{(n)}$ from R to S as follows: $\partial^{(n)}(c) = c$ for $c \in C$, if $k < n$ then $\partial^{(n)}(x^{(k)}) = \partial^{(n)}(x_1{}^{(k)}) = 2^p j^q$ where $p = 1 - (½^k)$, and $q = 2^{(n-k)}$, $\partial^{(n)}(x^{(n)}) = -\partial^{(n)}(x_1{}^{(n)}) = 2^r ij$ where $r = (2^n - 1)/2^n$, if $k > n$ then $\partial^{(n)}(x^{(k)}) = \partial^{(n)}(x_1{}^{(n)}) = 0$.

$\partial^{(n)}$ preserves each relation $x^{(k+1)}x_1{}^{(k+1)} = x_1{}^{(k)} + x^{(k)}$ since both sides are mapped to zero when $k \geq n$ and both sides are mapped to $2(2^p j^q)$ where $p = (2^k - 1)/2^k$ and $q = 2^{n-(k-1)}$ when $k < n$. Therefore $\partial^{(n)}$ extends to a difference homomorphism from R to S and $\ker(\partial^{(n)})$ is a prime reflexive difference ideal in R. Define $a(n) = \bigcap_{j=n}^{\infty} \ker(\partial^{(j)})$. Clearly a is an increasing sequence of perfect difference ideals. Further, $x_1{}^{(n)} - x^{(n)}$ is in the kernel of $\partial^{(k)}$ for $k \neq n$. Therefore $x_1{}^{(n)} - x^{(n)}$ is in $a(n + 1)$ but not in a(n), and the chain is strictly ascending.

The complex numbers were used in the proof as a matter of convenience. Since $\ker(\partial^{(n)}) = [x_1{}^{(0)} - x^{(0)}, \ldots, x_1{}^{(n)} + x^{(n)}, x^{(n+1)}, \ldots]$, and $a(n) = [x_1{}^{(0)} - x^{(0)}, \ldots, x_1{}^{(n-1)} - x^{(n-1)}]$ a similar proof can be constructed for arbitrary C.

LITERATURE CITED

1. Cohn, R. M. 1965. Difference algebra. Interscience, New York.

Further distribution of *Mustela nivalis* in Kentucky—Six least weasel skulls (*Mustela nivalis*) were recovered from barn owl pellets collected in February 1983 at 2 sites in Madison County, Kentucky. Five skulls were contained in pellets collected from the attic of a home in Richmond, Kentucky, approximately 1.5 km from the northern city limits. The area north of the city consisted of rolling pasture and farmland. The remaining skull was collected in barn-owl pellet debris from a tree cavity, located on a small farm at the southeast corner of Richmond, 150 m from the intersection of SR 25 and SR 876. This area was characterized by rolling pastureland and was surrounded by shopping centers to the south and east and residential areas to the north and west.

The pellets and pellet debris were soaked in a sodium hydroxide solution (Schueler, Bird Banding 43:142, 1972) to dissolve the hair and isolate the crania for easier identification. The length of the skulls ranged from 29 to 31 mm and the widths from 13 to 14 mm. The skulls exhibited complete sets of adult teeth.

The occurrence of least weasels in the diets of barn owls has been documented in Ohio by Phillips (Auk 68:239–241, 1951) and Takacs and McLean (Ohio J. Sci. 82:5, 1982). The range of *Mustela nivalis* includes southern Ohio (Hall, Mammals of North America, Wiley and Sons, 2nd ed., Vol. II, 1981), western Virginia (Handley, J. Mammal. 30:431, 1949) and eastern Tennessee (Tuttle, J. Mammal. 49:133, 1968). There have been 2 published reports of the least weasel in Kentucky, one from Letcher County (Davis and Barbour, Trans. Ky. Acad. of Sci. 40:111, 1979) and another from Woodford County (Prather, Trans. Ky. Acad. of Sci. 45:76, 1984). In each of these cases single specimens were reported. The discovery of 6 skulls in Madison County provides evidence that this species has a wider range than previously recorded and suggests that a sizeable population may exist in central Kentucky.

I would like to thank Robert J. Izor (Collection Manager, Field Museum of Natural History, Chicago, Illinois) for confirming the identification of the *M. nivalis* skulls. Thanks are also due Dr. Gary Ritchison for his assistance.—**Peter G. David**, South Florida Water Management District, West Palm Beach, Florida 33402.

Leaf fall as an ecotypic character of *Acer negundo* populations from Ohio and Mississippi—The existence of genotypically different populations, or ecotypes, in species of plants and animals is widely known and understood to show strategies of survival and compatibility with habitat variables in species that have natural distribution over a diversity of habitats. Although one might expect differing lengths of total growth periods in populations of plants from shorter growing seasons compared to populations from longer growth period habitats to be manifested in patterns of fall coloration and subsequent leaf fall, especially in deciduous woody plants, there is apparently little documentation of ecotypic patterns being expressed in such a manner. An exception is the study of *Liquidambar styraciflua* L. by McMillan and Winstead (Bot. Gaz. 137: 361–367, 1976). In that study, populations from more northern habitats (and shorter growing seasons) showed earlier leaf fall when geographically diverse populations were compared under uniform laboratory conditions. Previous work on the widespread deciduous tree *Acer negundo* L. (boxelder) showed populational differentiation expressed in chlorophyll levels (Greco, Winstead and Toman, Trans. Kentucky Acad. Sci. 43:144–146, 1980), seed germination (Williams and Winstead, Trans. Kentucky Acad. Sci. 34:33–36, 1972), wood fiber length (Winstead, Amer. J. Bot. 65:811–812, 1978), and the possibility of populational differences of seed size on a latitudinal gradient in boxelder was presented by Williams and Winstead (Castanea, 37:125–130, 1972).

Boxelder seed collections were obtained from Athens, Ohio and Greenville, Mississippi and stratified in moist sand at 4°C for 20 weeks prior to placement in a growth chamber regulated with a 16-hr day length (ca. 6,000 lux) and alternating 12-hr temperature cycles of 32/24°C with the higher temperature programmed to fit in the middle of the 16-hr light period. Maximum germination of the 2 populations was reached in 20 days, and 10 seedlings of the Ohio population and 11 plants from the Greenville, Mississippi site were potted individually in 10- × 10-cm plastic containers in a commercial potting soil and maintained in the growth chamber under the above stated conditions for 136 days. At the end of that period the chamber's temperature program was reduced to alternating 12-hr cycles of 27/16°C, again with the higher temperature centered within the 16-hr light period. After 18 days the temperature program was lowered to a cooler regime of 18/10°C (and the light-dark periods changed to equal 12-hr cycles) to simulate fall and early winter conditions. Seedlings were watered periodically and observed every 2–3 days for evidence of leaf senescence and the corresponding abcission. The time of complete defoliation (in absence of any significant wind current in the growth chamber) was recorded for each individual.

From the initiation of the 18/10°C temperature program 9 of the 10 seedlings from Athens, Ohio lost all leaves between the 34th and 36th day while 40 days elapsed before the first individual of the Greenville, Mississippi population was observed to be completely defoliated. After 44 days 1 additional plant of the more southern population lost its leaves, which coincided with the complete leaf dropping of the last individual from the Ohio population. Seven of the remaining 9 seedlings from Mississippi showed complete leaf fall between 49 and 60 days after the colder temperature programs were started. Daily checks were made on the last 2 plants and 1 defoliated after 66 days and the last plant in this test completed leaf fall 72 days from the start of the observation period. The comparisons of these 2 widely separated populations showed that 90% of the Ohio site progeny were completely defoliated by 36 days of treatment to cool day and cold night temperatures while 81% of the Mississippi population maintained leaves up to 49 days under the same condition. Color changes of leaves were gradual in all individual plants to a light yellow a few days prior to the compound leaves being lost from the stem.

These phenological differences being expressed by different genotypes of the same species are indications of the physiological processes that are selected for in populations that must survive in habitats of a shorter growing season. Earlier cessation of growth and the biochemical changes leading to winter dormancy and hardiness would be expected to enhance the survival of more northern populations. In the absence of shorter growing seasons and earlier exposure to fall or winter conditions early leaf abscission and fall would have little adaptive or selective value in populations from the Mississippi River Valley as typified by the Greenville, Mississippi progeny used in this test.

A practical value is suggested by these findings if the search for similar patterns were to be expanded to include hardwood species that show foliage coloration characters of horticultural and landscaping use. Although boxelder has little commercial value (except for potential paper pulp and, of course, its as yet unknown niche or functional role in natural ecosystems) the patterns indicated in this simple study would seem to hold promise in landscaping public areas with genotypes from different areas that would survive in a selected habitat. It might be possible by judicious selection to arrange plantings of trees to expand the fall coloration and leaf dropping time and enhance the aesthetics of commercial, public or private park type areas. A contrary approach could also be made to reduce the labor involvement in gathering and disposal of leaves by selecting genotypes of several species that would show synchronized leaf fall making it possible to only contend with leaf disposal in a short span of time. Landscape architects and horticulturists might well profit from an examination of the evolutionary patterns inherent in ecotypes of endemic species.—**Joe E. Winstead**, Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101, and **Anthony M. Greco**, Department of Marine Science, University of South Florida, St. Petersburg, Florida 33701.

A Life-form Spectrum for Ohio—This paper presents a life-form analysis of the native spermatophytes of Ohio. The life-form classification we use is that of Raunkiaer (The Life Forms of Plants and Statistical Geography, Clarendon Press, Oxford, 1934), based on the position of the perennating buds or meristems relative to the surface of the substrate. A summary of Raunkiaer's classification and of the use of life-form data in phytoclimatic studies is given in Gibson (Amer. Midl. Naturalist 66:1–60, 1952), McDonald (Amer. Midl. Naturalist 18:687–733, 1937), and Thieret (Michigan Bot. 16:27–33, 1977) and need not be repeated in full here.

TABLE 1. The Normal Spectrum, the Ohio spectrum, and available spectra for other central states.

	Ph	Ch	H	Cr	Th
Normal Spectrum	46.0	9.0	26.0	6.0	13.0
Ohio	15.3	1.6	50.0	20.6	12.5
Michigan	14.2	2.2	51.6	22.1	9.2
Kentucky	17.6	1.4	52.6	16.6	11.8
Indiana	15.3	1.7	50.3	19.6	13.0
Illinois	15.5	1.6	50.2	19.8	12.9
Iowa	14.8	1.0	48.6	20.9	14.2
Minnesota	13.0	3.0	49.0	22.0	13.0

Raunkiaer recognizes 5 principal life-form classes. In order of increasing protection of the buds, these are: Class I. Phanerophytes (Ph): meristems 25 cm or more above the soil surface; almost all are trees and shrubs. Especially characteristic of humid tropical forests, phanerophytes decrease with increase in latitude. Class II. Chamaephytes (Ch): meristems above the soil surface but lower than 25 cm. The Ch percentage in a flora tends to increase with increasing latitude or elevation. This class is especially characteristic of arctic and alpine areas. Class III. Hemicryptophytes (H): buds in the surface layer of the soil. This class tends to be dominant in temperate floras, and often constitutes half or more of the flora in grasslands and deciduous forests. Class IV. Cryptophytes (Cr): buds beneath the surface of the soil, in water, or in the substratum under the water. Cryptophytes appear not to be the dominant life-form of any particular area. Class V. Therophytes (Th): annual plants, which perennate by seeds. They are especially abundant in desert floras and in weedy communities developing after native vegetation is disturbed.

As a standard of comparison with spectra of various regions, Raunkiaer developed the "Normal Spectrum." He determined the life-form for each of 1,000 species randomly selected from the world's flora. Every regional spectrum will have, he asserted, 1 class (excluding cryptophytes) whose percentage is notably higher than that of the Normal. This class can be taken as an indicator of what he called the "phytoclimate" of the region.

Ohio has ca. 1,730 species of native seed plants (Weishaupt, Vascular Plants of Ohio, 3rd ed., Kendall/Hunt, Dubuque, Iowa, 1971; T. Cooperrider and A. Cusick, pers. comm.). For each of these we determined the life-form through field, herbarium, and literature studies. Results are shown in Table 1, where the life-spectrum of Ohio is contrasted with the Normal Spectrum and with available spectra of other central states (see Thieret, Michigan Bot. 16:27–33, 1977).

The Ohio spectrum indicates that the state's phytoclimate is hemicryptophytic. The H percentage is about double that of the Normal.

According to Raunkiaer, the life-form values that would be expected to show correlation with latitude are Ph, Ch, and Th. Our data for Ohio are mostly in line with Raunkiaer. Ohio Ph is greater than that of Michigan and less than that of Kentucky. Ohio Ch is intermediate between Michigan and Kentucky. Finally, Ohio Th is larger than that of Michigan; it is larger, also, than that of Kentucky, perhaps because a greater percentage of land in Ohio is under cultivation.

Life-form spectra have usually been compared along north–south gradients, Michigan vs. Kentucky, for example. But, with our Ohio spectrum, we can now compare 2 regions along an east–west line but separated by about 800 miles and in different biomes. Ohio lies in eastern deciduous forest; Iowa, largely in grassland. The 2 areas, however, have rather similar spectra. Remember that life-form data refer to *species* in a flora, rare species having just as much influence on a spectrum as do common or abundant ones. Such spectra are not meant to reflect differences in vegetation between 2 regions.

Comparison of Ohio's spectrum with that of Iowa shows, from the former to the latter, a decrease in Ph, a decrease in Ch, a decrease in H, and an increase in Th. Before we attempt some explanation of these differences, let us issue a disclaimer. The presence of small differences between spectra is a little understood—and little investigated—subject. We simply do not know what magnitude a difference must be to constitute an interpretable difference. Perhaps future students of life-forms will establish guidelines on this subject.

The slight decrease in Ph in Iowa doubtlessly reflects the less rich tree flora in that state. A quick check indicates that Iowa lacks at least 45 tree species found in Ohio, Indiana, and Illinois. We emphasize that the difference between forested areas and grasslands is not necessarily in the Ph percentage in the floras but in the dominance of trees in one and of grasses and forbs in the other. The decrease in Ch from Ohio to Iowa is attributable primarily to the scarcity in Iowa of Ericaceae and Pyrolaceae. The differences in H and Th between Ohio and Iowa are simply not explainable by us. In various spectra, one can see both small increases and small decreases in H and Th from forested areas to grasslands. Again, what is the significance of these differences? More study is required.

Lastly, it is clear that all of the life-form spectra presented here are dominated by H. Why such a large number of species with this life-form is present is open to hypothesis formulation and testing. Hemicryptophytes may be favored in environments with marked seasonality. The meristems in the soil surface may also be protected from extreme physical environment factors or grazers. Thermal advantages may also accrue in the soil surface because this is the microenvironment where solar radiation is most directly absorbed.—**James O. Luken** and **John W. Thieret**, Department of Biological Sciences, Northern Kentucky University, Highland Heights, Kentucky 41076.

Trans. Ky. Acad. Sci., 49(1–2), 1988, 40–44

ACADEMY AFFAIRS

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

Garrett Conference Center Auditorium
Western Kentucky University
Bowling Green, Kentucky

6–7 November 1987

Minutes of the Annual Meeting

The meeting was called to order at 0920, 7 November in the Garrett Conference Center Auditorium at Western Kentucky University. There were approximately 110 members in attendance.

In order to allow for the election and announcement of the new officers prior to the end of the business meeting, Dr. Elliott moved that the elections be held at this time. The motion passed. The nominating Committee presented the following slate of nominees:

Vice President

Debra Pearce — Douglas Dahlman

Secretary

Virginia Eaton — Varley Wiedeman

Treasurer

Charles Hendrickson — Paul Freytag

Board of Directors

Valgene Dunham — Karan Kaul
Blaine Early — William S. Davis

There being no nominations from the floor, a motion was made and passed to close nominations. The members then voted by secret ballots which were collected by the Nomination Committee for tabulation. The meeting then proceeded with the normal order of business.

The Secretary's report was made by Dr. Creek. Due to the delayed publication of Vol. 47(1–2) of the *Transactions*, it was necessary to approve the minutes of the 1985 annual business meeting. Following a motion by Secretary Creek and a second from the floor, the minutes of the 1985 annual business meeeting at Morehead University, as recorded in the *Transactions*, Vol. 47(1–2), were approved.

Following a motion by Secretary Creek and a second from the floor, the minutes of the 1986 annual business meeting at Lexington, Kentucky, as recorded in the *Transactions* Vol. 48(1–2) were approved. Dr. Creek reported that the 1988 dues must be paid by 1 February 1988 in order to receive Vol. 49(1–2) of the *Transactions*.

In the absence of Dr. Taylor, the following Treasurer's report was presented by Dr. Giesmann.

Treasurer's Report

Executive Committee
Kentucky Academy of Science
6 November 1987

Cash, November 4, 1986	$27,074.00	
Receipts		
SSMA	$ 2,400.00	
Membership	8,214.00	
Library Subscriptions	3,844.90	
Institutional Affiliations	6,100.00	
Page Charges, Reprints	3,721.22	
Griffith Fund	175.00	
Miscellaneous	425.00	
	$24,880.12	
Total cash and receipts		$51,954.12
Disbursements		
EKU	$ 217.95	
Hale's Office Supply	560.11	
NAS	50.00	
Postmaster	600.92	
UK Printing	4,274.36	
Allen Press, Vol. 48 No. 1, 2	3,592.50	
	$ 9,295.84	
Balance		
Total cash and receipts 1987		$51,954.12
Total disbursements		9,295.84
		$42,658.28
Kentucky Academy of Science Foundation		
KAS Endowment Fund Fall 1986		$ 1,040.00
Additional contributions		120.00
Interest		69.60
Total		$ 1,229.60
KSA Botany Fund		
Residual from 1986		$ 1,503.30
Interest 1987		841.64
Grants 1987		1,608.76
Total monies remaining		$ 736.18

Athey Memorial Fund

Residual from 1986	$ 6,226.70
Interest 1987	4,575.42
Grants for 1987	11,500.00

Note: The Athey Fund is not overdrawn. The cash value of the fund is $68,592.24 on an initial investment of $50,000.00 leaving a net gain of $18,592.24 as of September 1987 since January 1985. The interest reported in other financial reports is only current interest. The message is that we have depleted our reserve to some extent.

Dr. Giesmann reported that the annual audit would be done in December and presented to the Executive Committee in January and to the members in the Spring *Newsletter.* A motion was made and passed to accept the report.

COMMITTEE REPORTS

A. **PUBLICATION COMMITTEE.** Dr. Branson made the report.

The last 2 years of this editorship have been rocky ones, and frustrating in the extreme. However, during 1987 we have finally been able to get out the issue Vol. 46(3–4) that had to be reprinted, as well as Vol. 47(1–2) and (3–4) and Vol. 48(1–2) and (3–4). The 2 issues of Vol. 48 were produced by Allen Press, and, other than a minor problem concerning a few short-cut copies, those issues are virtually error free. I am now accumulating articles for the March 1988 [Vol. 49(1–2)] issue which will, hopefully, appear at the designated time.

Thus, we are essentially back on our printing schedule, and I hope we remain that way. Authors can be confident that their papers will appear without the long delays characteristic of the last 2 years.

Production Costs.—The cost of producing Vol. 47(1–2) at the University of Kentucky Printing Office was $4,275.36; the cost for Vol. 47(3–4) was $4,826.45. The total: $9,101.81. The cost of producing Vol. 48(1–2) at Allen Press was $3,592.50; the cost for Vol. 48(3–4) was $3,595.92. The total: $7,188.42. Of course, the difference in production costs between the 2 presses reflects the much smaller number of articles in Vol. 48—the direct result of all the problems we have experienced during the last 2 years. I expect the submissions to pick up dramatically now that we are back on track.

Volume 47(1–2) presented 8 feature articles, 1 note, Academy Affairs, the program, abstracts of papers presented at the 1986 meeting, and News and Comments, for a total of 78 pages. Volume 47(3–4) included 8 features, including the long-awaited rare-and-endangered species article, 3 notes, News and Comments, Academy Affairs, and Index, for a total of 76 pages. Volume 48(1–2) presented 4 features, 1 note, Academy Affairs, presidential address, program, abstracts of some papers presented at the annual meeting, and News and Comments, for a total of 50 pages. Volume 48(3–4) presented 6 features, News, Academy Affairs, and the index to Vol. 48, for a total of 46 pages.

We are in need of feature-length and note-length articles, particularly in the physical sciences, for Vol. 48(3–4). Now is an excellent time to submit articles, for there is plenty of time for review and revision.

A sad note: I am sorry to report that our longtime good friend, Arly Allen, Sr., passed away in October of this year. He will be sorely missed. The press will continue to operate under the aegis of his son and his associates.

B. **MARCIA ATHEY FUND COMMITTEE.** Dr. Giesmann made the report in the absence of Dr. Hammond.

During 1987 there were 4 proposals submitted to the Marcia Athey Fund requesting a total of $16,612. The Committee, after careful consideration of the proposals and the funds available, submitted to the Executive Committee their recommendations for funding the proposals. The Executive Committee accepted their recommendations and voted to fund the following proposals.

1. Dr. Blaine Ferrell. "Gas Chromatographic-Mass Spectrometer Determination of Serotonin Level in the 'Clock' Region of the Cockroach (*Leucophaea Maderae*) Brain." $1,760.00.
2. Dr. Gordon Weddle. "Life History and Resource Ecology of the Kentucky Snubnose Darter, *Etheostome rafenesquei.*" $1,255.00.
3. Dr. Paul McCormick. "Mechanisms of Benthic Algal Succession in Streams." $5,000.00
4. Ms. Jane Sisk. "The Psychological Types and Critical Thinking Abilities of Presidential Awardees in Mathematics and Science Teaching." $1,147.00.

C. **BOTANICAL GRANTS COMMITTEE.** Dr. Ron Jones made the report.

During the year, 1987, the Botanical Grants Committee reviewed and awarded 3 grant requests. Those receiving awards and their research are listed below.

1. Mr. Tom Bloom, Department of Biological Science, University of Kentucky. Population ecology study of *Arabis laevigata.* $383.76.
2. Mr. Richard G. Guetig, Department of Biological Science, Eastern Kentucky University. Floristic survey of Estill County. $500.00.
3. Mr. Jeffrey T. Grubbs, Department of Biological Science, Murray State University. Floristic survey of Hickman County. $500.00.

The total amount awarded was $1,383.76.

D. **SCIENCE EDUCATION COMMITTEE.** Dr. Gardella commented on the awards presented to the science fair winners and their sponsors at the annual banquet.

E. **MEMBERSHIP COMMITTEE.** Dr. Dahlman made the report.

A total of 68 individuals at 37 different Colleges, Universities, State Agencies and Private Organizations were contacted to serve as KAS Area Representatives at their respective work places. Each was provided with KAS application blanks, brochures, etc. A list of those individuals is attached and appreciation is expressed to each for their willingness to serve the Academy. The number of individuals contacted was increased over last year as the result of information obtained from the member survey conducted by President Giesmann. A total of 49 individuals indicated a willingness to serve on the Membership Committee.

We now have a total of 4 Corporate Affiliates, 2 of which resulted from the drive conducted late last year. President-Elect Hettinger intends to make this an area of emphasis during his term as President in 1988.

Formation of a collegiate level KAS program remains in the planning stages. We expect to see more tangible results in 1988.

Action was taken by the Board of Directors to strike the names from the membership list of anyone in arrears of their dues for more than 2 years. This action will be taken beginning in 1988. The total number of members as of 3 November 1987, that have paid dues at least through 1984 is 819. Of this number, 32 have paid only through 1984, 85 have paid only through 1985, 167 have paid only through 1986, 405 have paid through 1987, 73 have paid through 1988 and 7 have paid through 1989. The remainder of the 819 are Life and Emeritus Members. It should be noted that all individuals who have not paid their dues at least through 1988 will NOT receive copies of the 1988 *Transactions*. We have added 70 new members to the role since last year's meeting.

The Membership Committee strongly urges each member to serve as a committee of one in the recruitment of new KAS members.

Dr. Dahlmann also presented the following list of area representatives for the membership committee of KAS for 1988.

Alice Lloyd College
Jerry C. Davis
Ashland Petroleum Company
William Hettinger, Jr.
Bellarmine College
Thomas E. Bennett
Berea College
Thomas D. Strickler
Campbellsville College
Gordon K. Weddle
Franklin D. Cheatham
Centre College
Susan M. Studler
Cumberland College
W. Blaine Early
Dept. for Environmental Protection
Henry H. Lyon
Division of Water Quality-Frankfort
Ronald Houp
Eastern Kentucky University
Ted M. George
J. Allen Singleton
Donald L. Batch
Dan Varney
John L. Meisenheimer
Steve Falkenburg
T. J. Kubiak
Elizabethtown Community College
Charles C. Cantrell
Georgetown College
Thomas Seay
Hazard Community College
Valina Hurt
Henderson Community College
Cathy D. Hunt
Hopkinsville Community College
Mike McClure
Kentucky Geological Survey
Donald C. Haney
Kentucky State University
David E. Legg
Lees Junior College
Jonnie C. Blair
Madisonville College
Michael L. Trover
Morehead State University
Herbert Berry
Charles E. Mason
Steven Cody
Murray State University
Harold Eversmeyer
Tom J. Timmons
Northern Kentucky University
Carl Slater
Debra K. Pearce
Jerry Carpenter
Owensboro Community College
Lana K. Barrett
Paducah Community College
William F. Beasley, Jr.
Prestonburg Community College
Charles S. Robertson
St. Catherine College
Carolyn Clarke
Somerset Community College
James H. Anderson
Spalding University
Sister A. A. Green
Sue Bennett College
Lynn Allen
Thomas More College
Jack Wells
Transylvania College
J. Hill Hamon
Richard D. Honey
Union College
Ron Rosen
University of Kentucky
Ronald K. Atwood
Jerry M. Baskin
Paul H. Freytag
Douglas L. Johnson
Gerald I. Roth
Sam Turco
George B. Coltharp
T. Gregory McHone
Arthur J. Nonnoman
Donald E. Sands
University of Louisville
Manuel Schwartz
Robert M. Buchanan
Paul V. McCormik
Ronald Fell
Anne V. Noland
William D. Pearson
Western Kentucky University
Joe E. Winstead
Virginia J. Eaton
Frank Toman
Charles Hendrickson
Robert E. Simpson
Wood Hudson Cancer Research Lab
Julia H. Carter

F. **KENTUCKY JUNIOR ACADEMY OF SCIENCE.** Mr. Pat Stewart made the report.

Last year's operations culminated with the annual symposium being held at Eastern Kentucky University. Fifty-seven titles were scheduled of which 50 were read. Our other activities included Science-Bowl Competitions and refreshments at the conclusion of our organized activities. Science-Bowl winners included Notre Dame Academy (senior high division) and Beaumont Jr. High (junior high division).

The symposium was once again honored to have as special guests the KAS Executive Committee. This gave us an opportunity to show off our students who are actively involved in scientific research. We appreciate the fact that this was the third year for review by the KAS Executive Committee. We hope this will continue to be an annual part of the KJAS symposium.

Scholarships were once again offered by Cumberland

College and Western Kentucky University in conjunction with our "Outstanding Science Graduates" program.

This year promises to be another exciting year for KJAS. The data base has been established and we now have the capability to send personalized letters to our clubs. Our annual symposium is scheduled at Warren East High School on 29 and 30 April 1988.

G. **NOMINATING AND RESOLUTION COMMITTEE.** Dr. Kloek announced the results of the election for the new officers for 1988.

Vice President: Debra Pearce
Secretary: Virginia Eaton
Treasurer: Paul Freytag
Board of Directors: Blaine Early
Valgene Dunham

Dr. Kloek presented the following resolutions for consideration by the Academy.

Whereas the Kentucky Academy of Science has greatly enjoyed the gracious hospitality of Western Kentucky during this 73rd Annual Meeting of the Academy, *be it resolved* that we express our deep appreciation and gratitude to President Kern Alexander, Dean Charles Kupchella, and Dr. Joe Winstead and others who labored on local arrangements for their hard work and dedication in making this meeting a resounding success.

Whereas our Exhibitors have added substantially to the success of this meeting through their participation, *be it resolved* that a letter of thanks be sent by the Secretary to each participating company.

Whereas Dr. J. G. Rodriguez and his Constitution Revision Committee (Drs. Ted M. George and Gary W. Boggess) labored long and hard to effect improvements in our Constitution, *be it resolved* that the Academy extend to them our thanks.

Whereas President Larry A. Geismann, the other Officers, the Board of Directors, and the Committee Members of the Academy have labored diligently throughout 1987 to make the Academy programs a success, *be it resolved* that the members of the Academy extend them their gratitude for a job well done.

Whereas Dr. Robert O. Creek and Dr. Morris D. Taylor have served nine years in the offices of Secretary and Treasurer of the Academy, respectively, *be it resolved* that the members of the Academy hereby express their deep gratitude to them for their fine and faithful service.

A motion was made and passed to accept the resolutions as presented.

H. **AD HOC COMMITTEE ON SITE SELECTION.** Dr. Pearce reported that the committee has developed a manual on how to organize and conduct an annual meeting. This manual will be useful in standardizing future meetings. The committee also developed a form which will be used to screen potential annual meeting sites. The goal is to have annual meeting sites determined 3–5 years in advance. The meeting site for 1988 will be Eastern Kentucky University and for 1989, the 75th anniversary of the Academy, the University of Kentucky will be the host.

NEW BUSINESS

A REVISION OF THE ACADEMY CONSTITUTION AND BYLAWS. Dr. Giesmann went over the major changes as were highlighted in the cover letter that was sent to all members earlier. Following a short discussion a motion was made and passed to accept the revised Constitution and Bylaws.

SUMMARY OF ACADEMY'S ACTIVITIES IN 1987. Dr. Giesmann concluded his tenure as President by summarizing what had been accomplished during the past year. He discussed his theme "Service to and Through the Academy" and the goals that he had set for 1987.

The database has been started with close to 400 names entered. He feels that it will be extremely beneficial in obtaining names for offices and committee assignments. Dr. Giesmann said he would continue to handle the database information during his year as past president.

The necessity to improve the publication of the *Transactions* was accomplished by switching back to Allen Press. Vol. 48 (1987) was almost on schedule and Vol. 49 (1988) will be out on time.

The ad hoc Committee on Site Selection has worked hard on accomplishing the goal of setting up annual meeting sites 3–5 years in advance. A host handbook has been completed as well as a standardized form to be used in determining qualifications of prospective sites. Sites have been determined for the next 2 years with Eastern Kentucky University and the University of Kentucky serving as hosts. Future site selections should be determined by next year.

There was a continuing effort to obtain Institutional and Corporate Affiliations. At the present time there are 18 Institutional Affiliations and 3 Corporate Affiliations providing a total of $6,800. It is very important that these affiliations be maintained.

The acceptance of the revised Constitution and Bylaws by the members at this meeting has accomplished the goal of updating the Academy's Constitution.

Dr. Giesmann thanked everyone for their help in making the year a success then introduced the President for 1988, Dr. William Hettinger, Jr., and presented him with the gavel.

President Hettinger, upon accepting the gavel, addressed the Academy with the following acceptance comments.

"Larry, it is my pleasure to accept this gavel and to express my intent to carry on the exemplary traditions of you and other recent Presidents that I have had the pleasure of meeting and/or working with. In particular, I am referring to Charles Covell, last year's President, Joe Winstead who preceded him, and Gary Boggess, Rod Rodriguez, Ted George, John Philley and Charles Kupchella, to name a few. All have made fine contributions to the Academy and to Kentucky as well. You and they have all worked hard to obtain greater state recognition for the Academy, for science and education, and as these relate to the future intellectual and economic growth of the state. In this regard, Larry, you have especially made a number of remarkable contributions to the Academy this year. You have also displayed extraordinary leadership in the business affairs of the Academy, and always in good spirit and good humor.

I now have the distinct honor of acknowledging your many contributions to the Academy and, as the Academy's incoming President, to express for all of us our appreciation and thanks for a job well done. Please accept this plaque as a token of our high regard and thanks for a job well done.

Now the time has come for me to assume these many responsibilities, and I do so with a great deal of humility and trepidation. Larry's is a hard act to follow.

However, having had the pleasure of observing the Academy at work these past 5 or 6 years, and how enthusiastically the members respond to a call for help and assistance, I feel assured that you will all lend me a hand in this endeavor, because I certainly will need it.

The Academy is growing yearly in its vigor and scientific visibility in the state. I have no doubt that the role it will play in safeguarding, stimulating and advancing the cause of science and education, and as it also relates to economic growth of the state, will continue to increase steadily in the coming years.

As I've reflected on what goals or contributions I might be able to make or set for this coming year, the following thoughts arose.

1. With a new Constitution, and a new organizational structure, there will be a need to just get the ship on course and operating smoothly. Not only do we have a new constitution but we will also lose several key officers at this crucial time, who have been a very steadying influence and have provided outstanding leadership over the past 9 years, namely Bob Creek as Secretary and Morris Taylor as Treasurer. It will take time to regain the smooth operation they have provided. Hopefully, not too many things that we should do, and which they always reminded us to do, will drop between the cracks.

2. Also, it seems to me, and as it has to those who have come before, that we seek to obtain greater support, and more importantly greater affiliate membership from industry and participation from industrial and governmental scientists as well. Presently, out of more than 500 members, we have only 14 from industry and 19 from government, totaling about 7% participation. If government, academia and industry are to work more closely in the future, we need this interaction and participation. Therefore, an objective for the coming year, will be to try to gain more industrial affiliates, (we only have 3 at this time), and to double as a minimum, industrial and governmental membership, presentation of papers and attendance at annual meetings.

3. It seems to me, and I know I also speak for many of our past officers, that there is a need for the Academy to have a home. A place that can function not only to help our Academy grow and prosper, but one that will increase our visibility in the state. Therefore, I plan to explore what possibilities are open to us, to see if we might achieve such a goal, either in the coming year, and if not, then in a second or third year. Our new Constitution provides for an appointed Executive Secretary, which should also help administration of the Academy and tide us through the periods of transition from one administration to the next. Basically what we need are some bare essentials of a room, a phone so that the Academy can be reached easily, a desk and chair for our Executive Secretary and some space for files, Academy records and copies of the *Transactions*, in a central location in the state so as to properly house the Academy. This will be another goal for the year. Any suggestions or comments you may have, pro or con, will be most welcomed and very much appreciated.

4. Finally, I have noted that although those sections in the Physical, Mathematical and Computer Sciences Division are as active as those in the Biological Sciences, and Social Sciences and Science Education divisions at these meetings, there seems to be much imbalance in papers published in the *Transactions*. I'd like to learn more from all of you why this is so, and explore how we can achieve better balance in our journal. We have outstanding papers from the Biological Sciences and Social Science Education divisions. Can we find a way to also encourage more contributions in Chemistry, Physics, and Mathematics, to name a few, so as to achieve a better balance of representation of the Academy in the *Transactions*?

Thank you again for your warm welcome and this honor which you have bestowed on an Industrial Member of the Academy. I look forward to this year with great enthusiasm and encouragement and hope that I too can make a contribution to the continued growth of the Academy, scientifically, intellectually, spiritually and numerically."

With the conclusion of his remarks President Hettinger adjourned the meeting at 1020.

Robert Creek, Secretary
Kentucky Academy of Science

PROGRAM AND ABSTRACTS, ANNUAL MEETING

Kentucky Academy of Science
73rd Annual Meeting

Western Kentucky University
Bowling Green, Kentucky

6–7 November 1987

Officers of the Academy

Board of Directors

Program

Friday, 6 November 1987

0830–1115 *Coal and Petroleum Symposium,* Room 337, Environmental Sciences Building

1000–1200 *Community College Science Faculties,* Garrett Conference Center, Room 103, Garrett Conference Center Auditorium

1000–1200 *KAS Officers and Board Business Meeting,* Garrett Conference Center, Executive Dining Room

1200–1600 *Registration,* 1st Floor Garrett Conference Center

1200–1700 *Scientific Exhibits* 1st Floor Garrett Conference Center

1300–1500 *Sectional Meetings,* Garrett Conference Center and Environmental Sciences Building

1500–1530 *Coffee Break,* 1st Floor Garrett Conference Center

1530–1700 *Plenary Session,* Room 103, Garrett Conference Center Auditorium

1710–1845 *Social Gathering and Reception,* President's House

1900–2100 *Annual Banquet and Awards,* Garrett Conference Center Ballroom

2130–2330 *Hospitality Gathering,* Holidome, Midtown Holiday Inn

Saturday, 7 November 1987

0800–1000 *Registration,* 1st Floor Garrett Conference Center

0800–1200 *Scientific Exhibits*, 1st Floor Garrett Conference Center
0800–0900 *Sectional Meetings*, Garrett Conference Center and Environmental Sciences Building
0910–1030 *Annual Business Meeting*, Room 103, Garrett Conference Center Auditorium
1030–1200 *Sectional Meetings*, Garrett Conference Center and Environmental Sciences Building
1030–1600 *Symposium on Rare Plants of Kentucky*, Room 103, Garrett Conference Center Auditorium
1300–1700 *Sectional Meetings*, Garrett Conference Center and Environmental Sciences Building

PLENARY SESSION

Friday, 6 November

1530 Room 103, Garrett Conference Center Auditorium

Speaker: Dr. William C. DeVries
Director of the Artificial Heart Program
Humana Heart Institute International

ANNUAL BANQUET

Friday, 6 November

1930 Garrett Conference Center Ballroom

Speaker: Mr. Thomas J. Fitzgerald
Director
Kentucky Governmental Accountability Project
"Science and Politics in Environmental Policy Making"

ANTHROPOLOGY SECTION

John Hale, Chairperson, Presiding
Jim Murray Walker, Secretary
Room 104—Garrett Conference Center

Friday, 6 November 1987

1300 Reconstructing an Early Christian Population in Portugal. John Hale, University of Louisville.
1310 Evidence for Re-reading Petroglyphs of the Chaco Supernova Site. Robert Vallier, University of Tennessee, Chattanooga.
1320 Prehistoric Indians of Louisiana: Poverty Point Village. Dudley Yates, Kentucky Wesleyan College.
1330 ES-1: Pryse Cave in Estill County, Kentucky. Earl Robbins, Jr., Irvine, Kentucky.
1340 A Nurse's Approach to Cherokee Health Practices. Betty Wahlstedt (sponsored by Jim Murray Walker), Eastern Kentucky University.
1350 Auras, Pyramid Power, and Other Psychic or Paranormal Phenomena: A Scientific Appraisal. Rose Marie Helfrich (sponsored by Jim Murray Walker), Eastern Kentucky University.
1400 The Unknown Native Americans. Cara E. Richards, Transylvania University.
1410 A Social Scientist's View of U.S. Immigration at the Turn of the Century. Joel Roitman, Eastern Kentucky University.
1420 A Flatlander's Adjustment to Appalachia and "Appalachiaphiles." Jim Murray Walker, Eastern Kentucky University.
1430 Longitudinal Urban Studies in Monterrey, Mexico: An Update. James F. Hopgood, Northern Kentucky University.
1440 A Cross-Cultural Investigation of Crime and Deviation. Travis Eaton, Campbellsville College.
1450 The Washington-DuBois Ideological Conflict: Reflections on the Development of Instruction in Black Higher Education from 1900 to 1940. Alvin Seales, Kentucky State University.
1515 Coffee Break
1530 Plenary Session

Saturday, 7 November 1987

0900 Coffee Break
0910 Annual Business Meeting

BOTANY AND MICROBIOLOGY SECTION

Hal Bryan, Chairperson
Julian Campbell, Secretary, Presiding
Room 103—Garrett Conference Center

Friday, 6 November 1987

1300 Responses of the Naturalized Shrub *Lonicera maackii* to Clipping. James O. Luken, Northern Kentucky University.
1315 Man and the Biosphere Program: New Biosphere Reserve Proposal for Interior Low Plateau and Ozark Plateau Regions. Tom Forsythe, Tennessee Valley Authority, Land Between the Lakes.
1330 Designation of Wetlands by Weighted Averages of Vegetation Data. George P. Johnson, Lindsey Wilson College.
1345 Life-Forms of Ohio Flowering Plants. *James O. Luken* and John W. Thieret, Northern Kentucky University.
1400 Contribution to the Flora of Kentucky: *Castanea* (Fagaceae). George P. Johnson, Lindsey Wilson College.

1415 Kentucky *Crataegus*: Who's Afraid of the Big Bad Genus? Johnnie B. Varner, Georgetown College.

1430 Botanical Inventory of the Somerset District, Daniel Boone National Forest. *Julian Campbell*, University of Kentucky, and Max Medley, University of Louisville.

1445 Floristic Comparison of the Appalachian Rheophytic Boulder-Cobble Bar Communities on the Cumberland, Big South Fork and Rockcastle Rivers. *Max Medley*, University of Louisville, and Julian Campbell, University of Kentucky.

1500 Grazing-Nutrients Interactions and Their Influence on Benthic Algal Assemblages. Paul V. McCormick, University of Louisville.

1515 Election of Sectional Officers

1530 Plenary Session

Saturday, 7 November 1987

0800 Is *Aster sericeus* a Rare Plant of Kentucky? Ron Jones, Eastern Kentucky University.

0815 An Unusual Habitat Type for Three Rare Kentucky Plants. Edward W. Chester, Austin Peay State University.

0830 A Preliminary Report on the Taxonomic Status of *Arabis perstellata* Braun and its Varieties. Landon E. McKinney, Vanderbilt University.

0845 *Solidago albopilosa* E.L. Br.: A Species in Population Decline. *Johnnie B. Varner*, Theresa Phillips and Robby Hutchinson, Georgetown College.

0900 Coffee Break

0910 Annual Business Meeting

Julian Campbell, Presiding
Room 102, Garrett Conference Center

1030 A Botanical Inventory of Shawnee Run in the Kentucky River Palisades. Susan Moyle Studlar, Centre College.

1045 The Isolation and Identification of Filamentous Fungi from Distribution Systems, Ground Waters, and Hemodialysis Waters. *Tammy J. Liles* and Ted Pass, Morehead State University.

1100 Micropropagation of *Pinus strobus* L. Karan Kaul, Kentucky State University.

1115 Population Differentiation of Ragweed from Metal Mine Waste Dumps. Robin Kimmerer, Centre College.

1130 Sulfur Accumulation in the Wood of *Pinus echinata* Mill. from the Cumberland Plateau. *Darrell L. Ray* and Joe E. Winstead, Western Kentucky University.

1145 Temperature Tolerance of Forest Soil Seed Banks. *Gary Wade*, U.S. Forest Service, Berea, and Ralph Thompson, Berea College.

1200 Effects of Sodium Chloride on Beta-Hemolytic Streptococci. *Bola Fashola* and Larry P. Elliott, Western Kentucky University.

SYMPOSIUM ON RARE PLANTS OF KENTUCKY

Co-Sponsored by the Kentucky Academy of Science and the Kentucky Native Plant Society
Saturday, 7 November 1987
Room 103—Garrett Conference Center

1030 Introduction, Hal D. Bryan, Chairman, Botany and Microbiology Section, Kentucky Academy of Science.

I. *Habitats of Rare Plants*

1045 Some Rare Plants of Wetlands in Kentucky. Max Medley, University of Louisville.

1105 Some Rare Plants of Kentucky's Woodlands. John R. MacGregor, Kentucky Department of Fish and Wildlife Resources.

1125 Rare and Endangered Prairie Plants of Kentucky. Marc Evans, Kentucky Nature Preserves Commission.

1145 Unglaciated Eastern U.S. Endemics of Glades, Cliffs and Rockhouses in Kentucky, and their Geographical Distribution. Dr. Jerry M. Baskin, University of Kentucky.

II. *Ecology of Rare Plants*

1300 The Biology of *Leavenworthia*. Dr. Carol Baskin, University of Kentucky.

1320 Population Biology of a Rare Prairie Plant (*Silene regia*) in Ohio and Indiana. Dr. Eric Menges, Holcomb Institute, Butler University.

1340 The Ecology and Distribution of the Rare Endemic. Stephen P. Rice and Hal D. Bryan, Division of Environmental Analysis, Kentucky Transportation Cabinet.

1400 A Community Ecology and Life History Study of *Solidago shortii* (Short's goldenrod). David E. Buchele, University of Kentucky.

III. *Protection of Rare Plants*

1420 The Status of Plant Protection in Kentucky. Richard Hannan, Kentucky Nature Preserves Commission.

1440 The Plant Protection Program in Tennessee. Scott Gunn, Tennessee Department of Conservation.

1500 Plant Protection and the Federal Endangered Species Act. Robert Currie, Endangered Species Section, U.S. Fish and Wildlife Service.

IV. *Open Discussion*

1520–1600

CHEMISTRY SECTION

Vaughn Vandergrift, Chairperson, Presiding
Lowell W. Shank, Secretary
Room 337—Environmental Sciences and Technology Building

Friday, 6 November 1987

1300 Isotopic Tracer Studies of Alcohol Conversion. *Hossein Dabbaqh* and Burton H. Davis, Kentucky Energy Cabinet Laboratory.

1315 An Empirical Relation Between the Theory of Proton Spin Lattice Relaxation and the Stokes-Einstein Equation. *Charles A. Girard* and Ann Helton, Centre College.

1330 Development of An Automated Titration System. *John W. Shadrick* and Jeffrey E. Anderson, Murray State University.

1345 Dinuclear Molybdenum (II) Complexes Containing 5-Alkylthio-1,3,4-thiadiazole-2-thioate and Polydentate Ligand. *Michael L. Estes* and David A. Owen, Murray State University.

1400–1500 Recent Advances in Supercritical Fluid Chromatography, Theory and Applications. Mustafa I. Selim, Murray State University.

In this 1-hour lecture presentation, the basic theory and instrumentation of SFC will be described with a review of some applications from literature. The author will also describe his current research work in the area and its significance to the instrumental and theoretical development of supercritical fluid chromatography.

1500 Coffee Break

1530 Plenary Session. Lowell W. Shank, Secretary Presiding.

Saturday, 7 November 1987

0815 Stochastic Dynamics of Spontaneous Nucleation. Earl Pearson and *Tony Simpao*, Western Kentucky University.

0830 Solid Phase Extraction Cartridges for Simazine Analysis. Wm. D. Schulz and *Steven E. Baugh*, Eastern Kentucky University.

0845 Fuel Analysis of Fire Training Facility Wastewater. *Wm. D. Schulz* and Howard Mayfield, Eastern Kentucky University.

0900 Coffee Break

0910 Annual Business Meeting

1030 Synthesis of Poly-6-amino-3-chloro-2-benzo[b]thiophene Carboxylic Acid. Laychoo Lee, E. Wheeler Conover and *Larry J. Baldwind*, Cumberland College.

1045 The Hydrolysis of 2-Fluoro-1-methylpyridinium Iodide in Aqueous Sulfuric Acid. *Meng Jia Lun* and Oliver J. Muscio, Jr., Murray State University.

1100 Chemistry Section Meeting: Election of Officers.

1115 Interaction of Cyanide with Cobalt(II)-Phthalocyanine. *H. M. King, Jr.* and R. D. Farina, Western Kentucky University.

1130 Studies of the Lux Operon of *Xenorhabdis luminescens*. *Ed. B. Rucker*, T. Johnston and V. Vandergrift, Murray State University.

COAL AND PETROLEUM SYMPOSIUM

John T. Riley, Presiding
Room 337—Environmental Science and Technology Building

Friday, 6 November 1987

0830 Coal Sulfur Forms Analysis. *John T. Riley*, Gary M. Ruba and W. G. Lloyd, Western Kentucky University.

0845 Differential Scanning Calorimetry Studies of Wood. *Chris Howeltt*, Wei-Ping Pan and John T. Riley, Western Kentucky University.

0900 Heat Content of Coal. *Carlo Biones*, Wei-Ping Pan and Fred J. Hayes, Western Kentucky University.

0915 Co-Processing of Kentucky and Ohio Coals. *K. Tsai* and L. Xu, Kentucky Energy Cabinet Laboratory.

0930 Separation and Liquefaction of Coal Macerals. *R. Keogh*, S. Poe and D. Taulbee, Kentucky Energy Cabinet Laboratory.

0945 The Hydroliquefaction Potential of Micronized Coal. *Deborah W. Kuehn*, W. G. Lloyd and Dawn Ramsey, Western Kentucky University.

1000 Chemical Oxidation of Micronized Coal. Rita K. Hessley, Western Kentucky University.

1015 Coffee break

1030 High Performance Liquid Chromatographic Analysis of Oil Fractions of Some Liquefied Coals. *B. Chawla* and B. H. Davis, Kentucky Energy Cabinet Laboratory.

1045 Basic Nitrogen Compounds in Distillate Fractions of Coal Liquids. Rita H. Hardy, Kentucky Energy Cabinet Laboratory.

1100 Artificial Crosslinking of Coal Extracts. *Doug Kimbler* and Thomas K. Green, Western Kentucky University.

1115 Characterization of a Synthetic Coal via Analytical Pyrolysis. *John W. Reasoner*, Thomas K. Green and Marcia H. Downing, Western Kentucky University.

GEOGRAPHY SECTION

C. Michael Trapasso, Chairperson, Presiding
Wilma J. Walker, Secretary
Room 338—Environmental Sciences and Technology Building

Friday 6 November 1987

1300 Geography and Literature: A Case Study of Two Willa Cather Novels. *James L. Davis* and Nancy H. Davis, Western Kentucky University.

1315 Kentucky as Perceived and in Reality. William A. Withington, University of Kentucky.

1330 Journey to Work: The 1970 and 1980 Commuting Patterns of Kentucky Counties. *Wayne L. Hoffman* and James M. Bingham, Western Kentucky University.

1345 Measuring Metropolitan Activity: The Case of Kentucky's Largest Cities. Mark R. Bryant. Sponsor: James L. Davis, Western Kentucky University.

1400 The Changing Role of Bowling Green: A Time Series Analysis. Kenneth M. Baker. Sponsor: James L. Davis, Western Kentucky University.

1415 Chota; All-Black Pueblo in Ecuador. Mark Lowry II, Western Kentucky University.

1430 A Kaleidoscope of Colombia's Boundaries and Frontiers. Edmund E. Hegen, Western Kentucky University.

1445 Exploration and Mapping of Sistema Huautia: America's Most Significant Vertical Cave Exploration. James Harry Smith, Jr. Sponsor: Nicholas C. Crawford, Western Kentucky University.

1500 Coffee Break

1530 Plenary Session

Saturday, 7 November 1987

0800 Kentucky's Center of Excellence for Reservoir Ecology—A Geographer's Perspective. Neil V. Weber, Murray State University.

0815 The Geography of Cigarette Smoking in the United States. Edwin T. Weiss, Jr., Northern Kentucky University.

0830 Digital Geographic Information System Technology for the Commonwealth of Kentucky. *C. M. Cobb*, D. W. Eichert, L. A. Bartolucci and N. V. Weber, Murray State University.

0845 Women's Role in the Developing World: A Case Study. Wilma J. Walker, Eastern Kentucky University.

0900 Coffee Break

0910 Annual Business Meeting

1030 Regional Planning in Tropical Lands. Milos Sebor, Eastern Kentucky University.

1045 Trans-Himalayan Settlement Factors in Nepal. David N. Zurick. Sponsor: Wilma J. Walker, Eastern Kentucky University.

1100 Shifting Gears: Middle Atlantic Cities Changing Economies. Jefferson J. Beeckler. Sponsor: James L. Davis, Western Kentucky University.

1115 Development of an Economic Data Information Base: The Case of Richmond, Kentucky. David Groth. Sponsor: Milos Sebor, Eastern Kentucky University.

1130 State Geographer's Report

1145 Election of Sectional Officers

1200 Lunch

1300 Geographic Alliance Report.

1315 Temperature Extremes in Kentucky. Glen Conner and *Tony Fugate*. Western Kentucky University.

1330 A Comparison of Severe Historic Droughts in Kentucky, 1854–1904. *Conrad T. Moore* and Glen Conner, Western Kentucky University.

1345 The Sinking and Resurgence of Black Lick Creek, Auburn, Kentucky. David G. Blaize. Sponsor: Nicholas Crawford, Western Kentucky University.

1400 Down-Hole Video Camera: A New Tool in Applied Karst Hydrology. *Philip P. Reeder* and Nicholas C. Crawford, Western Kentucky University.

1415 Preliminary Investigation of the Association Between Radon Levels in Homes and Caves of Bowling Green, Kentucky. James W. Webster. Sponsor: Nicholas Crawford, Western Kentucky University.

1430 Statistical Sampling for Assessing Land Cover Classification Accuracy. *Burl I. Naugle* and William C. McGuyer. Sponsor: Neil V. Weber, Murray State University.

1445 Environmental Disruption and the Dendrochronology of the White Ash. *Layne Price Mason* and L. Michael Trapasso, Western Kentucky University.

Geology Section

Charles E. Mason, Chairperson, Presiding
Kenneth W. Kuehn, Secretary
Room 328—Environmental Sciences and Technology Building

Friday, 6 November 1987

1300 Paleontology and Stratigraphy of the Middle Silurian (Niagaran) Laurel Dolomite in Kentucky. *Richard Todd Hendricks,** University of Kentucky. Sponsored by Frank Ettensohn, University of Kentucky.

1315 Scolecodonts (annelid jaws) from the Lower New Providence Shale Member of the Borden Formation; Jefferson and Bullitt Counties, Kentucky. *Jeffery T. Stewart,** Charles E. Mason and R. Thomas Lierman, Morehead State University.

1330 Petroleum Exploration Techniques for Fractured Terrains in Kentucky. *Shaun A. Winter** and Kenneth W. Kuehn. Western Kentucky University.

1345 Coffee Break

1400 Internal Stratigraphy of the Borden Formation (Mississippian); Eastern and South-Central Kentucky. *Lawrence H. Howard,** Eastern Kentucky University. Sponsored by Roy C. Kepferle, Eastern Kentucky University.

1415 A comparison of Clay Mineral Assemblages from the Lower Borden Formation (Lower Mississippian) along the East and West Flanks of the Cincinnati Arch. *R. Thomas Lierman,** Jeffery T. Stewart and Charles E. Mason, Morehead State University.

1430 Depositional History of Murphy's Pond; A Freshwater Cypress Swamp in Hickman County, Kentucky. *W. Stanely Wilkerson** and Kenneth W. Kuehn, Western Kentucky University.

1445 Effects of Recent Volcanism Along Kilauea's East Rift One. Armin L. Clark, Murray State University.

1500 Coffee Break

1530 Plenary Session

*Denotes student paper.

Saturday, 7 November 1987

0815 Adsorption of Aromatic Hydrocarbons from Groundwater onto Quartz Sands. Janet Smith, Murray State University.

0830 Chesterian and Valmeyeran Stratigraphic Section at New Entrance, Mammoth Cave, Kentucky. Garre A. Conner, Petroleum and Engineering Geologist, Indianapolis, Indiana.

0845 Petroleum Geology of Eastern Kentucky. Graham Hunt, University of Louisville.

0900 Coffee Break

0910 Annual Business Meeting

1030 The Search for Jeptha Knob Iridium. *C. Ronald Seeger*, Western Kentucky University, Frank Asaro and Helen Michel, Lawrence Berkeley Lab, University of California, and Anne V. Noland, University of Louisville.

1045 A New Look at Conodonts from the Lower New Providence Shale Member of the Borden Formation; Jefferson and Bullitt Counties, Kentucky. *Charles E. Mason*, R. Thomas Lierman and Jeffery T. Stewart, Morehead State University.

1100 Mining Education: Is the Technical Component Sufficient Preparation for the Job Market? Alan D. Smith, Robert Morris College.

1115 Geometric and Kinematic Models of Fold-Thrust Structures. Steven I. Usdansky, Murray State University.

1130 Election of Geology Section Officers

PHYSICS SECTION

Vincent DiNoto, Presiding
Jack Wells, Secretary
Room 350—Environmental Science and Technology Building

Friday, 6 November 1987

1500 Coffee Break

1515 Plenary Session

Saturday, 7 November 1987

0800 Physics Project for High School Students. Dewey Beadle, Seneca High School.

0815 Kinematics Using the PASCO Sonic Ranger. Dewey Beadle, Seneca High School.

0830 Air Pulse Well Pump. William G. Buckman, Western Kentucky University.

0845 Initial Studies of Radon Gas at Mammoth Cave National Park with Activated Carbon Canisters. *Vincent DiNoto*, Jefferson Community College, and John Swez, Indiana State University.

0910 Annual Business Meeting

1030 Clustering of Galaxies. *Philip Price* and Suketa Bhavsar, University of Kentucky.

1045 A Stellar Association with Infrared and Radio Molecular Emission, *Lauri Wardell* and Frank O. Clark, University of Kentucky.

1100 Infrared Emission from Dust Surrounding Bi-Polar Flows from Young Stars. Frank O. Clark, University of Kentucky.

1115 Microcomputer Control of the Starlight-1 Photometer for High Speed Occultation Measurements. William S. Wagner, Northern Kentucky University.

1130 Scanning Tunnelling Microscope. P. J. Ouseph, University of Louisville.

1145 Preparation of High-Tc Superconductors. P. J. Ouseph, University of Louisville.

1200 Lunch

1300 Non-Spherical Sm and Pm Nuclei. Bernard D. Kern, University of Kentucky.

1315 New Determination of Terrestrial Aerosol Characteristics which Show a Smaller Depletion of Ozone. Is the Freon Legislation Aimed at the Wrong Culprit? James O. Manning, Cumberland College, and Frank O. Clark, University of Kentucky.

1330 Ozone, Current Developments. Frank O. Clark, University of Kentucky.

1400 Teaching Conceptual Physics. Lester Evans, Tates Creek High School, and Douglas Jenkins, Warren Central High School.

1500 KAPT Business Meeting
Election of Sectional Officers

PHYSIOLOGY, BIOPHYSICS BIOCHEMISTRY AND PHARMACOLOGY

Nancy Alsip, Chairperson, Presiding
John J. Just, Secretary
Room 402—Enviromental Sciences and Technology Building

Friday, 6 November 1987

1300 Electrical Stimulation Effects on Atrophied Rat Muscle. *K. A. Mook* and R. D. Fell, University of Louisville.

1315 Hormonal Modulation of Panting in the Desert Iguana. *E. C. Wurster* and E. C. Crawford.

1330 Histamine-Induced Arteriolar Dilation May Not be Mediated by Endothelium Derived Relaxing Factor (EDRF). *P. Zhang*, N. Alsip and P. Harris, University of Louisville.

1345 Composition and Function of Urine in the Developing Bullfrog. *J. L. Goldsmith* and J. J. Just, University of Kentucky.

1400 *In vitro* Responses to Antidiuretic in the Developing Amphibian Urinary Bladder. *T. L. Powell* and J. J. Just, University of Kentucky.

1415 Localization of Facilitated Diffusion and Active Glucose Transport in Cysticercoids of *Hymenolepis diminuta*. *R. Rosen* and G. Uglem, Union College and University of Kentucky.

1430 An Extract of Endophyte Infected Tall Fescue Seed and its Effect on Laboratory Rodent Models. *D. R. Varney*, Z. A. Ruhman, M. R. Siegel and P. M. Zavos, Eastern Kentucky University and University of Kentucky.

1445 Suckling of Mouse Pups from Dams Fed Tall Fescue Seed. *D. R. Varney*, L. A. Wiles, M. R. Siegel and P. M. Zavos, Eastern Kentucky University and University of Kentucky.

1500 Election of Sectional Officers

1515 Coffee Break

1530 Plenary Session

Physiology, Biophysics, Biochemistry and Pharmacology

Nancy Alsip, Chairman
John J. Just, Secretary

Botany and Microbiology Section

Hal Bryan, Chairman
Julian Campbell, Secretary
T. L. Powell, Presiding

Saturday, 7 November 1987

0900 Coffee Break

0910 Annual Business Meeting

1030 Isolation and Partial Characterization of Topoisomerase from the Hypocotyl Region of Etiolated Soybeans. *R. B. Dye* and V. L. Dunham, Western Kentucky University.

1045 Partial Characterization of DNA Polymerase *a* from Soybean (*Glycine max*) and Turnip (*Brassica rapa*). *D. R. Hill* and V. L. Dunham, Western Kentucky University.

1100 The Effects of Manganese Toxicity on Isocitrate Dehydrogenase Activity. *J. W. Pfeiffer* and F. R. Toman, Western Kentucky University.

1115 Effects of Mg^{++} and EDTA on Microsomal UDP-Glucuronosyltransferase Activity. *R. F. Volp* and C. Dietsch, Murray State University.

1130 Basic Molecular Biology: A Computational Educational Experience. *A. K. Raby*, L. L. Wheeler, V. L. Dunham and J. Crenshaw, Western Kentucky University.

1145 Recognition Sequences: A Sequence Searching Software Package. *L. L. Wheeler*, A. K. Raby, V. L. Dunham and J. Crenshaw, Western Kentucky University.

1200 Closing Comments. J. J. Just, Sectional Secretary.

Science Education Section

Curtis C. Wilkins, Chairperson
Earl F. Pearson, Secretary, Presiding
Room 105—Garrett Conference Center

Friday, 6 November 1987

1300 Teaching Chemistry by Closed-Circuit Television—Personal Observations. David R. Hartman, Western Kentucky University.

1315 Charles Babbage: Father of the Computer. Norman W. Hunter, Western Kentucky University.

1330 An Analysis of Student Performance in Freshman Chemistry. Norman W. Hunter and *Jeff Timmons*, Western Kentucky University.

1440 Comparative Study of Environmental Education in Britain and the United States. Ron Gardella, Northern Kentucky University.

1500 Coffee Break

1530 Plenary Session

Curtis C. Wilkins, Presiding

Saturday, 7 November 1987

0900 Coffee Break

0910 Annual Business Meeting

1030 The WKU SPAN Chemistry Program. Larry C. Byrd, Western Kentucky University.

1045 SPAN Chemistry—A High School Perspective. Steve Zimmer, Warren East High School.

1100 Science Education Section Meeting—Election of Officers

1115 A New Approach to Descriptive Chemistry in the Classroom—Organization and Description. Earl F. Pearson, *Curtis C. Wilkins* and Norman W. Hunter, Western Kentucky University.

1130 A New Approach to Descriptive Chemistry in the Classroom—Examples. *Earl F. Pearson*, Curtis C. Wilkins and Norman W. Hunter, Western Kentucky University.

Psychology Section

Bruce Mattingly, Chairperson, Presiding
Robert Adams, Secretary
Room 349—Environmental Sciences and Technology Building

Friday, 6 November 1987

1300 Comprehension Monitoring in the Mildly Mentally Retarded: A Study on Eye Movements and Their Relationship to Information Intake and Evaluation. Melissa G. Whitfield, Murray State University. Sponsored by Terry R. Barrett.

1315 A Survey of the Educational Effectiveness of Museum Displays at the Woodlands Nature Center in Land Between the Lakes. Lili A. Anderson, Murray State University. Sponsored by Terry R. Barrett.

1330 The Behavioral Effects of Propanolol and Isoproteranol in Pregnant Rats on Their Offspring. Philip J. Luecke, Murray State University. Sponsored by Terry R. Barrett.
1345 Examining the Stress-Illness Model by Weighing Life Events of Adults Over 65. Judy C. Hayes, Murray State University. Sponsored by Terry R. Barrett.
1400 The Effects of Task Difficulty and Practice Time in Comparing Competence of Subjects. Michael A. Porta, Murray State University. Sponsored by Terry R. Barrett.
1415 Effects of Positive Affect on Problem Solving Tasks. Victoria Passaflume, Murray State University. Sponsored by Terry R. Barrett.
1430 The Effects of Chronic Propranolol Treatment on Aggressive Behavior in Dominant and Submissive Rats. Dana J. Jones, Murray State University. Sponsored by Terry R. Barrett.
1445 The Effect of Olfactory Stimulation on Recall. Kenneth Foster, Murray State University. Sponsored by Terry R. Barrett.
1500 Coffee Break
1530 Plenary Session

Saturday, 7 November 1987

0800 Effects of Sulpiride on the Development of Apomorphine-Induced Sensitization. *Billie Jo Hatton*, Bruce A. Mattingly and John White, Morehead State University.
0815 Effects of Repeated Apomorphine Treatments on Locomotor Activity and ^{3}H-Spiroperidol Receptor Binding in Rats. *James R. Rowlett*, Bruce A. Mattingly and Michael T. Bardo, Morehead State University.
0830 How Do I Need Thee? Let Me Count the Ways. A Look Into Why People Need Religion. Jodi K. Walker, Murray State University. Sponsored by Terry R. Barrett.
0845 Examining Awareness of Land Between the Lakes. Tracy S. Bell, Murray State University. Sponsored by Terry R. Barrett.
0900 Coffee Break
0910 Annual Business Meeting
1030 Imagery Effects on Eyewitness Susceptibility to Misleading Postevent Information. Julie M. Hicks, Murray State University. Sponsored by Terry R. Barrett.
1045 Auditory Hallucinations and Mental Imagery. Lori Burkeen, Murray State University. Sponsored by Terry R. Barrett.
1100 Children's Understanding and Ability to Create Class-Inclusion Hierarchies. Brigette R. Oliver, Murray State University. Sponsored by Terry R. Barrett.
1115 Do Blonds have More Fun? Bryan Bush, Murray State University. Sponsored by Terry R. Barrett.
1130 Individual Differences in Age-Related Recall Deficits: More Evidence. Terry R. Barrett, Murray State University.
1145 Evolution: Attitudes and the Effects of Exposure. Mike Daniel, Murray State University. Sponsored by Terry R. Barrett.
1200 Lunch
1300 The Relationship of Personality Characteristics and Group Size to Perceptions of Television Violence. *M. Shannon Mackie*, Ragan D. Schriver and Maria S. McLean, Thomas More College.
1315 Alcohol Abuse Opinion Survey of College Students and Recovering Alcoholics. Peggy D. Blanton, Eastern Kentucky University. Sponsored by Richard J. Shuntich.
1330 The Role of Sign Stimuli in Human Aesthetic Judgments. *Jack Thompson* and Tammy Day, Centre College.
1345 The Validity of LD/EMH Placement Tests. Tracy Burnham, Centre College. Sponsored by Jack Thompson.
1400 Break
1415 Stereotypy of a Spatial Operant and the Law of Effect. George Hiller, Morehead State University. Sponsored by Bruce A. Mattingly.
1430 Assessment of Interpersonal Skills: The Interpersonal Problem Solving Assessment Technique. Steven G. Cody and Amy Lighthizer, Morehead State University.
1445 Haloperidol Blocks the Development of Behavioral Sensitization to Apomorphine. *John White*, Bruce A. Mattingly and James R. Rowlett, Morehead State University.
1500 Behavioral Sensitivity to Apomorphine Following Chromic Sulpiride Treatments. *Jamison Graff*, Bruce A. Mattingly and Billie Jo Ratton, Morehead State University.

SOCIOLOGY SECTION

Craig Taylor, Co-chairperson, Presiding
Reid Luhman, Co-chairperson
Room 107—Garrett Conference Center

Friday, 6 November 1987

1300 The Politics of Water in Kentucky. Allen Singleton, Eastern Kentucky University.
1320 From Closed to Open Shop: Unionization Struggles in Southeastern Kentucky and the 1922 Coal Strike. Alan Banks, Eastern Kentucky University.
1340 Dilemmas of Feminist Practice in Rural Communities. Karen Tice, Western Kentucky University.
1400 Language Survival in Ethnic Stratification. Reid Luhman, Eastern Kentucky University.
1500 Coffee Break
1530 Plenary Session

Saturday, 7 November 1987

0900 Coffee Break
0910 Annual Business Meeting

ZOOLOGY AND ENTOMOLOGY SECTION

Blaine R. Ferrell, Chairperson, Presiding
Barbara A. Ramey, Secretary
Room 442—Environmental Sciences and Technology Building

Friday, 6 November 1987

1300 Responses of the Amphipod, *Gammarus pseudolimnaeus*, to Experimental Infections with the Acanthocephalan, *Pomphorhynchus bulbocolli*. Larry N. Gleason, Western Kentucky University.
1315 Fishes of Murphy's Pond, a Cypress Swamp in Western Kentucky. Tom J. Timmons, Murray State University.
1330 The Insect Fauna of Kentucky: A Status Report. Charles V. Covell, Jr., University of Louisville.
1345 Circadian Changes in Ommatidial Structure in the Cockroach, *Leucophaea madera*. *Becky Green*, Signe Hamlin, Rodney McCurry and Blaine Ferrell, Western Kentucky University.
1400 Sensory Stimuli Involved in Eliciting Agonistic Behavior in the Northern Fence Lizard, *Sceloporus undulatus*. Kathy Taylor and *Blaine R. Ferrell*, Western Kentucky University.
1415 Aggressive Behavior in the Cumberland Plateau Salamander, *Plethodon kentucki*. *Donna L. Delpont* and Paul V. Cupp, Jr., Eastern Kentucky University.
1430 Development of Sequential Sampling Plans for the Alfalfa Weevil. *Robert J. Barney* and David E. Legg, Kentucky State University.
1445 Value of Validating Decision-Making Models: Alfalfa Weevil as an Example. David E. Legg and *Robert J. Barney*, Kentucky State University.
1500 Election of Sectional Officers
1515 Coffee Break
1530 Plenary Session

Barbara A. Ramey, Presiding

Saturday, 7 November 1987

0800 Teratogenic Effects of Zinc on Developing Fathead Minnows, *Pimephales promelas*. A Preliminary Report. Barbara A. Ramey, Eastern Kentucky University.
0815 Toxicological Studies on a Novel Group of Nicotine Alkaloids. *Jeffrey H. Botkin*, Davy Jones, Deborah Scarborough, Ray Severson and Michael Jackson, University of Kentucky.
0830 Relationship Between Plant Age, Endophyte Infection and Loline Alkaloid Concentration to Aphid Survival on Tall Fescue. *Herbert Eichenseer* and Douglas L. Dahlman, University of Kentucky.
0845 Effect of Redbud Leaf Powder and Nitrogen Concentration on Growth and Development of *Heliothis virescens* Larvae. *Douglas L. Dahlman* and Latasha Felder, University of Kentucky.
0900 Coffee Break
0910 Annual Business Meeting
1030 The Nuclear Matrix of Normal and Baculovirus-infected Insect Cells. *Kathleen H. Price* and Marijo E. Wilson, University of Kentucky.
1045 Predator Response to the Escape Mechanisms of Their Prey: *Nabis roseipennis* and *Orius insidiosus* versus the Green Cloverworm. Dottie J. Clements and K. V. Yeargan, University of Kentucky.
1100 An Equilibrium Model of Protistan Colonization in Barren Aquatic Systems. Paul V. McCormick, University of Louisville.
1115 Korean (Epidemic) Hemorrhagic Fever: Aerosol vs. Vector-borne Transmission. Allen N. Hunt, Elizabethtown Community College.
1130 The Life History of the Orangefin Darter *Etheostoma bellum* in South Fork Green River, Kentucky. William L. Fisher, University of Louisville.

MATHEMATICS AND COMPUTER SCIENCE SECTION

Russel M. Brengelman, Chairperson, Presiding
John Crenshaw, Secretary

Computer Science Session
Room 204—Garrett Conference Center

Friday, 6 November 1987

1500 Coffee Break
1530 Plenary Session

Saturday, 7 November 1987

0800 Use of Computers in Medicine. Sylvia Pulliam, Western Kentucky University.
0815 Programming Applications: A Case Study in Advanced COBOL. Angela R. Keith, Elizabethtown Community College.
0830 Using Software Engineering Principles to Develop Computerized Instructional Software. Richard A. Rink, Eastern Kentucky University.
0845 Computer Security: What's New. Marlene Campbell, Murray State University.
0900 Coffee Break
0910 Annual Business Meeting
1030 Profiles in Pascal: Where Does the Time Go? John Crenshaw, Western Kentucky University.
1045 An Introduction to Object-Oriented Programming. John D. McGregor, Murray State University.
1100 A Look at Modula-2. Carol Wilson, Western Kentucky University.

1115 Expert Systems. Tom Cheatham, Western Kentucky University.
1130 TURBO BASIC by Borland vs. BASICA. *Darrell H. Abney* and Jean P. House, Maysville Community College.
1145 Debugging PC Assembler with Public Domain Software. Virginia Eaton, Western Kentucky University.
1200 Sectional Business Meeting

MATHEMATICS AND COMPUTER SCIENCE SECTION

Russel M. Brengelman, Chairperson
John H. Crenshaw, Secretary

Mathematics Session

Carroll Wells, Presiding
Room 205—Garrett Conference Center

Friday, 6 November 1987

1300 The History and Uses of "e." John Brevit, Western Kentucky University.
1315 Statistical Process Control—Transformation of American Industry. Linda Howard, Elizabethtown Community College.
1330 Some Properties of Hermite Polynomials. Joseph Stokes, Western Kentucky University.
1345 a,b-Paired Sets of Integers. Kyle Wallace, Western Kentucky University.
1400 The Size of Sums of Sets. Bettina Zoeller, Western Kentucky University.
1415 Lies, Spies, AIDS, and Drugs: Mathematical Consequences of Mass Testing. Barry Brunson, Western Kentucky University.
1430 Compactifications of Ordered Euclidean Spaces. Tom Richmond, Western Kentucky University.
1445 Green's Function and Reduction of Differential Equations to Integral Equations. Nexam Iraniparast, Western Kentucky University.
1500 Coffee Break
1530 Plenary Session

Saturday, 7 November 1987

0800 Perpendicular Least Square Estimators. Brian Anderson, Monroe County High School.
0815 Using a Microcomputer in Teaching Calculus. Stephen Jacobs, Western Kentucky University.
0830 Math Enrichment for Gifted Middle School Students. Hope Richards, Western Kentucky University.
0845 Using the Sylvester Eliminant in Row Reduction of Matrices. B. Pauline Lowman, Western Kentucky University.
0900 Coffee Break
0910 Annual Business Meeting
1030 Homotopy Lifting. Carroll Wells, Western Kentucky University.
1045 Two Observations of a Single Note. James Barksdale, Western Kentucky University.
1100 How Long is Long? John Spraker, Western Kentucky University.
1115 Sorted Integers. Glen Powers, Western Kentucky University.
1130 Sectional Meeting for Election of Officers.

COMMERCIAL EXHIBITORS SCHEDULED FOR 1987 KAS MEETING

Over 24 Scientific, Commercial and Educational Service Companies have reserved exhibitor space in the Garrett Conference Center for the 73rd Annual Meeting of the Academy. If you have specific equipment, publishing, textbook or other technical needs, an examination of the following list might provide the opportunity to schedule an appointment in advance for consultation.

Ashland Petroleum Co.
Carbon Fibers Division
Ashland, KY 41101

Bicron Corporation
12345 Kinsman Road
Newbury, OH 44065

Dixie Irrigation Company
4045 McCollums Court
Louisville, KY 40218

Eberline Instrument Corp.
P.O. Box 23087
Fayetteville, GA 30214

EG&G Ortec
100 Midland Road
Oak Ridge, TN 37830

Educational Activities, Inc.
1937 Grand Avenue
Baldwin, NY 11501

Huntington Laboratories
1658 Bristow Road
Bowling Green, KY 42101

IBM Corporation
1733 Harrodsburg Road
Lexington, KY 40504

Johnson Controls, Inc.
1808 Cargo Court
Louisville, KY 40299

Kinko's Copies
846 Old Scottsville Road
Bowling Green, KY 42101

Lee Allen & Associates
8746 E. 33rd Street
Indianapolis, IN 46226

Lone Star Computer
Corporation
18601 LBJ Freeway, Suite 330
Mesquite, TX 75150

Ogle Equipment Sales
P.O. Box 23087
Louisville, KY 40223

Premium Seed & Horticulture Supply
915 E. Jefferson Street
Louisville, KY 40206

Radio Shack Computer Center
214 Greenwood Mall
Bowling Green, KY 42101

Rohn Agri Products
P.O. Box 2000
Peoria, IL 61656

Scantron Corporation
10101 Linn Station Rd., Sta. 340
Louisville, KY 40233

Sargent-Welch Scientific Company
7300 North Linder
Skokie, IL 60077

The Carpenter Lithographing Co., Inc
P.O. Box 1385
1913 Commerce Road
Springfield, OH 45504

Teacher Insurance & Annuity Assoc.
730 Third Avenue
New York, NY 10017

United States Navy Engineer Officers Program
1619 Foxhaven Drive
Richmond, KY 40475

VWR Scientific
P.O. Box 66920
O'Hare AMF
Chicago, IL 60666

Watcom Products, Inc.
415 Phillip Street
Waterloo, Ontario
Canada N2L3X2

Wright Line, Inc.
7003 Chadwick Drive,
#281
Brentwood, TN 37027

Host Committee for 73rd Annual Meeting

Dr. Wayne Hoffman, Department of Geography/Geology
Dr. Charles Kupchella, Dean, Ogden College of Science,
Technology and Health

Dr. Rudy Prins, Department of Biology

Mr. Lynn Greeley, Ogden College of Science,
Technology and Health

Dr. Joe E. Winstead, Department of Biology

Trans. Ky. Acad. Sci., 49(1–2), 1988, 56–60

Abstracts of Some Papers Presented at the 1987 Meeting

ANTHROPOLOGY

A cross-cultural investigation of crime and deviance. TRAVIS EATON, Division of Social Sciences, Campbellsville College, Campbellsville, KY 42718.

The following topics were addressed in this presentation: (1) the significance of the study of crime and criminal law to anthropology, (2) some problems of doing cross-cultural research on crime, and (3) various contributions that can be made by conducting multi-cultural investigations of criminal and/or deviant behavior. Attention especially was focused on the last of these themes. By analyzing recent published research from a variety of disciplines (e.g., anthropology, criminal justice, history, political science, and sociology), the author identified at least 10 distinct ways in which inquiries of this type can be of both theoretical and practical relevance.

Longitudinal urban research in Monterrey, Mexico: an update. JAMES F. HOPGOOD, Anthropology Program, Department of Social Sciences, Northern Kentucky University, Highland Heights, KY 41076.

An urban ethnographic research project begun in 1971 is continuing as a longitudinal study of sociocultural adaptive strategies of a sector of the urban poor and their structural and organizational responses in Monterrey, a major metropolitan and industrial center of over 2 million population in Mexico's northeast. Persistence of certain types of neighborhood associations is a continuing research interest. Preliminary assessment of problems associated with long-term research indicate several advantages, disadvantages, and constraints in such areas as tracking of informants and maintenance of contacts, field terminology and data definition consistency, data collection management, and control of appropriate contextual variables.

Poverty Point, a prehistoric village. DUDLEY YATES, Director of the Library Learning Center and Chairman, Library and Audio Visual Services Department, Kentucky Wesleyan College, Owensboro, KY 42302-1039.

Poverty Point is the earliest large-scale earthwork in America and the most significant site in the Poverty Point Culture, which existed in the lower Mississippi Valley from about 2000 B.C. to 700 B.C. The 6,000 inhabitants constructed a complex village consisting of 6 rows of semi-octagonal concentric ridges ranging from about 2,000 to 4,000 ft in diameter. West of the ridges is a gargantuan bird-shaped mound 70 ft high, measuring 640 ft along the wing and 710 ft from head to tail. Remarkably, these Late Archaic people engaged in distant trading and existed on this site for hundreds of years as a hunter-gatherer society.

BOTANY & MICROBIOLOGY

An unusual habitat type for three rare Kentucky plants. EDWARD W. CHESTER, Department of Biology, Austin Peay State University, Clarksville, TN 37044.

Three rare Kentucky vascular plants grow on mudflats of an upland, temporarily ponded depression on the Pennyroyal Plain of Christian County. The site represents the only known Kentucky location for 2 taxa: *Echinodorus tenellus* (Mart.) Buch. and *Scirpus hallii* Gray. The 3rd taxon, *Heteranthera limosa* (Sw.) Willd., is a threatened species scattered over the state. Within an agricultural field and ponded in spring and early summer 1983 and 1984, receding water levels in July and August with complete drying in September allowed extensive colonies of the subject taxa to develop on the silty, muddy flats. Below normal rainfall permitted cultivation of rowcrops during 1985–1987, and no development of the species occurred. The number of plants present during normal precipitation years suggests an extensive seed bank. Studies elsewhere have shown that the 1st 2 species are especially well adapted to such ephemeral, unstable habitats and that seeds may survive for a number of years until conditions for germination are met. Observations in future years when rainfall is normal will probably show a return of these taxa.

Effects of sodium chloride on beta-hemolytic streptococci. BOLA FASHOLA* and LARRY P. ELLIOTT, Department of Biology, Western Kentucky University, Bowling Green, KY 42101.

Various investigations have proven beta-hemolytic streptococci groups A, B, and C as the main causes of streptococcal pharyngitis. The drug of choice for treatment of this infection is Penicillin G. However, a common home remedy involves the use of salt water for gargling. Experiments were conducted to study the effects of NaCl on beta-hemolytic streptococci groups A, B, and C. MICs of NaCl in Tryptic Soy Broth were determined, and such concentrations caused alterations of the ultrastructure of the streptococci as evidenced by EM. NaCl caused condensation of nucleoid DNA and some loss of ribosomes followed by dissolution of the cell contents.

The effect of grazing by the snail *Goniobasis* on benthic algal assemblages in different nutrient environments. PAUL V. MCCORMICK, Department of Biology, University of Louisville, Louisville, KY 40292.

In this in situ experiment, stream algal assemblages were allowed to develop on glass coverslips for 19 d under conditions of enrichment with (1) phosphate, (2), nitrate, or (3) no nutrient in 250-ml enclosures containing snail densities of 0, 40, 80, 120, or 160 snails/m^2. Total cell density and community biovolume decreased monotonically with increased grazing in unenriched and nitrate enriched samples, whereas the response was nonmonotonic in the phosphate enriched environment. A transition through 3 community types along the grazing gradient was also affected by nutrient levels: a moderately grazed community that developed in control and nitrate enriched samples never became dominant in phosphate enriched samples, and a prostrate community observed at high snail densities in other nutrient treatments showed little development in nitrate-enriched samples.

Sulfur accumulation in the wood of shortleaf pine (*Pinus echinata* Mill.) from the Cumberland Plateau of Kentucky. DARRELL L. RAY* and JOE E. WINSTEAD, Department of Biology, Western Kentucky University, Bowling Green, KY 42101.

Two populations of shortleaf pine from Rowan and Laurel counties, Kentucky, show almost doubled sulfur accumulation in wood formed during 1982–1986 compared to xylem produced between 1962 and 1965. Wood tissue in the 1982–1986 growth years showed from 0.06 to 0.11 mg S/g dry wt in 12 samples from 3 different trees compared to lower levels of 0.03–0.06 mg S/g in 10 samples formed in the trees between 1962 and 1965. Higher averages of sulfur (0.12–0.14 mg/g) were found in wood representing 1957–1986 growth in a Jackson County population. Atmospheric sulfur deposition in Kentucky is accumulating in shortleaf pine biomass.

CHEMISTRY

Fuel analysis of fire training facility wastewater. WILLIAM D. SCHULZ,* Department of Chemistry, Eastern Kentucky University, Richmond, KY 40475, and HOWARD MAYFIELD, RDVC, USAF Engineering Services Center, Tyndall AFB, FL 32403.

Live-fire training is a necessary U.S. Air Force activity. Wastewater from training pits contains unacceptable levels of JP-4 fuel and "aqueous film forming foam" (AFFF) fire fighting agent. Fuel and AFFF components mutually interfere in analytical methods. Solid phase extraction (SPE) C-18 cartridges were used to extract JP-4 components. Gradient water-methanol elution isolated JP-4 components and many AFFF components for GC-MS analysis. Fuel separators reduce AFFF component concentration by removing solubilizing agent ("butyl carbitol") from water. Fuel component concentrations up to 10 times pure water equilibrium (50 mg/liter) values are still found in effluent water.

Solid phase extraction cartridges for Simazine analysis. WILLIAM D. SCHULZ and STEVEN F. BAUGH,* Department of Chemistry, Eastern Kentucky University, Richmond, KY 40475, and U.S. Forest Service Co-op Education Program, Berea, KY 40403.

Simazine herbicide is widely used in surface mine reclamation. Persistence and migration under such conditions are unknown. Studies conducted by the U.S. Forest Service are hampered by costly and tedious standard analytical methods. Simple, rapid, inexpensive methods for sample clean-up and concentration, utilizing commercial "solid phase extraction" (SPE) cartridges, have been developed. Phenyl (poly)siloxane cartridges and methanol elution were used for water samples. Recovery rates were greater than 90% for 0.05–5.00 ppm Simazine spiked water samples. No interferences were present with even very dirty pond water. Standard deviation (10%) was consistent with the G.C. injection mode.

COAL AND PETROLEUM

Determination of compound class composition of oil fractions of some liquefied coals by liquid chromatography. B. CHAWLA* and B. H. DAVIS, Kentucky Energy Cabinet Laboratory, P.O. Box 13015, Lexington, KY 40512.

A high-performance liquid chromatography method for quantification of the compound class composition (such as saturates, aromatics and polars) of the oil solubility class (pentane soluble fractions of coal liquids) has been developed. The method utilizes bonded cyanosilane and aminocyanosilane columns and mixtures of benzene in normal hexane and tetrahydrofuran in methyl tertiary butyl ether solvent systems. A Tracor LC-rotating disc flame ionization detector was used to quantify the chromatographic peaks. Oil fractions of parent coals, extracted coals and demineralized coals of different rank liquefied at 3 temperatures (385°, 427° and 445°C) were analyzed for the compound class compositions. The results showed systematic trends in the percentages of saturates, aromatics and polars with the changes in liquefaction temperature and coal rank, etc.

GEOGRAPHY

A comparison of severe historic droughts in Kentucky, 1854–1904. CONRAD T. MOORE* and GLEN CONNER, Department of Geography and Geology, Western Kentucky University, Bowling Green, KY 42101.

Early weather records, newspaper accounts, and other historic documents were examined for references to severe droughts prior to the 1930s. Of the 8 identified, information sufficient for comparison was available for 5 occurring after 1850. Four with markedly adverse agricultural and social consequences resulted from a combination of record or near-record temperatures and moderate to substantial precipitation deficiencies. In 1904, temperatures were normal, but significant precipitation deficits from January through September followed by an extreme lack of precipitation in October and November produced a water famine never before experienced in the Commonwealth.

Perception and reality in Kentucky—1811. WILLIAM A. WITHINGTON, Department of Geography, University of Kentucky, Lexington, KY 40506-0027.

Kentucky throughout its post-Indian exploration and settlement years by Virginians and others has been described by a variety of tall tales, truths, and garbled folk knowledge, including an early conceptualization of Kentucky as an American "Eden." This discussion uses Jedidiah Morse's statement on Kentucky in his abridged 14th edition of *American Universal Geography*, published 1st in New Haven in 1789 but by 1811 in Charlestown on Boston's north side. The discussion examines a New England-based geographer's understanding and perception of a new western state—its character, resources, people and activities—versus the reality of that time.

GEOLOGY

The paleontology and stratigraphy of the Middle Silurian (Niagaran) Laurel Dolomite in Kentucky. RICHARD TODD HENDRICKS, Department of Geological Sciences, University of Kentucky, Lexington, KY 40506.

The Laurel Dolomite contains 6 lithologic subunits, including a basal dolomite, a dolomitic shale, the "lower vuggy," the "quarrystone," the "upper vuggy," and an oolite. Paleontologic investigation has shown each subunit to possess a distinctive fossil biota. Brachiopods (*Atrypa*, *Meristina*), rugose corals, and bryozoans predominate in the lower 2 zones. The "lower vuggy" exhibits abundant crinoid debris, cystoids (*Caryocrinites*), colonial corals, trilobites, gastropods, brachiopods, and algae (*Receptaculites*). The "quarrystone" contains trilobites (*Calymene*), corals (*Halysites*, *Heliolites*), brachiopods, and bryozoans. In contrast, the "upper vuggy" contains locally abundant *Pentamerus* brachiopods. The oolite is marked by locally abundant brachiopods (*Fardenia*) and large algal bioherms. In summary, lithologies and biotas appear to be environmentally controlled, and additional work is required to understand them fully.

Petroleum geology of eastern Kentucky: Rockcastle and Clay county areas. GRAHAM HUNT, Department of Geology, University of Louisville, Louisville, KY 40292.

Recent studies of correlation of mainly K-bentonite beds of the Mississippian Valley region suggest that a closer look is necessary for the problems concerning the surface-to-subsurface correlations of rocks found near the bentonitic beds in southeastern Kentucky. Most of the potential pay zones—the Knox Group (multi-pays), Middle and Upper Ordovician rocks (Stones River), Silurian-Devonian (Corniferous), and the Mississippian age rocks (Big Lime)—occur near bentonitic beds. Recent drilling in the study area indicates that at least 6 bentonitic beds of the Stones River units are useful for local and regional correlations.

Depositional history of Murphy's Pond, a freshwater cypress swamp in Hickman County, Kentucky. KENNETH W. KUEHN,* Department of Geography and Geology, Western Kentucky University, Bowling Green, KY 42101, and W. STANLEY WILKERSON, Department of Biology, Tennessee Tech University, Cookeville, TN 38505.

Murphy's Pond is located within the Mississippi Embayment in Hickman County, Kentucky, and occupies about 80 acres of the Obion Creek floodplain. Its flora is extremely diverse; an earlier survey encountered 158 taxa in 130 genera. There has been no prior investigation of the history of Murphy's Pond, though some workers believe it formed as a result of the New Madrid earthquakes of 1811–1812 A.D.

A series of 8 cores was collected for analysis and yielded peat accumulations ranging from 4.5 cm to 12.5 cm (average 7.5 cm). Two basal peats returned radiocarbon dates of (1) modern (post-1950) and (2) 320 ± 70 years, making 1630 A.D. the most likely date of the swamp's origin. This establishes Murphy's Pond as pre-settlement and precedent of the New Madrid earthquakes. A detailed investigation of peat palynomorphs is in progress and will establish the swamp's floral evolution.

A comparison of clay mineral assemblages from the lower Borden Formation (Lower Mississippian) along the east and west flanks of the Cincinnati Arch. R. THOMAS LIERMAN,* JEFFERY T. STEWART, and CHARLES E. MASON, Department of Physical Sciences, Morehead State University, Morehead, KY 40351.

This study attempts to characterize and compare clay mineral assemblages from the lower New Providence Shale Member of the Borden Formation, west central Kentucky, with the Henley Bed of the lower Borden Formation in east central Kentucky. This interval is thought to represent offshore, clay shale deposits that accumulated basinward of a prograding deltaic complex (Borden Formation). The clay size minerals found include illite, kaolinite, quartz, and chlorite in decreasing order of abundance. A statistical comparison of samples from these 2 locations suggests an increase in detrital kaolinite and a concurrent decrease in illite to the northeast, towards the source area.

Scolecodonts (annelid jaws) from the lower New Providence shale member of the Borden Formation, Jefferson and Bullitt counties, Kentucky. JEFFERY T. STEWART,* CHARLES E. MASON, and R. THOMAS LIERMAN, Department of Physical Sciences, Morehead State University, Morehead, KY 40351.

The basal 7 m of the Borden Formation (Lower Mississippian) were examined for microfossils in Jefferson and Bullitt counties, Kentucky. This part of the Borden, informally known as the Coral Ridge interval, is included in the New Providence Member. It is a greenish-gray, bioturbated, clay shale interpreted as basinal deposits in front of a prograding deltaic system. Scolecodonts were common elements among microfossil assemblages recovered. About 15 single elements or partially articulated assemblages per kilogram of processed sample were extracted from the light fractions of heavy mineral separations. Post-Devonian scolecodonts are rare, especially articulated forms from clastic sequences, and little is known about them. The scolecodont fauna reported herein contains important data for working out assemblage taxonomy, biostratigraphy, and paleoecology of Mississippian scolecodonts.

Petroleum exploration techniques for fractured terrains in Kentucky. SHAUN A. WINTER* and KENNETH W. KUEHN, Department of Geography and Geology, and WILLIAM G. BUCKMAN, Department of Physics and Astronomy, Western Kentucky University, Bowling Green, KY 42101.

Fracture reservoirs can be detected by a combination of remote sensing techniques. Reconnaissance mapping entails identification of lineaments from high-altitude color infrared (CIR) imagery, and topographic and geologic maps. Statistical analysis of the resultant lineament maps locates promising trends for detailed field evaluation. In the field, a radiometrics device provides 2-channel graphical output for radon and total radiation, which helps verify the existence of the photo-identified lineaments. Soil-gas samples collected from locations along the radiometrics anomalies are analyzed by gas chromatograph to determine relative concentrations of light hydrocarbons methane through butane. Results from test holes sited through these methods indicate that remote sensing techniques can significantly increase the probability of success in fractured terrains.

MATHEMATICS AND COMPUTER SCIENCE

Two observations of a single note. JAMES B. BARKSDALE, JR., Department of Mathematics, Western Kentucky University, Bowling Green, KY 42101.

During the mid 1700s Leonard Euler characterized the celebrated value of "e" as the limit of a sequence $[s_n]$, where $s_n = (1 + 1/n)^n$. In this presentation, the convergence of this famous sequence is established as a direct result of either of the following 2 observations: (1) If $f'' > 0$ on R^+ and $0 < a < b$, then $f(b) - (b - a)\cdot f'(b) < f(a)$; also, (2) If $f' > 0$ on R^+ and $0 < a < b$, then $I(f, a, b) < (b - a)\cdot f(b)$, where R^+ denotes the set of positive real numbers and $I(f, a, b)$ denotes the integral of f over the interval [a, b]. Special instances of (1) and (2) now yield sufficient (monotone and boundedness) conditions for $[s_n]$ to converge. Use (1) with $f(t) = t^{n+1}$, $a = 1 + 1/(n + 1)$, $b = 1 + 1/n$ to establish monotonicity, and use $a = 1$, $b = 1 + ½n$ to establish boundedness. Similar applications of (2) with $f(t) = t^n$ also yield such sufficient conditions for the convergence of $[s_n]$.

Profiles in Pascal: where does the time go? JOHN H. CRENSHAW, Department of Computer Science, Western Kentucky University, Bowling Green, KY 42101.

Two major techniques for analyzing the computational complexity of algorithms are: (1) a priori analysis utilizing Big-0 notation and (2) profiling analysis in which run-time statistics are obtained from an implemented algorithm. A software package called PROFILE for the VAX 11/750 permits Pascal programs to be analyzed in a variety of ways. The primary analysis technique discussed provides the user with a table showing the names of all modules in a program along with a count of how many times each module was executed. The execution of PROFILE is transparent to the user and leaves the user's program unchanged.

Using public domain software to debug PC assembler programs. VIRGINIA EATON, Department of Computer Science, Western Kentucky University, Bowling Green, KY 42101.

FSDEBUG is public domain software that has certain advantages over the DEBUG program that comes with PCs and PC clones. For one thing, the FSDEBUG screen lets users see contents of memory, contents of registers, and flag settings all at once. A second advantage is that it lets users alternate between the FSDEBUG screen and another screen that lets them see the output of an executing program. A third advantage is that there are excellent HELP screens available from within FSDEBUG. I would recommend FSDEBUG to anyone who is learning PC assembler.

Use of computers in medicine. SYLVIA CLARK PULLIAM, Department of Computer Science, Western Kentucky University, Bowling Green, KY 42101.

Computer utilization in medicine falls into 4 main categories: administration and record-keeping activities; high-tech, usually machine-related; clinical information services, using database or expert systems; and research, combining all techniques. Two fields using computers extensively are radiology and clinical pathology. Radiology applications are usually machine-related, as Digital Image Processing. Pathology applications are usually more record-related, as monitoring abnormal results. Computers are also used to perform instant calculations, often in emergency medicine, pediatrics, and physicians' offices, to determine dosage and assist in decision-making. A wide range of database services and expert systems is available for most medical specialties.

Homotopy lifting. CARROLL G. WELLS, Department of Mathematics, Western Kentucky University, Bowling Green, KY 42101.

A mapping $p: E \to B$ has homotopy lifting with respect to a space X if given mappings $f: X \times O \to E$ and $F: X \times I \to B$ such that $F(x, o) = p(f(x))$, $x \in X$, there is a mapping $G: X \times I \to E$ such that $f(x, o) = G(x, o)$, $x \in X$, and $p(G(x, t)) = F(x, t)$, $(x, t) \in X \times I$. Homotopy lifting with respect to the Cantor set (HLP/C) and to a sequence with 1 limit point (HLP/S) are studied. It is proven that a mapping has HLP/C if and only if it has HLP/C locally. Also mappings with HLP/C will have HLP/S and mappings with HLP/S will have HLP with respect to a point.

PSYCHOLOGY

Variables influencing adolescents' perceptions of television violence. M. SHANNON MACKIE,* MARIA S. MCLEAN, and JOHN W. PORTER, Department of Psychology, Thomas More College, Crestview Hills, KY 41017.

Twenty pre-delinquent adolescent subjects judged cartoon and crime drama scenes to be more violent as harm to the victims in the scenes increased. They judged cartoons to be more frightening and more personally disturbing as harm increased. There was a tendency for scenes to be rated as more humorous when subjects viewed scenes in a group than when alone. There was no relationship between personality, as measured by the Eysenck Personality Questionnaire, and the subjects' ratings. It is suggested that violence, even in fantasy settings, should be carefully monitored. The group effects observed were attributed to a diffusion of subjects' attention away from the violence in the scences. These results do not support previous research that suggests that personality variables are strongly correlated with perceptions of television violence.

SCIENCE EDUCATION

Teaching chemistry by closed-circuit television—personal observations. DAVID R. HARTMAN, Department of Chemistry, Western Kentucky University, Bowling Green, KY 42101.

"Biochemistry for the Health Sciences" was taught by closed-circuit television to a group of nursing and dietetics students in Owensboro and on campus in Bowling Green, simultaneously. Television production equipment and teaching techniques were examined. Student response to this unique experience was favorable.

ZOOLOGY & ENTOMOLOGY

Aggressive behavior in the Cumberland Plateau salamander, *Plethodon kentucki*. DONNA L. DELPONT* and PAUL V. CUPP, JR., Department of Biological Sciences, Eastern Kentucky University, Richmond, KY 40475.

Aggressive behavior in defense of areas by means of direct attacks and threat displays was observed in male and female *Plethodon kentucki*. All intruders (N = 96) immediately began exploring when introduced into a resident's chamber. Threat displays used by residents to deter intruders (60.4%, N = 58) included: orientation (97.9%, N = 94), partial head-raise (49.0%, N = 49), full head-raise (51.0%, N = 49), open-mouth display (35.2%, N = 19), and snapping (9.3%, N = 5). Contact occurred in 38 trials (39.6%), 19 (50%) resulting in aggressive encounters involving a biting/chasing/fleeing sequence. All contacts made by intruding males (44.7%, N = 17) resulted in aggressive encounters with residents always being the victor. Such behavior suggests that male and female *P. kentucki* may be territorial.

An equilibrium model of protistan colonization in barren aquatic systems. PAUL V. MCCORMICK, Department of Biology, University of Louisville, Louisville, KY 40292.

This research investigated the utility of equilibrium island theory in explaining patterns of protist colonization in isolated aquatic systems. There was no relationship between species richness and the rate of immigration, although a strong positive correlation with extinction was found. There was evidence of non-monotonicity in rate functions over time. Although a dynamic equilibrium appeared to be achieved within 8 wk, there were fluctuations around this level that could not be explained by changes in environmental parameters. Discrepancies between these results and theory may be explained by: (1) initially inhospitable conditions resulting in a lag in immigration, (2) decreases in microbial species richness below equilibrium levels as a result of predation by mosquito larvae, and (3) increases in microbial species richness above equilibrium levels following passive dispersal of colonists by mammals.

Trans. Ky. Acad. Sci., 49(1–2), 1988, 61–65

CONSTITUTION OF THE KENTUCKY ACADEMY OF SCIENCE

(Adopted 8 May 1914. Revised November 1951, 1970, 1979, 1987)

ARTICLE I

NAME AND OBJECTIVES

Section 1. 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, to promote the diffusion of scientific knowledge, and to unify the scientific interests of the Commonwealth of Kentucky.

ARTICLE II

MEMBERSHIP

Section 1. 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 Affiliates.

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 in 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. Emeritus 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 payment of dues. They shall receive all mailings except the *Transactions*.

Section 7. Corporate and Institutional Affiliates. Corporate Affiliates 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 decisions 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 and 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 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 those 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 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 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 activies. An alternate shall also be named to serve in the event that the the Representative is not able to serve.

Section 10. Chair of 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. Designation of Divisions. For representation on various bodies of the Academy and to 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 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, which shall recommend editorial policy for the *Transactions* to the Governing Board.
3. A Committee on Legislation that consists of three members. The Committee shall be responsible for the consideration of 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 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 the 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. This 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 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 Com-

mittee 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 Meeting. The Kentucky Academy of Science 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. This 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 that at least ten per cent of the members have voted.

KENTUCKY ACADEMY OF SCIENCE ORGANIZATION

GOVERNING BOARD

President President Elect Vice President Past President Secretary Treasurer Executive Secretary (*ex officio*) Editor (*ex officio*)	Executive Committee
Division Representatives—6 At-Large Representatives—2 AAAS/NAAS Representative 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

DISTINGUISHED SCIENTIST AND OUTSTANDING TEACHER AWARDS

Each year the Academy presents the Distinguished Scientist Award and awards to the Outstanding Teacher In Science at the College/University Level and at the Secondary Level.

This year the recipient of the Distinguished Scientist Award was Dr. Joseph V. Swintosky from the University of Kentucky College of Pharmacy and recent Dean of that College during 1967–1987. Dr. Swintosky has been a member of the Kentucky Academy of Science for many years and has contributed greatly to the scientific and intellectual growth of the Commonwealth. Dr. Swintosky has occupied a leadership role in pharmaceutical science in the Commonwealth and has been instrumental in the development of a nationally and internationally recognized College of Pharmacy at the University of Kentucky. He holds 10 U.S. patents for discoveries and development of new drugs and product processes and about 30 foreign patents. He has authored more than 115 refereed scientific and educational journal publications.

The award for the Outstanding Science Teacher at the College/University Level was given to Dr. Ray Kenneth Hammond of the Division of Science at Centre College, Danville, Kentucky. Dr. Hammond received his Ph.D. in Biochemistry from the University of Kentucky in 1965 and began his association with Centre College in 1972. He was noted for his excellent teaching in both lower and upper level undergraduate classes, for his involvement with the Governor's Scholars Program since its inception, for his advising activities with pre-medical students and for his teaching at various international universities.

Mr. Robert J. Hubler, a physics teacher at Trinity High School in Louisville, Kentucky, was the recipient of the award for the Outstanding Science Teacher at the Secondary Level. Mr. Hubler holds a B.A. in Secondary Education with a major in physics and math from Bellarmine College and a M.S. in Secondary Education with a physics major from Indiana University. He has been teaching at Trinity High School since 1965. He was voted "Teacher of the Year" by the student body at Trinity in 1985. Among other duties, he teaches an Advanced Placement Physics class where successful students can earn up to 8 college credits at Bellarmine College.

Winners of the Kentucky Junior Academy of Science Spring Symposium

Section A (Senior High)

Susan Reed

Sponsor:

Sr. Mary Ethel Parrott
Notre Dame Academy
Hilton Drive
Covington, KY 41011-2796
Phone number 606-261-4300

Section B (Senior High)

Malea Darlene Keahey

Sponsor:

Mrs. Carol Alexander
Trigg Co. High School
Cadiz, KY 42211
School Phone 502-522-6072
Home Phone 502-522-8110

Section C (Junior High)

Naomi Baer

Sponsor:

Ms. Michelle Waggoner
Beaumont Junior High School
2080 Georgian Way
Lexington, KY 40504
School Phone 606-277-2006
Home Phone 606-223-7972

Section D (Junior High)

Scott Logan

Sponsor:

Ms. Ann McCroskey
North-South Junior High
1707 2nd Street
Henderson, KY 42420
Home Phone 502-826-9520

NEWS AND COMMENTS

Annual Meeting

The 1988 meeting (74th) of the Kentucky Academy of Science will be at Eastern Kentucky University in Richmond, 4–5 November 1988. The 75th meeting (Diamond Anniversary) will be hosted by the University of Kentucky, site of the first meeting of the society, in Lexington. Exact dates will be supplied in an upcoming issue when they are confirmed by university and academy officials.

Morton B. Ryerson Fellowship

This fellowship is established through funds contributed by the Chicago Community Trust. Applications are being solicited for fellowships-in-residence to begin anytime in 1988. Open to any student, with preference to graduate students, the fellowship awards a monthly stipend of $800, plus room, for any period from 2 to 9 months. Fellows are granted full and private use of a comfortable 4-room log cabin with kitchen, spectacularly situated amidst floodplain, hardwood forest on the banks of the Des Plaines River in the Edward L. Ryerson Conservation Area, managed by the Lake County Illinois Forest Preserve District. Fellows will be expected to conduct independent field research on any topic relating to ecology and/or conservation in northern Illinois forests. Cooperation with a local interpretive nature center is encouraged, but the research project is paramount. Applicants should send a 2–3 page proposal, a resume or CV, 2 letters of recommendation, and a proposed schedule of residency at the Ryerson Conservation Area. Address applications and requests for information to:

Dr. John W. Fitzpatrick, Chairman
Morton B. Ryerson Fellowship Committee
Department of Zoology
Field Museum of Natural History
Roosevelt Road at Lake Shore Drive
Chicago, Illinois 60605

Louisville Museum of History and Science announced on 15 June 1987 the receipt of 2 grants, a $250,000 grant from the Kresge Foundation in Troy, Michigan, for the construction of an IMAX theater on the 3rd and 4th floors, and a $75,000 grant from the Institute of Museum Services (an agency within the National Foundation on Arts and Humanities).

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 49
Numbers 3–4
September 1988

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 $15.00 for Active Members; $7.00 for Student Members; $20.00 for Family; $250.00 for Life Members.

Subscription rates for nonmembers are: domestic, $30.00; foreign, $30.00; 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

Sustaining Members

University of Kentucky

Member

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

Associate Member

Alice Lloyd College
Bellarmine College
Berea College
Brescia College
Campbellsville College
Centre College
Cumberland College
Georgetown College
Kentucky State University
Kentucky Wesleyan College
Saint Catharine College

CORPORATE AFFILIATES

All-Rite Pest Control
Alltech, Inc.
International Business Machines
United Catalysts, Inc.

SUSTAINING CORPORATE AFFILIATES

Ashland Oil, Inc.

TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

September 1988
Volume 49
Numbers 3–4

Trans. Ky. Acad. Sci., 49(3–4), 1988, 69–73

Significance of Aquatic Surface Respiration in the Comparative Adaptation of Two Species of Fishes (*Notropis chrysocephalus* and *Fundulus catenatus*) to Headwater Environments

MICHAEL BARTON AND KIM ELKINS

Division of Science and Mathematics, Centre College, Danville, Kentucky 40422

ABSTRACT

Rates of dissolved oxygen consumption and capacity for aquatic surface respiration were measured for 2 species of fishes, the common shiner (*Notropis chrysocephalus*) and the northern studfish (*Fundulus catenatus*), common in headwater streams of the North Rolling Fork River. While both species assumed the body position characteristic of oxygen uptake at the water surface, the depletion of atmospheric oxygen within a respirometer was greater for *F. catenatus*, suggesting a more efficient mode of surface breathing under conditions of hypoxia. The survival times of both species were enhanced with access to atmosphere. Different strategies for coping with hypoxic conditions in the 2 species are apparent. The northern studfish maintains aerobic metabolic capacity through efficient aquatic surface respiration while the common shiner may increase anaerobic metabolism under conditions of hypoxia. Both species possess the requisite physiological capacities for survival in headwater stream systems subject to intermittent flow regimes.

INTRODUCTION

In freshwater environments, headwater streams offer the opportunity to assess the range of adaptive responses to fluctuations in the physicochemical environment. The capacity of an organism to adapt to such fluctuations, especially in temperature and oxygen availability, will determine its ability to become an integral component of headwater ecosystems. Species that dominate headwater communities that experience environmental fluctuation, however, may be less successful in more stable, more diverse downstream ecosystems where the intensity of biotic interactions is greater (1, 2). Thompson and Hunt (3) were the first to suggest that fishes inhabiting headwater streams subject to intermittency of flow demonstrated greater tolerance to fluctuations in the physicochemical environment than species inhabiting more stable and environmentally uniform downstream areas. This has been experimentally verified in the comparison of tolerances to changes in temperature, pH, and dissolved oxygen of headwater inhabiting versus mainstream inhabiting individuals of the same species of cyprinids and etheostomatines (4).

During late summer and early fall, large concentrations of fishes, chiefly cyprinids, often are trapped in standing pools in the headwaters of the North Rolling Fork River in central Kentucky. Here, the possibility exists for the rapid depletion of dissolved oxygen with uncertain opportunities for replenishment before critical levels are experienced. The purpose of this study is to compare the oxygen uptake patterns of 2 species of stream dwelling fishes: the common shiner (*Notropis chrysocephalus*) and the northern studfish (*Fundulus catenatus*). A common behavioral response of fishes exposed to hypoxic conditions is to move to the surface and breathe the thin film of richly oxygenated water at the surface. The role of aquatic surface respiration in facilitating the uptake of oxygen has been studied, especially in tropical species routinely exposed to hypoxic conditions (5, 6, 7, 8, 9). The role of aquatic surface respiration as an adaptation to the physicochemical conditions characteristic of headwaters was assessed for the two species mentioned above.

THE STUDY AREA

The 2 subject species of this study were collected from second order headwater streams (10) of the North Rolling Fork River in western Boyle County, Kentucky. The fishes of the North Rolling Fork constitute the most diverse ichthyofaunal community within the Salt River Drainage of central Kentucky (11). Moderate alkalinity, medium hard to hard water of generally good quality, a substratum of non-calcareous shales and limestone, and a circumneutral pH are all characteristics of this drainage (11). The fishes were collected from shallow (<0.5 m) pools with copious leaf litter and muddy bottoms and from the margins of small riffles.

MATERIALS AND METHODS

Fishes were collected during early autumn using a backpack electroshocker and transported in plastic buckets to the laboratory where they were acclimated in well-aerated water in aquaria for at least 10 days prior to experimentation. A constant photoperiod of 12 hr light : 12 hr dark was maintained.

In order to determine oxygen consumption rates and critical dissolved oxygen levels without access to an overlying atmospheric layer, individual fishes, ranging in weight from 2.93 to 6.45 g (*N. chrysocephalus*) and 1.62 to 3.12 g (*F. catenatus*) were placed in 300 ml B.O.D. bottles and subjected to gentle aeration for at least 4 hr to enable acclimation of the fish to its surroundings. Initial measurements of dissolved oxygen were made using an oxygen probe (Extech #8012) connected to a pH/mv meter (Cole-Parmer #5984-00). This probe is designed for use with B.O.D. bottles as it minimizes atmospheric exchange during measurements and can be left in the B.O.D. bottles between measurements. Bottles were sealed and held in a water bath maintained at 25°C. Hourly measurements of dissolved oxygen were made until critical levels, determined as the point of cessation of opercular beating, were reached. At this time, individuals were removed and wet weights determined. This procedure was repeated 5 times for each species for a total of 10 trials. This technique has proven useful in other studies of small fish metabolism (12).

In order to assess the impact of availability of atmospheric oxygen, a respirometer was constructed using a glass jar 12.0 cm long with a diameter of 7.5 cm. The cap for the jar was fitted with the oxygen probe used in the previous procedure. Another oxygen probe (YSI #54) was fitted through the cap such that it was positioned in an air space of 175 ml volume that overlaid the 300 ml volume of water within the respirometer. This enabled simultaneous measurement of dissolved oxygen, measured as mg 1-1 and atmospheric oxygen, measured as percent of atmospheric composition and converted to g 1-1. A pH probe was also fitted such that changes in pH accompanying oxygen uptake and carbon dioxide release could also be monitored. This procedure, using the respirometer and fitted probes, was again repeated 5 times for each species for a total of 10 trials.

RESULTS

Patterns of oxygen utilization, measured by comparison of depletion rates of atmospheric oxygen vs. dissolved oxygen, suggest different strategies of adaptation to oxygen deficient waters for *F. catenatus* and *N. chrysocephalus*. Survival times for both species increased dramatically with access to atmospheric oxygen (Table 1). Decreased oxygen consumption rates were recorded as dissolved oxygen diminished (Figs. 1, 2). As aquatic oxygen consumption rates declined, differences were observed in the rate of utilization of atmospheric oxygen (Figs. 1, 2). After approximately 22 hr, a sharp decline in atmospheric oxygen was recorded in the respirometer containing *F. catenatus* indicating a relatively rapid removal of oxygen from the atmospheric compartment. Decreases in dissolved oxygen resulted in both species assuming a posture in which aquatic surface respiration (ASR) would be facilitated. *Fundulus* appeared to be more efficient at this activity as it acquired a posture much like that observed by Lewis (9) for poeciliids and fun-

TABLE 1. Effect of access to surface air on mean survival times and lethal dissolved oxygen levels in 2 species of headwater stream fishes.

Species	n	Mean weight (g)	Range of weight (g)	Mean survival time (hr)	Mean lethal D.O. level (ppm)
F. catenatus					
Without surface access	5	2.72	2.30–3.12	8.4	0.52
With surface access	5	2.16	1.62–2.90	68.4	1.56
N. chrysocephalus					
Without surface access	5	3.26	2.93–5.54	3.5	0.53
With surface access	5	4.66	3.04–6.45	82.0	0.80

dulids and Kramer and Mehagen (7) in their studies of ASR in guppies. *Notropis* engaged in ASR but in a much more vertical position than that observed in *Fundulus*, which was able to orient its broad, flattened head almost parallel to the water surface. The uptake of atmospheric oxygen, measured as a decrease in oxygen content in the atmospheric compartment, was not as pronounced for *N. chrysocephalus* yet the longest survival times were recorded for this species (Table 1). Although a decline in pH was noted to occur within the respirometer during the course of the experiments using the respirometer, it never approached what would be considered critical levels.

DISCUSSION

Certain species of fishes are successful inhabitants of headwater environments because of the opportunistic mode of feeding that they may pursue (2) or because they possess the

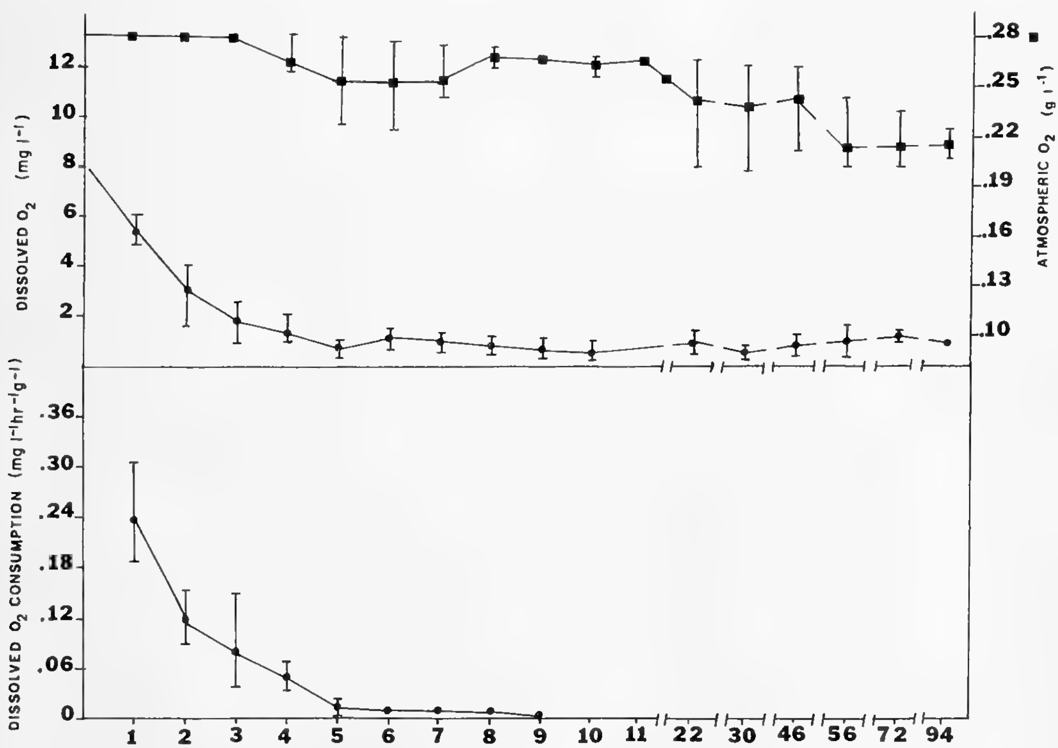


FIG. 1. Mean and range of dissolved oxygen concentrations, rates of dissolved oxygen consumption, and change in atmospheric oxygen content within the respirometer for *Notropis chrysocephalus* with access to surface.

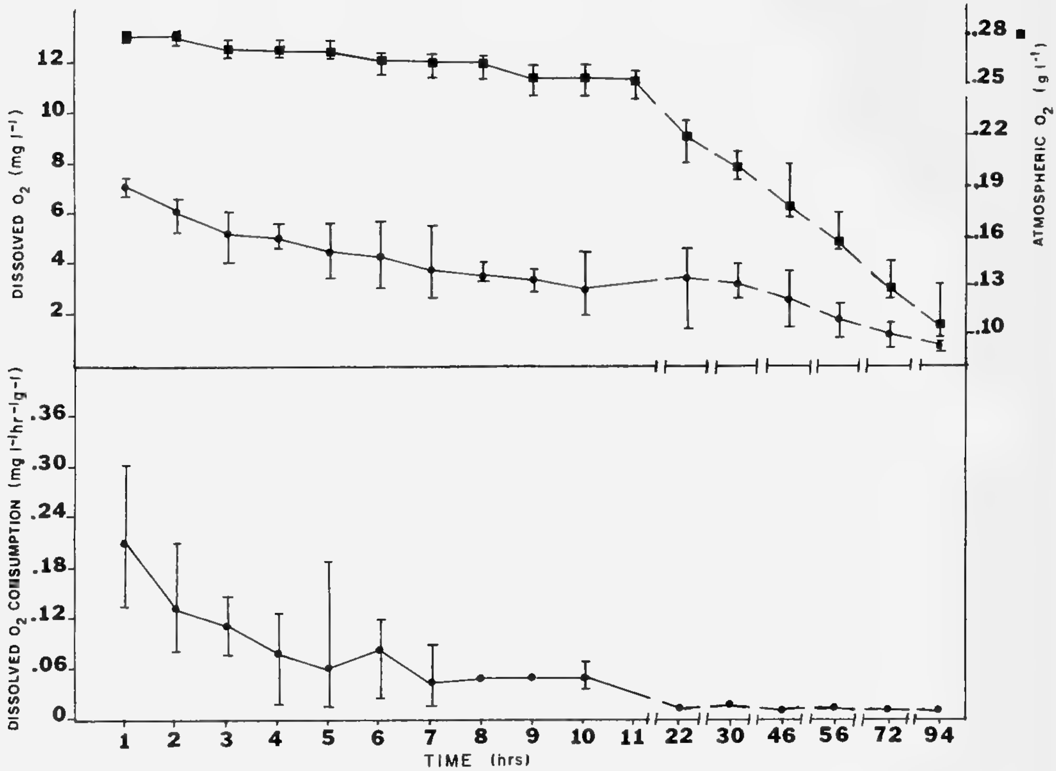


FIG. 2. Mean and range of dissolved oxygen concentrations, rates of dissolved oxygen consumption, and change in atmospheric oxygen content within the respirometer for *Fundulus catenatus* with access to surface.

requisite physiological adaptations to enable continual adjustments of their metabolic scope under conditions of fluctuation in the physicochemical environment. In the 2 species studied here, different modes of adaptation to headwater environments are evident.

Cyprinid species that inhabit shallow streams have been demonstrated to effectively optimize their combined temperature/dissolved oxygen requirements in order to balance aerobic metabolic needs with ambient oxygen (13). Members of the family Cyprinidae are effective also at switching to anaerobic pathways under conditions of oxygen deprivation (14, 15, 16). The results of this study suggest that *N. chrysocephalus* may shift to increased anaerobic metabolism under prolonged conditions of diminished oxygen availability. The levels of atmospheric oxygen in the respirometer did not exhibit as pronounced a decline for *N. chrysocephalus*, suggesting a decreased oxygen requirement with time for this species. Studies on lactate accumulation under hypoxic conditions would substantiate the role of anaerobic metabolism suggested by this investigation.

Lewis (9) postulated that the small, upturned mouth and the dorso-ventrally flattened head of fundulid and poeciliid fishes optimize their capacity for ASR. Laboratory studies of microhabitat selection have revealed that *Poecilia reticulata* (family Poeciliidae) chose shallow areas of an experimental aquarium that were closest to the air-water interface (17). Our study verified Lewis' observations that cyprinid species assume a greater inclination of body axis while engaging in ASR and that the body form of fundulids best accommodates this activity. This study further substantiates the observations by several researchers that cyprinodontiform fishes are the best adapted headwater species in terms of capacity for ASR (7, 8, 9). While our study appears to attribute the survival capacity of *F. catenatus* in oxygen deficient waters to an enhanced capacity for ASR, *N. chrysocephalus* appears equally adapted to these conditions because of its enhanced anaerobic capabilities. Surface dwelling species that engage in ASR may be subjected to greater risk of avian predation (18). Enhanced anaerobic capacity would enable optimization of metabolic scope in the face of physicochemical fluctuation yet avoid the potential liabilities of surface confinement during periods of oxygen deprivation.

ACKNOWLEDGMENTS

Financial support for the preparation of this paper was made available by the Faculty Development Committee of Centre College.

LITERATURE CITED

1. Diamond, J. M. 1978. Niche shifts and the rediscovery of interspecific competition. Am. Sci. 66:322–331.

2. Moyle, P. B. and J. J. Cech, Jr. 1982. Fishes: an introduction to ichthyology. Prentice-Hall, Inc., New Jersey.

3. Thompson, D. H. and F. D. Hunt. 1930. The fishes of Champaign County—a study of the distribution and abundance of fishes in small streams. Ill. Nat. Hist. Surv. Bull. 19:5–101.

4. Matthews, W. J. and J. T. Styron, Jr. 1981. Tolerance of headwater vs. mainstream fishes for abrupt physicochemical changes. Amer. Midl. Nat. 105:149–158.

5. Gee, J. H. 1986. Bouyancy control of four species of eleotrid fishes during aquatic surface respiration. Env. Biol. Fish. 16:269–278.

6. Kramer, D. L. 1983. Aquatic surface respiration in the fishes of Panama: distribution in relation to risk of hypoxia. Env. Biol. Fish. 8:49–54.

7. Kramer, D. L. and J. P. Mehagen. 1981. Aquatic surface respiration, an adaptive response to hypoxia in the guppy, *Poecilia reticulata* (Pisces: Poeciliidae). Env. Biol. Fish. 6:299–313.

8. Kramer, D. L. and M. McClure. 1982. Aquatic surface respiration, a widespread adaptation to hypoxia in tropical freshwater fishes. Env. Biol. Fish. 7:47–55.

9. Lewis, W. M., Jr. 1970. Morphological adaptations of cyprinodontoids for inhabiting oxygen deficient waters. Copeia 1970:319–326.

10. Kuehne, R. A. 1962. A classification of streams, illustrated by fish distribution in an eastern Kentucky creek. Ecol. 43:608–614.

11. Fisher, W. L. and R. R. Cicerello. 1985. Fishes of the Rolling Fork of the Salt River, Kentucky. Trans. Ky. Acad. Sci. 46:108–115.

12. Barton, M. G. and A. C. Barton. 1987. Effects of salinity on oxygen consumption of *Cyprinodon variegatus*. Copeia 1987:230–232.

13. Bryan, J. D., L. G. Hill, and W. H. Neill. 1984. Interdependence of acute temperature preference and respiration in the plains minnow. Trans. Am. Fish. Soc. 113: 557–562.

14. Blazka, P. 1958. The anaerobic metabolism of fish. Physiol. Zool. 31:117–128.

15. Cech, J. J., Jr., S. J. Mitchell, and M. J. Massingill. 1979. Respiratory adaptations of Sacramento blackfish, *Orthodon microlepidotus* (Ayres), for hypoxia. Comp. Biochem. Physiol. 63A:411–415.

16. Johnston, I. A. 1975. Anaerobic metabolism in the carp *Carassius carassius* L. Comp. Biochem. Physiol. 51B: 235–241.

17. Nolte, D. B. and P. H. Johansen. 1986. Laboratory studies of microhabitat selection by the guppy, *Poecilia reticulata* (Peters). J. Freshwater Ecol. 3:299–307.

18. Kramer, D. L., D. Manley, and R. Bourgeois. 1983. The effect of respiratory mode and oxygen concentration on the risk of aerial predation in fishes. Can. J. Zool. 61: 653–665.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 74–79

Some Stand Characteristics of Bald Cypress, *Taxodium distichum* (L.), in an Oxbow Lake in Extreme Southwestern Indiana

THOMAS R. KOZEL,[1] JOHN DAILEY, JAY CRAIG, AND KATHY WELBORN

Department of Biology, University of Southern Indiana, Evansville, Indiana 47712

ABSTRACT

A stand of bald cypress, *Taxodium distichum* (L.) Richard, in Hovey Lake, Posey County, Indiana was sampled for age, growth and reproductive characteristics. This stand is located in the Hovey Lake Fish and Wildlife Area and is one of the northernmost in the middle of the *T. distichum* east–west range. Thirty-three 25-m^2 sample plots were established and 359 trees measured for DBH. Fifty-seven specimens were cored for age determination. Mean DBH for all trees was 251.4 ± SE 36.1 mm and trees between 101 and 400 mm DBH were most frequently encountered. We counted 114 trees in the 201–300 mm size class, making it the largest class. The smallest tree measured 30 mm DBH and the largest 1,240 mm DBH. The mean DBH of cored trees was 183.6 ± SE 13.6 mm, mean age 56.5 ± SE 3.5 yr and mean growth rate 3.25 ± SE 0.83 mm/yr. Mean growth rate for cored trees increased from 2.84 ± SE 0.16 mm/yr in 0–100 mm DBH trees to 3.86 ± SE 1.39 mm/yr in 401–500 mm DBH size class trees. Based upon regression analysis of data from cored trees, the average age of all trees was 74.8 ± SE 7.5 yr. The age of most specimens was between 50 and 100 yr. Large numbers of 0–100 mm size class were not observed, but germination and seedling growth are still occurring along some of the lake's margin.

INTRODUCTION

The bald cypress, *Taxodium distichum* (L.) Richard, reaches its northernmost limit of distribution in the middle of its east–west range in southern Illinois, western Kentucky and southern Indiana. Many isolated stands of this tree have been lost in these areas due to habitat modification caused by wetlands draining, siltation and pollution. One stand, which has not been lost, is located in the extreme southwestern corner of Indiana in Hovey Lake, on the Hovey Lake Fish and Wildlife Area, Posey County, Indiana.

Taxodium distichum is most successful in regions with fluctuating water levels. It produces seeds that apparently must germinate on ground which is very moist but not submerged (1). The seedlings must then reach a height greater than the next sustained high water if they are to become established (2). It has been demonstrated (3) that seedlings can survive submergence for several weeks, but will not grow during that time. High seed production seems to occur in 3-year cycles (1) and must coincide with high water which will allow seeds to soak for 1–3 months for best germination. An absence of reproduction has been noted in swampy areas which are silted-in even though mature trees are still growing there (1).

Hovey Lake was formed about 500 years ago as a large oxbow of the Ohio River, and it is presently contained within Hovey Lake Fish and Wildlife Area in Posey County, Indiana (4). Originally, the maximum depth of the lake was about 12.3 m, but siltation gradually reduced this value to approximately 1.2 m and the surface area was reduced to about 120 ha.

In 1975 the Uniontown Navigation Locks and Dam was completed and the project, by increasing the mean depth of the Ohio River, backed an additional 2.2 m of water into the lake basin. At present, Hovey Lake has a maximum depth of approximately 3.4 m and a surface area of about 560 ha. It retains a narrow connection with the Ohio River and its level is therefore dependent upon the mean pool of the river.

Despite its geographic location, Hovey Lake, like other areas of the lower Ohio River valley, exhibits a flora and fauna with distinct south-

[1] Present address and reprint requests: Department of Biology and Life Sciences, Box 20483, Savannah State College, Savannah, Georgia 31404.

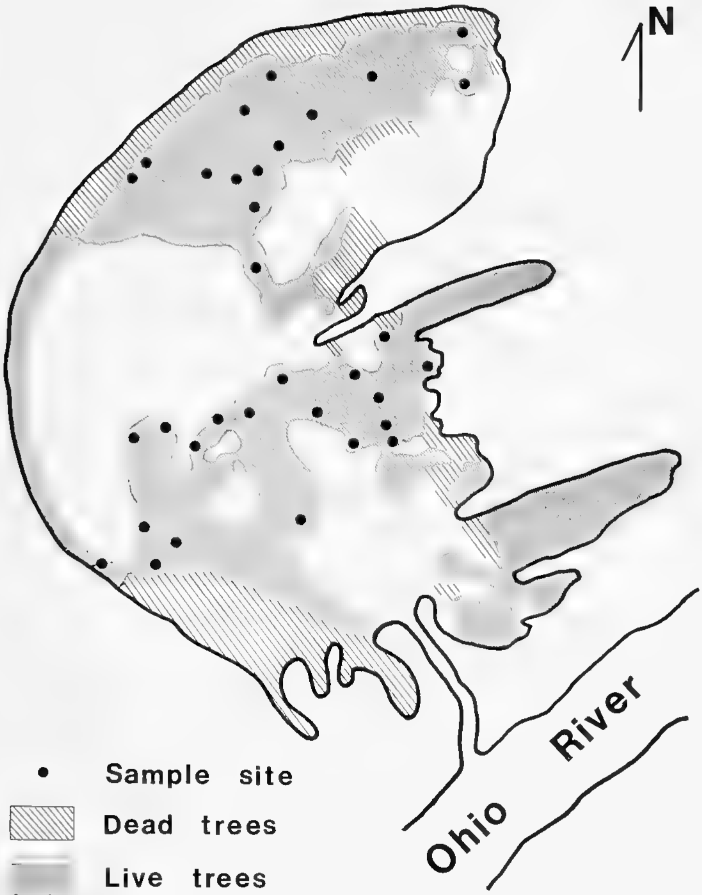


FIG. 1. Generalized outline map of Hovey Lake, Posey County, Indiana showing location of 33 25-m² sample plots, and areas where living and dead *Taxodium distichum* could be found. Length of outlet and Ohio River not same scale as lake.

ern affinities. Examples of woody species cited by Cain (5) and observed in the present study include: pecan, *Carya illinoensis* (Wang.) Koch; overcup oak, *Quercus lyrata* Walt.; shumard oak, *Q. shumardii* Buckl.; red oak, *Q. rubra* L.; red maple, *Acer rubrum* L.; water locust *Gleditsia aquatica* Marsh.; catawba, *Catalpa speciosa* Warder; and deciduous holly, *Ilex decidua* Walt.

Only 2 previous studies of *T. distichum* in Hovey Lake (5, 6) are known to the authors. This study was undertaken to determine the present status of the bald cypress (no distinction between varieties and/or sub-species of *T. distichum* was attempted here) in Hovey Lake. Such baseline studies are necessary in ecologically important sites now subject to environmental modification.

MATERIALS AND METHODS

Aerial maps of Hovey Lake were used to locate areas containing living *Taxodium distichum*. Grids were drawn on these maps, assigned numbers, and 33 sample points were selected at random for study. The points were then located on the lake and 25-m² sample plots established by tagging "corner" trees (Fig. 1). Within each plot the diameter (DBH) of every bald cypress was measured to the nearest mm using a diameter tape.

An age-estimate of all trees measured was made as follows. One or 2 specimens were selected at random from each plot (total = 57 trees) and their ages were directly determined by coring and counting rings. Increment borers were used to obtain samples of trees up to 500

TABLE 1. Density and frequency of *Taxodium distichum* sampled at Hovey Lake, Posey County, Indiana. Trees grouped into 100 mm diameter size classes. N = 359. Thirty-three 25-m² plots.

Size class (mm)	Number of individuals	Density (no./m²)	Relative density (%)	Frequency (%)	Relative frequency (%)
0–100	36	0.058	10.11	24.2	7.69
101–200	89	0.142	24.83	60.6	19.55
201–300	114	0.182	31.72	78.8	25.32
301–400	72	0.115	20.00	81.8	26.28
401–500	24	0.038	6.67	27.3	8.65
501–600	20	0.032	5.52	27.3	8.65
601–700	1	0.002	0.23	3.0	0.96
701–800	2	0.003	0.46	6.1	1.92
>800 (1,240 mm tree)	1	0.002	0.23	3.0	0.96
Total	359	0.574			

mm DBH. Whole cores (cork to past the pith) were used to calculate growth rates. Two cores were taken 180° apart and then averaged. Since all of the sampling was done from canoes on partially submerged trees, cores and DBH measurements were made 1 m above the water line. Most trees were submerged in water approximately 1 m deep. Core preparation and age-determination methods were adapted from standard methods (7). Cores were mounted in clear epoxy resin, sectioned, lightly sanded, rubbed with a small amount of vegetable oil to make the rings more visible and examined by means of a 30× dissecting microscope.

Linear regression analysis was then used to demonstrate the relationship between age and DBH and to provide a method for estimating the age of trees greater than 500-mm DBH. Trees were grouped into 100-mm DBH size classes and values for the following parameters in each calculated: numbers of individuals; density (no./m²); relative density; % frequency; relative frequency; mean DBH (in mm); mean age (in yr); and mean growth (in mm/yr).

RESULTS

We measured 359 trees for DBH and cored 57 to determine age (Table 1). The mean DBH was 251.4 ± SE 36.1 mm. Trees with a DBH between 101 and 400 mm were the most frequently encountered. Their densities were also greatest. One hundred fourteen trees were measured in the 201–300 mm size class, making it the largest size class. Size classes greater than 400 mm were poorly represented, but 36 individuals were found in the 0–100 mm size class. The smallest tree measured was 30 mm DBH, and the largest 1,240 mm DBH (neither was cored).

Trees from which cores were taken were also arrayed into 100 mm size classes (Table 2). The mean DBH of all cored trees was 183.6 ± SE 13.6 mm. Based upon direct counts of growth rings from these cores the mean age in years and mean growth rate in mm/yr were estimated. The mean age and growth rate of all cored trees was 56.5 ± SE 3.5 yr and 3.25 ± SE 0.83 mm/yr, respectively. The mean age of trees from the largest size class (401–500

TABLE 2. Mean DBH (mm), mean age (yr) and mean growth (mm/yr) for 57 cored *Taxodium distichum* sampled at Hovey Lake, Posey County, Indiana. Trees grouped into 100 mm diameter size classes. Values are means ± standard error.

Size class (mm)	Number of individuals	Mean DBH (mm)	Mean age (yr)	Mean growth (mm/yr)
0–100	17	82.6 ± 2.2	29.1 ± 1.3	2.84 ± 0.16
101–200	18	151.9 ± 2.9	49.8 ± 1.7	3.05 ± 0.41
201–300	15	244.2 ± 4.0	73.1 ± 2.2	3.34 ± 0.86
301–400	5	353.8 ± 8.4	100.6 ± 4.5	3.52 ± 1.57
401–500	2	447.5 ± 15.0	116.0 ± 7.7	3.86 ± 1.39

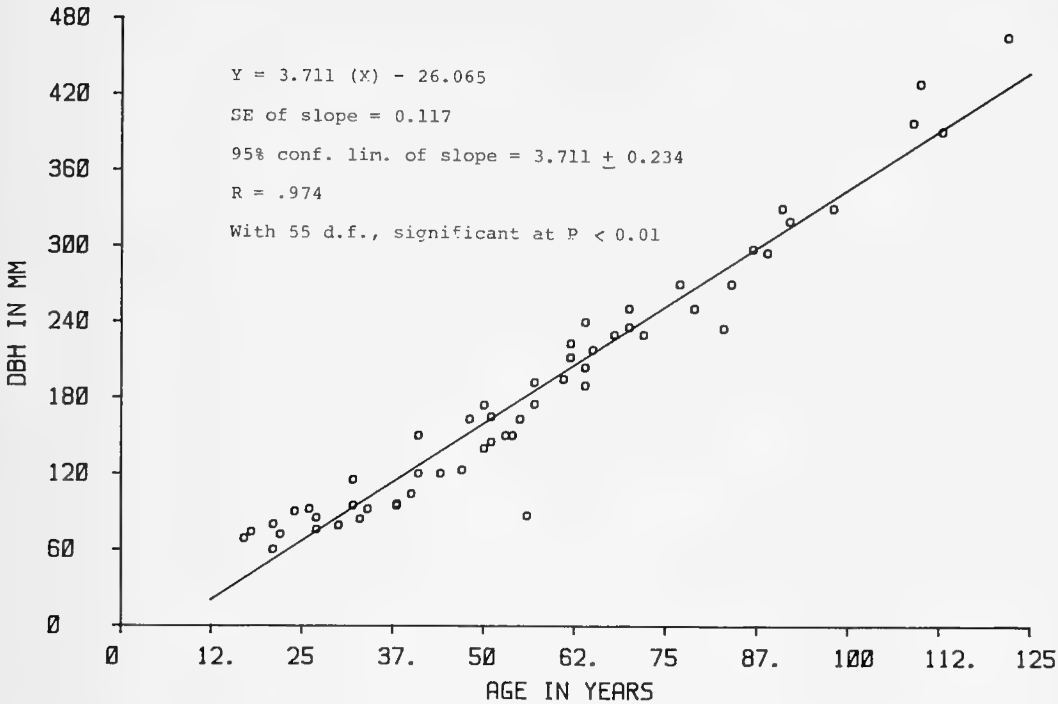


FIG. 2. The relationship between DBH and age of 57 cored *T. distichum*. Linear regression model.

mm DBH) was 116.0 ± SE 7.7 yr. The mean growth rate of trees 0-100 mm DBH was 2.84 ± SE 0.16 mm/yr and this rate appeared to increase gradually to 3.86 ± SE 1.39 mm/yr in the 401–500 mm size class. The small number of trees sampled in the 2 largest size classes should be noted. It should also be noted that the mean growth rates are estimates of all years of tree life, and are not present growth rates.

The relationship between DBH and age for *T. distichum* was determined by linear regression analysis of the cored trees (Fig. 2).

Curvilinear regression produced a slightly higher R value (0.978), but it is believed that the number of large trees which seem to be responsible for the deviation from linearity is not great enough to warrant this equation's use.

The linear regression model was extended to allow the age of larger (DBH) trees to be estimated. Using this model, the age of the 1,240 mm DBH tree was estimated to be approximately 325 yr.

DISCUSSION

The average age of all measured trees, determined using the regression equation, was 74.8 ± SE 7.5 yr. The difference of 18.3 yr between all specimens and cored trees is probably due to the inclusion of 24 trees over 500 mm DBH in the former group. The ages of most *T. distichum* studied were between 50 and 100 yr. The germination time of these trees is therefore placed approximately between the years 1880 and 1930. This interval was before the principal periods of levee and dam construction along and on the Ohio River. Such construction has the effect of reducing water level fluctuations along the river and in Hovey Lake. Since fluctuating water levels seem to be necessary for the establishment of successful stands of *T. distichum*, it is not surprising that the smallest size class was not strongly represented in our samples. Sherrod et al. (8) thought that the placement of flood control dams on the Savannah River might inhibit *T. distichum* establishment in South Carolina.

Cain (5) seems to support, and provide background for, the present observations of size class distribution in Hovey Lake. He noticed a "... general absence of cypress reproduction and hence development in stands where mature trees are now dominant ..." in his 1932

FIG. 3. Dead bald cypress forming partial ring around outer perimeter of Hovey Lake, Posey County, Indiana.

report, and suggested that recently completed agricultural levees might be restricting the rise and fall of water in the lake.

When we checked for cypress reproduction in our sample plots no measured tree reproduction was found. A few seedlings less than 20 cm high were seen along short stretches of shoreline, indicating that reproduction and germination are still occurring. Cain (5) found seedlings abundant only at the lake outlet, an area not sampled in the present study. Munson (6) did not mention seedling germination or saplings in his report, but Spitznagle, the Property Manager at Hovey Lake Fish and Wildlife Area (pers. comm.) has seen both seedlings and saplings along the perimeter of the lake's eastern side. He stated that they are found in dense willow stands which suggests that they must be shade tolerant. Others feel that willows will competitively exclude cypress (8, 9) and that the latter are understory intolerant (10).

Spitznagle (pers. comm.) believes that silt deposition, which has been very high in recent years, provides conditions for *T. distichum* population along the lake margin. This siltation may be compensating for the lack of water level fluctuation in some parts of the lake and allowing germination to occur.

The effects of siltation on mature trees are less clear. Approximately one-half the lake shore is enclosed by a ring of dead bald cypress (Fig. 3). The exact cause of their demise is uncertain, but their presence is noted because of their large numbers.

The mean growth rate of 3.25 ± SE 0.83 mm/yr is slightly higher than that reported by Mitsch and Ewel (11) for two cypress domes in Florida receiving treated sewage and hard groundwater (2.8–3.0 mm/yr). It is lower than that found by Langdon (12) in Louisiana (4.6–5.3 mm/yr). Schlesinger (13) indicated that as cypress stands mature the above-water production per tree increases. Our data showing an increase in growth rate with increasing age and size support this conclusion.

The relatively low numbers of small diameter size class *T. distichum* and the limited population size of seedlings noted here, and by others, indicates the need for further study of these trees in habitats with artificially restricted water level fluctuations.

ACKNOWLEDGMENTS

I would like to express my sincere appreciation to Dr. Joe P. Richardson for a critical reading of the manuscript and to Dr. Matthew R. Gilligan for computational assistance and advice. Financial support for this project was made available through the Division of Science and Mathematics at Indiana State University Evansville (now University of Southern Indiana). Dr. Melvin W. Denner, Chairperson, Division of Science and Mathematics, supported and encouraged this project.

LITERATURE CITED

1. Mattoon, W. R. 1915. The southern cypress. U.S. Dept. Agric. Bull. 272:1–74.

2. Demaree, D. 1932. Submerging experiments with *Taxodium*. Ecol. 13:258–262.

3. Welch, W. H. 1932. An ecological study of the bald cypress in Indiana. Proc. Ind. Acad. Sci. 41:207–213.

4. Indiana Dept. of Natural Resources, Division of Fish and Wildlife. Hovey Lake Fish and Wildlife Area. Descriptive pamphlet; 8 folded pages.

5. Cain, S. A. 1935. Bald cypress, *Taxodium distichum* (L.) Rich., at Hovey Lake, Posey County, Indiana. Am. Midl. Nat. 16:72–82.

6. Munson, P. J. 1975. Dendrochronology. Dept. of Anthropology, Indiana University. 12 pp. (Obtained from D. Spitznagle, Property Manager, Hovey Lake Fish and Wildlife Area.)

7. Cuno, J. B. 1934. Increment borer and core technic. Jour. Forestry. 33:368–369.

8. Sherrod, C., Jr., D. E. Somers, and K. W. McLeod. 1980. Potential for bald cypress establishment in thermally altered sites. J. Therm. Biol. 5:107–111.

9. McLeod, K. W. and C. Sherrod, Jr. 1981. Baldcypress seedling growth in thermally altered habitats. Amer. J. Bot. 68:918–923.

10. Good, B. J. and S. A. Whipple. 1982. Tree spatial patterns: South Carolina bottomland and swamp forests. Bull. Torrey Bot. Club. 109:529–536.

11. Mitsch, W. J. and K. C. Ewel. 1979. Comparative biomass and growth of cypress in Florida wetlands. Am. Midl. Nat. 101:417–426.

12. Langdon, O. G. 1958. Silvical characteristics of bald cypress. USDA S.E. Forest Exp. St. Pap. 94. 7 pp.

13. Schlesinger, W. H. 1978. Community structure, dynamics and nutrient cycling in the Okefenokee cypress swamp-forest. Ecological Monographs 48:43–65.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 80–84

Carbofuran Effect on Alfalfa Establishment Under No-Tillage Conditions

Robert J. Barney

Community Research Service Program, Kentucky State University, Frankfort, Kentucky 40601

AND

J. C. Parr and B. C. Pass

Department of Entomology, University of Kentucky, Lexington, Kentucky 40546-0091

Abstract

Carbofuran granules were applied at planting to determine whether this systemic insecticide would increase seedling establishment, growth and yield of alfalfa. Spring plantings were made in the field under no-tillage conditions and in the greenhouse under simulated no-tillage and conventional-tillage conditions.

In the field, alfalfa measurements were often greater in treated plots but results were inconsistent and not correlated with carbofuran rate. Pests and predators were largely unaffected. In the greenhouse, the high rate of carbofuran increased stem height and yield under simulated no-tillage but not conventional-tillage conditions.

Introduction

Establishment of alfalfa, using conservation-tillage methods, is increasing in the southern and eastern United States. Some extension personnel have included an application of carbofuran, a carbamate insecticide, into their recommendations for planting under the assumption that it is necessary to control the pests which may be present in damaging numbers under reduced tillage conditions.

Carbofuran has been reported to stimulate growth in tobacco (1), corn (2), soybeans (3), and alfalfa (4). One mechanism to explain growth differences in plants treated with carbofuran is a response to reduced feeding pressure by insects. Increased yields following repeated carbofuran (10G) treatments have been found in alfalfa (5) and ladino clover (6). Each study attributed this increase to less root injury by the clover root curculio (CRC), *Sitona hispidulus* (F.). However, in a laboratory study (7), dry-weight reductions of leaves, stems, and top growth (=yield) were not significantly correlated with numbers of CRC.

Another hypothesis is that the insecticide or its metabolites function as growth stimulants within the plant. Enhanced growth and yield of burley tobacco treated with carbofuran has been attributed to an unknown physiological response of the plants to the insecticide (1).

Our study was done to determine if the application of carbofuran at planting would increase seedling establishment, growth, and ultimately yield of alfalfa. The study was conducted in 2 parts: in the presence of pests in the field (1985 and 1986) under no-tillage conditions and in the absence of pests in the greenhouse (1985) under simulated no-tillage and conventional-tillage conditions.

Materials and Methods

Field.—Field experiments were conducted at the Spindletop Research Farm, Kentucky Agricultural Experiment Station, Lexington. Glyphosate herbicide was applied at the rate of 2.5 kg (AI)/ha on 10 April 1985 to a 0.14-ha area of a 5-yr-old alfalfa stand and on 30 April 1986 to an adjacent 0.07-ha area of the same stand to kill existing vegetation. Sixteen plots in 1985 (7.3 by 12.2 m) and 1986 (4.9 by 9.1 m) were established in a randomized complete block design (RCBD). Carbofuran granules were broadcast at 0, 1.1, 2.2, and 4.4 kg (AI)/ha on 6 May 1985 and 7 May 1986. 'Buffalo' alfalfa was no-till planted later the same day at the rate of 16.8 kg of seed per ha each year.

Alfalfa stem length and density were monitored in a 0.09-m^2 area randomly chosen in each plot. Stem densities were measured during seedling establishment and periodically until harvest. Yield was evaluated by harvesting a 4.1-m^2 area (0.9 by 4.5 m strip) of alfalfa in each plot on 23 July and 3 September 1985 and an 8.2-m^2 area (0.9 by 9.1 m strip) on 4 August and 7 October 1986. Harvest dates were delayed in 1986 due to the lack of rainfall in June (2.2 cm) and the slower growth of alfalfa. The strip samples were weighed in the field and a subsample was removed and sorted into alfalfa and weed components. Subsamples were weighed, oven dried for 24 hr at 80°C, and the dry weight yield of alfalfa in each sample was determined.

Pests and Predators.—Insects active on the soil surface were monitored weekly in each plot with a pitfall trap (8) from 14 May to 2 September 1985. Foliar-inhabiting insects were monitored with a sweep net (38.1 cm diam) by taking 15 sweeps per plot weekly from 4 June to 2 September 1985.

Two emergence traps (30 cm^3) were installed in each plot on 21 May 1985 and 15 May 1986 to sample the emerging adult CRC. Cages were removed at first harvest, and the foliage and soil vacuumed with a suction sampler. Four cages were also placed in the old alfalfa surrounding the plots in 1985 and 1986 to estimate the existing CRC populations. In addition, 2 uncaged areas per plot (0.09 m^2) were vacuumed with a suction sampler on 29 May 1986 to collect CRC adults.

Greenhouse.—Conventional-tillage planting conditions were simulated in the greenhouse in 1985 by adding unsterilized soil (beneath non-legume sod) from the research farm to plastic flats (30 by 60 by 3 cm). 'Apollo II' alfalfa was planted in the flats at the field rates. The same rates of carbofuran granules used in the field were broadcast on the flats and then covered with soil (2 cm). Treatments were replicated 4 times.

No-tillage planting conditions were simulated in the greenhouse by filling flats with nonleguminous sod cut from the research farm. Paraquat herbicide was applied on 6 June at the rate of 1.1 kg (AI)/ha to kill the sod. The same carbofuran rates as used in the field were applied on 10 June 1985. Two furrows (2–3 cm deep and 10 cm apart) were cut lengthwise in the dead sod within the flats. 'Apollo II' alfalfa seed was planted in the furrows. Treatments were replicated 4 times. The 32 flats were arranged on 4 tables in a RCBD and were watered and hand-weeded as needed.

Alfalfa stem length was monitored by randomly measuring 5 stems/flat each week. Stem density was monitored periodically by counting the number of stems in a designated 234-cm^2 area/flat. All stems were harvested 36 and 60 days after planting and yields calculated.

The data were subjected to analysis of variance and the means separated with Duncan's multiple range test (9) (P = 0.05) with the general linear models procedure of the statistical analysis system (10).

RESULTS

Field.—The application of carbofuran granules at planting under no-tillage conditions had a positive effect on alfalfa stem length. Alfalfa stems from plots receiving the high rate of carbofuran in 1985 and all rates in 1986 were significantly longer than alfalfa in untreated plots at the first harvest (Table 1). This effect was reduced by the second harvest.

Carbofuran had no effect on alfalfa seedling establishment or survival in 1985, but had a significant effect in 1986 (Table 1). Stem densities were much lower overall in 1986 than in 1985, probably because seedlings succumbed to the lack of soil moisture in June 1986.

The increased stem length found at the high carbofuran rate in 1985 did not produce significantly greater dry weight yields at either harvest (Table 1). However, the increased stem lengths and stem densities found in carbofuran treated plots in 1986 did result in increased yields, although not in proportion to the carbofuran rates applied. Yields were not significantly different at the delayed second harvest in 1986 due to the large variability between replications. Variability in 1986 was caused by extremely dry weather and a broadleaf weed problem which resulted in a poor, spotty alfalfa stand.

Pests and Predators.—CRC adults were much more abundant in 1986 than in 1985. Only one adult CRC was found in 32 emergence traps in 1985. Emergence of CRC from cages during the first cutting period of 1986 was not reduced in carbofuran treated plots (Table 2). Vacuum sampling in uncaged areas on 29 May 1986 revealed significant reductions in catches of adult CRC in plots treated with the highest rates of carbofuran. However, 4

TABLE 1. Harvest data ($\bar{x}$ ± SE) for alfalfa planted under no-tillage conditions with different rates of carbofuran, Lexington, Kentucky.

Carbofuran [kg (AI)/ha]	Alfalfa stem height (cm)		Alfalfa stem density/0.09 m²		Alfalfa dry weight yield (g/m²)	
	1985	1986	1985	1986	1985	1986
			1st Harvest			
4.4	32.7 ± 1.2a	28.7 ± 1.8a	54.1 ± 10.2a	21.5 ± 4.2a	95.1 ± 36.0a	73.1 ± 13.1a
2.2	28.7 ± 1.1b	28.2 ± 1.0a	47.5 ± 10.3a	24.9 ± 4.7a	88.9 ± 13.2a	98.1 ± 17.3a
1.1	26.5 ± 1.0b	28.4 ± 1.8a	42.8 ± 13.5a	17.2 ± 5.1ab	49.6 ± 8.5a	62.8 ± 23.5a
Untreated	26.5 ± 1.0b	12.1 ± 4.8b	62.0 ± 13.1a	4.0 ± 2.5b	84.1 ± 14.7a	3.2 ± 1.3b
			2nd Harvest			
4.4	39.6 ± 1.2a	31.0 ± 1.3ab	51.0 ± 6.7a	17.4 ± 2.8a	171.9 ± 54.0a	85.1 ± 16.9a
2.2	36.1 ± 0.9b	34.5 ± 1.3a	49.5 ± 12.0a	22.4 ± 2.8a	156.8 ± 21.0a	128.1 ± 18.3a
1.1	31.2 ± 1.1c	32.3 ± 1.5ab	43.5 ± 15.3a	16.9 ± 2.5a	136.5 ± 11.4a	158.7 ± 106.9a
Untreated	36.0 ± 1.4b	27.4 ± 2.0b	49.8 ± 4.3a	2.7 ± 0.6b	143.1 ± 31.5a	7.9 ± 4.0a

Means in columns per harvest followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

cages placed in alfalfa bordering the experimental area were found to average 4.1 ± 3.2 and 15.5 ± 10.6 CRC adults per 0.09 m² during 1985 and 1986, respectively. This suggests that the overall CRC population was reduced in the treatment area, irrespective of treatment.

Sweep-net sampling for pests with the potential to damage alfalfa seedlings revealed no significant differences between populations of CRC or the potato leafhopper, *Empoasca fabae* (Harris), in carbofuran treated and untreated plots. The most abundant predaceous insects in sweep samples were damsel bugs (Hemiptera: Nabidae), which were negatively affected by the carbofuran treatment during the first cutting period.

Pitfall trap catches of CRC adults were very small in all plots, regardless of insecticide treatment. Catches of slugs were not significantly different between plots. Predaceous ground beetle (Coleoptera: Carabidae) adults and immatures were abundant in pitfall traps. Adults of the most abundant species, *Evarthrus sodalis* LeConte, and the immatures collectively, were caught more frequently (though not significantly so) in untreated plots.

TABLE 2. Density of clover root curculio adults at first harvest in caged and uncaged 0.09-m² areas in no-till alfalfa planted with different rates of carbofuran in 1986, Lexington, Kentucky.

Carbofuran [kg (AI)/ha]	Caged[a]	Uncaged[b]
4.4	1.4 ± 0.3b	0.0 ± 0.0b
2.2	3.1 ± 0.8ab	0.5 ± 0.4b
1.1	4.7 ± 1.5a	1.6 ± 0.5a
Untreated	1.7 ± 0.9b	1.7 ± 0.3a

Means in columns followed by the same letter are not significantly different ($P > 0.05$; SAS Institute [1982])

[a] Emergence traps during 1st cutting period (n = 8).

[b] Area sampled with a suction sampler on 29 May (n = 8).

Greenhouse.—Flats treated with the high rate of carbofuran had significantly taller alfalfa under simulated no-tillage conditions in the greenhouse (Table 3). Although the carbofuran did not prevent a decline in stem density, the increased growth resulted in increased yield at the high carbofuran rate under no-till conditions. However, under simulated conventional-tillage conditions, no effects of carbofuran application were apparent.

DISCUSSION

The seedbeds used in this study were old, declining alfalfa stands which contained a resident root-inhabiting CRC larval population. Few CRC adults were collected by sweep-net, pitfall or emergence trapping in the treatment area, including the untreated control plots. However, the 4 emergence traps placed in alfalfa surrounding the treatment area contained a high population of CRC adults (4.1 and 15.5/trap, 1985 and 1986, respectively), and a concurrent study in another part of the old field indicated that CRC larvae had been present (J.C.P., unpublished data). We believe that the resident CRC larval population was reduced prior to the carbofuran treatment by the herbicide application used to kill all existing vegetation before no-tillage planting during 1985. Once the existing alfalfa and clover plants were killed the larvae may have starved before the establishment of the new seedling root systems. The majority of other potentially important pests and predators, both foliage- and sub-

TABLE 3. Harvest data comparison between alfalfa planted under conventional-tillage (CONV) and no-tillage (NOTL) conditions in the greenhouse with different rates of carbofuran, 1985, Lexington, Kentucky.

Carbofuran [kg (AI)/ha]	Alfalfa stem height (cm)		Alfalfa stand density/flat		Alfalfa dry weight yield (g/flat)	
	CONV	NOTL	CONV	NOTL	CONV	NOTL
			1st Harvest			
4.4	14.9 ± 1.2b	22.3 ± 2.1a	94.5 ± 4.6a	70.5 ± 10.6a	5.1 ± 0.6a	6.8 ± 1.0a
2.2	19.5 ± 1.9a	17.6 ± 0.7b	95.0 ± 1.5a	68.5 ± 4.7a	5.6 ± 0.7a	4.4 ± 0.6ab
1.1	13.3 ± 1.1b	14.3 ± 3.3b	88.5 ± 3.2a	56.5 ± 5.4a	4.2 ± 0.8a	3.6 ± 1.1b
Untreated	13.8 ± 1.8b	16.8 ± 3.8b	93.5 ± 2.8a	52.8 ± 7.6a	4.6 ± 0.9a	3.6 ± 1.5b
			2nd Harvest			
4.4	15.1 ± 1.5a	21.1 ± 1.4a	84.0 ± 8.0a	73.8 ± 9.0a	3.8 ± 0.5a	6.3 ± 1.0a
2.2	15.1 ± 1.8a	14.9 ± 1.0b	89.8 ± 9.0a	53.5 ± 11.8a	3.9 ± 0.3a	3.1 ± 1.0b
1.1	12.2 ± 0.9a	19.4 ± 2.5a	89.3 ± 2.6a	58.8 ± 8.6a	3.7 ± 0.7a	4.4 ± 1.2ab
Untreated	14.2 ± 2.4a	16.1 ± 2.7b	89.8 ± 13.6a	42.8 ± 8.4a	3.9 ± 1.1a	3.1 ± 1.2b

Means in columns per harvest followed by the same letter are not significantly different ($P > 0.05$; Duncan's [1955] multiple range test).

strate-inhabiting, were also largely unaffected by the carbofuran treatment.

An inconsistent growth response due to carbofuran was observed in the field, and stem density loss was not prevented by the carbofuran. Grant et al. (11) arrived at the same conclusion using a low rate of carbofuran [1.1 kg (AI)/ha] while establishing alfalfa into sod. Byers et al. (12), working in conservation-tillage alfalfa following alfalfa, found none of the mean alfalfa yields of plots treated with different combinations of carbofuran [1.1 kg (AI)/ha], herbicides, and a molluscicide to differ significantly from that of the check.

Alfalfa stem heights were greater in no-tillage than in conventional-tillage greenhouse trials. The greater organic matter content of the no-tillage flats may have slowed the leaching of the carbofuran from the flats, thereby increasing its availability for plant uptake. Also, the bare soil of the conventional-tillage flats would absorb much more heat in the greenhouse, which could lead to hotter, drier soil conditions and subsequently, reduction of plant growth, regardless of carbofuran treatment.

In contrast to the tillage response observed in stem length, stand densities were greater in conventional-tillage trials. Stand decline in no-tillage trials was believed to be due to competition from weeds which recovered from the herbicide treatment. Flats were hand-weeded on a regular basis to control broadleaf weeds but grasses were impossible to eliminate from the sod.

In summary, an inconsistent seedling growth response resulted from the application of carbofuran at the time of planting alfalfa under no-tillage conditions. The positive response to carbofuran in some instances may have been due to the control of root-inhabiting CRC larvae, nematodes or some other factor not sampled in this study, or to the presence of plant diseases in the unresponsive plots. A more consistent positive response to carbofuran may result if the granules are placed in the furrow with the seed. Stand establishment under no-tillage conditions will remain erratic and unpredictable until we have a greater understanding of the influence of insects, nematodes, slugs, diseases, and field history on alfalfa seedling establishment.

ACKNOWLEDGMENTS

Thanks are extended to S. A. Barney for technical assistance. The investigation reported in this paper (No. 87-7-199) is in connection with a project of the Ky. Agric. Exp. Stn. and is published with approval of the director.

LITERATURE CITED

1. Pless, C. D., E. T. Cherry, and H. Morgan, Jr. 1971. Growth and yield of burley tobacco as affected by two systemic insecticides. J. Econ. Entomol. 64:172–175.

2. Daynard, T. B., C. R. Ellis, B. Bolwyn, and R. L. Misener. 1975. Effects of carbofuran on grain yield of corn. Can. J. Plant Sci. 55:637–639.

3. Mellors, W. K., A. Allegro, and A. N. Hsu. 1984. Effects of carbofuran and water stress on growth of soybean plants and twospotted spider mite (Acari: Tetranychidae) populations under greenhouse conditions. Environ. Entomol. 13:561–567.

4. Byers, R. A. and D. L. Bierlein. 1984. Continuous alfalfa: invertebrate pests during establishment. J. Econ. Entomol. 77:1500–1503.

5. Neal, J. W., Jr., and R. H. Ratcliffe. 1975. Clover

root curculio: control with granular carbofuran as measured by alfalfa regrowth, yield, and root damage. J. Econ. Entomol. 68:829–831.

6. James, J. R., L. T. Lucas, D. S. Chamblee, and W. V. Campbell. 1980. Influence of fungicide and insecticide applications on persistence of ladino clover. Agron. J. 72:781–784.

7. Dintenfass, L. P. and G. C. Brown. 1988. Quantifying effects of clover root curculio (Coleoptera: Curculionidae) larval feeding on biomass and root reserves of alfalfa. J. Econ. Entomol. 81:641–648.

8. Barney, R. J. and B. C. Pass. 1986. Ground beetle (Coleoptera: Carabidae) populations in Kentucky alfalfa and influence of tillage. J. Econ. Entomol. 79:511–517.

9. Duncan, D. B. 1955. Multiple range and multiple *F* tests. Biometrics 11:1–42.

10. SAS Institute. 1982. SAS user's guide: statistics. SAS Institute, Cary, N.C.

11. Grant, J. P., K. V. Yeargan, B. C. Pass, and J. C. Parr. 1982. Invertebrate organisms associated with alfalfa seedling loss in complete-tillage and no-tillage plantings. J. Econ. Entomol. 75:822–826.

12. Byers, R. A., J. W. Neal, Jr., J. H. Elgin, Jr., K. R. Hill, J. E. McMurtrey, III, and J. Feldmesser. 1977. Systemic insecticides with spring-seeded alfalfa for control of potato leafhopper. J. Econ. Entomol. 70:337–340.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 85–88

Formation Constants of Transition Metal EDTA Complexes as a Function of Temperature

HARRY M. SMILEY
Department of Chemistry, Eastern Kentucky University, Richmond, Kentucky 40475

AND

VICKIE TRIANTAFYLLAKIS[1]
Department of Chemistry, University of Kentucky, Lexington, Kentucky 40506

ABSTRACT

A spectrophotometric technique was used to obtain formation constants of ethylenediaminetetraacetic acid (EDTA) complexes of Cr(III), Co(III), Ni(II), and Cu(II) at temperatures of 30, 40, 60, and 80°C. Enthalpies of formation were endothermic showing the free energy to be entropy controlled.

INTRODUCTION

Although a considerable number of publications can be found related to formation constants of ethylenediaminetetraacetic acid (EDTA) complexes (1–4), most of them report values at standard temperatures, with only a few constants measured at 40°C. Temperature dependence on these formation constants are of interest from both a practical and thermodynamic standpoint.

The formation constants of the complexes are based on the reaction $M^n + Y^{4-} \rightarrow MY^{n-4}$, where M^n represents a metal ion and Y represents EDTA. From the law of mass action the formation constant is given by:

$$K = \frac{[MY^{n-4}]}{[M^n][Y^{4-}]} \qquad (1)$$

If the molar concentration of the complex at equilibrium is C_c, the concentrations of the unreacted "free" metal ion and EDTA are $C_m - C_c$ and $C_y - C_c$, respectively, where C_m and C_y represent initial concentrations of metal ion and EDTA. Consequently, the equilibrium constant for the formation of the complex, K_c, is:

$$K_c = \frac{C_c}{(C_m - C_c)(C_y - C_c)} \qquad (2)$$

The equilibrium concentration of the complex is expressed by the following equation:

$$C_c = \frac{A_t - \epsilon_m C_m}{\epsilon_c - \epsilon_m} \qquad (3)$$

where ϵ_m and ϵ_c represent molar absorptivities of the metal ion and the complex. Equation 3 is based on the idea that the total absorbance at equilibrium, A_t, equals the sum of the absorbances of the complex, the unreacted metal ion, and the unreacted ligand.

$$A_t = A_c + A_m^* + A_y^* \qquad (4)$$

In equation 4, A_c, A_m^*, and A_y^* represent the absorbances of the complex, the unreacted metal ion, and the unreacted EDTA, respectively. At the wavelengths employed EDTA does not absorb so equation 4 becomes:

$$A_t = A_c + A_m^* \qquad (5)$$

Assuming the applicability of Beer's Law and because $C_m^* = C_m - C_c$, substitution into equation 5 yields:

$$A_t = \epsilon_c C_c + \epsilon_m C_m - \epsilon_m C_c \qquad (6)$$

which rearranges to equation 3. The spectrophotometric technique for the determination of K_c, therefore, consisted of determination of values of A_t, ϵ_m, and ϵ_c at 30, 40, 60, and 80°C.

However, equation 1 implies that all the uncombined EDTA is present in the completely dissociated form Y^{4-}. At lower pH values, though, the uncombined EDTA will also be present also in its protonated forms HY^{3-}, H_2Y^{2-}, H_3Y^{1-}, and H_4Y, which vary in their

[1] This paper is part of a M.S. Thesis written by Vickie Triantafyllakis who is currently pursuing the Ph.D. degree in the Department of Chemistry at the University of Kentucky.

TABLE 1. pH and a_H values for reported systems.

System	pH	a_H
Cr(III)	2.50	7.80×10^{11}
Co(III)	2.20	6.14×10^{12}
Ni(II)	1.80	1.33×10^{14}
Cu(II)	2.40	1.51×10^{12}

amounts according to the pH of the solution. To account for this fact, Flaschka (5) gave the equation:

$$K_c = \frac{K_{corr}}{a_H} \quad (7)$$

which can be rearranged to give the corrected stability constant, $K_{corr} = a_H \cdot K_c$,

where: K_{corr} = apparent or effective stability constant based on all the dissociation forms of EDTA which may exist at a particular pH.

$$a_H = 1 + K_1[H^+] + K_1K_2[H^+]^2 + K_1K_2K_3[H^+]^3 + K_1K_2K_3K_4[H^+]^4 \quad (8)$$

In a_H, the "stability constants" of the "proton complexes" of EDTA are used and are the reciprocals of the dissociation constants in reverse order. Their values were calculated from the pK of EDTA given by Schwarzenbach and Ackermann (6):

$$K_1 = 1.828 \times 10^{10}$$
$$K_2 = 1.449 \times 10^{6}$$
$$K_3 = 4.699 \times 10^{2}$$
$$K_4 = 9.908 \times 10^{1}$$

The values of the hydrogen ion concentrations in equation 8 were determined from pH measurements.

EXPERIMENTAL

The pH values of the systems reported were measured using a Fisher Accumet Model 230A pH meter and did not vary significantly over the reported temperature range. The measured pH values and the calculated a_H values are listed in Table 1.

TABLE 2. Concentrations (moles/liter) of equimolar mixtures of metal and EDTA in all determinations.

Cr(III)	2.00×10^{-3}	Ni(II)	1.00×10^{-1}
Co(III)	4.00×10^{-2}	Cu(II)	1.00×10^{-2}

TABLE 3. Total absorbances (A_t) of metal-EDTA systems.

Metal	30°C	40°C	60°C	80°C
Cr(III)	0.323	0.299	0.294	0.292
Co(III)	0.597	0.595	0.589	0.582
Ni(II)	0.760	0.746	0.735	0.741
Cu(II)	0.480	0.490	0.558	—

All absorbance measurements and curves were made using a Coleman Model EPS-3T Hitachi Ratio Recording Spectrophotometer. For measurement of the absorbances at higher temperatures, a Model 123-0702 Hitachi thermostatted 10 mm Path Cell Holder was also used. This attachment is composed of a thermostatted cell holder and a temperature controller, and can maintain a constant temperature of a cell filled with sample between 30–80°C. The temperature range accuracy is ±1°C for the temperature range of 30–50°C, and ±1.5°C for 50–80°C.

To ensure complex formation, equimolar mixtures of the metal ion and the disodium salt of EDTA were prepared, using deionized water as a solvent (Table 2). The absorbance was measured as a function of time, starting immediately after mixing the reagents. In all cases, with the exception of Cr(III), the absorbance graphs measured at different time intervals were within instrumental error (i.e., within ±0.3%) indicating a rapid complex formation. The spectrum of an equal concentration of the metal ion was also recorded and compared to the spectrum of the complex. In this manner, total absorbances, A_t, and molar absorptivities of the metal ions, ϵ_m, were determined at the indicated temperatures, and the data are listed in Tables 3 and 4, respectively.

To find the molar absorptivity of the complex the following method was used: keeping the concentration of the metal constant, the EDTA amount was varied, and the absorbance was plotted vs. the EDTA/metal concentration ratio. The curve reaches a maximum and levels

TABLE 4. Molar absorptivities of the metal ions.

Metal	30°C	40°C	60°C	80°C
Cr(III)	10.3	10.2	9.98	9.01
Co(III)	5.14	5.11	5.08	5.05
Ni(II)	0.651	0.514	0.497	0.378
Cu(II)	8.46	7.95	7.56	—

TABLE 5. Molar absorptivities of the metal-EDTA complexes.

Metal	30°C	40°C	60°C	80°C
Cr(III)	248	213	205	202
Co(III)	15.6	15.4	15.2	15.0
Ni(II)	8.95	8.40	7.95	7.90
Cu(II)	81.0	85.2	89.0	—

TABLE 7. Least squares parameters and enthalpies of formation.

System	Slope	Correlation coefficient	Std deviation of slope	ΔH cal/mole
Cr(III)	−1,239	−0.875	485	2,462
Co(III)	−1,401	−0.868	567	2,784
Ni(II)	−4,119	−0.988	49.8	8,184
Cu(II)	−1,122	−0.847	704	2,229

off. The molar absorptivity of the complex (ϵ_c) can be determined by extrapolation of the curve back to the y axis. Values of molar absorptivities for the complexes are given in Table 5.

Before each measurement the instrument was set to 100%T and 0 absorbance using both cuvettes filled with deionized water. A curve was then recorded to check 100% flatness. Variations on the flatness of the 100% line were corrected by subtracting the absorbance of this line from the absorbance curve of the sample.

DISCUSSION

Using the technique described above, formation constants for the 4 metal complexes were determined at the indicated temperatures, and the values are listed in Table 6. From the slopes of the plots of ln K_{corr} vs. 1/T negative slopes, indicating positive enthalpies of formation, were determined. The values determined for ΔH from the least squares determination of the slopes are somewhat questionable since the correlation coefficients vary from 0.84 to 0.99 and the standard deviations of the slopes have higher than desired values, with the exception of the Ni(II) system (Table 7). However, the slopes are definitely negative indicating positive values for ΔH. The expression for the Gibbs free energy is

$$\Delta G = \Delta H - T\Delta S \qquad (9)$$

Inspection of this equation, in conjunction with experimental results, leads to the conclusion that the formation of the reported EDTA complexes are entropy dominated. The Gibbs free energy, ΔG, must have a negative value in order for the formation of the complex to occur. Since ΔH, as determined from the slope of ln K_{corr} vs. 1/T, has a positive value, then ΔS must have a positive value in order for TΔS to offset the positive ΔH, resulting in a negative value for ΔG. This is not surprising since the metal ions are hydrated to 6 water molecules and, the formation of the complex releases these 6 molecules, resulting in a more disordered state than that represented by the reactants. From the slopes of the plots of ln K_{corr} vs. 1/T, the enthalpies of formation of the complexes were determined. The values are listed in Table 7.

The values of K_{corr} reported here are concentration values rather than thermodynamic values. Ideally K_{corr} should be determined at different concentrations and plotted as a function of concentration such that an extrapolated value at infinite dilution could be obtained. This would represent the thermodynamic value of K_{corr}, since, at this condition all activity coefficients would be unity.

The thermodynamic formation constant is given by the expression

$$K = \frac{a_{complex}}{a_y \cdot a_m} \qquad (10)$$

where $a_{complex}$, a_y, and a_m represent the activities of the complex, the unreacted ligand, and the unreacted metal ion, respectively. Since activity is the product of concentration and activity coefficient, equation 10 becomes:

TABLE 6. Apparent stability constants, K_{corr}, for metal-EDTA systems.

Metal	30°C	40°C	60°C	80°C
Cr(III)	1.73×10^{15}	2.69×10^{15}	3.16×10^{15}	3.29×10^{15}
Co(III)	3.40×10^{16}	5.83×10^{16}	6.48×10^{16}	7.24×10^{16}
Ni(II)	4.20×10^{16}	8.25×10^{16}	1.86×10^{17}	2.96×10^{17}
Cu(II)	3.97×10^{14}	3.68×10^{14}	5.38×10^{14}	—

$$K = \frac{\gamma_{complex}}{\gamma_y \cdot \gamma_m} K_{corr} \qquad (11)$$

where γ represents the activity coefficient values of the respective species. If one assumes that the activity coefficients for the complex and the ligand are not too different in numerical value, then equation 11 takes the form:

$$K = \frac{1}{\gamma_m} K_{corr} \qquad (12)$$

Since γ_m is a fraction between zero and unity depending upon concentration, the thermodynamic value of the formation constant is greater than K_{corr}, possibly by one order of magnitude.

Literature values for the formation constants of the EDTA complexes of Ni(II) and Cu(II) at 20°C are reported by Schwarzenbach and Freitag (1) to have values of 2.5×10^{18} and 2.0×10^{18}, respectively. These values were not determined by a spectrophotometric technique.

LITERATURE CITED

1. Schwarzenbach, G. and E. Freitag. 1951. Complexions XX. Stability constants of heavy metal complexes of ethylenediaminetetraacetic acid. Helv. Chim. Acta 34: 1503.

2. Hughes, V. and A. E. Martell. 1953. Spectrophotometric determination of the stabilities of ethylenediaminetetraacetate chelates. J. Phys. Chem. 57:694.

3. Bhat, T. R. and M. Krishnamurthy. 1962. Spectrophotometric studies of protonated, ammino, and hydroxo complexes of copper (II), nickel (II), and cobalt (II) versenates. J. Inorg. and Nuc. Chem. 25:1147.

4. Carini, F. F. and A. E. Martell. 1954. Thermodynamic quantities associated with the interaction between ethylenediaminetetraacetate and alkaline earth ions. J. Am. Chem. Soc. 76:2153.

5. Flaschka, H. A. 1959. EDTA titrations. Pergamon Press, New York.

6. Schwarzenbach, G. and H. Ackermann. 1947. Complexions V. Ethylenediaminetetraacetic acid. Helv. Chim. Acta 30:1798.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 89–95

Evaluation of Five Sequential Sampling Models for Use in an Alfalfa Weevil (Coleoptera: Curculionidae) Integrated Pest Management Program

DAVID E. LEGG AND ROBERT J. BARNEY

Community Research Service, Kentucky State University, Frankfort, Kentucky 40601

ABSTRACT

This paper compares 4 precision-based and 1 fixed-error probability sequential sampling models to determine which would be most suitable for use in an alfalfa weevil (AW), *Hypera postica* (Gyllenhal), integrated pest management program. Field tests indicated that the precision-based models with a precision (D) of 0.3 require essentially the same average number of samples to terminate sampling as the fixed-error probability model. However, using either of the precision-based models ($D = 0.3$) in an integrated pest management program when the fixed-error probability model is desired will result in too many management errors because they do not identify the range of population densities (i.e., intermediate zone) within which management decisions are unreliable. One method for calculating such an intermediate zone for use with precision-based models is discussed.

INTRODUCTION

The stem-count technique for assessing alfalfa weevil (AW), *Hypera postica* (Gyllenhal), larva infestations was first used by Hamlin et al. (1) and entailed removing stems within a square-foot quadrat and extracting the larvae in the laboratory. This technique provided absolute estimates of AW larva densities but was quite laborious. Subsequent modifications of this technique involved collecting individual stems over the entire alfalfa field with recommended number of stems ranging from 1 20-stem sample (2) to 10 50-stem samples (3). These modifications have generally improved the utility of this technique for an integrated pest management (IPM) program. A stem-count technique (4) is currently being used in Kentucky's AW IPM program and involves collecting 1 30-stem sample per field.

The 30-stem technique was recently reviewed (5) and was found to provide imprecise mean-density estimates which can lead to considerable management errors. This situation is primarily caused by collecting just one sample per field; collecting as many as 10 30-stem samples per field can greatly reduce the per cent of management errors but requires too much time to be cost effective (5).

To facilitate multiple sample collecting, Legg et al. (6) suggested collecting 1 6-stem sample from each of several randomly selected 100-m^2 subunits per field. This technique was found to be quite efficient when compared with collecting either 6 stems from 2,500-m^2 areas or 12 stems from 100- or 2,500-m^2 subunits per field (6).

Using the 6-stem, 100-m^2 sampling technique, Barney and Legg (7) constructed 4 precision-based sequential sampling models (precision [D] is defined as the ratio of the standard error of the mean to the mean) and have also constructed a computer-based fixed-error probability sequential sampling system (8). Precision-based sequential sampling models require that a predetermined level of precision be reached before sampling is terminated. Precision-based models do not, however, control the probability of misclassifying a population density relative to an economic threshold (ET). Fixed-error probability sequential sampling models control the probability of misclassifying a population relative to an ET but they do not control the precision at which mean population densities are estimated. Fixed-error probability models are more desirable for use in IPM programs because they facilitate the rapid classification of a pest population density into high or low categories relative to an ET, thus controlling the probability of misclassification.

Use of the fixed-error probability sequential sampling system of Legg and Barney (8) would require purchasing a portable computer. Presently, this would be economically feasible only for a select group of individuals (e.g., private IPM consultants, industry, and scouts in special university-sponsored IPM programs). Alter-natively, the low-cost precision-based models are available but little is known about their probability of misclassifying a population density relative to an ET. To explore the possibility of substituting precision-based sequential sampling models for the fixed-error probability model in an AW IPM program, we evaluated each model's performance as measured by number of samples required for sampling termination, observed precision and mean population density estimates. In addition, the probability of misclassifying a population density when using the precision-based models was estimated over a range of population densities.

MATERIALS AND METHODS

Thirteen alfalfa fields in Franklin County, Kentucky, were selected for sampling and represented a range in stand densities and ages. Each field was sampled weekly from 4 April through 7 May 1987 using 4 precision-based sequential sampling models (7), a fixed-error probability model (8) and a comprehensive whole-field sampling effort which served as an experimental control (whole-field control). Precision-based models ($D = 0.2$ and 0.3) were based on the equations of Kuno (9) and Green (10). The fixed-error probability model was based on Iwao's (11) equation and operated in a BASIC program that ran on an Epson HX-20 hand-held computer.

Order of visitation to fields within week and the order of sampling models per visit per field were random. The 6-stem, 100-m^2 sampling technique (6-stem count technique) (6) was used for all 5 models and the whole-field control. Briefly, the 6-stem count technique entailed randomly selecting 100-m^2 subunits from each field and collecting 6 stems from each subunit. Collected stems were vigorously shaken into a plastic bucket (10 liter) to dislodge large larvae. Dislodged larvae were emptied into a white enamel tray where they were counted. Subunits were independently and randomly selected for each model and whole-field control per visit per field. The 5 models and whole-field control were used in each field on each visit for 3 weeks except on 3 occasions when AW densities were too low to use the precision-based models at $D = 0.2$. Thirteen fields were sampled each week providing a total of 228 samples.

Average number of AW larvae and variance were calculated per sampling model and whole-field control per visit per field. Total number of samples required for model termination was also recorded. These statistics were used to calculate precision. Dependent variables of interest were mean AW densities, precision, and required number of samples for model termination. These are important statistics in IPM-related work.

Unlike the sequential sampling models, the whole-field control functioned independently of population density and hence the number of samples required to terminate sampling was not a response variable. To create a varying response for this sampling method, we selected a sample size range ($n = 10$–13 samples) within which the total number of samples was randomly chosen at each visit to each field. Based on the work of Barney and Legg (7), we felt that a minimum of 10 samples was necessary to consistently provide mean AW population estimates that would be more precise than those of the precision-based models (i.e., $D < 0.2$). This arrangement provided an estimate of variance. Variances within each dependent variable were tested for homogeneity between the sequential sampling models and whole-field control by calculating the s^2_{max}/s^2_{min} statistic (where s^2_{max} and s^2_{min} are the largest and smallest variances, respectively) and comparing it with the tabulated upper 5% value (12). Data were then transformed, when necessary, to stabilize the variance. Transformations used were $x^{1.25}$ and $\sqrt{X}$ for number of samples and calculated precision, respectively.

Data were subjected to a split-plot analysis of variance with sampling week (a time factor) representing the whole plot, fields within week being factor a, and sampling model and whole-field control within fields being factor b. Computations were facilitated by using the Linear Analysis of Variance Procedure of STATISTIX (13).

Orthogonal linear contrasts (14) were conducted to determine the significance of 5 specific comparisons: (1) whole-field control vs. all sequential sampling models, (2) precision-based models vs. fixed-error probability model, (3) precision-based models at $D = 0.3$ vs. precision-based models at $D = 0.2$, (4) Green's precision-based models at $D = 0.3$ vs. Kuno's precision-based model at $D = 0.3$ and (5) Green's precision-based model at $D = 0.2$ vs. Kuno's precision-based model at $D = 0.2$. Significance of these comparisons was determined by Student's t test. In addition, 4 nonorthogonal contrasts were performed to determine whether their contribution to the sums of squares of each dependent variable was significant: (1) Green's and Kuno's precision-based models at $D = 0.3$ vs. the fixed-error probability model, (2) Green's precision-based model at $D = 0.3$ vs. the fixed-error probability model, (3) Kuno's precision-based model at $D = 0.3$ vs. the fixed-error probability model and (4) Green's and Kuno's precision-based models at $D = 0.2$ vs. the fixed-error probability model. Since these latter comparisons were neither orthogonal to one another nor to the previous group of comparisons, their significance was determined by Scheffé's (15) F test which is designed for use with arbitrary simultaneous comparisons. Linear contrasts and related statistics were computed by the General Contrasts Option of STATISTIX (13).

The probability of misclassifying a population density when using the precision-based models was determined by the methods of Barney and Legg (5). These involved collecting 5 6-stem samples for each visit to each of 4 alfalfa fields (7) and calculating, for each visit to each field, the variance (s^2) and mean population density ($\bar{x}$). These statistics were then transformed to the Napierian log scale (ln) with $\ln(s^2)$ being regressed on $\ln(\bar{x})$ (16) using Bartlett's (17) method ($s^2 = 1.0124\bar{x}^{1.2707}$; 95% confidence interval for slope = 0.37, 2.19; r^2 = 0.37). A computer program (18) was used to facilitate computations of this regression. Using this relationship, the average variance can be estimated for each mean population density. Forty-two means, selected to cover the range (2–32) of AW larvae per 6 stems that are usually found in the field, were substituted individually into this equation to calculate their respective variances. Each of the 42 selected means and variances was then used to generate 100 sets of 3, 7, and 11 6-stem samples; thus spanning the range of very low (3) to very high (11) numbers of samples per population density. Each set of 6-stem samples was randomly selected from an assumed normal distribution. Although insect populations are rarely normally distributed, the distribution of sample averages often conforms to the normal as the number of samples increases (14). Averages were calculated for each set of 3, 7, and 11 samples per population density, and compared with each of 6 ETs that were selected to cover the range of AW densities normally encountered in the field (3, 7, 12, 16, 21, and 26 larvae per 6-stem sample). From these comparisons 1 of 2 possible management decisions were made (to apply or not to apply an insecticide) with each resulting in one of the following situations: (1) the estimated average *and* the true average were below the ET and a hypothetical insecticide application was not made (correct decision), (2) the estimated average was greater than the ET but the true average was less than the ET and an unnecessary insecticide application was made (unnecessary spray), (3) the estimated average *and* the true average were greater than the ET and an insecticide application was made (correct decision), and (4) the estimated average was less than the ET but the true average was greater than the ET and a necessary insecticide application was not made (failure to spray). Proportion of unnecessary sprays was calculated by summing the number of unnecessary sprays and dividing it by 100. Proportion of failures to spray was calculated by summing the number of failures to spray and dividing it by 100.

RESULTS AND DISCUSSION

Analysis of variance for mean AW larva estimates indicated that significant differences did not occur between any of the sampling models and/or whole-field control ($F = 0.39$, $P = 0.86$, df = 5,124). Therefore, linear contrasts were not conducted for this variable. Analysis of variance for number of samples and precision, however, indicated that significant differences existed between some of the sampling models and/or whole-field control (number of samples: $F = 145.5$, $P < 0.0001$; precision: $F = 4.7$, $P = 0.0006$; df for both analyses = 5,124). Linear contrasts for number of samples and precision are shown in Tables 1 and 2, from which the following conclusions can be made: (1) average number of samples required for terminating sampling and observed precision of the sequential sampling models was much less than that of the whole-field control. These results were expected and they reflect both the savings in sampling effort realized through the use of sequential sampling models over the whole-field control and the lower precision associated with fewer samples. (2) Average number of samples required to terminate sampling was lower for the precision-based models with $D = 0.3$ than for the precision-based models with $D = 0.2$. This result was expected since required number of samples is less for lower precision. (3) Average number of samples required to terminate sampling and observed precision of all precision-based models (combined) or the precision-based models with $D = 0.3$ was not different from that of the fixed-error model. Number of samples required to terminate sampling was, however, greater for precision-based models with $D = 0.2$ than for the fixed-error probability model. Interestingly, average observed precision did not differ between precision-based models with $D = 0.2$ and the fixed-error probability model. These results indicate that the precision-based models with $D = 0.3$ will not require more effort, as measured by number of samples, than the fixed-error probability model. Also, the average precision realized when using the fixed-error probability model is essentially equivalent to but is more variable than that of the precision-based models.

From the results obtained thus far it appears that either of the precision-based models with $D = 0.3$ can be substituted for the fixed-error probability model in an AW IPM program. However, fixed-error probability models possess an "intermediate" category that corresponds to observed population densities which are too near the ET for distinct classification into "high" or "low" categories at the maximum allowable proportion of unnecessary sprays and failures to spray. Precision-based models do not have this intermediate zone.

One method of determining the intermediate zone for the precision-based models is to calculate, via computer-simulated sampling experiments, the probability of misclassifying mean population densities for each ET at various population densities. These probabilities can then be used to estimate, via the standard normal curve, AW densities corresponding to the specified proportion of unnecessary sprays and failures to spray. Population densities between and including those associated with these error probabilities constitute the intermediate zone.

Probabilities of misclassifying mean AW larva population densities when the estimates were based on 3, 7, and 11 6-stem samples are shown in Figure 1. Maximum errors (height of the curves) occur, as expected, when population densities are nearest the ET (5). Height of the curves was not reduced when the number of samples was increased from 3 to 11 but the proportion of errors was reduced when the number of samples was increased as mean population densities moved away from the ET (width of the curves). It appears that relatively few errors occurred at very low population densities (3 larvae per 6-stem sample) as compared with very high population densities (26 larvae per 6-stem sample). Width of the curves increased noticeably from the lowest to highest ET for mean estimates that were based on 3 6-stem samples but this trend was reduced when 7 and 11 6-stem samples were taken.

Curves for the normal distribution were fitted to these data and the average AW larvae per 6-stem sample corresponding to a 0.25 probability of spraying unnecessarily and a 0.20 probability of failing to spray were calculated for each ET and each level of sample number per mean. These values were then pooled over sample number per mean and regressed on their respective ETs (Fig. 2). Relationships for controlling the number of unnecessary sprays (bottom regression) and failures to spray (top regression) were linear and explained 99% of the observed variance. These equations may now be used to calculate error zones for any ET that is based on a 6-stem sample. Resulting error zones, however, are valid only for AW population estimates calculated from 11 or fewer samples.

It is now possible to modify Kentucky's AW IPM program to make use of these new sampling technologies. Such modification will involve 4 phases: adoption of the 6-stem, 100-m^2 sampling method, selection of a precision-based model ($D = 0.3$), calculation of error zones, and modification of the AW IPM recommendation tables (i.e., replacing the ETs with error zones). Implementation would be a straightforward process of sampling a field with the selected model, estimating the average AW population density, and consulting the error zone corresponding to the correct cumulative degree days and alfalfa growth stage. If the average AW population density is less than the

TABLE 1. Orthogonal and nonorthogonal contrasts between various combinations of five sequential sampling models (four precision-based and one fixed-error probability model) and an intensive whole-field sampling effort (whole-field control) as measured by average number of samples required to terminate sampling.

Contrast		Mean number of samples factor 1	Mean number of samples factor 2	Critical statistic	P
Factor 1	Factor 2				
Whole-field control	All sequential sampling models	12.2	4.3	$t = 25.01$	<0.0001
Precision-based models	Fixed-error probability model	4.5	3.7	$t = -1.85$	0.0635
Precision-based models, $D = 0.3$	Precision-based models, $D = 0.2$	2.9	6.0	$t = 9.78$	<0.0001
Green's precision-based model, $D = 0.3$	Kuno's precision-based model, $D = 0.3$	3.0	2.9	$t = -1.68$	0.0917
Green's precision-based model, $D = 0.2$	Kuno's precision-based model, $D = 0.2$	6.4	5.7	$t = -0.18$	0.8330
Precision-based models, $D = 0.3$	Fixed-error probability model	2.9	3.7	$F = 1.06$	0.3843
Green's precision-based model, $D = 0.3$	Fixed-error probability model	3.0	3.7	$F = 0.87$	0.5032
Kuno's precision-based model, $D = 0.3$	Fixed-error probability model	2.9	3.7	$F = 0.73$	0.6075
Precision-based models, $D = 0.2$	Fixed-error probability model	6.0	3.7	$F = 6.46$	<0.0001

TABLE 2. Orthogonal and nonorthogonal contrasts between various combinations of five sequential sampling models (four precision-based and one fixed-error probability model) and an intensive whole-field sampling effort (whole-field control) as measured by average observed precision.

Contrast		Mean precision factor 1	Mean precision factor 2	Critical statistic	P
Factor 1	Factor 2				
Whole-field control	All sequential sampling models	0.150	0.263	$t = -3.71$	0.0004
Precision-based models	Fixed-error probability model	0.252	0.311	$t = 1.11$	0.2683
Precision-based models, $D = 0.3$	Precision-based models, $D = 0.2$	0.294	0.209	$t = -2.41$	0.0164
Green's precision-based model, $D = 0.3$	Kuno's precision-based model, $D = 0.3$	0.280	0.309	$t = 1.44$	0.1481
Green's precision-based model, $D = 0.2$	Kuno's precision-based model, $D = 0.2$	0.183	0.234	$t = 0.8$	0.4299
Precision-based models, $D = 0.3$	Fixed-error probability model	0.294	0.311	$F = 0.00$	1.00
Green's precision-based model, $D = 0.3$	Fixed-error probability model	0.280	0.311	$F = 0.03$	0.99
Kuno's precision-based model, $D = 0.3$	Fixed-error probability model	0.309	0.311	$F = 0.04$	0.99
Precision-based models, $D = 0.2$	Fixed-error probability model	0.209	0.311	$F = 0.8$	0.55

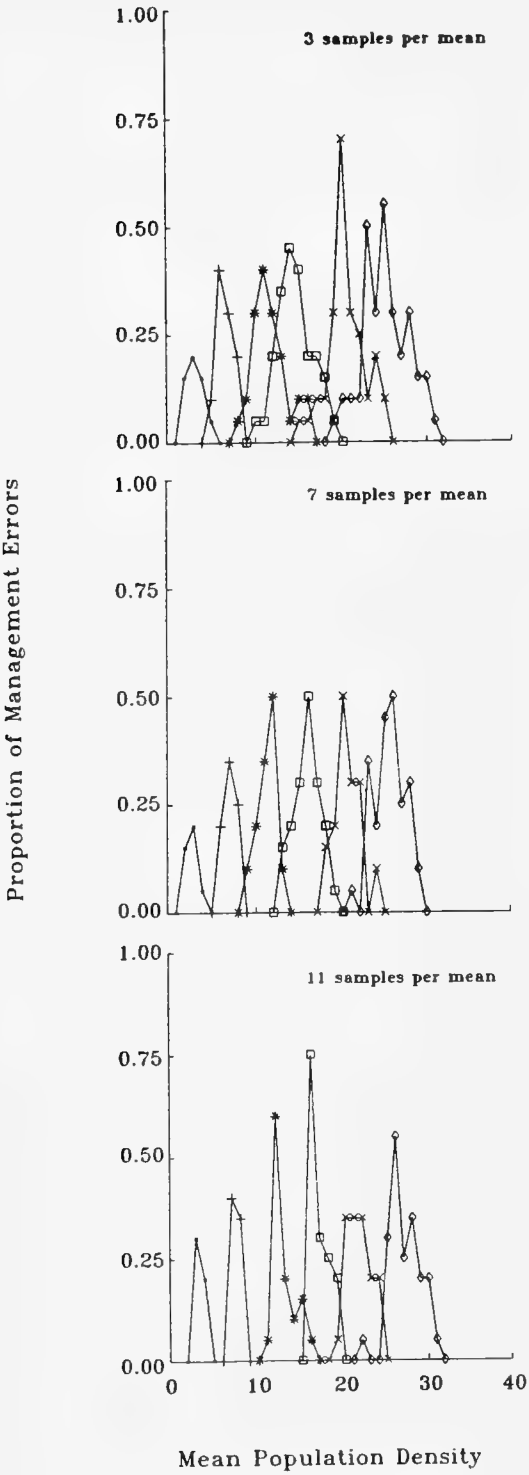


FIG. 1. Probabilities of making alfalfa weevil (AW) management errors when comparing mean estimates (based on 3, 7, or 11 samples) at each of 42 population densities ← to six ETs: 3(·), 7 (+), 12 (*),16 (□), 21 (×) and 26 (◇) larvae per 6-stem sample. Probabilities were calculated via computer-simultaed sampling experiments.

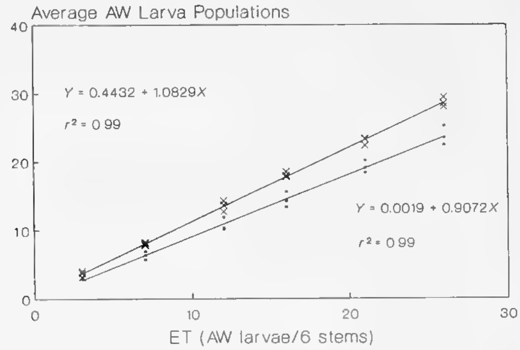


FIG. 2. Linear regression equations for estimating the lower (bottom regression) and upper (top regression) values of error zones about various economic thresholds (ET). Error zones correspond to a 0.25 maximum probability of spraying unnecessarily or a 0.20 maximum probability of failing to spray economically damaging alfalfa weevil (AW) populations.

lowest value of the error zone then an insecticide spray is not recommended. If the average AW population density is greater than the largest value of the error zone then an insecticide application or early cutting is recommended. If the average AW population density falls within the error zone then the larval density is too near the ET to make reliable decisions. Growers are thus advised that the AW population may or may not reach economic levels and are recommended to either take more samples now or resample in 2 days.

ACKNOWLEDGMENT

This investigation was supported in part by a USDA/CSRS grant to Kentucky State University under agreement KYX-10-85-04P.

LITERATURE CITED

1. Hamlin, J. C., F. W. Lieberman, R. W. Bunn, W. C. McDuffie, R. C. Newton, and L. J. Jones. 1949. Field studies of the alfalfa weevil and its environment. U.S. Dep. Agric. Tech. Bull. No. 975.

2. Armbrust, E. J., H. D. Niemczyk, B. C. Pass, and M. C. Wilson. 1969. Standardized procedures for cooperative Ohio Valley states alfalfa weevil research. J. Econ. Entomol. 62:250–251.

3. Christensen, J. B., A. P. Gutierrez, W. R. Cothran, and C. G. Summers. 1977. The within field spatial pattern of the larval Egyptian alfalfa weevil, *Hypera brunneipennis* (Coleoptera: Curculionidae): an application of parameter estimates in simulation. Can. Entomol. 109: 1599–1604.

4. Wedberg, J. L., W. G. Ruesink, E. J. Armbrust, and D. P. Bartell. 1977. Alfalfa weevil pest management program. Ill. Coop. Ext. Serv. Circ. 1136.

5. Barney, R. J. and D. E. Legg. 1987. Accuracy of a single 30-stem sample for detecting alfalfa weevil larvae (Coleoptera: Curculionidae) and making management decisions. J. Econ. Entomol. 80:512–516.

6. Legg, D. E., R. J. Barney, and R. J. Kyrscio. 1988. Improved sampling plans for monitoring alfalfa weevil (Coleoptera: Curculionidae) larva infestations in Kentucky. J. Econ. Entomol. 81:215–219.

7. Barney, R. J. and D. E. Legg. 1988. Development and validation of sequential sampling plans for alfalfa weevil (Coleoptera: Curculionidae) larvae using a 6-stem, 100 square-meter subsampling method. J. Econ. Entomol. 81:658–662.

8. Legg, D. E. and R. J. Barney. 1988. Use of portable computers to assess insect populations in advanced integrated pest management programs: alfalfa weevil as an example. J. Econ. Entomol. 81:995–999.

9. Kuno, E. 1969. A new method of sequential sampling to obtain the population estimates with a mixed level of precision. Res. Popul. Ecol. (Kyoto) 11:127–136.

10. Green, R. H. 1970. On fixed precision level sequential sampling. Res. Popul. Ecol. (Kyoto) 12:249–251.

11. Iwao, S. 1975. A new method of sequential sampling to classify populations relative to a critical density. Res. Popul. Ecol. (Kyoto) 16:281–288.

12. Pearson, E. S. and H. O. Hartley. 1966. Biometrika tables for statisticians, Vol. 1. Cambridge Univ., Cambridge, London.

13. Nimis, G. and D. Heisey. 1985. NH Analytical Software, St. Paul, Minnesota.

14. Snedecor, G. W. and W. G. Cochran. 1980. Statistical methods, 7th ed. Iowa State Univ., Ames.

15. Scheffé, H. 1977. The analysis of variance. Wiley, New York.

16. Taylor, L. R. 1961. Aggregation, variance and the mean. Nature (London) 189:732–735.

17. Bartlett, M. S. 1949. Fitting a straight line when both variables are subject to error. Biometrics 5:207–212.

18. Legg, D. E. 1986. An interactive computer program for calculating Bartlett's regression method. North Cent. Computer Inst. Software J. 2(3):1–23.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 96–100

Pollen Diet of Some Predator Mites

A. M. Afifi,[1] M. F. Potts, C. G. Patterson,
and J. G. Rodriguez

Department of Entomology, University of Kentucky, Lexington, Kentucky 40546

Abstract

Some commercial types of pollen (plum, pecan, pistachio, apple, kiwi fruit, almond and pear) were compared with local corn pollen as alternate foods for *Neoseiulus fallacis* (Garman), an important phytoseiid predator of orchard mites. Efficiency of food as measured against time required for development between egg oviposition and adult emergence, as influenced by relative humidity (RH), pointed to pistachio as a superior alternate food and 85% RH promoting the most rapid development. These same pollens were challenged under the same RH conditions by 2 additional phytoseiids, *Phytoseiulus persimilis* Athias-Henriot and *Typhlodromus occidentalis* (Nesbitt) and monitored for egg production as a parameter of food efficiency. None of these pollens were nutritionally adequate to continue oogenesis beyond exhaustion of the stored-up food reserve, from prey consumed while the predator females were in the immature stages. Other corollary studies with *N. fallacis* demonstrated that locally produced tulip poplar pollen provided adequate nutrition, and was comparable to pistachio but Zumi crab apple was superior since it sustained 11 continuous generations without supplementation with prey.

Introduction

Phytoseiid mites have long been recognized as an important component in the management strategy of tetranychid mites, especially in orchards. This family of predator mites generally develops and reproduces best when preying on spider mites but can subsist on such alternate foods as pollen, scale crawlers and honeydew (1, 2). Pollens from various sources have often proven to be acceptable and efficient alternate foods for some species of phytoseiids, as shown by McMurtry and Rodriguez (3) who recently reviewed the nutritional ecology of phytoseiids.

The main objectives in this study were to examine comparative acceptance and general nutritional efficiency of 10 different pollens on 3 important phytoseiid predators, namely, *Phytoseiulus persimilis* Athias-Henriot, *Neoseiulus* (=*Amblyseius*) *fallacis* (Garman) and *Typhlodromus occidentalis* (Nesbitt). Major emphasis was given *N. fallacis*, an important predator of apple orchard mites in Kentucky.

Materials and Methods

The predatory mites, *P. persimilis*, *N. fallacis* and *T. occidentalis* were sub-cultured from stocks maintained in the Acarology Laboratory. The prey, the twospotted spider mite (TSSM), *Tetranychus urticae* (Koch), was highly acceptable in all stages to the 3 species of phytoseiids in our study (3). The experiments were conducted under laboratory conditions of 16 hr photoperiod and 27°C.

Development of *N. fallacis*

Detached bean leaves were divided into 6 sections by streaks of tree Tanglefoot® and were placed on moist filter paper in petri dishes (90 mm diam). The dishes were in turn placed in clear plastic containers (19 × 28 cm) containing saturated salts to provide relative humidities (RH) of 75, 81, 85, 92, and 97 per cent. In addition, water only was included in one treatment to provide nearly 100% RH. Seven commercial types of pollen grains, namely, almond, apple, kiwi fruit, pear, pecan, pistachio and plum (Fireman Pollen Co., Stockton, California) plus corn pollen from a local hybrid cornfield, were individually supplied on the leaf surface as food for the predator, *N. fallacis*, that developed from one egg placed on each section. The immature stages of *N. fallacis* were transferred every 2 days to detached bean leaves and pollen grains. Data were obtained from 12 mites observed from each treatment.

In a corollary study, this same group of pollens were tested for their influence on longevity of *N. fallacis*, adult emergence to death (N = 24).

[1] Present address: Acarology Division, Faculty of Agriculture, Cairo University, Giza, Egypt.

POLLEN EFFICIENCY IN *N. FALLACIS* DEVELOPMENT

In these tests, the same pollen types (except that local tulip poplar was substituted for corn) used previously were placed on 90-mm disks cut from black polyethylene sheeting and divided into 6 sections with Tanglefoot. One *N. fallacis* egg was placed in each section and distilled water was supplied by soaking a small lump of filter pulp. The rearing dishes (N = 24) were maintained at 90% RH with other conditions as described previously. Growth and life stage development were determined.

Two other corollary tests were also conducted. One test involved apple pollen and prey fed to 2 generations of *N. fallacis*. In another study, crab apple pollen (University of Kentucky Farm) of the Zumi variety was used as food for *N. fallacis*. Growth/development, longevity, and fecundity were determined. The tests were conducted on disks cut from black polyethylene with conditions as described above.

STUDIES ON EGG PRODUCTION

Detached bean leaves were partitioned into 6 approximately equal parts with use of Tanglefoot. Newly emerged male and female *N. fallacis* and *T. occidentalis* were offered the same 8 pollen types and the test was repeated 4 times. Males were removed after 2 days and the females (N = 24) were then maintained for 15 days using the same procedures and conditions as in the previous study. The Tanglefoot confinement method used successfully for *N. fallacis* and *T. occidentalis* proved unsuitable for *P. persimilis*, hence a Plexiglas® rearing cell was used for this species. The cell consisted of 3 Plexiglas pieces. The top and bottom were 3 mm in thickness and 4 × 6 cm. The middle piece had a thickness of 6 mm and a hole 2.5 cm in diameter which together with the bottom and top pieces comprised a cell. The top piece was vented with a hole 0.6 cm in diameter and covered with a cemented fine mesh screen. Bean leaf disks (3 cm in diameter) were placed in the rearing cells (N = 20) and pollen grains were supplied as food. The assembled cell was held together with rubber bands. Again, rearing conditions/procedures were as used in the studies described previously.

TABLE 1. Comparative developmental time of *N. fallacis* in days from egg oviposition to adult emergence on pollens at varying relative humidities at 27°C (N = 12) (81 and 97% RH data not shown).

Pollen type	Relative humidity			
	75%	85%	92%	100%
Plum	13.3b	11.2a	12.5ab	13.5b
Corn	13.0b	10.7a	12.2ab	13.2b
Pecan	12.6a	11.2a	11.3a	12.4a
Pistachio	11.7b	10.0a	10.8ab	12.0b
Apple (Delicious)	13.8b	12.5a	13.4ab	14.3b
Kiwi fruit	14.0ab	12.5a	13.7ab	14.2b
Almond	13.0b	11.3a	12.5ab	13.7b
Pear (Bartlett)	13.2b	11.7a	13.0b	14.0b
L.S.D.	N.S.	1.3	1.3	1.2

N.S. = not significant. Means followed by the same letter within a row are not significantly different, $P = 0.05$; Duncan's multiple range test

A corollary study made use of tulip poplar, a meridic diet, or a combination thereof to determine their efficiency compared with TSSM prey when fed to *N. fallacis*. The test procedure entailed isolating *N. fallacis* eggs and rearing the immatures to adults (N = 25). Egg production was then monitored over a 28 day period.

RESULTS

DEVELOPMENT OF *N. FALLACIS*

Neoseiulus fallacis fed and developed on all pollen types and at all RH levels tested. The effects of various pollen types on development as influenced (from oviposition to adult emergence) by RH are shown in Table 1. Generally, the 85% RH promoted the shortest development time, especially when compared against 75% and 100% RH (Table 1). Only in the case of pecan and kiwi pollens were these differences, i.e., between 85% RH and the extremes, not significant. Examining the effect of pollens on development time, pistachio clearly was superior to other pollens, accelerating rate of development, followed by pecan or corn. Kiwi fruit or apple were the least efficient (Table 1). In the corollary study on longevity (tabulated data not given for sake of brevity), pistachio pollen prolonged adult longevity to the greatest degree, a mean of 47.8 days at 85% RH as compared to kiwi fruit, the most likely to shorten life, with 41.5 days. None of the pollen types used as food during the life span of *N. fallacis* proved suitable for egg production.

TABLE 2. Development of *N. fallacis* from egg to the adult stage when fed on various pollen types at 27°C and 85% RH (N = 24).

Pollen type	% Reaching adult stage
Pistachio	77.8a
Tulip Poplar	60.0ab
Apple (Delicious)	55.6ab
Pecan	48.1ab
Plum	29.6bc
Kiwi fruit	29.6bc
Almond	7.4c
Pear (Bartlett)	6.0c
Control (Blank)	0.0c

Means followed by the same letter are not significantly different, $P = 0.05$; Duncan's multiple range test

POLLEN EFFICIENCIES IN *N. FALLACIS* DEVELOPMENT

Pistachio pollen provided the highest per cent of individuals reaching the adult stage (77.8%) followed by tulip poplar, apple and pecan pollens in the moderate range while plum, kiwi fruit, almond, and pear were the most inefficient, ranging from 30% (plum) to 6% (pear) (Table 2). The adults were then mated and each female was isolated, and fed the same pollen on which it had developed. Tulip poplar pollen gave 60% of adult development and females laid an average of 33.6 eggs during 28 days. There was no egg production in *N. fallacis* when fed other pollens at this time.

When *N. fallacis* was fed apple pollen during its developing stages, 56% reached adult stage but did not produce eggs. These adults were then supplied with spider mites and subsequently an abundance of eggs were produced. F_1 immatures were 80% developed into adults when fed on apple pollen. When those female adults were once again fed spider mites they produced eggs that resulted in emergence of an F_2 generation (Table 3).

TABLE 3. Development of *N. fallacis* from egg to adult stage when fed on apple pollen over 3 generations at 27°C and 85% RH. Spider mites were fed to the adults to obtain eggs for the next generation (N = 18).

Generation	% Reaching adult stage
Parent generation	55.6b
F_1 generation	80.0a
F_2 generation	87.0a

Means followed by the same letter are not significantly different, $P = 0.05$; Duncan's multiple range test

TABLE 4. Development and fecundity of *N. fallacis* when fed on Zumi crab apple pollen for 11 generations at 27°C and 85% RH.

Stage	Avg. duration in days
Life cycle (egg to adult)	7.5
Pre-oviposition period	9.0
Oviposition period	7.0
	(9.1 eggs/female)
Post-oviposition period	40.8
Adult longevity	56.8

* Total number of eggs/female = 1.3

A corollary study involved Zumi crab apple pollen fed to *N. fallacis*. Zumi crab apple pollen was readily accepted and *N. fallacis* was successfully reared on this pollen for 11 generations (Table 4).

EGG PRODUCTION

The oviposition study on the 3 phytoseiid species, *N. fallacis*, *P. persimilis* and *T. occidentalis*, involved the use of newly emerged mated females. They were fed on the various pollen types (see Tables 1, 2) for 15 days. This study showed that a small quantity of eggs were produced over the initial 2 to 3 day period. However, females ceased to oviposit after this initial period, indicating that the prey food reserve built up during the immature stages had been exhausted.

No significant differences were found among the 8 pollen types analyzed across all humidities or humidities analyzed across all pollens. The initial egg production was the result of the immature stages previously feeding on the spider mites. The results of this test indicated that these 8 pollen types, when supplied as food for the 3 phytoseiid predators, proved to be nutritionally deficient for oviposition. However, the pollens could sustain the mites for a limited period. It should be noted, however, that local crab apple (Zumi) pollen was used in another test to successfully rear 11 generations of *N. fallacis* (Table 4).

A diet regimen of prey eggs was slightly more efficient nutritionally than a diet of protonymphs. When offered a meridic diet (Table 5), development of egg to adult occurred, but egg production did not occur. When this diet was supplemented with tulip poplar pollen, egg production (1.2 per day) occurred, and this

TABLE 5. Composition of meridic diet, ingredients to make up 100 ml.

Nutrient	g/100 ml
Honey	15
Sodium caseinate	6
Nutrex 2000	6
Cholesterol	0.01
Soy lecithin	0.005
Beta sitosterol	0.001
Ascorbic acid	0.1
Vitamin mixture	0.3
Streptomycin sulfate	0.05
Methylparaben	0.15
Formalin	(0.1 ml of 10% formalin)

supplemented diet was superior to the pollen alone (Table 6).

TABLE 6. Effect of diet on egg production of *N. fallacis* over a 28 day period (N = 25).

Diet	Avg. number of eggs per female/day	SD
T. urticae eggs	2.7	0.52
T. urticae protonymphs	2.3	0.53
Meridic diet + poplar pollen	2.1	1.88
Tulip poplar pollen only	1.2	0.66
Meridic diet only	0	

DISCUSSION AND CONCLUSION

Neoseiulus fallacis that fed on the various pollen types at various RH levels for its entire life span had a developmental rate that was generally significantly affected by the pollen types when analyzed across all RH levels. However, the effects on adult female longevity were not significant. The mite, during larval, protonymphal and deutonymphal stages, must feed before developing to the subsequent stage. Food value and acceptability can greatly influence the development of these life stages, as was shown by feeding the various pollen types. The 8 pollens used in the study to determine their efficiency, as measured by egg productivity in the 3 predator species, proved to be nutritionally inadequate. Egg production did not occur after the initial burst of oviposition, demonstrating that the immature stages feeding on prey eggs laid down food reserves essential for oogenesis but once that limited reserve was exhausted, oogenesis did not continue under a pollen food regimen. The specific nature of pollen adequacy, however, was apparent by the comparative efficiency of Zumi crab apple pollen that successfully produced 11 successive generations of *N. fallacis* without the benefit of spider mite prey. By the same token, while *P. persimilis* and *T. occidentalis* accepted Zumi pollen, they did not produce eggs.

Ahlstrom and Rock (4) reported that *N. fallacis* fed and reproduced on pollens from the trumpet creeper vine and the tulip poplar. Moreover, this species adapted and accepted these pollens as food, as indicated by the increasing percentage of immatures reaching adult stage, from 55.6 in the parent generation to 80 and 87 per cent in the first and second generation respectively.

Phytoseiid mites vary in their ability to efficiently convert pollen food into resources for egg production. For example, pollen grains of castor bean, avocado, maize and carpobrotus (*Mesembryanthemum*) were shown in laboratory studies to have high food value for *Euseius* (=*Amblyseius*) *hibisci* (Chant) and *Amblyseius limonicus* Gar. MCG. (5, 6). *Amblyseius hibisci* was continuously cultured on pollen alone, but *T. occidentalis* Nesbitt did not feed on pollens (7). *Phytoseiulus persimilis* and *T. occidentalis* failed to oviposit when fed an artificial diet, while *E. hibisci, A. largoensis* (Muma) and *T. arboreus* (Chant) developed and oviposited when fed on both oak pollen and on artificial diet (8).

When the artificial diet was combined with tulip poplar pollen and fed to *N. fallacis*, the females produced an average of 2.1 eggs per female per day, compared to 2.3 when TSSM protonymphs were provided as food.

It was demonstrated that the three phytoseiid predators, *P. persimilis*, *N. fallacis* and *T. occidentalis*, can survive for a period of time on various pollens. This is a very important attribute for these predators, especially during the absence of the natural prey.

Pollens vary in their chemical composition and not all pollen types are efficient food for phytoseiids (3). Our results also support Kennett and Hamai (8) who found that neither *P. persimilis* nor *T. occidentalis* oviposited when fed on any food other than tetranychid mites.

Finally, although the 3 phytoseiid predators may accept different pollens, generalizations cannot be made on nutritional adequacy. *Neoseiulus fallacis* is clearly a species that can live and reproduce on certain pollens such as Zumi crab apple. Studies are needed to determine why tulip poplar and Zumi crab apple pollens are superior food and to examine techniques of utilizing these pollens in orchards as alternate foods.

Acknowledgment

The investigation reported in this paper (No. 88-7-132) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director.

Literature Cited

1. Swirski, E. and N. Dorzia. 1969. Laboratory studies on the feeding, development and fecundity of the predaceous mite *Typhlodromus occidentalis* Nesbitt (Acarina: Phytoseiidae) on various kinds of food substances. Israel J. Agr. Res. 19:143–145.

2. Kamburov, S. S. 1971. Feeding, development and reproduction of *Amblyseius largoensis* on various food substances. J. Econ. Ent. 64:643–648.

3. McMurtry, J. A. and J. G. Rodriguez. 1987. Nutritional ecology of phytoseiid mites. Pp. 609–644. In F. Slansky and J. G. Rodriguez (eds.) The nutritional ecology of insects, mites, spiders, and related invertebrates. John Wiley & Sons, New York.

4. Ahlstrom, K. R. and G. C. Rock. 1973. Comparative studies on *Neoseiulus fallacis* for azinphosmethyl toxicity and effects of prey and pollen on growth. Ann. Ent. Soc. Amer. 66:1109–1113.

5. McMurtry, J. A. and G. T. Scriven. 1964. Studies on the feeding, reproduction and development of *Amblyseius hibisci* (Acarina: Phytoseiidae) on various food substances. Ann. Ent. Soc. Am. 57:649–655.

6. McMurtry, J. A. and G. T. Scriven. 1965. Life history studies of *Amblyseius limonicus* with comparative observations of *Amblyseius hibisci* (Acarina: Phytoseiidae). Ann. Ent. Soc. Am. 58:106–111.

7. Huffaker, C. B., M. Van de Vrie, and J. A. McMurtry. 1970. Tetranychid population and their possible control by predators. An evaluation. Hilgardia 40:391–458.

8. Kennett, C. E. and J. Hamai. 1980. Oviposition and development in predaceous mites fed with artificial and natural diets (Acari—Phytoseiidae). Ent. Exp. Appl. 22: 116–122.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 101–116

Distribution of Kentucky Land Snails (Mollusca: Gastropoda)

Branley Allan Branson and Donald L. Batch

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

Collecting in 55 counties yielded data for 19 families, 45 genera, and 138 species of Kentucky land snails and slugs. Five species were previously unreported from the state: *Vertigo rugosula* Sterki, *V. parvula* Sterki, *Arion subfuscus* (Draparnaud), *Oxychilus draparnauldi* (Beck), and *Polygyra cereolus* (Muhfeld). Ecological and distributional information is presented for each species. A general biogeographical discussion pertaining to the relationships of the Kentucky terrestrial gastropod fauna is presented that suggests a relationship principally with the fauna of the southeastern United States and, to a lesser degree, with that of the midwest and the east.

Introduction

Since publication of the principal checklists of Kentucky land snails (1, 2), many taxonomic and biogeographic changes have been reported in the literature. In order to bring interested investigators up to date, the more recent findings are summarized. Hubricht (3) relegated *Glyphyalinia burringtoni* Pilsbry to the synonymy of *G. wheatleyi* (Bland) and elevated to full generic level *Megapallifera* from a position of subgenus in *Pallifera*; *Megapallifera* includes *M. mutabilis* (Hubricht), *M. ragsdalei* (Webb), and *M. wetherbyi* (W. G. Binney). In 1977, Hubricht (4) found that *Catinella vagans* (Pilsbry) was probably a distinct species rather than a synonym of *C. vermeta* (Say) and described *Paravitrea subtilis* and *Carychium riparium*, both from Kentucky. During that period, *Vitrizonites latissimus* (Lewis) and *Vertigo clappi* (Brooks and Hunt) were reported from Kentucky (5), as was *Glyphyalinia raderi* (Pilsbry) (6). Petranka's (7) thesis research recorded *Vertigo bollesianna* (Morse), *Mesomphix rugeli* (Binney), and *Triodopsis dentifera* (Binney) from the state. Finally, in a much needed revision of known terrestrial molluscan distribution in the eastern United States, Hubricht (8) summarized the recent family and generic changes that have been wrought during the last 12 years. The most important changes, affecting the Kentucky fauna, follow: *Cionella* was placed in the genus *Cochlicopa* and *C. lubrica morseana* (Doherty) was elevated to full species; *Vallonia perspectiva* Sterki was reported from Kentucky; *Columella edentula* (Draparnaud) was placed in the synonymy of *C. simplex* (Gould); *Succinea forsheyi* I. Lea was reported from Kentucky; *Philomycus togatus* (Gould) was elevated to full species; *Megapallifera mutabilis* (Hubricht) was reported; *Pallifera secreta* (Cockerell) was resurrected as a full species, as was *Anguispira strongyloides* (Pfeiffer) and *A. rugoderma* (Hubricht); *Discus catskillensis* (Pilsbry) was elevated to full species and *H. fimbriatus* Wetherby was reported from the state; *Mesomphix globosus* (MacMillan) was reported; *Paravitrea subtilis* Hubricht and *P. blarina* Hubricht were reported, as was *Hawaiia alachuana* Dall; *Ventridens elliotti* (Redfield) was shifted into *Zonitoides*; and *Euconulus dentatus* (Sterki) was resurrected and reported from Kentucky. In the Polygyridae, Hubricht (8) reported *Polygyra troostiana* I. Lea from the state and restricted the range of *P. fatigiata* (Say) to extreme western Kentucky only; *Mesodon panselenus* Hubricht was reported, but not *M. perigraptus* (Pilsbry); *M. laevior* Hubricht was retained as a full species distinct from *M. appressus* (Say); *Triodopsis rugosa anteridon* Pilsbry was elevated to full species; *T. fraudulenta* (Pilsbry) was not reported; and *T. hopetonensis* (Shuttleworth) was reported.

In spite of all this recent information, the distributional data on the Kentucky terrestrial molluscan fauna remain woefully inadequate and incomplete. Many of the counties have not been sampled for mollusks. Thus, this contribution attempts to partially rectify this situation by presenting data from 55 Kentucky counties, plus some data from adjacent Virginia and Indiana, including records for 19 families, 45 genera, and 138 species of terrestrial snails and slugs.

COLLECTING SITES

1. In leaf litter at Yeaddis, Leslie Co.; 22 October 1976.
2. In a tilled flower bed, Eastern Kentucky University, Madison Co.; 14 November 1971.
3. Top of Black Mountain, below radar tower, in mesophytic woods, off SR 160, Harlan Co.; 13 September 1980.
4. Lawn, State Office Building, Frankfort, Franklin Co.; 4 December 1980.
5. Mesophytic woods, 150 m below summit, Black Mountain, SR 160, Harlan Co.; 13 September 1980.
6. Mesophytic woods at base of Black Mountain, SR 160, Harlan Co.; 13 September 1980.
7. Moist mesophytic woods, Yahoo Falls, off SR 700, McCreary Co.; 14 September 1980.
8. Floodplains of Otter Creek, 8.2 km north of Richmond, CR 1927, Madison Co.; 3 December 1970.
9. At mouth of Bylew Cave, off SR 728, Edmonson Co.; 30 September 1980.
10. Kentucky River Campground, open woods, Frankfort, Franklin Co.; 19 September 1980.
11. Sparsely wooded hillside overlooking confluence of Goose Creek and Salt River, Spencer Co.; 19 September 1980.
12. Moist woods at Ritner Ford, McCreary Co.; 11 October 1980.
13. Moist woods, Devil's Hollow, Devil's Hollow Road, Franklin Co.; 22 October 1980.
14. Grassy hill at junction of SR 420 with the E-W connector, Frankfort, Franklin Co.; 17 November 1980.
15. Wooded ravine near entrance to Lake Cumberland State Park, Russell Co.; 22 April 1979.
16. Dry woods along Kentucky River, Boonesboro State Park, Madison Co.; 27 September 1980.
17. Bypass Cave near junction of US 60 and US 127, Franklin Co.; 13 October 1980.
18. Wooded banks of Dix River at SR 52, Boyle Co.; 11 October 1980.
19. Low hillside at junction of US 420 E and W, Frankfort, Franklin Co.; 17 September 1980.
20. Low-lying woods at Whayne's Corner, Hickman Co.; summer 1980.
21. Grounds at Lt. Governor's Mansion, Frankfort Co.; 17 September 1980.
22. Wooded banks of Town Branch at Viley Road, Lexington, Fayette Co.; 27 September 1980.
23. Managed woods, Cherokee Park, Louisville, Jefferson Co.; November 1980.
24. Moist woods at High Bridge, Jessamine Co.; 6 November 1980.
25. Wet woods at Hurricane Slough of Taylor Lake, Butler Co.; 26 September 1980.
26. Dry channel along SR 94 at Tennessee border, Fulton Co.; 21 August 1978.
27. Rough River Dam State Park, Grayson Co.; 20 October 1980.
28. Moist woods along Boone Creek at Grimes Mill Road, Fayette Co.; 13 September 1980.
29. Banks of the Kentucky River at CR 1927, Madison Co.; 13 November 1980.
30. Woods along the Kentucky River at US 68, Mercer Co.; 12 October 1980.
31. Woods along the Salt River at US 31E, Bullitt Co.; 8 December 1980.
32. Woods at Camp Nelson, Jessamine Co.; 22 October 1980.
33. Minor E. Clark Fish Hatchery, Morehead, Rowan Co.; 6 September 1980.
34. Woods along Silver Creek at Barnes Mill crossing, Madison Co.; 27 September 1980.
35. Woods at Burkesville, Cumberland Co.; 6 October 1979.
36. Dense woods and undergrowth, Black Mountain, 3.6 km downgrade from junction of Roberts Branch Road with SR 934, Letcher Co.; 13 September 1980.
37. In tropical vegetation inside Fayette Mall, Lexington, Fayette Co.; 6 September 1980.
38. Game Farm Woods, at Game Farm, Frankfort, Franklin Co.; 4 December 1980.
39. Woods near fire tower just off Roberts Branch Road, Letcher Co.; 13 September 1980.
40. In entrance of Steel Hollow Cave, McCreary Co.; 11 October 1980.
41. Woods, 6.6 km north of Elizabethtown, off I-65, Hardin Co.; October 1980.
42. Bedford, Trimble Co.; 21 September 1980.
43. Woods along Muddy Creek at Doylesville, Madison Co.; 16 October 1979.
44. Rocky hillside at junction of US 421 and CR 1211, Franklin Co.; 20 October 1982.
45. Moist woods at Brooklyn Bridge, Woodford Co.; 18 September 1980.
46. Moist woods at Benson Creek Falls, Franklin Co.; 9 October 1980.
47. Falls of the Ohio River on Indiana side; September 1980.
48. Woods at Iroquois Hunt Club, Grimes Mill Road, Fayette Co.; 2 November 1982.
49. Woods, 1.6 km above Indian Fort Theatre, Berea, Madison Co.; 4 November 1980.
50. Along foundation of U.S. Post Office, Water Street, Richmond, Madison Co.; 6 December 1980.
51. Wet woods, 12.8 km northwest of New Concord at Pottertown, Calloway Co.; 11 October 1964.
52. Woods along Triplett Creek, 6.4 km west of Morehead on US 60, Rowan Co.; 23 October 1964.
53. Mouth of Eureka Cave, McCreary Co.; 19 September 1980.
54. Wherry Bog, 0.3 km north of Tennessee border on US 27, McCreary Co.; 27 September 1980.
55. Belmont Battlefield, 1.6 km north of Columbus, Hickman Co.; 24 December 1967.

56. S-Tree Recreation Area forest, Jackson Co.; 4 September 1980.
57. Floodplain forest along Paint Lick Creek, 0.4 km above mouth of Dry Run, Madison Co.; 6 October 1979.
58. Moist woods off Barren Fork Road, 2.4 km north of Whitley City, McCreary Co.; 19 September 1980.
59. Laketon, Carlisle Co.; 9 September 1980.
60. Dripping shale bluffs at Allen, Floyd Co.; 20 July 1980.
61. In flower bed, Capital Plaza shopping center, Frankfort, Franklin Co.; September 1980.
62. Moist woods at Indian Falls, Jessamine Co.; 30 November 1980.
63. Woods along US 460 at junction with Pepper Pike, Scott Co.; 12 October 1980.
64. Grassy woods at Central Kentucky Wildlife Management Area, Madison Co.; 6 October 1980.
65. Below US 60 bridge at Otter Creek, Meade Co.; 6 October 1980.
66. Woods along Muddy Creek at US 23, Ohio Co.; September 1980.
67. Swan Lake, Ballard County Wildlife Management Area, Ballard Co.; 30 September 1980.
68. Southshore, Greenup Co.; 10 October 1980.
69. Virgin forest, Lilley Cornett Woods, Letcher Co.; 14 May 1983.
70. Woods just north of Raven Run Park, Fayette Co.; 2 November 1980.
71. Moist woods 0.8 km above mouth of Pigeon Creek, Edmonson Co.; 3 September 1980.
72. Sink hole 0.4 km north of Raven Run Park off Jacks Creek Pike, Fayette Co.; 2 November 1980.
73. Woods at Lock 4 of Kentucky River, Franklin Co.; 20 November 1980.
74. On lawn grass at Wooten, Leslie Co.; 1 October 1983.
75. Cedar glade at Simpson–Warren county line at US 31W; October 1983.
76. Big Clifty Prairie, Grayson Co.; 15 September 1983.
77. Wooded hills at Clay's Ferry, below I-75 bridge, Fayette Co.; 14 September 1980.
78. Along baseboards of house, Elizabethtown, Hardin Co.; 10 November 1980.
79. Barrow ditch off SR 510, 9.6 km east of Harlan Co. line in Letcher Co.; 22 October 1983.
80. Woods 2.0 km downstream from CR 1900, Franklin Co.; 19 September 1980.
81. Wooded ravine at mouth of Little South Fork of Cumberland River, McCreary Co.; 6 September 1981.
82. Greenhouse at University of Kentucky, Lexington, Fayette Co.; 12 March 1983.
83. Wooded hillside at junction of SR 804 and 114, Letcher Co.; 11 October 1972.
84. Streamside forest 8.0 km north of Middlesboro at US 25E crossing of Yellow Creek, Bell Co.; 20 July 1980.
85. Woods at US 60 crossing of Slate Creek, Bath Co.; 25 February 1984.
86. Baseboards of house, Payne Street, Lexington, Fayette Co.; 8 March 1979.
87. Beneath flood debris along Levisa Fork of Big Sandy River, Paintsville, Johnson Co.; 12 September 1984.
88. Wooded banks of Yellow Creek, 0.6 km above confluence with Carr Fork Lake, Knott Co.; 28 September 1970.
89. Wooded bluffs of Laurel Lake, Breaks Interstate Park, Virginia; 20 July 1980.
90. Woods at Cumberland Falls, McCreary Co.; 12 September 1980.
91. Hickory woods at Indian Fort Theatre, Berea, Madison Co.; 11 September 1983.
92. Woods along Tygarts Creek at SR 7, Greenup Co.; 5 October 1968.
93. Wooded bluffs of Ohio River, 3.2 km east of Dayton on SR 8, Campbell Co.; 8 September 1984.
94. Woods along Rockcastle River at I-75, Rockcastle Co.; 23 October 1982.
95. Woods at Cumberland Gap National Historical Park campground, Virginia; 5 October 1970.
96. Dense woods below Natural Bridge, Natural Bridge State Park, Powell Co.; 23 October 1970.
97. Woods at confluence of Line Fork Creek and the North Fork of Kentucky River, Letcher Co.; 15 April 1984.
98. Heavily shaded, moist ravine near entrance to Pine Mountain State Park, Bell Co.; 23 October 1970.
99. Woods along Line Fork Creek at mouth of Defeated Creek on CR 1103, Letcher Co.; 13 April 1984.
100. Wooded banks of North Fork of Kentucky River, 1.2 km east of Banks on CR 1103, Letcher Co.; 13 April 1984.
101. Wet woods at upper end of Lake Wilgreen, Madison Co.; 30 April 1982.
102. Woods at mouth of Lower Howard Creek, Clark Co.; 14 April 1978.
103. Woods along Middle Fork of Kentucky River, 30 km south of Hyden on US 421, Leslie Co.; 1 April 1978.
104. Floodplains of Eagle Creek, 1.6 km north of Wheatley, Owen Co.; 18 October 1978.
105. Woods at end of SR 211 at Licking River (Moore's Ferry), Bath Co.; 25 February 1984.
106. Moist woods 3.0 km south of Mt. Vernon off US 25, Rockcastle Co.; 15 April 1978.
107. Vegetated sinkhole at Jessamine–Woodford co. line; 27 April 1978.
108. Woods along Kentucky River, 1.2 km above mouth of Smith Creek, Jessamine Co.; 8 May 1975.
109. Woods at junction of US 441 and SR 90, Cumberland Co.; 11 April 1981.
110. Woods 1.6 km south of Glencoe on Eagle Hill Road, Owen Co.; 5 September 1984.
111. Woods along Fish Trap Creek, 300 m above Licking River, Clay Wildlife Management Area, Nicholas Co.; 16 March 1984.
112. Woods at junction of Laurel Fork Creek and South Fork Road, Breathitt Co.; 20 April 1984.

113. Woods along Kentucky River at old US 25 bridge, Madison Co.; 14 October 1982.
114. Lilley Cornett Woods at Line Fork Creek, Letcher Co.; 14 April 1984.
115. Moist wooded hillside, 7.3 km north of Richmond on SR 60 (Tates Creek Road), Madison Co.; 13 November 1979.
116. Woods along SR 353, 10.6 km south of SR 62, Bourbon Co.; 8 September 1984.
117. Wooded slopes of Cumberland Gap, Bell Co.; 20 July 1968.
118. Shores of Lake Cumberland, Pulaski Co.; 26 August 1968.
119. Red River Gorge at mouth of Swift Camp Creek, Wolfe Co.; 27 March 1971.
120. Woods along Beaver Creek at Frenchburg, Menifee Co.; 12 October 1980.
121. Muddy forest floor along Davis Branch of Clear Creek near Pine Mountain State Park, Bell Co.; 25 October 1970.
122. Woods along Kentucky River at Boonesville, Owsley Co.; 20 February 1971.
123. Baseboards of a house, Harlan, Harlan Co.; 14 November 1984.
124. Woods at Brassfield, Madison Co.; 29 September 1979.
125. Sparse woods along Townsend Creek at Bourbon–Harrison co. line in Bourbon Co. off US 27; 15 March 1986.
126. Woods, 1.6 km west of junction of SR 111 with CR 1990 on CR 1990, Montgomery Co.; 25 March 1984.
127. Woods at mouth of Grier Creek, Woodford Co.; 19 March 1984.
128. Dale Hollow Lake State Park campground, Cumberland Co.; 11 October 1981.
129. Roadside ditch at Monticello, Wayne Co.; 15 October 1982.
130. Woods at end of Mallory Spring Road (of SR 594), Madison Co.; 20 February 1984.
131. Woods along Kentucky River at Valley View, SR 60, Madison Co.; 26 August 1984.
132. Behind slaughter house at junction of Thompson Road with Old Frankfort Pike, Lexington, Fayette Co.; 9 April 1984.
133. Woods at mouth of Stratton Branch on CR 2061, Pike Co.; 25 July 1984.
134. Woods below Daniel Boone Memorial Bridge, Clark Co.; 27 April 1984.
135. Woods, 4.8 km northwest of CR 1105 crossing of Hazel Creek, Ballard Co.; 18 May 1982.
136. Wet woods along Licking River on US 60 at Bath–Rowan co. line in Rowan Co.; 6 September 1980.
137. Lawn in Deacon Hills Estates, Richmond, Madison Co.; 16 May 1985.
138. Woods at upper end of Owsley Fork Lake, Jackson Co.; 28 July 1984.
139. Woods behind Owsley Fork Church, Owsley Fork Road, Jackson Co.; 11 September 1982.
140. Moist woods at Alum Ford at SR 700, McCreary Co.; 29 April 1984.
141. Moist woods, 0.5 km south of US 27 crossing of Elkhorn Creek, Owen Co.; 31 March 1984.
142. Railroad station, Nicholasville, Jessamine Co.; 23 October 1980.
143. Moist ravine, 9.6 km southwest of Oven Fork on US 119, Letcher Co.; 14 April 1984.
144. Woods along Four Mile Creek at South Fork Road, Breathitt Co.; 18 March 1984.
145. Hillside, 0.8 km east of I-64 on SR 22, Jefferson Co.; 31 March 1984.
146. Low, open hillside, 1.6 km south of Wayne–Clinton co. line in Clinton Co., on SR 90; 18 March 1980.
147. Big Bone Lick State Park, Boone Co.; 29 November 1980.

RESULTS

In the annotated list that follows, specimens are correlated with collecting sites by station number. The figures in parentheses represent the sample size in each case. The taxonomic designations, except where noted, follow Hubricht (8).

Family Helicinidae

Two genera and species of the primitive order Archaeogastropoda occur in Kentucky. These are operculated, mostly calciphilic land snails with a propensity for moist ravines in Kentucky, although *Helicina* is often found on relatively dry, grassy hillsides.

Helicina orbiculata (Say)

Collections: 12 (1).

Although locally abundant, the distribution of this species is poorly understood in Kentucky. It prefers sunny locations (8) but is often found along the margins of woods.

Hendersonia occulta (Say)

Collections: 5(3), 12 (1), 15 (2), 143 (1), 146 (1).

All these sites were in moist ravines with an abundance of decaying vegetation and fairly deep horizon A soil. Fresh specimens are usually pale rusty red in color, although yellowish is not uncommon (8).

Family Carychiidae

Because of their minute size and habitat in leaf litter and soil, the distribution of the species of *Carychium* in Kentucky is poorly delineated. Furthermore, some of the species are relatively difficult to distinguish, causing some confusion in the literature. Burch and Van Devender (9) published excellent keys and photographs of the described species, and their taxonomy is followed here. Data for three species are reported.

Carychium clappi Hubricht

Collections: 4 (12), 10 (50), 13 (7), 125 (1).

The only previously reported records for this species in Kentucky were from Harlan County (5, 7), and some authors (9) do not consider the species to be distinct from *C. exile canadense* Clapp.

Carychium exiguum (Say)

Collections: 10 (23), 13 (3), 16 (1), 115 (10).

Because confusion between this species and *C. exile*, records from Kentucky may be in confusion.

Carychium nannodes Clapp

Collections: 4 (9), 10 (23), 13 (7), 16 (6), 73 (9).

As our records indicate, this very slender species is often found associated with *C. exiguum*. It is one of the smallest snails in America, measuring only 1.3–1.5 mm in length (8).

Family Cochlicopidae

Formerly included in the family Cionellidae (1, and elsewhere), the genus *Cionella* has been placed in the synonymy of *Cochlicopa* with 4 species in North America (8), one of which is known from Kentucky.

Cochlicopa morseana Doherty

Collections: 2 (9), 13 (1), 34 (1), 43 (1), 119 (2), 134 (1).

Hubricht (8) has *C. lubrica* (Muller) and *C. morseana* as full and distinct species, which we accept. This very secretive, woodlands species is often missed by general collectors. The habitat is mostly in moist decaying wood and leaves, although it is often found deep beneath piles of unconsolidated rocks.

Family Valloniidae

Distributional data for these small ground-dwelling snails is very limited for Kentucky. Soil sieves are required for efficient collecting. Data for 3 species are presented.

Vallonia pulchella (Müller)

Collections: 2 (2), 4 (15), 10 (61), 13 (1), 16 (1), 115 (5), 125 (13).

This small, white species prefers grassy fields, lawns, and weedy hillsides (8), where it is most easily collected by means of graduated soil sieves.

Vallonia costata (Müller)

Collections: 4 (145), 10 (110), 13 (4), 16 (3), 49 (6), 91 (3).

Living in a habitat similar to the last mentioned, this species is often collected with *V. pulchella*.

Vallonia perspectiva Sterki

Collection: 115 (2).

The only other record for this species in Kentucky is from Mercer County (8). The snail should be sought in heavily wooded ravines and talus slopes.

Family Pupillidae

Since most of these small to minute, seedlike snails are easily overlooked during collecting, the poor representation in Kentucky records is not startling. Data for 4 genera and 14 species are reported here.

Pupoides albilabris (C. B. Adams)

Collections: 24 (2), 28 (3), 29 (1), 50 (6), 115 (13), 125 (1), 137 (1).

The largest species of the family, this snail frequents grassy areas, open hillsides, woodland margins, and similar habitats.

Gastrocopta armifera (Say)

Collections: 10 (2), 13 (2), 16 (1), 24 (6), 27 (1), 38 (1), 44 (1), 50 (4), 56 (1), 77 (2), 115 (69), 125 (8), 130 (1).

Found mostly in open, sunny areas, this snail is not infrequently found in marginal forests. Hubricht (10) separated *G. clappi* (Sterki) from *G. armifera*, raised it to full species level, and listed it from 3 Kentucky counties (8). The two forms are easily distinguished by means of the characters presented by Hubricht (10): in *G. armifera* the columellar lamella has a forward-projecting lobe and the shell measures 3.7–5.0 mm in length and 2.0–2.6 mm in diameter. In *G. clappi* there is no forward-projecting lobe on the columellar lamella and the shell is smaller, 3.5–4.3 mm in length and 1.8–2.0 mm in diameter. There is an excellent illustration of *G. clappi* on page 876 of Pilsbry's (11) monograph.

Gastrocopta contracta (Say)

Collections: 4 (7), 10 (17), 13 (6), 16 (1), 24 (1), 29 (4), 32 (5), 115 (60), 125 (9), 130 (10).

A very environmentally plastic species, *G. contracta* doubtless occurs throughout Kentucky.

Gastrocopta pentadon (Say)

Collections: 10 (11), 13 (4), 29 (1), 115 (3), 125 (8).

Often confused with the next species, which is larger, this species prefers upland woods with well-drained, calcareous soils.

Gastrocopta tappaniana (C. B. Adams)

Collections: 115 (2), 125 (1), 130 (1).

With far fewer records from Kentucky than *G. pentadon*, *G. tappaniana* lives in moist situations, mostly on floodplains, around ponds and lakes, and in swamplands.

Gastrocopta corticaria (Say)

Collections: 4 (21), 10 (25), 13 (7), 115 (1).

Prior to this report, *G. corticaria* was known from Clark, Jefferson, and Edmonson counties only. It is a moist forest species.

Gastrocopta procera (Gould)

Collections: 4 (1), 115 (4), 116 (1).

This thick-shelled snail has habitat requirements similar to those of *Pupoides albilabris*.

Vertigo rugosula Sterki

Collection: 10 (1).

Not previously reported from Kentucky, this species prefers rather dry situations on open hillsides.

Vertigo ovata Say

Collection: 10 (2).

The only other record for this lowland species in Kentucky is from Edmonson County (1).

Vertigo ventricosa (Morse)

Collections: 10 (2), 16 (2), 125 (2).

Previous records for this lowlands, moisture-loving snail were from Harlan (8) and Madison (1) counties.

Vertigo tridentata Wolf

Collections: 8 (1), 115 (5), 125 (2).

This very small snail lives in moist, lowland situations, usually on the lower sides of fallen leaves.

Vertigo parvula Sterki

Collection: 115 (1).

Heretofore unknown from Kentucky, this minute species is similar to *V. tridentata*, though it is much smaller, measuring about 1.5 mm in length and 0.9 mm in diameter. According to Pilsbry (11) it is a relatively rare species. The favored habitat is leaf litter (8).

Vertigo gouldi (A. Binney)

Collections: 115 (1).

Of widespread but sporadic occurrence in Kentucky, this is another small snail that prefers leaf litter as habitat.

Columella simplex (Gould)

Collections: 4 (1), 10 (1), 27 (1), 29 (1).

This is not a common species in Kentucky, nor does it apparently produce large populations where it is found in moist lowland woods and ravines. Previously reported from Kentucky as *C. edentula* (Draparnaud) (1), a name now placed in the synonymy of *C. simplex* (8).

Family Strobilopsidae

Three species of *Strobilops* are known from Kentucky. We present data for one.

Strobilops labyrinthica (Say)

Collections: 45 (1), 91 (6), 145 (1).

Mostly a woodlands species with an affinity for leaf litter and decaying wood.

Family Succineidae

The amber snails, of which 3 genera and 9 species have been reported from Kentucky (1, 8), is a rather difficult taxonomic group. In most instances dissection of the reproductive organs is required for species designation. We report data for 2 genera and species.

Succinea ovalis Say

Collections: 3 (13), 5 (7), 8 (1), 23 (2), 32 (1), 62 (1), 113 (3), 115 (1), 134 (2), 136 (8).

This distinctive succineid is most often found in moist woodlands or on floodplains.

Catinella avara (Say)

Collections: 29 (1), 52 (1), 83 (1), 92 (1).

The records established in Kentucky for *C. vermeta* (Say) apply to *C. avara* (8). The snail inhabits lowland situations, mostly around bodies of water.

Family Philomycidae

Slugs are more often than not slighted in regional treatments of terrestrial mollusks. They are difficult to preserve satisfactorily and many of them must be dissected to verify species diagnoses. Three genera are known from Kentucky.

Philomycus carolinianus (Bosc)

Collections: 7 (1), 33 (1), 63 (4), 64 (2), 98 (9).

This variable slug prefers floodplains and moist upland woods as habitat. Hubricht (8) elevated the subspecies *P. carolinianus togatus* (Gould) to full species.

Philomycus flexuolaris Rafinesque

Collections: 3 (1), 64 (1), 94 (1).

For many years *P. flexuolaris* was considered as a subspecies of *P. carolinianus* (11). It is an upland congener of the latter species (8).

Philomycus virginicus Hubricht

Collection: 7 (1).

Another uplands woods slug, this species was previously known from Pike, Madison (1), and Harlan (7) counties.

Philomycus venustus Hubricht

Collections: 12 (1), 60 (2), 95 (1), 96 (3), 98 (2), 114 (1), 124 (1).

This pale slug prefers moist woods as habitat. Hubricht (8) placed *P. bisdosus* Branson in its synonymy.

Pallifera dorsalis (A. Binney)

Collection: 3 (1).

Previously reported from Pike, Wolfe, Powell, and Madison counties (1), this distinctive slug is most often found in leaf litter of moist forests.

Pallifera fosteri F. C. Baker

Collections: 27 (1), 64 (2).

Hubricht (8) removed *P. secreta* (Cockerell) from the synonymy of this species, and reported it from several Kentucky localities.

Megapallifera ragsdalei (Webb)

Collections: 13 (1), 27 (1).

This large slug prefers moist, wooded ravines and streamside bluffs.

Family Discidae

The members of this family were previously placed in the Anguispiridae (*Anguispira*) and the Endodontidae (*Discus*) (1). The other genera previously assigned to the Endodontidae are now assigned to the families Helicodiscidae (*Polygyriscus, Helicodisus*) and Punctidae (*Punctum*).

Anguispira alternata (Say)

Collections: 3 (1), 8 (1), 10 (2), 13 (3), 16 (8), 22 (2), 23 (3), 29 (1), 32 (1), 43 (2), 48 (3), 80 (1), 101 (4), 102 (2), 115 (4), 119 (5).

This is a highly variable species, particularly with regard to the peripheral angulation of the body whorl (8). Hubricht (8) believes that, along with some of the differences in sculpturing, is the result of introgressive hybridization with the next species but it is more apt to reflect a plastic genome and ecophenotypy.

Anguispira mordax (Shuttleworth)

Collections: 5 (1), 12 (14), 40 (8), 56 (3), 81 (1).

This heavily sculptured (rib striate) snail is widespread in Kentucky. Breeding experiments need to be accomplished to give credence to Hubricht's (8) hypothesis of widespread hybridization between *A. mordax* and *A. alternata*.

Anguispira kochi (Pfeiffer)

Collections: 17 (3), 28 (3), 130 (1), 141 (1).

Anguispira kochi prefers undisturbed, moist, wooded ravines. The species is not common in Kentucky and may be worthy of consideration for inclusion on the threatened list (12).

Discus cronkhitei (Newcomb)

Collections: 1 (11), 18 (4), 24 (3), 28 (1), 34 (4), 49 (1), 115 (5), 119 (7), 125 (3).

This small, heavily sculptured snail frequents moist ditches and woodlands, often in association with the next two species.

Discus catskillensis (Pilsbry)

Collection: 1 (11).

Usually found in uplands woods near logs (8), this species was previously known from Fulton, Daviess, and Henderson counties (8).

Discus patulus (Deshayes)

Collections: 3 (2), 10 (4), 12 (1), 13 (13), 15 (1), 16 (1), 17 (2), 23 (3), 29 (2), 56 (5), 98 (30), 99 (4), 127 (1), 139 (3), 144 (4).

One of the largest species in the genus, *D. patulus* has a strong affinity for wet, decaying wood in upland forests.

Discus rotundatus (Müller)

Collection: 47 (3).

This introduced species (11) has not been found in Kentucky but doubtless occurs in Jefferson County in the vicinity of Louisville.

Family Helicodiscidae

There are at least 8 species of *Helicodiscus* known from Kentucky. We present data for 2 of them.

Helicodiscus parallelus (Say)

Collections: 28 (1), 92 (1), 98 (1), 115 (1), 125 (4).

Primarily found in woods associated with leaf litter and decaying wood, this species is also often found in ditches, around wooden houses, and in trash.

Helicodiscus singleyanus (Pilsbry)

Collections: 4 (1), 28 (1), 115 (1), 125 (2).

Previously known from Floyd, Fayette, and Jefferson counties only, this minute white snail prefers open, grassy habitats (8).

Family Punctidae

Four species of these minute snails are known from Kentucky (1). *Punctum lamellatum* Hubricht has been synonymized with *P. smithi* Morrison (8).

Punctum minutissimum (I. Lea)

Collections: 4 (2), 10 (15), 115 (3).

The preferred habitat is deep leaf litter, and the species is seldom found elsewhere. Sieves must be used to secure specimens.

Punctum vitreum H. B. Baker

Collection: 29 (1).

Known previously from Edmonson and Spencer counties only, *P. vitreum* is one of America's smallest snails, measuring only about 1.3 mm in diameter. The habitat is identical to that of the last species.

Family Arionidae

Arionid slugs are Holarctic in distribution, with native species occurring in the western segments of North America, Asia, Europe, and north Africa (11). There are several introduced species of *Arion* in the eastern and western United States and adjacent Canada (11). None of these sometimes noxious species have heretofore been reported from Kentucky.

Arion subfuscus (Draparnaud)

Collection: 123 (2).

All arionids live in areas of relatively high rainfall. This dull, dark-brown slug with two indistinct black, longitudinal bands on the mantle, was introduced into America from central Europe (11).

Family Limacidae

Most of the dozen or more genera and large number of species of limacid slugs are natives of Europe and adjacent parts of Africa and Asia, although several species in the genera *Lehmannia, Limax, Deroceras,* and *Milax* have been introduced into America (11). Representatives of all these genera have been found in Kentucky, including the single native species *Deroceras laeve.*

Lehmannia valentianus (Ferussac)

Collections: 2 (8), 4 (1), 82 (4), 93 (2).

Previously reported from Bell County only, this European exotic is widespread in and around greenhouses. The colony on the University of Kentucky campus is a large one.

Limax maximus Linnaeus

Collections: 2 (4), 50 (1), 74 (1), 79 (3).

Another European exotic, this large (100 mm or more), yellowish-gray, mottled slug is a common urban species and is often found in large numbers at trash-dumping sites. It can become a garden pest. The specimen from Station 74 was melanistic.

Milax gagates (Draparnaud)

Collection: 50 (1).

This record indicates that *Milax* is persisting in Madison County, where it was previously reported (13), the only known locality in Kentucky.

Deroceras reticulatum (Müller)

Collections: 32 (2), 50 (6), 61 (5), 64 (1), 147 (1).

Still another European exotic, this slug has become widely distributed in North America through agricultural commerce. It is a common garden pest, often in association with the next species below.

Deroceras laeve (Müller)

Collections: 1 (1), 23 (1), 93 (2), 142 (1).

The only native limacid slug in Kentucky, this species doubtless occurs throughout the state in spite of the few published records.

Family Zonitidae

With the Polygyridae, the Zonitidae is one of the most speciose molluscan families in America. It is second to none in Kentucky, being represented by a long list of genera and species. However, biological and distributional data are scanty for the small to minute species.

Nesovitrea electrina (Gould)

Collections: 13 (1), 72 (1), 85 (1).

Known previously from Jefferson and

Daviess counties, this small, nearly transparent snail frequents wet lowlands.

Nesovitrea binneyana (Morse)

Collection: 36 (1).

Previously recorded from Henderson and Union counties, *N. binneyana* lives in upland woods in leaf litter.

Glyphyalinia cumberlandiana (Clapp)

Collections: 10 (4), 117 (2).

Only recently reported from Kentucky (5, 7, 8), this snail's habitat is in leaf litter and decaying wood in forested ravines, sinkholes, and rocky, shaded hillsides.

Glyphyalinia wheatleyi (Bland)

Collections: 21 (1), 29 (1), 84 (1).

The habitat is similar to that of the last species.

Glyphyalinia rhoadsi (Pilsbry)

Collection: 125 (4).

Only recently reported from Kentucky (8), this beautiful little snail occurs in much of eastern Kentucky, mostly in upland forest litter.

Glyphyalinia indentata (Say)

Collections: 3 (2), 29 (4), 84 (1), 85 (2), 95 (1), 99 (1), 115 (34), 117 (1), 121 (1), 125 (12), 126 (1), 131 (2).

Occurring in many kinds of habitats, *G. indentata* is the most widespread member of its genus. As pointed out by Hubricht (8), *G. indentata* so-called is actually a complex of very similar species awaiting monographic treatment. There are at least 3 morphologically different species in Kentucky, 2 in the eastern highlands.

Glyphyalinia caroliniensis (Cockerell)

Collection: 6 (1).

Mostly a species of leaf litter in the Cumberland Mountains.

Glyphyalinia cryptomphala (Clapp)

Collections: 9 (1), 29 (6), 56 (1), 71 (1), 115 (10).

Because the next species was for many years considered as a subspecies of *G. cryptomphala* (14), the distribution of both species in Kentucky is probably confused. The preferred habitat is leaf litter along river bluffs.

Glyphyalinia solida (H. B. Baker)

Collections: 7 (1), 16 (1), 56 (2), 84 (3), 91 (1), 95 (2), 98 (1), 101 (3), 117 (1), 121 (1).

This rather large *Glyphyalinia* is usually found in leaf litter and decaying wood in ravines or on rocky hillsides.

Glyphyalinia praecox (H. B. Baker)

Collections: 99 (2), 100 (1).

A beautifully sculptured snail, *G. praecox* prefers leaf litter on rocky hillsides and adjacent floodplains.

Glyphyalinia sculptilis (Bland)

Collection: 12 (6).

Mostly found in upland forests in leaf litter.

Mesomphix inornatus (Say)

Collections: 3 (2), 5 (13), 6 (8), 7 (2), 8 (8), 29 (2), 53 (1), 60 (1), 89 (5), 98 (1), 104 (1), 106 (1), 112 (3), 114 (1), 119 (1).

Mesomphix rugeli (W. G. Binney)

Collections: 3 (1), 5 (5).

Thus far known only from Harlan County, this species is found principally on wooded hillsides on relatively high mountains such as Black and Pine mountains.

Mesomphix latior (Pilsbry)

Collections: 2 (1), 7 (1), 12 (1).

Previously known from Bell County only, *M. latior* has an exceptionally flat apex. It prefers leaf litter in upland woods.

Mesomphix perlaevis (Pilsbry)

Collections: 3 (5), 5 (4), 7 (5), 13 (1), 29 (1), 32 (3), 40 (1), 91 (4), 98 (6), 114 (1), 119 (2).

With *M. inornatus* one of the most abundant species of the genus in eastern Kentucky, this species has habitat requirements like those of *M. latior.*

Mesomphix vulgatus H. B. Baker

Collections: 7 (1), 8 (1), 11 (1), 12 (1), 23 (1), 27 (1), 59 (1), 91 (2), 108 (1).

Mesomphix vulgatus, of which *M. derochetus* Hubricht is a synonym, is somewhat variable in coloration and sculpturing. The specimen from Station 59 may be *M. globosus* (MacMillan).

Mesomphix friabilis (W. G. Binney)

Collections: 13 (5), 53 (1).

A species of floodplains and low-lying adjacent bluffs, *M. friabilis* is often confused with the next species.

Mesomphix cupreus (Rafinesque)

Collections: 3 (3), 6 (6), 7 (1), 13 (2), 32

(1), 56 (10), 60 (1), 102 (4), 110 (1), 119 (3), 121 (1).

This thin-shelled snail is mostly found in the leaf litter of uplands woods.

Mesomphix capnodes (W. G. Binney)

Collection: 6 (1).

Previously known from Warren, Cumberland (8), and Powell and Bell (1) counties in Kentucky, *M. capnodes* is usually found in upland woods underlain by calcium rocks (8).

Vitrizonites latissimus (Lewis)

Collections: 3 (14), 5 (5).

Although previously reported from Harlan County (5, 7), additional comments on this interesting Blue Ridge Province snail are in order. The colony is apparently a rather large one in the mesophytic environments of this area. However, clearcutting and/or stripmining could easily eliminate the proper habitat. The snail should be listed as of Special Concern since this is the only population known in Kentucky.

Paravitrea multidentata (A. Binney)

Collection: 91 (1).

This 2.5 mm snail has an internal armature arrangement like that described for *P. m.* forma *lamellata* H. B. Baker (14). However, shells with these oblique rows of lamellae (instead of the more common rows of teeth) do not seem to be of taxonomic importance (8).

Paravitrea placentula (Shuttleworth)

Collections: 12 (2), 58 (1).

This is one of the most common species of *Paravitrea* in eastern Kentucky, mostly in leaf litter.

Paravitrea cf. *capsella* of various authors

Collections: 18 (2), 27 (2), 29 (1), 95 (2), 99 (2), 115 (7), 121 (4).

Hubricht (8) has ascertained that what most authors have been diagnosing as *P. capsella* is actually a complex of several species that cannot be distinguished by shell characteristics alone. Hubricht (pers. comm.) is working on a revision of the group.

Paravitrea reesei Morrison

Collection: 7 (1).

Previously known from Pike County only (1), this small snail frequents leaf litter along river bluffs (8). The shell is waxen white with incised radial striations and bears within the aperture 3 prominent teeth in a row. There are 6 whorls.

Hawaiia minuscula (B. Binney)

Collections: 2 (1), 10 (1), 24 (1), 29 (2), 85 (1), 91 (1), 115 (13), 125 (30).

Although reported sporadically only, mostly because of the small size, this species is widespread in Kentucky. Since Hubricht (8) has elevated *H. alachuana* Dall to full species (Jefferson, Union, Hickman, and Fulton counties), collectors should use caution in diagnosing specimens from western Kentucky. The latter species is a calciphile in leaf litter, whereas *H. minuscula* is a ground-dwelling species, seldom being found in leaf litter (8).

Gastrodonta interna (Say)

Collections: 5 (3), 6 (2), 12 (2), 13 (1), 15 (3), 24 (1), 32 (1), 56 (2), 98 (4), 103 (1), 120 (1), 128 (1), 140 (1).

A secretive species that is widespread in the eastern half of the state in moist woods, *G. interna* is one of the most easily identified members of the family.

Ventridens collisella (Pilsbry)

Collection: 3 (5).

A lowland species that is mostly restricted to calcium-rich soils in leaf litter (8).

Ventridens pilsbryi Hubricht

Collection: 12 (1).

Ventridens pilsbry appears to be restricted in distribution to southeastern Kentucky counties, where it is found mostly in leaf litter.

Ventridens theloides (Walker and Pilsbry)

Collections: 3 (2), 5 (2), 6 (6), 13 (2), 39 (4), 98 (3).

Previously known as a subspecies of *V. gularis*, Hubricht (8) elevated *V. theloides* to full species and relegated *V. gularis nodus* Pilsbry and *V. nodus* Pilsbry to its synonymy. Hence, all records published previously under the epithet *V. nodus* should be relisted as *V. theloides*.

Ventridens lawae (W. G. Binney)

Collections: 39 (1), 98 (1).

Although locally abundant, this species is not found much beyond the Cumberland Mountains.

Ventridens lasmodon (Phillips)

Collections: 36 (1), 84 (2), 98 (34).

Another species entirely restricted to southeastern Kentucky, *V. lasmodon* prefers leaf litter as habitat.

Ventridens gularis (Say)

Collections: 3 (1), 5 (1), 6 (3), 12 (3), 13 (2), 95 (1), 98 (18), 103 (1), 117 (9).

Widespread in Kentucky, *V. gularis* is found mostly in forest leaf litter and on floodplains.

Ventridens demissus (A. Binney)

Collections: 3 (28), 5 (1), 6 (3), 7 (1), 13 (2), 14 (1), 16 (2), 24 (2), 38 (1), 40 (1), 55 (7), 75 (1), 84 (9), 95 (4), 97 (1), 98 (3), 101 (8), 115 (15), 121 (4), 136 (1), 146 (1).

The most widespread *Ventridens* in Kentucky, *V. demissus* lives in many types of habitats, from lowlands to rock hillsides.

Ventridens percallosus (Pilsbry)

Collections: 12 (2), 36 (2).

Previously known from Todd County only, *V. percallosus* occupies a habitat similar to that of *V. demissus*, though it is much less common.

Ventridens ligera (Say)

Collections: 6 (1), 8 (1), 16 (1), 23 (2), 29 (6), 46 (1), 67 (3), 92 (1), 93 (2), 117 (6).

Ventridens ligera mostly avoids slopes, preferring weedy, wet lowlands (8).

Ventridens intertextus (A. Binney)

Collections: 6 (3), 12 (1), 8 (1), 9 (1), 24 (16), 28 (2), 52 (13), 110 (1).

The habitat is mostly woodland leaf litter (8), but the species is often found on a sandstone substrate.

Ventridens suppressus (Say)

Collection: 36 (2).

Previously known from Pike and Harlan counties (1, 8), this is another woodlands snail with affinities for leaf litter.

Zonitoides elliotti (Redfield)

Collection: 36 (1).

Previously placed in the genus *Ventridens* (1, 14) on the basis of shell morphology, this odd little snail has been reassigned to *Zonitoides* (8). The preferred habitat is thick leaf litter near decaying wood.

Zonitoides lateumbilicatus (Pilsbry)

Collection: 85 (1).

Found mostly in woods on calcium-rich soils, this species does not appear to maintain large populations in Kentucky.

Zonitoides arboreus (Say)

Collections: 8 (1), 10 (1), 16 (1), 21 (1), 36 (1), 39 (1), 50 (4), 55 (2), 115 (1), 119 (3), 125 (3).

The most widespread member of its genus, this little amber snail is found in many types of habitats, from woodlands to floodplains and city gardens.

Oxychilus draparnauldi (Beck)

Collection: 132 (3).

An introduced species from Europe and adjacent Africa, *O. draparnauldi* has not previously been reported from Kentucky. In the United States, the snail is usually found around human habitations and disturbed areas. The snail, measuring 15–17 mm in diameter and 6–8 mm in height, is translucent when fresh, light tan above and paler below, with 5½ whorls, the last of which is much wider than the others. The large umbilicus is contained about 6 times in the greatest diameter (14). The snail is predaceous upon invertebrate animals, including other snails.

Striatura milium (Morse)

Collections: 10 (3), 13 (1), 29 (1).

Previously known from Edmonson County only, this is one of America's smallest snails, measuring about 1.5 mm in diameter and 0.75 mm in height. Usually with 3 whorls, the beautifully sculptured shell is usually found by sifting leaf litter.

Family Helicarionidae

Most of the older literature includes the members of this family in the Zonitidae (14). Three genera are known from the eastern United States, *Dryachloa* (Florida, Alabama), *Euconulus*, and *Guppya*. Representatives of the last two genera occur in Kentucky.

Euconulus fulvus (Müller)

Collections: 29 (3), 115 (9).

This small, broadly domed-shaped species is found primarily in moist leaf litter.

Euconulus chersinus (Say)

Collections: 16 (1), 29 (1), 115 (3).

Collectors should use care in identifying this species for it is often collected with *E. trochulus* (Reinhardt) and *E. dentatus* (Sterki), especially in the western two-thirds of the state (8).

Guppya sterkii (Dall)

Collections: 10 (8), 18 (1).

This minute (1.2 mm diameter, 0.7 mm height, 3½ whorls) snail is usually found in moist leaf litter.

Family Haplotrematidae

Haplotrema concavum (Say)

Collections: 3 (1), 5 (2), 6 (2), 7 (3), 11 (2), 12 (3), 13 (2), 15 (1), 23 (2), 29 (5), 40 (1), 43 (1), 49 (5), 56 (3), 60 (1), 68 (1), 81 (1), 89 (1), 94 (3), 95 (1), 98 (8), 99 (3), 104 (1), 115 (4), 119 (4), 121 (2).

This carnivorous snail doubtless occurs throughout Kentucky.

Family Bulimulidae

Mostly a western–southwestern family of snails, the Bulimulidae is represented in western Kentucky by a single species.

Rhabdotus (*Bulimulus*) *dealbatus* (Say)

Collection: 75 (12).

This relatively large, mottled, heliciform snail lives around low vegetation and grasses. In Kentucky, it has been reported from Warren and Logan counties only (1).

Family Helicidae

Cepaea nemoralis (Linnaeus)

Collections: 86 (10), 132 (2).

This pretty, banded, multicolored species, an exotic from Europe, is known in Kentucky from Boone, Fayette, and Franklin counties (1, 15).

Family Polygyridae

Of the larger land snails, the Polygyridae is the most speciose and widely distributed in Kentucky.

Polygyra cereolus (Muhfeld)

Collection: 37 (5).

This Floridian snail has been widely disseminated in shopping malls and greenhouses by the importation of subtropical vegetation. The species also occurs in the greenhouses at Eastern Kentucky University. It has not been previously reported from Kentucky.

Polygyra plicata (Say)

Collections: 12 (6), 19 (1), 62 (5), 75 (3), 108 (2), 117 (1), 118 (13).

Mostly a species of calcium-rich forest floors, this snail is sometimes locally abundant.

Stenotrema evardsi (Bland)

Collections: 3 (6), 5 (3), 6 (2), 13 (2), 28 (2), 36 (1), 98 (5), 119 (1), 121 (2), 130 (1).

Stenotrema evardsi is widespread in leaf litter in the eastern third of Kentucky.

Stenotrema barbatum (Clapp)

Collections: 10 (1), 29 (4), 40 (1), 104 (2), 105 (1), 128 (1).

Although principally a lowland, floodplains snail, *S. barbatum* is found associated with decaying wood in eastern Kentucky.

Stenotrema angellum Hubricht

Collections: 18 (1), 119 (2).

Often confused with the next species below, *S. angellum* lives in leaf litter and around decaying logs (8), mostly on upland slopes.

Stenotrema stenotrema (Pfeiffer)

Collections: 3 (4), 5 (1), 7 (1), 8 (4), 9 (1), 10 (2), 12 (17), 13 (10), 14 (7), 15 (1), 29 (10), 48 (2), 56 (12), 75 (5), 90 (2), 91 (1), 99 (6), 115 (4), 117 (3), 119 (1), 121 (1), 141 (1).

The most abundant and widespread member of the genus, *S. stenotrema* is a highly adaptable species that is found in a variety of habitats, from floodplains to upland slopes. There is considerable phenotypic variation.

Stenotrema hirsutum (Say)

Collections: 12 (1), 23 (2), 40 (1), 56 (1), 91 (1), 92 (1), 98 (7), 120 (3).

This small species is found mostly in leaf litter on well-drained slopes.

Stenotrema leai aliciae (Pilsbry)

Collections: 10 (1), 16 (1), 18 (2), 42 (1), 49 (1), 66 (1), 75 (3), 104 (2), 115 (2).

The principal habitats are in lowland situations in grass, decaying wood, and in floodplains woods (8).

Stenotrema fraternum (Say)

Collections: 8 (1), 10 (7), 34 (1), 41 (2), 70 (2), 78 (1), 85 (2), 120 (1), 126 (1), 130 (1), 131 (1).

The specimen from Station 34 resembles *S. fraternum montanum* Archer (16). In all cases the habitat was in leaf litter and under logs.

Mesodon rugeli (Shuttleworth)

Collections: 3 (9), 6 (1), 8 (8), 9 (1), 10 (3), 12 (4), 13 (2), 15 (6), 18 (6), 23 (1), 24 (1), 25 (3), 29 (9), 32 (1), 56 (3), 83 (1), 84 (3), 89 (3), 91 (4), 98 (1), 105 (1), 109 (1), 114 (1), 115 (11), 117 (1), 119 (2), 121 (4), 136 (3).

Although this snail mostly frequents upland woods, it apparently sometimes hybridizes with *M. inflectus* (17).

Mesodon inflectus (Say)

Collections: 5 (18), 7 (1), 8 (1), 23 (2), 27 (5), 28 (7), 32 (1), 50 (5), 51 (1), 52 (37), 57 (8), 75 (6), 101 (26), 105 (1), 117 (2).

Contrasted with *S. rugeli*, *M. inflectus* is principally a lowlands species, usually found on floodplains, rocky outcrops, leaf litter, and often in urban gardens.

Mesodon appressus (Say)

Collections: 4 (1), 6 (2), 7 (2), 10 (5), 12 (3), 13 (4), 18 (3), 24 (1), 28 (3), 29 (8), 30 (3), 40 (1), 44 (1), 49 (2), 52 (5), 56 (7), 81 (10), 88 (12), 89 (4), 91 (13), 92 (1), 95 (2), 98 (3), 99 (4), 114 (1), 117 (11), 119 (2), 121 (2), 122 (5), 130 (9), 141 (4).

A very widespread species under woody vegetation on rocky slopes, in moist ditches, and in urban settings, *M. appressus* is a variable species by way of sculpture and size. Specimens from various sites on Pine Mountain are consistently smaller than average (14.0–14.6 mm in diameter, 6.8–7.5 mm in height) and have angular peripheries. The base is marked by close-set, thread-like, raised spiral striae. This form warrants additional investigation, including the reproductive anatomy. It is probably an undescribed species.

Mesodon laevior Hubricht

Collection: 98 (2).

Originally described as a variant form of *M. appressus* based upon specimens from Mammoth Cave National Park, Warren and Wayne counties (16), Hubricht officially described the species in 1968 (2).

Mesodon perigraptus (Pilsbry)

Collections: 53 (9), 60 (2), 89 (3).

Previously known from Pike and Bell counties in Kentucky, this distinctive polygyrid prefers leaf litter in upland woods as habitat. Hubricht (8) did not map this snail in Kentucky (8, 19).

Mesodon wetherbyi (Bland)

Collection: 12 (2).

Known only from Pulaski, Laurel, McCreary, and Whitley counties in Kentucky and 5 adjacent counties in Tennessee, this snail is nowhere common.

Mesodon sayanus (Pilsbry)

Collections: 3 (13), 6 (2), 60 (1), 69 (1), 89 (1), 91 (1), 98 (2), 112 (3), 114 (1), 119 (1), 122 (1).

Specimens of this woodlands species from Black Mountain average larger than any we have seen elsewhere.

Mesodon chilhoweensis (Lewis)

Collections: 7 (5), 140 (1).

Following extensive collecting in southern Kentucky, this large polygyrid (regularly 40 mm in diameter) remains known from McCreary County only (1). The center of distribution is principally east Tennessee, where it lives in leaf litter and around decaying logs. Hubricht (8) believes that the population size is kept at low numbers by predation from birds.

Mesodon elevatus (Say)

Collections: 10 (2), 11 (5), 12 (1), 15 (1), 27 (1), 31 (4), 32 (1), 110 (3).

These records double the known range of this heavy shelled species in Kentucky. The preferred habitat is wooded bluffs above rivers and large creeks (8).

Mesodon zaletus (A. Binney)

Collections: 5 (1), 6 (3), 7 (2), 8 (2), 11 (1), 13 (2), 14 (3), 24 (1), 28 (4), 32 (1), 45 (19), 56 (1), 76 (3), 91 (2), 110 (3), 119 (1), 128 (1), 129 (2).

Another species that prefers river-bluff forests, although found elsewhere, *M. zaletus* is sometimes confused with *Triodopsis albolabris*.

Mesodon normalis (Pilsbry)

Collection: 3 (2).

First reported from Kentucky by Hubricht (20) in McCreary County, this large species has been treated as a subspecies of *M. andrewsae* W. G. Binney (16). Hubricht (8) elevated it to full species. *Mesodon normalis* represents an extension of a Tennessee–North Carolina complex into Kentucky.

Mesodon downieanus (Bland)

Collections: 51 (9), 52 (9), 54 (2), 95 (8), 125 (1).

Hubricht (8) contends that he has never seen *M. downieanus* north of Tennessee (restricts the distribution to Tennessee and Alabama), preferring to call specimens from southern Kentucky *M. kalmianus* Hubricht. However, we are unable to distinguish between *M. downieanus* from Kentucky localities and those from Tennessee, or between *M. kalmianus* and *M. downieanus*.

Mesodon mitchellianus (I. Lea)
Collection: 87 (3).
This species' known habitat includes lowland meadows and floodplains (8). *Mesodon burringtoni* Hubricht is a synonym. It was previously known from Bell, Harlan, and Nicholas counties only.

Mesodon clausus (Say)
Collections: 4 (1), 8 (2), 11 (1), 12 (1), 13 (3), 23 (3), 29 (2), 34 (1), 83 (4), 84 (1), 94 (1), 97 (2), 101 (5), 109 (1), 121 (3), 122 (3).
Found principally in moist lowland situations, *M. clausus* is sometimes confused with *M. downieanus*.

Mesodon thyroidus (Say)
Collections: 6 (2), 8 (5), 10 (1), 11 (1), 12 (1), 13 (6), 17 (3), 24 (1), 26 (1), 28 (1), 29 (1), 51 (2), 52 (18), 55 (3), 56 (1), 58 (1), 75 (1), 89 (3), 91 (1), 94 (1), 98 (2), 99 (1), 101 (1), 107 (1), 110 (1), 111 (2), 115 (3), 119 (2), 135 (1).
One of the most widely distributed polygyrids in the Commonwealth, *M. thyroidus* is found mostly in floodplain woods, but it is not uncommon on rocky slopes and in urban settings.

Mesodon wetherbyi (Bland)
Collection: 7 (2).
Known from Laurel, Pulaski, McCreary, and Whitley counties only, this is another species that represents an extension from the Blue Ridge Province into Kentucky. It prefers moist leaf litter and decaying wood as habitat.

Triodopsis anteridon Pilsbry
Collections: 3 (8), 12 (1), 13 (3), 138 (1).
Previously reported from Kentucky as *T. rugosa anteridon*, this form has been elevated to full species (8). Hubricht (8) restricted the range of *T. rugosa* Brooks and MacMillan to its type locality in West Virginia. Thus, all records from Kentucky are based upon *T. anteridon*.

Triodopsis fraudulenta (Pilsbry)
Collections: 8 (3), 29 (1), 35 (2), 119 (3).
Not a very common species in Kentucky, this snail prefers leaf litter on upland slopes for habitat.

Triodopsis vulgata Pilsbry
Collections: 8 (1), 67 (1), 121 (2).
This is a locally common snail in the leaf litter of upland forests.

Triodopsis claibornensis Lutz
Collections: 3 (9), 5 (1), 6 (2), 89 (2), 95 (1), 98 (1).
Previously known from Whitley County, Kentucky (1) and from two counties in adjacent Tennessee (8), *T. claibornensis* is yet another extension from the Tennessee fauna into the Commonwealth.

Triodopsis discoidea (Pilsbry)
Collection: 117 (5).
The habitat of this locally common snail is principally beneath rocks and logs on river bluffs (8).

Triodopsis tridentata (Say)
Collections: 9 (3), 10 (1), 12 (2), 13 (3), 15 (1), 27 (3), 28 (5), 29 (1), 40 (5), 52 (15), 65 (1), 83 (1), 84 (7), 91 (19), 98 (1), 99 (3), 120 (6), 121 (3), 128 (2).
In the usual habitat—leaf litter and around logs in upland forests (also occurs in a variety of other situations)—*T. tridentata* commonly constitutes 45% of randomly collected polygyrids, and *Mesodon appressus* 30–32%.

Triodopsis juxtidens (Pilsbry)
Collection: 99 (3).
This species was long considered as a subspecies of *T. tridentata* until Hubricht (21) elevated it to full species. The snail, relatively less common than *T. tridentata,* is probably widespread in Pike, Floyd, and Letcher counties. Adult shells are around 17.5–18.5 mm in diameter, and the outer tip of the parietal tooth is directed toward a point above the outer lip tooth or directly at it. However, the apertural teeth of *T. tridentata* are variable in shape and size (22).

Triodopsis tennesseensis (Walker and Pilsbry)
Collections: 9 (1), 60 (4), 87 (6), 98 (4).

Considered to be a subspecies of *T. tridentata* until Hubricht (23) elevated it to full species, this snail is widely distributed in the eastern half of the Commonwealth.

Triodopsis complanata (Pilsbry)

Collections: 8 (1), 10 (1), 13 (3), 18 (2), 56 (6), 84 (1), 91 (1), 120 (3), 133 (1), 139 (2).

This relatively large snail, which prefers leaf litter and decaying wood on river bluffs as habitat, is not very common in its range. However, Hubricht (8) limited its distribution to the south side of the Cumberland River in the vicinity of Lake Cumberland.

Triodopsis denotata (Férussac)

Collections: 7 (1), 12 (1), 13 (2), 64 (1), 97 (1), 104 (1), 119 (1), 130 (1).

Although relatively widespread in the state, this snail does not appear to maintain large populations.

Triodopsis fosteri (F. C. Baker)

Collections: 13 (2), 40 (4).

In Kentucky, *T. fosteri* is a very uncommon snail, one which ought to be considered for listing by the Rare and Endangered Species Committee.

Triodopsis albolabris (Say)

Collections: 3 (2), 5 (3), 6 (1), 9 (1), 10 (1), 12 (1), 28 (2), 35 (6), 53 (1), 56 (2), 75 (11), 98 (2), 112 (1), 117 (2), 120 (4).

Since this species is often confused with *Mesodon zaletus*, collectors should use care in diagnosing dead specimens.

Triodopsis dentifera (A. Binney)

Collections: 3 (2), 5 (1).

Only recently reported from Kentucky (7), this distinctive snail is known from Harlan County only, though it doubtless occurs in Pike and Letcher counties as well.

Triodopsis multilineata (Say)

Collections: 20 (1), 26 (7), 55 (2).

This large, beautifully banded species is known in Kentucky from Hickman, Fulton, Henderson, Bell, and Union counties. In distribution it is restricted to low-lying, wet marshes, floodplains, and similar habitats.

Allogona profunda (Say)

Collections: 8 (1), 10 (7), 13 (3), 29 (1), 107 (2), 111 (2).

Nowhere very abundant in Kentucky, this large polygyrid prefers deep leaf litter near decaying wood as habitat.

DISCUSSION

Henderson's (24) eastern land snail division includes all of the contiguous states east of the plains bordering the eastern slopes of the Rocky Mountains. That division includes the Northern, Interior, Cumberland, Texan, and Austroriparian provinces. Most of Kentucky lies in the Interior Province; the southeastern corner belongs to the Cumberland Province. The principal gastropod affinities of the southeastern section of the state is with the Great Smokies–Blue Ridge sections of the Cumberland Province, with some segments of the fauna showing relationships with more easterly areas, i.e., through Virginia and West Virginia. Examples of the latter affinities include *Philomycus togatus*, *P. venustus*, *P. flexuolaris*, *Pallifera dorsalis*, *Discus cronkhitei*, *Glyphyalinia rhoadsi*, *G. inornatus*, *Mesomphix rugeli*, *Paravitrea multidentata*, *Stenotrema hirsutum*, *Triodopsis albolabris*, and *T. tridentata*.

Species demonstrative of the Blue Ridge–Great Smokies relationship include *Carychium clappi*, *Cochlicopa morseana*, *Paravitrea subtilis*, *P. placentula*, *P. blarina*, *Glyphyalinia caroliniensis*, *G. rimula*, *G. praecox*, *Ventridens collisella*, *V. theloides*, *V. lawae*, *Zonitoides elliotti*, *Vitrinzonites latissimus*, *Anguispira mordax*, *Mesodon wetherbyi*, *M. normalis*, *M. kalmianus*, *M. appressus*, *Stenotrema evardsi*, *Triodopsis clairbornensis*, *Polygyra plicata*, and *P. troostiana*. Actually, the genus *Polygyra* is mainly a southern group with relatively few species extending their ranges into the Appalachians and a short distance beyond, whereas *Mesodon*, *Stenotrema*, and *Triodopsis* were evolved in the southern United States (25).

There are other segments of the Kentucky gastropod fauna, in addition to *Polygyra* (*P. pustuloides*, *P. leporina*), that show definite origins from southern areas. Included in this list are the following: *Glyphyalinia cryptomphala*, *G. sculptilis*, *Mesomphix globosus*, *Ventridens demissus*, *Gastrodonta interna*, *Stenotrema stenotrema*, *Mesodon rugeli*, and *Mesodon perigraptus*.

There is also a small segment of the Kentucky fauna that has its greatest affinities with more northerly faunas, including *Carychium exiguum*, the species of *Vallonia*, *Succinea ovalis*, *Anguispira alternata* (ss), *Stenotrema* *fraternum*, *Mesodon pennsylvanicus*, and *Triodopsis denotata*. This is, of course, a secondary relationship, compared with the primary one with the southeast.

Finally, a western–midwest relationship is demonstrated by the presence of *Anguispira kochi*, *Mesomphix friabilis*, *Zonitoides limatulus*, *Rhabdotus dealbatus*, *Stenotrema leai*, *Triodopsis multilineata*, and the primitive genus *Allogona*.

SUGGESTIONS FOR FURTHER STUDY

The southeastern section of Kentucky and the section bordering Virginia and West Virginia are nearly unscathed by gastropod collecting, particularly with regard to the Zonitidae. Likewise, extreme southwestern Kentucky, especially along the Mississippi Embayment, is deserving of some concentrated investigation. Collectors may be confident that work in these areas will disclose a relatively long list of terrestrial snails that have not been reported from the Commonwealth.

ACKNOWLEDGMENTS

The authors are greatly indebted to the following associates and students for their assistance in making the extensive collections: Gary Bastin, Rogers MacG. Branson, Hal Bryan, Robert Butler, Peter David, John MacGregor, Mike Mills, John Omer, David Prior, Steve Rice, the late Morgan Sisk, Douglas Stephens, Yvonne Thompson, Tim Towles, Mark Vogel, Melvin Warren, and John Williams.

LITERATURE CITED

1. Branson, B. A. 1973. Kentucky land Mollusca: checklist, distribution, and keys for identification. Bull. Kentucky Fish Wildl. Res. 1973:1–67.

2. Bickel, D. 1967. Preliminary checklist of Recent and Pleistocene Mollusca of Kentucky. Sterkiana 28:7–20.

3. Hubricht, L. 1976. Notes on some land snails of the eastern United States. Nautilus 90:104–107.

4. Hubricht, L. 1977. Thirteen new species of land snails from the southwestern United States with notes on other species. Malacol. Rev. 10:37–52.

5. Hubricht, L., R. S. Caldwell, and J. G. Petranka. 1983. *Vitrizonites latissimus* (Pulmonata: Zonitidae) and *Vertigo clappi* (Pupillidae) from eastern Kentucky. Nautilus 97:20–22.

6. Taylor, R. W., C. L. Counts, and S. L. Stryler. 1977. The land snails of Carter Caves State Park, Carter County, Kentucky. Sterkiana 65–66:37–38.

7. Petranka, J. G. 1982. The distribution and diversity of land snails on Big Black Mountain, Kentucky. M.S. thesis. Univ. Kentucky.

8. Hubricht, L. 1985. The distribution of the native land mollusks of the eastern United States. Fieldiana n.s. 24:1–191.

9. Burch, J. B. and A. S. Van Devender. 1980. Identification of eastern North American land snails. Trans. Poets Soc. 2:33–80.

10. Hubricht, L. 1972. *Gastrocopta armifera* (Say). Nautilus 85:73–78.

11. Pilsbry, H. A. 1948. Land Mollusca of North America (north of Mexico). Acad. Nat. Sci. Philadelphia Monogr. 3 II(2):i–xiviii, 521–1113.

12. Branson, B. A. 1984. Observations on *Anguispira kochi* (Mollusca: Gastropoda) in Kentucky. Trans. Kentucky Acad. Sci. 45:74.

13. Branson, B. A. and D. L. Batch. 1969. Notes on exotic mollusks in Kentucky. Nautilus 82:102–106.

14. Pilsbry, H. A. 1946. Land Mollusca of North America (north of Mexico). Acad. Nat. Sci. Philadelphia Monogr. 3 II(1):i–viii, 1–520.

15. Branson, B. A. 1985. Shell polymorphism in Kentucky colonies of the exotic snail *Cepaea nemoralis* (Linnaeus) (Mollusca: Gastropoda). Trans. Kentucky Acad. Sci. 46:81–86.

16. Pilsbry, H. A. 1940. Land Mollusca of North America (north of Mexico). Acad. Nat. Sci. Philadelphia Monogr. 3 I(2):i–viii, 575–994, i–ix.

17. Hubricht, L. 1984. Hybridization in the land snails of eastern United States. Gastropodia 2:20–21.

18. Hubricht, L. 1968. The land snails of Mammoth Cave National Park, Kentucky. Nautilus 82:24–28.

19. Hubricht, L. 1976. Five new species of land snails from the eastern United States. Malacol. Rev. 9:126–130.

20. Hubricht, L. 1950. *Mesodon andrewsae normalis* (Pils.) in Kentucky. Nautilus 63:106.

21. Hubricht, L. 1953. Land snails of the southern Atlantic coastal plain. Nautilus 66:114–125.

22. Feinberg, H. S. 1970. Variations of the aperture teeth of *Triodopsis tridentata* (Say, 1816) (Polygyridae). Ann. Rept. American Malacol. Union 36:60–61.

23. Hubricht, L. 1950. The Polygyridae of Pittsylvania County, Virginia. Nautilus 64:6–9.

24. Henderson, J. 1931. Molluscan provinces in the western United States. Univ. Colorado. Stud. 18:177–186.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 117–119

The Distribution of the Big South Fork Crayfish, *Cambarus bouchardi*, with General Notes on Its Habitat

CHRISTOPHER J. O'BARA
Tennessee Cooperative Fishery Research Unit, Tennessee Technological University, Cookeville, Tennessee 38505

ABSTRACT
The Big South Fork crayfish, *Cambarus bouchardi*, was originally known from 3 locations within the Roaring Paunch Creek system, Tennessee and Kentucky. As a result of the current survey, the species is now known from 21 locations, all within the Roaring Paunch Creek system. The species exhibited a plastic tendency in habitat selection, occupying both moderate and small streams with diverse substrate types.

INTRODUCTION

The Big South Fork crayfish, *Cambarus bouchardi* Hobbs, is an epigean decapod endemic to the Roaring Paunch Creek system of Scott County, Tennessee, and McCreary County, Kentucky. The species was originally known from Perkins Creek (type-locality), Roaring Paunch Creek, and an unnamed tributary of Roaring Paunch Creek (1). Bakaletz and Barclay (2) reported the species from the middle and lower portions of Roaring Paunch Creek, McCreary County, Kentucky, and a tributary, Icecamp Branch, McCreary County, Kentucky. Due to its restricted distribution and possible threats from coal mining activities, Bouchard (3) considered *C. bouchardi* one of 14 species of jeopardized freshwater decapods in the United States. A lack of cover in the form of numerous rocks was believed to be the greatest limiting factor (3).

Cambarus bouchardi is a member of the primitive, polytypic subgenus *Veticambarus*. All 3 species are endemic to the Cumberland Plateau Region (*C. pristinus*: Caney Fork system, Tennessee; *C. obeyensis*: Obey River system, Tennessee). A complete description of the 3 species can be found in Hobbs (1).

The goal of this study was to determine the current distribution of *C. bouchardi*. Habitat requirements were also examined to a limited extent.

STUDY AREA

Sampling was conducted within the Cumberland River system of Tennessee and Kentucky. The majority of streams sampled were part of the Big South Fork of the Cumberland River system, although adjacent systems, such as Marsh Creek, Murphy Creek, Trammel Branch, and Gum Fork, were also sampled.

The Roaring Paunch Creek system originates in northeastern Scott County, Tennessee, and flows northwesterly into the Big South Fork of the Cumberland River. The system is entirely within the Cumberland Plateau section of the Appalachian Plateau Physiographic Province. The Cumberland Plateau is underlain by Pennsylvanian age shale, sandstone, siltstone, and coal. Soils are of the Ramsey-Hartsells-Grimsley-Gilpin type which are well drained and loamy. Most of the landcover is deciduous forest, with clusters of agricultural and mined lands (4).

METHODS AND MATERIALS

All collections were made with an aquatic dip net during the day. Sampling was conducted from March 1986 to June 1987, primarily during the period when males were of the first form (fall and spring).

RESULTS AND DISCUSSION

Cambarus bouchardi was collected at 21 locations, all within the Roaring Paunch Creek system (Table 1). Order Creek was the only stream sampled within the Roaring Paunch Creek system that did not contain *C. bouchardi*. Other sites sampled adjacent to the Roaring Paunch Creek system did not yield *C. bouchardi*. Similar distributional trends have been reported, confirming that the species is currently restricted to the Roaring Paunch Creek system (1, 2, 5).

Within the Roaring Paunch Creek system, the Big South Fork crayfish inhabited a wide variety of habitats. At the stream's confluence

TABLE 1. Distribution of *Cambarus bouchardi*, 1986–1987.

Stream name	Location	County/state
Roaring Paunch Creek	Mouth	McCreary, KY
Roaring Paunch Creek	Barthell	McCreary, KY
Roaring Paunch Creek	Confluence with Buncomb Br.	McCreary, KY
Roaring Paunch Creek	County Road 1470	McCreary, KY
Roaring Paunch Creek	Kingtown Road	McCreary, KY
Roaring Paunch Creek	RPC Road	McCreary, KY
Roaring Paunch Creek	County Road 2449	Scott, TN
Roaring Paunch Creek	Headwaters	Scott, TN
Icecamp Branch	Mouth	McCreary, KY
Smith Creek	Pine Knot Road	McCreary, KY
Jones Branch	0.32 km W of Winfield	Scott, TN
Unnamed Creek	0.64 km W of Winfield	Scott, TN
Perkins Creek	State Route 27	Scott, TN
Unnamed Creek	County Road 2449	Scott, TN
Unnamed Creek	1.56 km NE Winfield	Scott, TN
Unnamed Creek	0.94 km S Winfield	Scott, TN
Unnamed Creek	Piney Grove Church	Scott, TN
Unnamed Creek	0.47 km E Winfield	Scott, TN
Unnamed Creek	0.94 km S Winfield	Scott, TN
Unnamed Creek	1.25 km S Winfield	Scott, TN
Unnamed Creek	1.40 km S Winfield	Scott, TN

with the Big South Fork of the Cumberland River, stream width is 20 meters, in contrast with headwater sites in which stream width is less than 3 meters. Specimens were collected from boulder runs, silt inundated pools, and vegetative clumps in a heavily silted stream. This is contrary to habitat preference reported by Bouchard (3), in which large rocks were considered a limiting factor. It appears that *C. bouchardi* exhibits plasticity in its habitat selection within the small- to moderate-size streams of the Roaring Paunch Creek system. This plasticity in habitat selection appears to have enabled *C. bouchardi* to exist in severely degraded sections of the Roaring Paunch Creek system. Coal mining activities, especially surface mines, have adversely affected most of the tributaries, as well as Roaring Paunch Creek. Although *C. bouchardi* has survived under these adverse conditions, concern should be given if new and possibly degrading activities are considered.

The restricted range of *C. bouchardi* may be explained by the theory that the Cumberland Plateau was the center of origin for the genus *Cambarus*. Hobbs (6) proposed this due to the presence of the endemic primitive crayfish *C. pristinus*, *C. bouchardi*, and *C. obeyensis*. If *C. bouchardi* evolved in the Roaring Paunch Creek system, it appears that the species has been naturally isolated by the Big South Fork of the Cumberland River. This is supported by the greater relative abundance of the Big South Fork crayfish in upstream sections and its absence in the Big South Fork of the Cumberland River in the vicinity of the confluence with Roaring Paunch Creek.

ACKNOWLEDGMENTS

Critical review of the manuscript by Ronald Cicerello (Kentucky Nature Preserves Commission), Richard Biggins (U.S. Fish and Wildlife Service) and Anita Bailey (Tennessee Technological University) were greatly appreciated. This project was funded by the Endangered Species Office of the U.S. Fish and Wildlife Service. The Tennessee Cooperative Fishery Research Unit is supported by the Tennessee Wildlife Resources Agency, Tennessee Technological University, and the U.S. Fish and Wildlife Service.

LITERATURE CITED

1. Hobbs, H. H., Jr. 1970. New crayfishes of the genus *Cambarus* from Tennessee and Georgia (Decapoda, Astacidae). Proc. Biol. Soc. Washington 83:241–259.

2. Bakaletz, S. and L. A. Barclay. 1984. Management plan for the Big South Fork crayfish (*Cambarus bouchardi*) in the Big South Fork National River and Recreational Area. National Park Service. Oneida, Tennessee. 29 pp.

3. Bouchard, R. W. 1976. Investigations on the status of fourteen species of freshwater decapod crustaceans in

the United States. U.S. Department of Interior, Fish and Wildlife Service, Office of Endangered Species, Washington, D.C.

4. Gaydos, M. W. 1982. Hydrology of area 17, eastern coal province, Tennessee and Kentucky. U.S. Geological Survey, Nashville, Tennessee.

5. Bouchard, R. W. 1975. Geography and ecology of crayfishes of the Cumberland Plateau and Cumberland Mountains, Kentucky, Virginia, Tennessee, Georgia, and Alabama, Part II: The genera *Fallicambarus* and *Cambarus*. Pp. 585–606. In J. W. Avault, Jr. (ed.) Freshwater Crayfish: Second International Symp. Baton Rouge, Louisiana.

6. Hobbs, H. H., Jr. 1965. A new crayfish of the genus *Cambarus* from Tennessee with an amended definition of the genus (Decapoda, Astacidae). Proc. Biol. Soc. Washington 78:265–273.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 120–127

Comparative Attractancy of Three Phytoseiid Predator Species to the Twospotted Spider Mite, *Tetranychus urticae* Koch

A. M. Afifi,[1] C. G. Patterson, M. F. Potts, and J. G. Rodriguez

Department of Entomology, University of Kentucky, Lexington, Kentucky 40546

Abstract

Eggs, immature stages, and adults of *Tetranychus urticae* possess volatile kairomones that are quantitatively determined. Teneral and ovipositing females are the chief sources of these chemicals which are solvent extractable and which strongly attract 3 species of predatory phytoseiid mites, *Phytoseiulus persimilis* Athias-Hermiot, *Neoseiulus fallacis* (Garman), and *Typhlodromus occidentalis* Nesbitt, in that order. In choice-tube assay, extracts of ovipositing prey females or of fresh material (killed by freezing) were highly attractive to *P. persimilis* in concentrations as low as 50 μg. The predator responded rapidly (within 15 min) to the attractant in the choice tube.

Introduction

Phytoseiid mites play an important role in the pest management of tetranychid mites in various agroecosystems. Phytoseiids are aggressive predators, although some genera or species groups are general feeders, feeding on such alternate foods as small arthropods, nematodes, pollen and fungi, as noted in the review by McMurtry and Rodriguez (1).

Several investigators have studied phytoseiid behavior but only in recent years have these studies focused on the chemical ecology aspects of food finding. For example, conclusive evidence for an attractant, i.e., a kairomone, was first presented by Hislop and Prokopy (2), who showed that filter-paper disks treated with extracts from silk and associated feces of *Tetranychus urticae* Koch are attractive to *Neoseiulus* (=*Amblyseius*) *fallacis* (Garman). Sabelis et al. (3, 4) also demonstrated arrestment responses of *Phytoseiulus persimilis* Athias-Henriot to odor gradients of *T. urticae*. The kairomone(s) responsible for distant attraction of *P. persimilis* is present on the eggs and feces of the spider mites as well as on the exploited leaf surface, but not on the webbing produced by the mites. According to de Moraes and McMurtry (5), kairomone(s) responsible for arrestment of *P. persimilis* was present in extracts from adults, eggs, and webbing plus excreta of *Tetranychus evansi* (Baker and Pritchard) and *T. urticae*. However, in work reported by Dong and Chant (6), *P. persimilis* was attracted to the adult and webbing of *Tetranychus pacificus* McGregor and not to prey eggs, larvae and protonymphs.

Researchers have utilized several methods to assay tetranychids or their products and extracts for kairomones. For example, a single choice observation chamber has been used (2) as has a Y-tube olfactometer (3, 4). The objectives in our study were to challenge species representives of three phytoseiid genera, namely *P. persimilis*, *N. fallacis*, and *Typhlodromus occidentalis* Nesbitt, with all stages of the prey *T. urticae* using a two-choice tube technique developed in this laboratory. This would also permit us to examine the behavior of the 3 species under comparable conditions.

Materials and Methods

Stock Cultures

Phytoseiulus persimilis, *N. fallacis* and *T. occidentalis* were taken from a stock colony maintained on *T. urticae* which was cultured on bean plants (*Phaseolus vulgaris* L.) in the Acarology Laboratory at the University of Kentucky. Females of *N. fallacis* and *T. occidentalis* were starved for 5–6 hours before being used in the experiments. However, this procedure was unnecessary for *P. persimilis* (5, 6).

Weight/Number Relation of *T. urticae* Developmental Stages

Fresh weights of *T. urticae* eggs, larvae, protonymphs, deutonymphs, adult males and fe-

[1] Present address: Acarology Division, Agriculture Faculty, Cairo University, Giza, Egypt.

TABLE 1. Approximate numbers of individuals of *T. urticae* stages used for each treatment.

Stages/weight in μg	Egg	Larva	Proto-nymph	Deuto-nymph	Adult	Adult teneral	Adult ovipositing
50	49	25	14	7	7	6	3
100	98	51	28	13	13	12	7
150	147	76	42	20	20	18	10
200	196	102	56	27	26	24	13
Number tested	520	380	320	280	200	200	245
Mean wt. (μg) each	1.02	1.96	3.54	7.51	7.61	8.33	15.10

males (teneral and ovipositing) were made using a CAHN 27 Automatic Electro Balance. The active stages were killed by freezing for 15 minutes. The weights were obtained for mites at every stage and the mean weights were related to numbers of mites in each developmental stage to give a fresh weight of mite tissue of 50, 100, 150, and 200 μg (Table 1). The weight/number relationship of all stages of *T. urticae* was used for each choice test for fresh material or extract of an organic solvent.

Tetranychus urticae eggs (2–3 days old) were removed from bean leaves by shaking the leaves over black filter paper and the eggs were individually collected with a fine tipped brush. This method was used, instead of collecting the eggs directly from the leaves, to avoid contamination by silk (which sticks to the egg), fecal matter or other materials on the leaf. Active stages of *T. urticae* were sampled by shaking infested bean leaves over black plastic sheeting in a petri dish, killed by freezing, and collected with a fine tipped brush.

KAIROMONE EXTRACTION

Ethanol, hexane, ether and water were used as solvents for kairomone extraction. The appropriate number of *T. urticae* for each developmental stage (depending on weight/number relationship) was placed into a 5 ml beaker with 1.0 ml solvent. The mites were removed by filtration after 5 minutes and the filtrate was placed into micro cells[2] containing a filter paper disk (1.0 cm diameter). The solvent was then evaporated at ambient conditions. The evaporation time varied among the solvents. Ether and hexane required 30 minutes, ethanol required 1.5–2 hours while water required 6–8 hours. The control was prepared by treating a filter paper disk with solvent minus mite extracts.

A preliminary test, with the adult females of *N. fallacis*, was conducted to determine the best solvent to be used in the extraction of kairomones from ovipositing adult females of *T. urticae*. Extracts were tested for attractiveness to the predators by the choice-tube technique (Table 2).

CHOICE-TUBE TECHNIQUE

The choice-tube technique used in this test was originally used by Winston (7), modified by Jalil and Rodriguez (8) and Wicht et al. (9) to test the attraction of *Macrocheles muscaedomesticae* to substances present in the house fly, *Muscae domesticae*, and used by Rodriguez et al. (10) to study the attraction or repellency of *T. urticae* and *T. turkestani* Ugarov and Nikolski to water-soluble extracts from strawberry foliage.

Five adult females of the phytoseiid predators of standard age (3–5 days after their final molt) were introduced into each end of the choice tube and the ends closed by rubber stoppers. The fresh related weight/number of each prey stage was put into the tube cup (test) and fixed to the choice tube with Scotch Tape®. An empty cup (blank) was fixed to the other side.

TABLE 2. Attraction response of *N. fallacis* to solvent extractions of 200 μg of *T. urticae* adult ovipositing females, in choice-tubes. (T = test extraction, B = blank-solvent only.)

Solvent	Test interval (min) and response ratio (T:B)			
	15	30	45	60
Ethanol	37:13***	35:15**	31:19	27:23
Hexane	39:11***	34:16*	28:22	26:24
Ether	41:9***	33:17*	30:20	27:23
Water	32:18*	32:18*	31:19	28:22

Chi-square test for each ratio
*, ≥0.05; **, $P \geq 0.01$, ***, $P \geq 0.001$.
Values less than 0.05 are not considered to be significant

[2] Disposo-Tray, Linbro Chemical Company, Inc., New Haven, Connecticut.

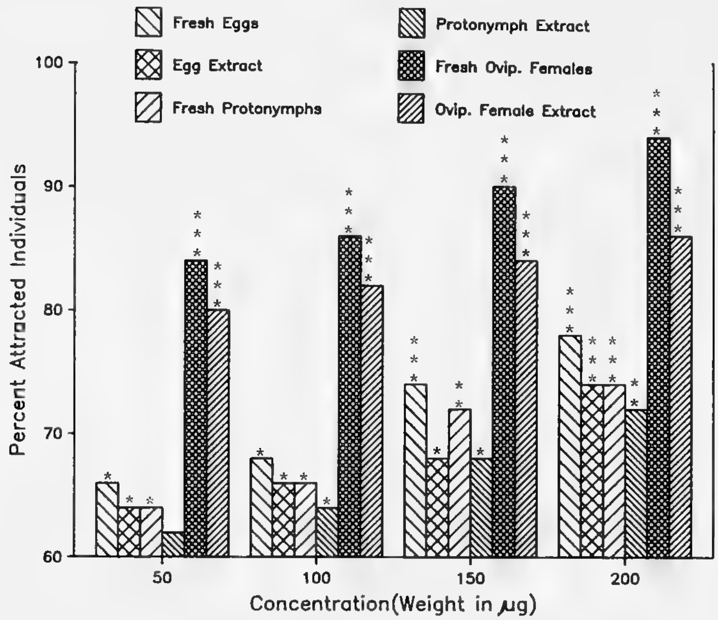


FIG. 1. Attraction response of *Phytoseiulus persimilis* to various concentrations (weight) of *Tetranychus urticae* eggs, protonymphs ovipositing female, or their respective extracts measured at 15 minutes in choice tube. Chi-square test for each choice-tube ratio: *$P \leq 0.05$, **$P \leq 0.01$, values greater than 0.05 are not considered significant.

The number of predator individuals in each side of the choice tube was determined at 15-minute intervals for one hour. This procedure was repeated 5 times with each replicate (tube) having a different group of 10 mites. After each count, the choice tubes were rotated 180° to avoid any chance of attraction to light.

All experiments were carried out at 25 ± 2°C and 50–55% RH and under standard fluorescent light.

RESULTS

KAIROMONE EXTRACTION

The initial experiment, to select the best solvent to extract kairomones, showed that the phytoseiid predator, *N. fallacis,* was significantly attracted to ethanol, ether, hexane and water extracts of *T. urticae* adult ovipositing females. Significant responses occurred at 15 and 30 minutes after the initiation of test. Ether extracts gave the greatest attraction followed by hexane, ethanol and water extracts (Table 2). Ether then became the solvent of choice for the extractions.

ATTRACTION RESPONSE OF *P. PERSIMILIS*

Phytoseiulus persimilis reacted positively in response to both fresh material and ether extracts of all stages of the spider mite *T. urticae* (Figs. 1, 2). Significant positive responses occurred at 15 minutes toward all stages and concentrations except for fresh larvae (not shown) and protonymph extract (Fig. 1). Larval and protonymph extracts at the 50 µg and 100 µg levels elicited a significant response at 30 minutes. *Phytoseiulus persimilis* females showed highly significant attraction at 15 minutes toward *T. urticae* eggs at high concentration such as 150 µg and 200 µg of fresh eggs and 200 µg of ether extract. Highly significant attraction was shown toward both fresh and ether extracted materials at all concentrations of *T. urticae* ovipositing females (Fig. 1).

Generally, the highest response values were recorded at 15 minutes and decreased with time (Fig. 2). No significant attraction was recorded at 60 minutes for any concentration of any developmental stage of *T. urticae* whether used as fresh materials or extracts. The control, a solvent-treated filter disk without mite extracts, when compared to an untreated blank, resulted in no attraction at any observation period. The increase in weight (concentration) of all *T. urticae* developmental stages increased the attraction response of *P. persimilis*

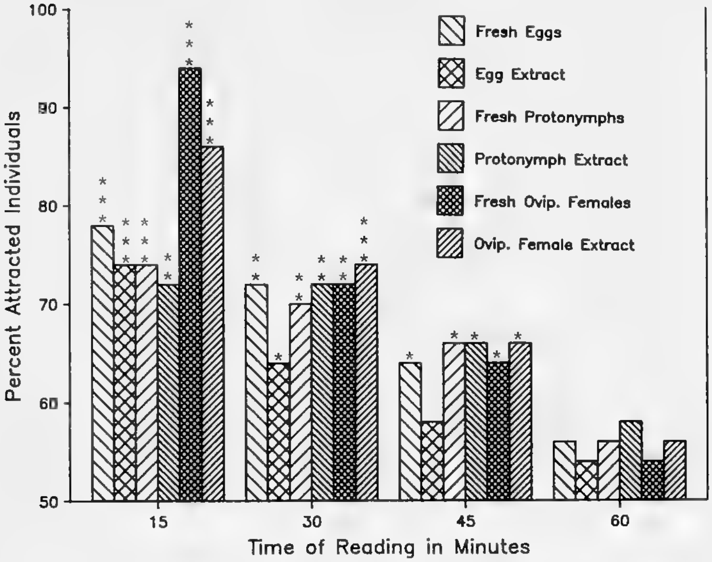


FIG. 2. Attraction response of *Phytoseiulus persimilis* to 200 μg of *Tetranychus urticae* of eggs, protonymphs, ovipositing female or their respective extracts as influenced by elapsed time in choice tube. Chi-square test, see Figure 1 legend.

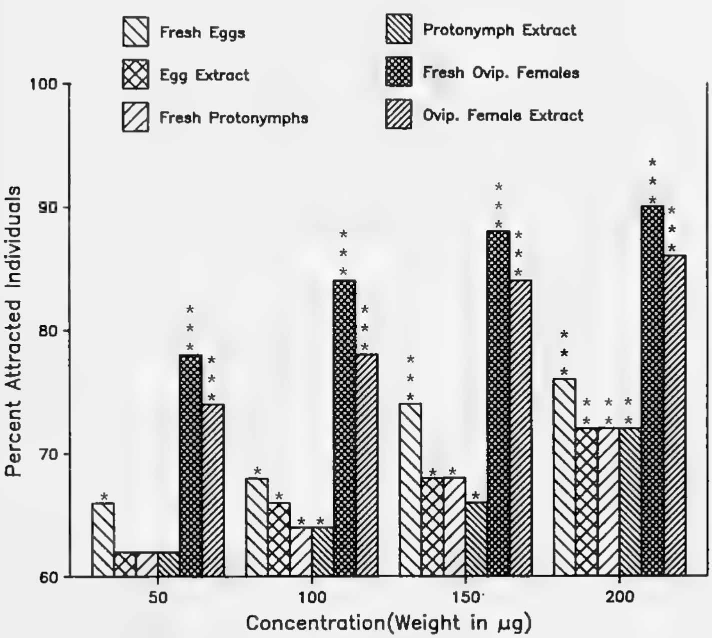


FIG. 3. Attraction response of *Neoseiulus fallacis* to various concentrations (weight) of *Tetranychus urticae* eggs, protonymphs ovipositing female, or their respective extracts measured at 15 minutes in choice tube. Chi-square test, see Figure 1 legend.

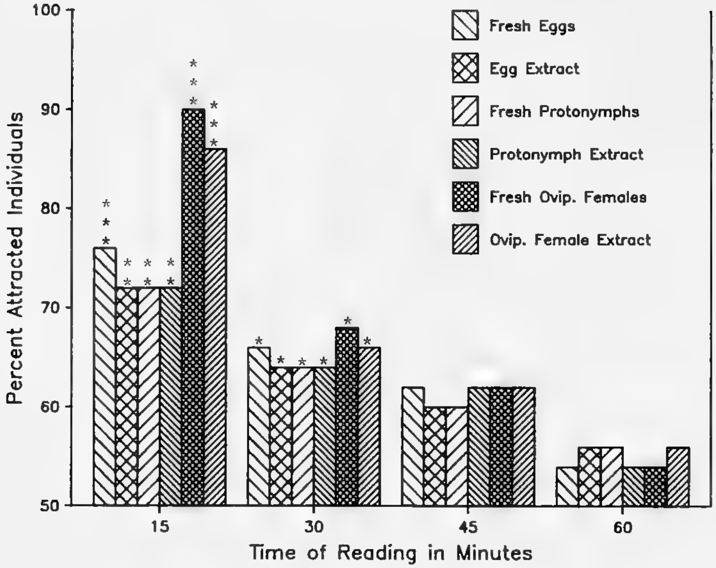


FIG. 4. Attraction response of *Neoseiulus fallacis* to 200 μg of *Tetranychus urticae* of eggs, protonymphs, ovipositing female or their respective extracts as influenced by elapsed time in choice tube. Chi-square test, see Figure 1 legend.

females when tested with the choice-tube method (Figs. 1, 2).

ATTRACTION RESPONSE OF *N. FALLACIS*

Neoseiulus fallacis was significantly attracted to both fresh and ether-extracted materials of all stages of *T. urticae* (Figs. 3, 4). A weight increase of all stages of *T. urticae* material resulted in increased attraction. The greatest attraction was recorded generally at 15 minutes for all stages of *T. urticae* and all concentrations. No significant responses were recorded for ether extracts of 50 μg of larvae, deutonymphs and adult males at any time period, and no significant responses were observed for any stage of *T. urticae* or extract concentration level at 60 minutes. No attraction was observed in the control.

ATTRACTION RESPONSE OF *T. OCCIDENTALIS*

Typhlodromus occidentalis showed a positive significant response to either fresh or ether-extracted materials of all *T. urticae* stages. The attraction response increased concomitantly with weight (concentration) of *T. urticae* stages (Fig. 5), and the greatest response values were recorded at the first 15-minute count (Figs. 5, 6). No significant responses were recorded at any time when fresh larvae and adult males were used at the 50 μg concentration level or for extractions of 50 μg of eggs, larvae, deutonymphs and adult males. No significant responses were recorded at 60 minutes for any mite stage or extract concentration.

DISCUSSION

Experiments utilizing two-choice-tube tests illustrated that eggs, immature stages and adults of the twospotted spider mite possess volatile chemical(s) which attracted the three species of phytoseiids. We have demonstrated that these chemicals (kairomones) are attractive quantitatively to the predators and can be extracted by organic solvents. The adult teneral and ovipositing females of *T. urticae* are the most important sources of the kairomones followed by eggs, adult males, and then the immature stages. Increased weight increment in spider mites (concentration) resulted in increased attraction response. The 3 phytoseiid predators demonstrate a strong attraction response to the volatiles that emanate from the test source. *Phytoseiulus persimilis* is strongly attracted to either fresh material or extracts of the various stages of the prey followed by *N. fallacis* and *T. occidentalis*.

The choice-tube assay produced rapid results indicating that the kairomone(s) tested were relatively volatile as these odors equili-

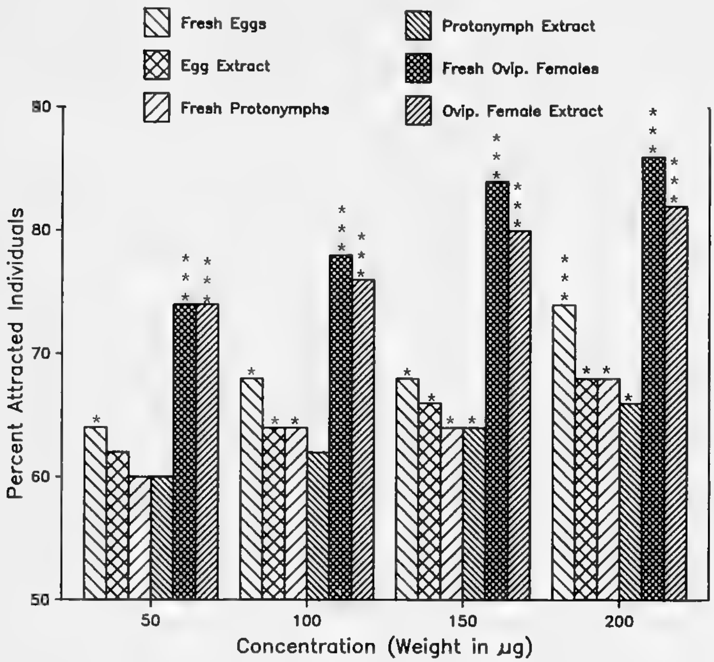


FIG. 5. Attraction response of *Typhlodromus occidentalis* to various concentrations (weight) of *Tetranychus urticae* eggs, protonymphs ovipositing female, or their respective extracts measured at 15 minutes in choice tube. Chi-square test, see Figure 1 legend.

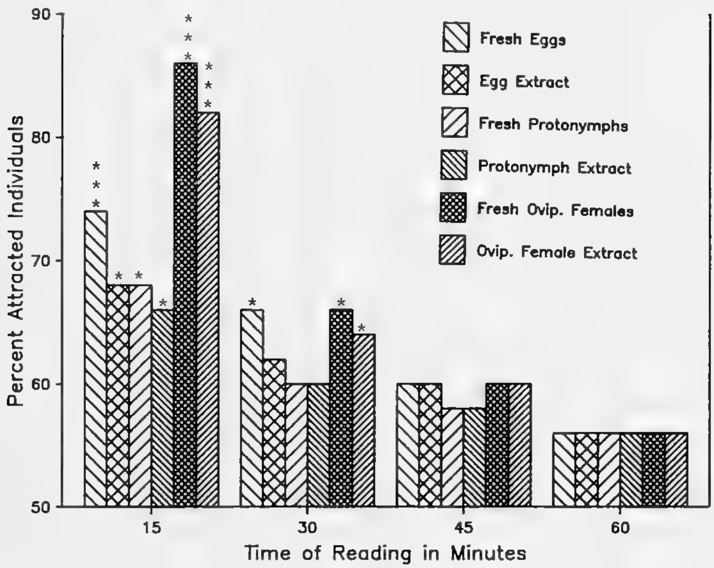


FIG. 6. Attraction response of *Typhlodromus occidentalis* to 200 μg of *Tetranychus urticae* of eggs, protonymphs, ovipositing female or their respective extracts as influenced by elapsed time in choice tube. Chi-square test, see Figure 1 legend.

brated from the test cup to the opposite (blank) side. Positive responses were obtained within 15 minutes as indicated in Figures 2, 4, 6 and, although data are not shown in this report for the sake of brevity, our recorded data show that the lower weight or concentration levels, usually took 30–45 min to elicit an attraction response, however weak, from the predator. Later, the predator moved randomly about the tube as was the case in the control.

Eggs of *T. urticae* proved to be a good source of kairomones, but the eggs may have acquired the kairomones as contaminates from webbing or feces. Jackson and Ford (11) found that when *T. urticae* egg kairomones were extracted away with distilled water, *P. persimilis* consumed about 50% the number of unwashed eggs. Also, *T. urticae* eggs which were deposited on glass plates apparently did not have kairomones (3, 4). However, *T. pacificus* eggs, larvae and protonymphs did not attract *P. persimilis* (6).

Although the immature stages of *T. urticae* were a source of kairomones, our data (unpublished) showed that deutonymphal and teneral stages were more attractive than the protonymphal and larval stages to the three phytoseiid species. Adult males gave a response similar to that of the deutonymphal female stage. Our results agree with those of Sabelis et al. (3, 4) who used the Y-tube olfactometer and reported that all feeding stages of *T. urticae* produced kairomones. *Phytoseiulus persimilis*, however, did not show significant preference for disks treated with extracts of *T. evansi* larvae, protonymphs, deutonymphs and adult males at any concentration, (5), nor were they attracted to *T. pacificus* eggs, larvae and protonymphs (6).

Our data strongly indicate that the adult teneral and ovipositing females of *T. urticae* are a strong source of kairomones. Adult ovipositing females elicited higher attraction responses than the teneral females when either fresh or extracted material was used. Our results generally support those of Sabelis et al. (3, 4), who reported that *P. persimilis* response to pre-oviposition females of *T. urticae* was not matched by the response of any other stage.

Kairomone chemistry apparently differs from one prey species to another, and the kairomone of the prey species may attract one predator species but not another. Hoy and Smilanick (12) found that *T. occidentalis* females are arrested in searching behavior in webbing produced by *T. urticae* but only slightly by webbing of *Panonychus ulmi*. Sabelis and Van de Baan (13) showed that *P. persimilis* and *T. occidentalis* reacted positively to the odor emanating from bean leaves infested by *T. urticae*, but they did not react to the air stream blown over apple leaves infested by *P. ulmi*.

Acknowledgment

The investigation reported in this paper (No. 88-7-131) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director.

Literature Cited

1. McMurtry, J. A. and J. G. Rodriguez. 1987. Nutritional ecology of phytoseiid mites. In F. Slansky and J. G. Rodriguez (eds.) The nutritional ecology of insects, mites, spiders, and related invertebrates. John Wiley and Sons, New York.

2. Hislop, R. G. and R. J. Prokopy. 1981. Mite predator responses to prey and predator—emitted stimuli. J. Chem. Ecol. 7:895–904.

3. Sabelis, M. W., B. P. Afman, and P. J. Slim. 1984a. Location of distant spider mite colonies by *Phytoseiulus persimilis* Athias-Henriot (Acarina: Phytoseiidae). Localization and extraction of a kairomone. Proc. 6th Int. Congr. Acarol. Edinburgh, U.K. Vol. 1, pp. 431–440.

4. Sabelis, M. W., J. E. Vermaat, and A. Groeneveld. 1984b. Arrestment responses of the predatory mite, *Phytoseiulus persimilis*, to steep odor gradients of a kairomone. Physiol. Entomol. 9:437–446.

5. Moraes, G. J. de and J. A. McMurtry. 1985. Chemically mediated arrestment of the predaceous mite *Phytoseiulus persimilis* by extracts of *Tetranychus evansi* and *Tetranychus urticae*. Exp. Appl. Acarol. 1:127–138.

6. Dong, H. and D. A. Chant. 1986. The olfactory response of three species of predaceous phytoseiid mites (Acarina: Gamasina) to a prey tetranychid species. Intern. J. Acarol. 12:51–55.

7. Winston, P. W. 1963. Possible humidity receptor mechanisms in the clover mite, *Bryobia praetiosa* Koch. J. Insect Physiol. 9:89–103.

8. Jalil, M. and J. G. Rodriguez. 1970. Studies of behavior of *Macrocheles muscaedomesticae* (Acarina—Macrochelidae) with emphasis on its attraction to the house fly. Ann. Entomol. Soc. Amer. 63:738–744.

9. Wicht, M. C., J. G. Rodriguez, W. T. Smith, and M. Jalil. 1971. Attraction to *Macrocheles muscaedomesticae* (Acarina: Macrochelidae) present in the house fly *Musca domestica*. J. Insect Physiol. 17:63–67.

10. Rodriguez, J. G., Z. T. Dabrowski, L. P. Stoltz, C. E. Chaplin, and W. O. Smith, Jr. 1971. Studies on resistance of strawberries to mites 2. Preference and non-preference response of *Tetranychus urticae* and *T. turkestani* to water-soluble extracts of foliage. J. Econ. Ent. 64:383–387.

11. Jackson, G. J. and J. B. Ford. 1973. The feeding behavior of *Phytoseiulus persimilis* Athias-Henriot (Acarina—Phytoseiidae), particularly as affected by certain pesticides. Ann. Appl. Biol. 75:165–171.

12. Hoy, M. A. and J. M. Smilanick. 1981. Non-random prey location by the phytoseiid predator *Metaseiulus occidentalis*. Different response to several spider mite species. Entomol. Exp. Appl. 29:241–253.

13. Sabelis, M. W. and H. E. Van de Baan. 1983. Location of distant spider mite colonies by phytoseiid predators: demonstration of specific kairomones emitted by *Tetranychus urticae* and *Panonychus ulmi*. Entomol. Exp. Appl. 33:303–314.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 128–120

Observations on Ascomycetes and Myxomycetes from Eastern Kentucky

Branley Allan Branson

Department of Biological sciences, Eastern Kentucky University,
Richmond, Kentucky 40475

Abstract

Distributional and habitat data are supplied for 15 genera and 16 species of ascomycete and 6 genera and 6 species of myxomycete fungi in eastern Kentucky.

Introduction

During the spring and early summer of 1987, the author conducted several field exercises for the purpose of collecting a variety of mostly fleshy fungi, principally in the eastern sections of the state. Included in these collections were representatives of 15 genera and 16 species of ascomycetes and 6 genera and 6 species of myxomycetes. Since there are very few published reports for these and other fungi in Kentucky, it is appropriate to publish these results.

The principal features utilized in making diagnoses were standard ones of general morphology, color, details of subterrranean parts, microscopic anatomy of spores and other parts, chemical reactions, and habitat.

Collecting Sites

Most of the specimens were secured from 3 main locations.

1. A "knob" hill area, 6.6 km east of Berea off SR 21, in the vicinity of Indian Fort Theatre, Madison County, Kentucky. The flatter-lying land around the entrance to the area has relatively deep, lignin-rich soil and an open mixed forest of hickories (principally pignut), maples, ashes, and Virginia pine; willows, hackberry and sweetgum occur along two small creeks. On the steep knobs above the theatre area, crisscrossed by a maintained hiking trail, are heavy growths of tulip poplar, sugar and red maples, hickories, oaks, and some beech. On the drier uplands there are abundant stands of Virginia pine and cedar.
2. Big Hill, a historically important landmark knob 16.4 km south of Kingston on U.S. 421, extreme southeastern section of Madison County, Kentucky. This is a very steep hill with considerable deep, lignin-rich soil and much fallen woody debris, rotten logs, and moss and ferns. Tulip poplars, maples and hickories dominate the woodlands with scattered stands of Virginia pine and eastern hemlock.
3. Red River Gorge area, from the Nada Tunnel (SR 77) to a point 6.0 km eastward. This is a mixed mesophytic section of Daniel Boone National Forest in Powell County, Kentucky. The soil is rich in lignin beneath a canopy of tulip poplar, maples, oaks, rhododendron, white pine, eastern hemlock, many other tree species and myriad small woody plants in the undercover. Moss and ferns abound.

Results

Ascomycetes

PEZIZALES. Five genera of these interesting cup fungi were collected.

Galiella rufa (Schw.) Nannf and Korf. Sparse fruitings were found on soil-covered wood beneath hickories and pines in the lowlands around the Indian Fort Theatre location on 9 September 1987. The fertile surface of the fungus was reddish-brown and the outside of the cup was heavily covered with black "hairs". The species is illustrated (plate 56) by Seaver (1) as *Bulgaria rufa*. I follow Pfister (2) in assigning the name.

Sarcoscypha occidentalis (Schw.) Sacc. Hundreds of specimens of this pretty little fungus were observed on decaying wood, 27 June 1987, at the Big Hill location. The species was discussed by Seaver (1) as *Plectania occidentalis* and placed in *Sarcoscypha* by Denison (3) and Pfister (2).

Sarcoscypha conninea (Scop.) Sacc. Many specimens were found on sticks buried in muddy soil on the Kentucky River bluffs near the

I-75 bridge, Madison County, Kentucky, 2 July 1987. This was rather late in the season for this species, but since the early summer was cool and wet the occurrence was not unexpected. The fungus is illustrated in Seaver's (1) plate 19. Denison (3) placed the species in *Sarcoscypha*.

Microstoma fluccosa (Schw.) Raitviir. Many specimens were found on dead twigs at the Big Hill location, 27 June 1987. This shaggy, red-cupped fungus was illustrated by Seaver (10 on plate 20).

Urnula craterium (Schw.) Fr. Two specimens were found on the ground under pines and hickories at the Indian Fort Theatre lowlands, 9 September 1987. This was an unusual fruiting period for the species (4).

Cheilymenia coprinaria (Cooke) Boud. Thousands of specimens were found on semidry cow dung at the Eastern Kentucky University dairy farm, Madison County, Kentucky, 19 July 1987. Widely distributed in North America and Europe (1), there are few reported records for the species in our area. *Cheilymenia michiganensis* Povah is a synonym (2).

HELOTIALES. Representatives of 4 genera were collected.

Chlorociboria aeruginascens (Karst.) Fenn. Numerous specimens were found on rotten eastern hemlock logs on a hillside above the Nada Tunnel at the Red River Gorge site, 9 June 1987. This small to minute fungus is widespread in America and Europe (5).

Bisporella citrina (Batsch) Korf. and Carp. Abundant specimens were secured from dead twigs and leaves on the ground in a low-lying swale, 5.3 km east of Nada Tunnel, 9 June 1987. This bright yellow fungus is discussed by Seaver (5) as a *Helotium* and illustrated on plate 104.

Leotia lubrica (Scop.) Pers. Several specimens were found in the same locality as the last species, on dead leaves and twigs. The species is illustrated on Arora's (4) color plate 215.

Leotia viscosa Fries. Six specimens were removed from decaying maple leaves at Levi Jackson State Park, Laurel County, Kentucky, 3 December 1978. Arora (4) presented a color illustration (plate 215).

Spathularia flavida Pers. A few specimens were found growing on much-decayed wood at the Indian Fort Theatre locality, 15 July 1987. Seaver (5) considered the species to be a synonym of *S. clavata* (Schaeff) Sacc., but Arora (4) indicated the reverse.

HELVELLACEAE. One genus and 2 species were collected.

Helvella crispa (Scop.) Fr. One beautiful example of this elfin saddle was found growing at the base of a Virginia pine, 15 July 1987, in the flatlands below Indian Fort Theatre. Lincoff (6) presented a color illustration.

Helvella elastica Bull. One specimen was found growing on the ground below a mixture of sugar maples and eastern hemlocks, 9 June 1987, near the eastern end of Nada Tunnel at the Red River Gorge locality. The ellipse-shaped spores each had a large, centrally located oil droplet.

MORCHELLACEAE. One species was collected.

Morchella angusticeps Pk. A single specimen of this black morel was secured from the edge of a grove of young tulip poplars above the Natural Bridge State Park Lodge, Powell County, Kentucky, 8 May 1987. Sundberg and Richardson (7) reported and color-illustrated the species from Land Between the Lakes, western Kentucky.

PYRENOMYCETES. Representatives of 4 genera were collected.

Cordyceps capitata (Holmsk.) Link. Two specimens were found growing on underground fungi beneath tulip poplars 0.8 km above Indian Fort Theatre, 15 July 1987, a typical habitat for this species (8).

Cordyceps militaris (L.) Link. A single specimen was found on a partially buried insect larva at a site 7.0 km west of Richmond via Barnesmill Road, Madison County, Kentucky, 23 June 1987. The marginal forest along Silver Creek consisted principally of sycamore, maples, willows, black walnut and hackberry. This is a provisional diagnosis (see 8, 9).

Xylaria hypoxylon (L.) Grev. Many specimens of this easily recognized fungus were collected from a moss-covered, burn-scarred log on a hillside above Nada Tunnel in the Red River Gorge locality (9 June 1987) and from the burned, inner surface of an old whiskey barrel at Deacon Hills Estates, Madison County, Kentucky (22 July 1987).

Ustulina deusta (Fr.) Pers. Several large colonies of this encrusting fungus were found on burned logs at the Big Hill locality, 3 July 1987. The spore print was very black and the large perithecia had their pores immersed in light-colored tissues.

Hypoxylon fragiforme (Pers.) Kickx. Two large populations were found at the Big Hill locality on burned logs (2 July 1987) and one population was observed on a standing beech stump 5.8 km north of Richmond, Madison County, Kentucky, just off SR 60, 3 November 1986.

MYXOMYCETES

The occurrence and distribution of slime molds in Kentucky is very poorly documented. Representatives of 6 genera are reported here.

Arcyria incarnata (L.) Welt. A nicely differentiated colony was found on a wet log at the Indian Fort Theatre locality, 3 June 1987.

Brefeldia maxima (Fr.) Rost. A large colony was found on a standing dead ash tree on the campus of Eastern Kentucky University, Richmond, Madison County, Kentucky, 28 June 1985.

Ceratiomyxa fructiculosa (Mull.) Mac. Two colonies of this easily recognized slime mold were found, one on a dead hackberry log in Deacon Hills estates, Richmond (19 June 1987), and one on a dead pignut hickory at the Indian Fort Theatre lowlands (15 July 1987), both in Madison County. The species was previously reported from western Kentucky (7).

Leocarpus fragilis (Dicks.) Rost. A colony of yellow-brown, insect-egg-like cases was found on very rotten wood at the Indian Fort Theatre site, 15 July 1987. Microscopic examination demonstrated the typical three-layered arrangement of this slime mold (6).

Lycogala epidendrum (L.) Fr. A small colony of this interesting slime mold was found on a dead, barkless tree trunk 7.0 km west of Richmond, Madison County, Kentucky, Barnesmill Road, 23 June 1987. The species has also been reported from Land Between the Lakes in western Kentucky (7).

Stemonitis splendens Rost. One small colony was found on dead wood 0.3 km above Indian Fort Theatre (15 July 1987), a site heavily shaded by tulip poplars and beeches. Sundberg and Richardson (7) reported the related form *S. axifera* (Bull.) Macbr. from Land Between the Lakes. This slime mold is one of the most common and is worldwide in distribution.

ACKNOWLEDGMENTS

I appreciate Dr. Ronald R. Petersen's (Department of Botany, University of Tennessee) critical reading of the manuscript.

LITERATURE CITED

1. Seaver, F. J. 1928–1942. The North American cup-fungi (operculates). Pub. by the author, New York, Lancaster Press, Lancaster, New York.

2. Pfister, D. H. 1982. A nomenclatural revision of F. J. Seaver's North American cup-fungi (operculates). Occ. Pap. Farlow Herb. Crypt. Bot. 17:1–32.

3. Denison, W. C. 1972. Central American Pezizales. IV. The genera *Sarcoscypha, Pithya* and *Nanoscypha*. Mycologia 64:609–623.

4. Arora, D. 1986. Mushrooms demystified. Ten Speed Press, Berkeley, California.

5. Seaver, F. J. 1951. The North American cup-fungi (inoperculates). Pub. by the author, Lancaster Press, Lancaster, New York.

6. Lincoff, G. H. 1981. The Audubon Society field guide to North American mushrooms. Alfred A. Knopf, New York.

7. Sundberg, W. J. and J. A. Richardson. 1980. Mushrooms and other fungi of Land Between the Lakes. Tennessee Valley Authority Handbook.

8. Mains, E. B. 1940. Species of *Cordyceps*. Mycologia 32:310–320.

9. Mains, E. B. 1947. New and interesting species of *Cordyceps*. Mycologia 39:535–545.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 131–139

Isolation Techniques for Surveying the Fungi of Stored Maize

S. A. Frey and David E. Legg[1]

Community Research Service, Kentucky State University, Frankfort, Kentucky 40601

Abstract

Ten media were compared for isolating fungi from stored maize, *Zea mays* L., in Kentucky. Laboratory tests indicated that Czapek-Dox solution containing 20% sucrose and filter paper soaked with sterilized distilled water were among the least species-restrictive, easiest to prepare, and most economical to use for isolation of fungi. Additional experimentation suggested that 25°C was a better incubation temperature than 30°C and that colony counts of the species present were equivalent when cultured in complete darkness or under a 12:12 (L:D) photoperiod.

Introduction

Isolation techniques for fungi can be species specific. Species selectivity is preferred when recording the presence and quantity of a given fungus. It is, however, of little use in survey-oriented work where detection of the widest possible species range is desired.

Many techniques for fungal isolation and culture are available (1) but few have been designed for extensive survey work in post-harvest stored grains (2). Notable exceptions are those of Mills et al. (2) who designed, tested, and selected mycological isolation techniques for surveying the fungi of stored rapeseed, *Brassica napus* L., in western Canada.

Isolation media have also been tested for determining the "numbers and kinds" of fungi associated with stored maize, *Zea mays* L. (3). These, however, were used with the dilution-plating technique which later was found to be not as effective for detecting the presence of fungi as the whole-kernel plating technique (4). These results were supported by Pixton et al. (5) who used cornmeal agar and plain agar, which Christensen did not use in his earlier work (6, 4, 3). In contrast, Mills et al. (2) made use of the whole kernel plating technique.

It is well known that environmental conditions can significantly affect fungal growth (4). However, experiments conducted by Mills et al. (2) were carried out under one temperature (25°C) in complete darkness without documenting the number of kernel surface contaminants relative to the degree of infection. Christensen (4) used a 30°C incubation temperature because it promoted "a more rapid appearance of most of the common species of the *Aspergillus glaucus*, *A. candidus* and *A. flavus* groups than incubation at 25°C." He made no mention of or placed any importance on photoperiod. Information concerning the amount of surface contaminants and degree of infestation is useful when determining the microbial contamination of the grain.

The purpose of this paper is to compare 10 isolation media, using the whole-kernel plating technique, in order to determine which media would be most suitable for survey work on stored maize in Kentucky. In addition, 2 culturing temperatures, 2 photoperiod regimes, and 2 grain surface treatments were tested for possible influence on number of colonies per species.

Materials and Methods

Experimental maize was grown, combine-harvested, and shelled in 1984 and stored on the University of Kentucky Coldstream Farm. Approximately 25.5 kg was obtained in November of 1985, taken to Kentucky State University, and placed in cold storage prior to experimentation. Experimental maize consisted of broken, cracked, and sound kernels, bits of maize cobs, stalks, and leaves, weed seeds, and a moderate to high infestation of *Tribolium castaneum* (Herbst) (i.e., more than 1 adult per 0.9 liter of grain). Kernels were carefully scrutinized for cracks or broken parts with only sound kernels being used in this study. Kernels were placed in an environmental

[1] Current address: Department of Plant, Soil and Insect Sciences, P.O. Box 3354, University of Wyoming, Laramie, Wyoming 82071.

chamber and held at 27°C, 80% RH until they had equilibrated to an 11% moisture content.

Effect of Medium, Temperature, and Grain Surface Treatment

Half of the experimental kernels were immersed in 1% sodium hypochlorite for 1 minute, followed by 2 rinses in sterilized distilled water (sterilized maize); remaining kernels were not rinsed in sodium hypochlorite. The term "sterilized maize" denotes surface disinfection only. Eight sterile petri dishes were then set up for each of 10 media: plain agar (PA), filter paper + 4.5 ml of sterilized distilled water (FP), standard Czapek-Dox agar (CZA), filter paper + 4.5 ml of standard Czapek-Dox solution (CZFP), malt-salt agar (MSA) (4), filter paper + 4.5 ml of sterilized 7.5% NaCl solution (SFP), malt-salt agar with 18% NaCl (MSA18), filter paper + 4.5 ml of sterilized water containing 18% NaCl (SFP18), (Czapek-Dox agar with 20% sucrose (CZA20), and filter paper + 4.5 ml of Czapek-Dox solution containing 20% sucrose (CZFP20). Media choice was based on those used by Mills et al. (2) as well as the Czapek-Dox variants suggested by Christensen (4). Four petri dishes per medium received 10 kernels each from the sterilized treatment and the remaining 4 received 10 kernels each from the unsterilized treatment. Two petri dishes each of the sterilized and nonsterilized maize were then placed in a programmed environmental chamber set at 25°C, 12:12 (L:D), and 67% RH. The remainder were placed in a 30°C, 12:12 (L:D), 67% RH environmental regime. Photoperiod was produced with fluorescent lighting (GE F20T12-CW bulbs). The cultures were allowed to incubate for 4 days after which the number of colonies per species per kernel was counted. Cultures were then incubated 3 additional days after which time the number of colonies per species per kernel was again counted with the newly-emerged colonies being added to the previous count. Colonies per species were totaled over kernels per petri dish.

Total number of colonies per petri dish were analyzed for possible effects of temperature, surface treatment, medium, and species that were present (independent variables) in a completely randomized factorial analysis of variance (7). Various combinations of the independent variables were also tested for a significant interaction effect on number of colonies that were counted. Significance of each independent variable by itself (main effect) or in combination with one or more of the others (interactive effect) was determined by the *F* test (7). F values for main or interactive effects associated with probabilities that were less than 0.05 were considered significant. Although the complete analysis of variance was computed, the influence of main effects, the species × medium interaction and higher order interactions involving species and media were of primary interest; *F* and *P* values were reported for these factors only.

Fisher's protected least significant difference (LSD) was used to separate mean colony responses of various levels of the main and interactive effects. The LSD for comparing mean colony counts of the main effects was based on the pooled experimental error. The LSD for comparing mean colony counts of the interactions was based on the pooled error of specific comparisons. Interactions were presented graphically because, by definition, they appear as nonparallel responses of each level of one factor over all levels of the others (8).

Effect of Photoperiod Regime

The effect of complete darkness and 12 h of light on fungal colony count was assessed by setting up 4 petri dishes for each of 8 isolation media (PA, MSA, CZA20, FP, SFP, CZFP, and CZFP20), plating 10 maize kernels per dish, placing 2 dishes in complete darkness and 2 in a 12:12 (L:D) photoperiod. Both photoperiod regimes were held at 25°C and 67% RH. Inoculated media were allowed to incubate for 4 days after which the number of colonies per species per kernel was counted. Then the plates were incubated 3 additional days after which the number of colonies per species per kernel was again counted. New colonies were then added to those of the previous count. Colonies per species were totaled over kernels for each plate. Experimental maize was not rinsed in sodium hypochlorite.

Total number of colonies per plate were analyzed for the direct effect of photoperiod on fungal colony count. In addition, a potential influence of photoperiod on individual fungal species or on colony counts taken from specific media (interactive effects) was also investigated. The experimental design was a completely randomized factorial analysis of variance (7).

TABLE 1. *F* and *P* values and degrees of freedom (df) in an analysis of variance for influence of two culturing temperatures, two seed surface sterilization treatments, ten culturing media, and ten fungal species on fungal colony counts.

Source of variation	*F* value[a]	*P* value	df
Main effects			
Temperature	1.47	0.225	1
Grain surface treatment	261.13	<0.001	1
Media	8.78	<0.001	9
Fungal species	116.32	<0.001	9
Two-factor interactions			
Temperature × fungal species	6.00	<0.001	9
Grain surface treatment × fungal species	41.97	<0.001	9
Media × fungal species	5.23	<0.001	81
Three-factor interactions			
Temperature × media × fungal species	1.65	0.001	81
Grain surface treatment × media × fungal species	3.14	<0.001	81

[a] *F* ratios were based on a pooled experimental error of 1.365 with 400 df. Total sums of squares was 4,405.6 with 799 df

Factors included in the analysis were photoperiod, fungal species, and isolation medium and, of these, photoperiod and fungal species were of sole concern; *F* and *P* values were reported for these variables and their interactions.

RESULTS AND DISCUSSION

Effect of Medium, Temperature, and Grain Surface Treatment

Analysis of variance (Table 1) indicated that all main effects except temperature significantly influenced average colony counts. Also, the medium × species interaction and two 3-factor interactions involving medium and species were significant. The 4-factor interaction was not significant.

Comparisons between average colony count for various levels of the main effects showed that fungal infection was low relative to the amount of inoculum that was present (sterilized maize mean = 0.388 ± 0.062, nonsterilized mean = 1.722 ± 0.147, n = 400). Analysis for species abundance indicated that 10 species were present and they occurred in varying amounts (Fig. 1). *Aspergillus glaucus* was the dominant species followed by *A. flavus, Penicillium* spp., and *Mucor* spp.; *Fusarium* spp., *A. fumigatus, A. niger*, and *A. clavatus* occurred in low but approximately equal numbers while *A. ochraceous* and *A. candidus* were rarely observed. *Aspergillus ochraceous* and *A. candidus* were subsequently dropped from further analysis because their occurrence was so rare that it was not possible to determine the effect of each treatment and their interactions on these species. Comparisons between mean colony counts for the different media (Fig. 1) indicated that no clear distinction oc-

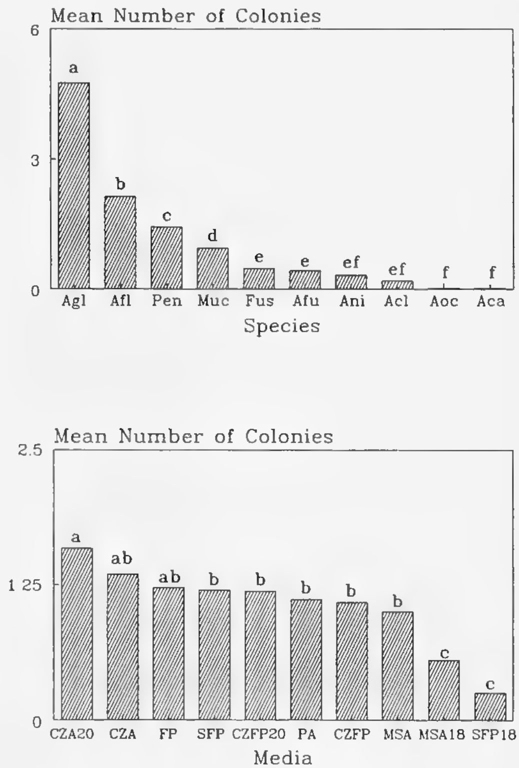


FIG. 1. Average number of colonies for each of ten fungal species (top) and isolation media (bottom). Means followed by the same letter are not significantly different; Fisher's protected least significant difference.

TABLE 2. Comparisons[1] of average colony counts within fungal species between isolation media, n = 8.

Medium[2]	Average fungal colony counts per species							
	A. glaucus	*A. flavus*	*A. fumigatus*	*A. niger*	*A. clavatus*	*Penicillium*	*Mucor*	*Fusarium*
PA	1.63e	3.63	0.50	0.13b	0.50ab	1.88	1.88a	1.00a
FP	2.25de	3.25	0.38	0.88a	0.50ab	2.63	1.88a	0.50ab
CZA	5.13bcd	2.25	1.00	0.50ab	0.63a	2.25	1.00ab	0.75ab
CZFP	2.88cde	3.38	1.00	0.13b	0.13ab	2.00	0.88ab	0.38ab
MSA	3.38cde	2.38	0.25	0.38ab	0.13ab	1.00	1.88a	0.50ab
SFP	8.88cde	1.75	0.38	0.00b	0.00b	0.63	0.25b	0.00b
CZA20	7.50ab	2.50	0.63	0.88a	0.00b	2.50	1.13ab	0.63ab
CZFP20	6.13abc	2.25	0.13	0.37ab	0.00b	1.50	0.50ab	1.00a

[1] Means within column followed by the same letter are not significantly different; Least Significant Difference
[2] Media are plain agar (PA), filter paper + 4.5 ml of sterilized distilled water (FP), standard Czapek-Dox agar (CZA), filter paper + 4.5 ml of standard Czapek-Dox solution (CZFP), malt-salt agar (MSA) (4), filter paper + 4.5 ml of sterilized 7.5% NaCl solution (SFP), Czapek-Dox agar with 20% sucrose (CZA20), and filter paper + 4.5 ml of Czapek-Dox solution containing 20% sucrose (CZFP20).

curred between most, excepting MSA18 and SFP18. These media were quite species selective and effectively prevented all but *A. glaucus* from growing. Since MSA18 and SFP18 did not meet the requirement of low species selectivity they were eliminated from further analysis.

Analyses of the medium × species interaction is comprised of eight sub-figures (Fig. 2). Each sub-figure represents a different species arranged from the most (upper left corner) to the least abundant (lower right corner). Media within a sub-figure are arranged by osmophilic properties (water binding potential) and media-base within osmophilic property (agar or filter paper). PA and FP were the least osmophilic (containing 0% water binding molecules by weight) while CZA20 and CZFP20 were the most (containing 21.9 and 20.4% water binding molecules by weight, respectively). Standard CZA and CZFP, MSA and SFP had intermediate osmophilic properties (4.9, 3.4, 11.0, and 7.5% water binding molecules by weight, respectively).

Specific comparisons first focused on testing for a possible filter paper-agar influence on mean colony counts; all possible comparisons between mean colony counts of media within species were then performed. Possible filter paper-agar influence on mean colony counts was tested within osmophilic groups for each species. Results indicated that just 4 of 32 comparisons were significant and 3 of these concerned the MSA-SFP osmophilic group (Fig. 2). SFP significantly enhanced colony counts of *A. glaucus* but did not do so for *Mucor* or *Fusarium* spp. These data support the findings of Mills et al. (2) who showed that SFP preferentially selects for *A. glaucus*. These data also indicate that a general filter paper-agar influence on mean colony counts did not occur.

All possible comparisons between the average number of colonies per medium for each species were conducted in an effort to determine those media that consistently promote the greatest colony growth over the species that are present (Table 2). Comparisons showed that no one medium significantly influenced mean colony counts for *A. flavus*, *A. fumigatus*, or *Penicillium*. Mean comparisons for the remaining five species showed that SFP was ranked in the top group just once (for *A. glaucus*) but was associated with the bottom group for the remaining 4 species. PA and CZFP were statistically ranked in the top group for isolation of 3 species (*Fusarium*, *Mucor*, and *A. clavatus*) but each fell into the bottom-most group of two species (*A. glaucus* and *A. niger*). CZA20 was ranked in the top-most group of three species but it fell into the bottom-most group of *A. clavatus*. CZA and MSA were each ranked in the top-most group in four species but both appeared to hinder colony growth of the most prevalent fungus (*A. glaucus*). CZFP20 and FP were ranked in the top-most group for isolation of four species; CZFP20 did not appear to hinder growth of *A. glaucus* but FP did. CZFP20 and FP each were ranked into the bottom-most group just once.

While various isolation media had a wide-ranging impact on observed number of colonies across species, the performance of CZFP20 and FP most closely matched our stated characteristics of the ideal survey medium. In ad-

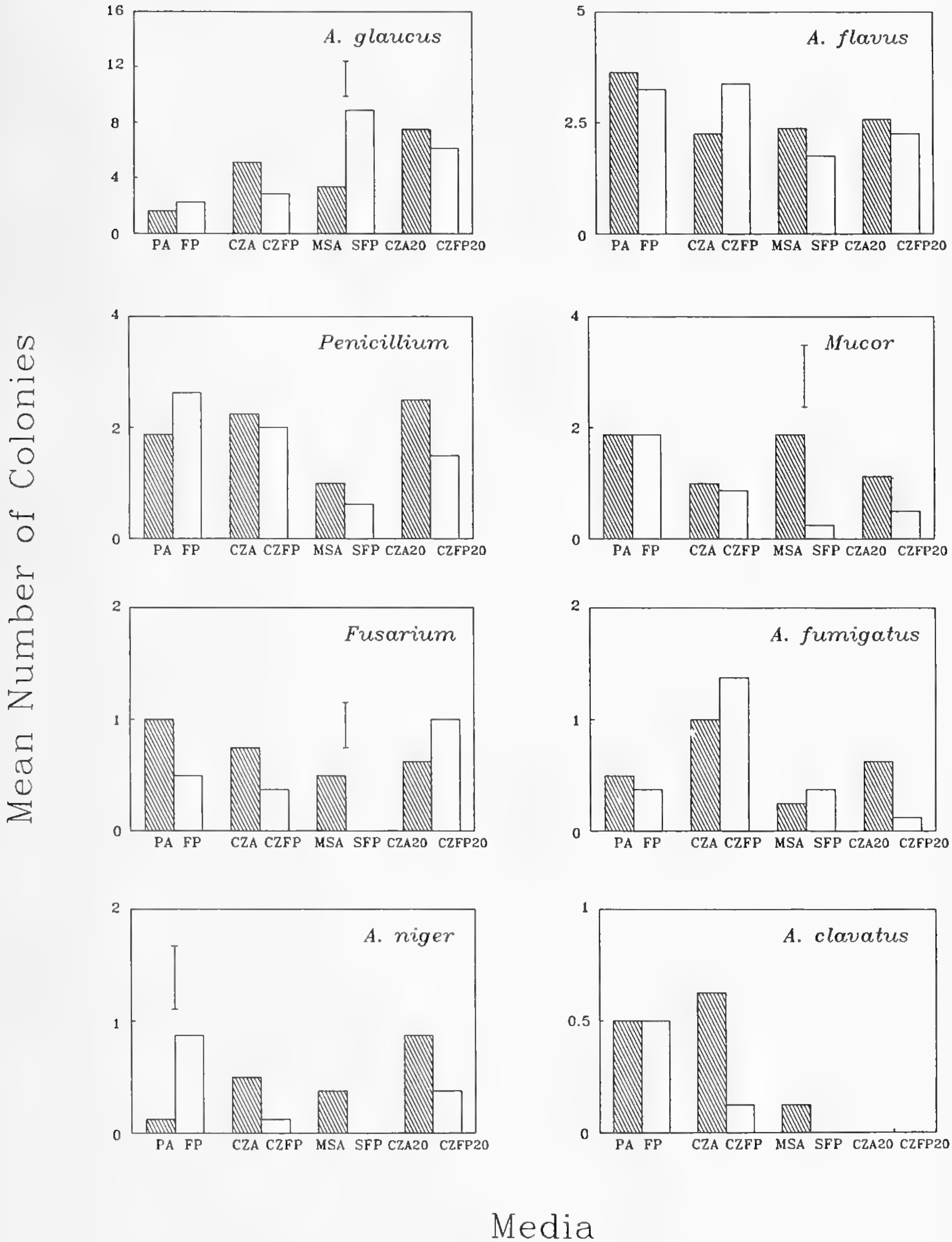


FIG. 2. Average number of colonies for each of eight isolation media for each of eight fungal species. Fungal species (sub-figures) are arranged from the most (upper left corner) to the least abundant (lower right corner); media within sub-figure are arranged by osmophilic properties (water binding potential) and media-base within osmophilic property (agar or filter paper). Vertical bars represent the 95% least significant difference between agar-based (striped bars) and filter paper-based (open bars) media within osmophilic grouping.

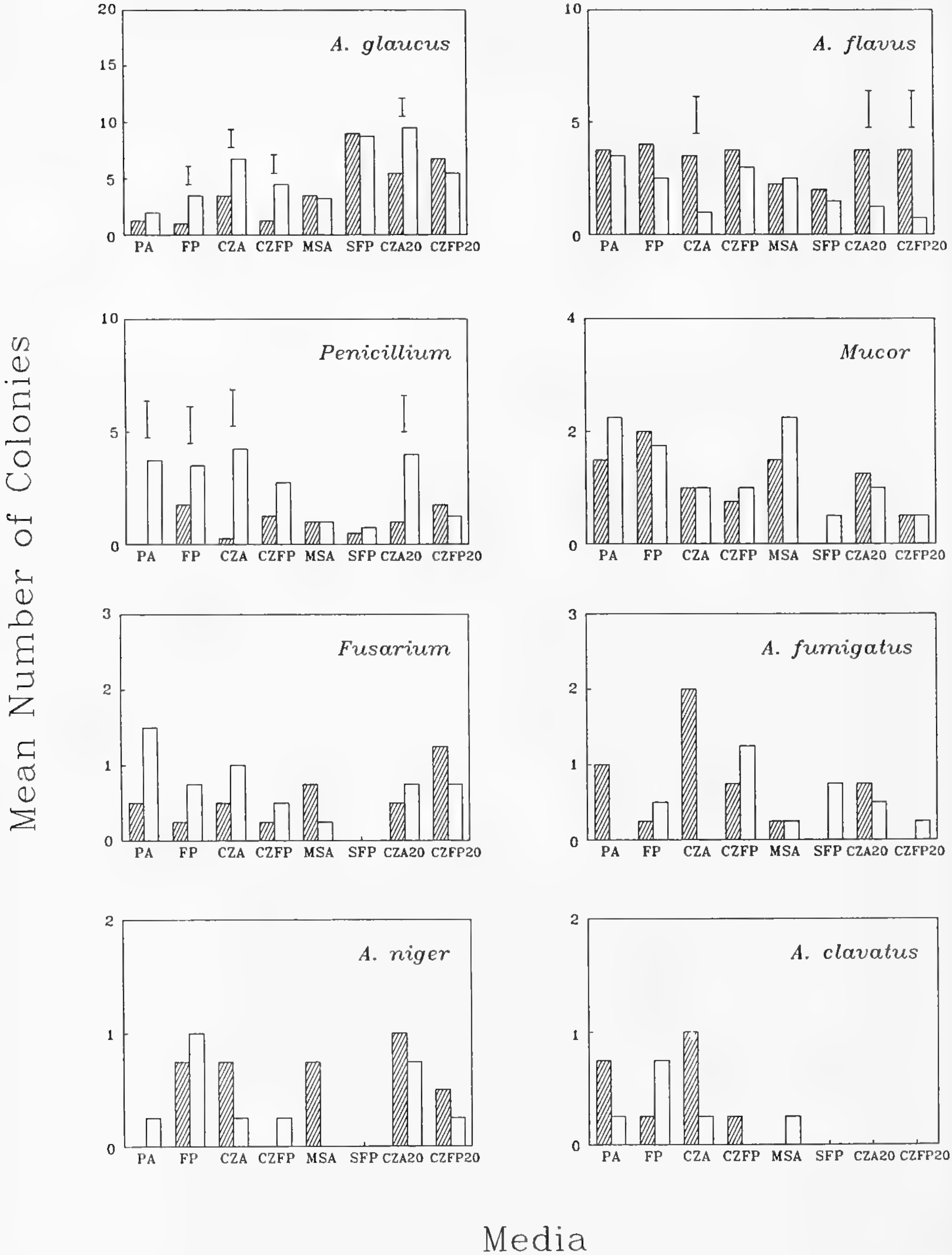


FIG. 3. Average number of colonies for each of eight fungal species (sub-figures), eight isolation media, and two temperature regimes (25°C [open bars] and 30°C [striped bars]) for the fungal species × media × temperature interaction. Vertical bars represent the 95% least significant difference between temperatures at a given isolation medium and fungal species. Note that, when significant differences occur, *A. glaucus* and *Penicillium* consistently produce more colonies at 25°C on certain media but *A. flavus* consistently produces more colonies at 30°C on some media.

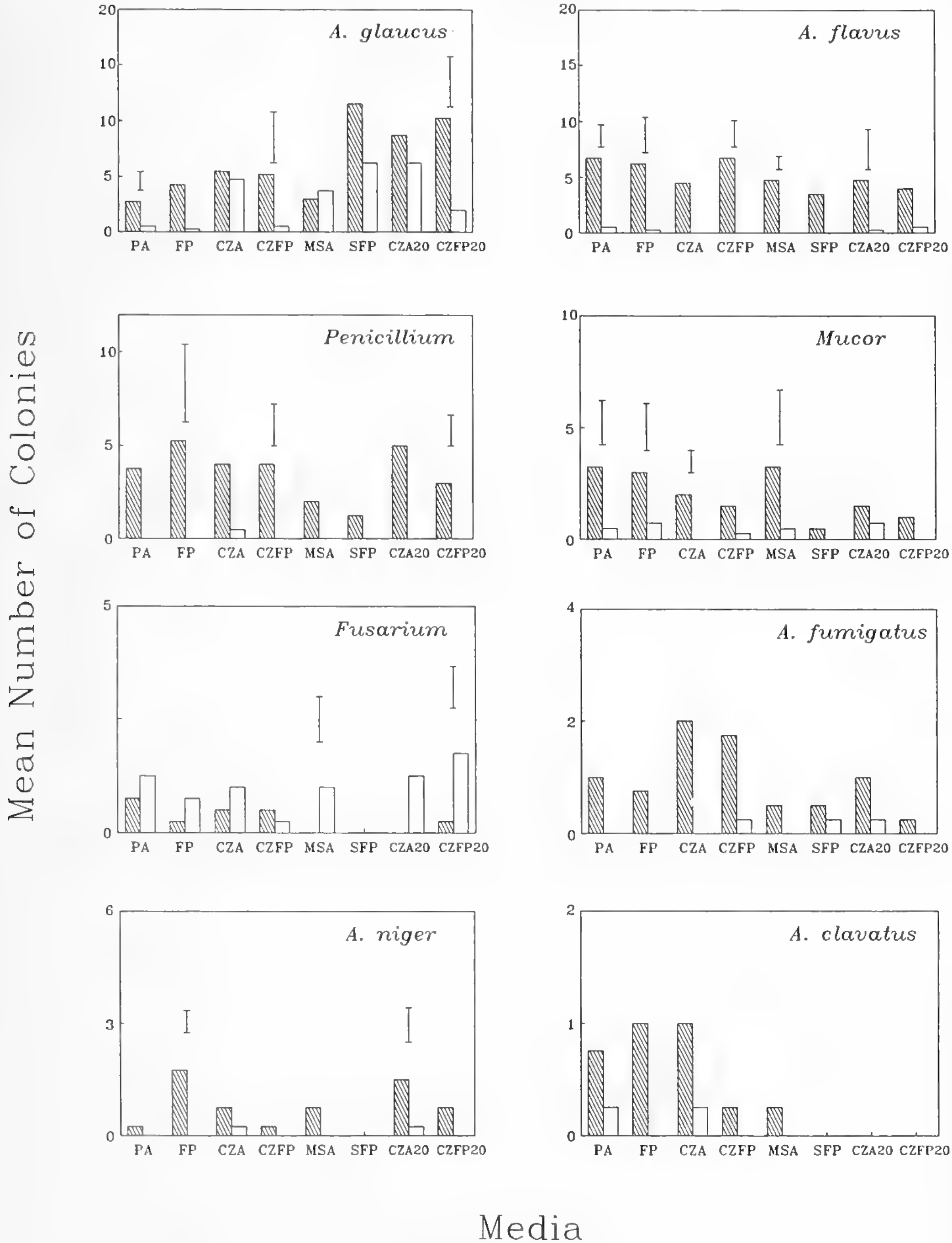


FIG. 4. Average number of colonies for each of eight fungal species (sub-figures), eight media, and two grain surface treatments (striped bars are non-surface rinsed and open bars are rinsed with sodium hypochlorite). Vertical bars represent the 95% least significant difference between surface sterilization regimes per medium per fungal species. Note the substantial *A. glaucus* infection on most media relative to the amount of inoculum that was present; *Fusarium* infection on CZFP20 and MSA, however, was very high relative to the amount of inoculum.

TABLE 3. *F* and *P* values and degrees of freedom (df) in an analysis of variance for the influence of photoperiod regime (complete darkness and 12:12 L:D) and its interaction with eight media and species on fungal colony counts.

Source of variation	*F* value[a]	*P* value	df
Photoperiod regime	0.97	0.328	1
Photoperiod regime × media	0.62	0.743	7
Photoperiod regime × fungal species	1.51	0.149	9
Photoperiod regime × media × fungal species	0.63	0.980	63

[a] *F* ratios were based on a pooled experimental error of 2.525 with 160 df Total sums of squares was 2,619.0 with 319 df

dition, both are filter paper-based media which makes them easier to prepare and less costly to use. Also, CZFP20 and FP are on opposite ends of the osmophilic spectrum and if both are used on kernels drawn from the same sample they would tend to complement each other. Thus, because of ease of preparation and osmophilic properties, it is concluded that CZFP20 and FP generally were the least species specific and enhanced colony growth more than the other isolation techniques.

Analysis of the temperature × medium × species interaction (Fig. 3) indicated that most species were either unaffected by temperature (*Mucor, Fusarium, A. fumigatus, A. niger,* and *A. clavatus*) or growth was enhanced at 25°C on certain media (*A. glaucus* and *Penicillium*). The exception, however, was *A. flavus* for which enhanced growth (colony production) occurred at 30°C on CZA, CZA20, and CZFP20. These data support the findings of Christensen and Kaufmann (9) and Christensen (10) who reported that optimal growth of *A. glaucus* and *A. flavus* are 24 and 36–38°C, respectively. Optimum temperatures for *Penicillium* growth is species dependent but it generally occurs at temperatures less than 30°C. These data suggest that while no one incubation temperature was ideal for growing all fungi, growth at 25°C was as good as if not better than that at 30°C except for *A. flavus.*

The sterilization regime × media × species interaction (Fig. 4) indicated that the level of infection was quite low for all species except *A. glaucus* and *Fusarium* and that the increase in *Fusarium* colonies on MSA and CZFP20 for the sterilized maize was the primary cause for the interaction. The reason that *Fusarium* was more prevalent in the sterilized maize may be due to an antagonistic effect of one or more of the other fungi on *Fusarium*. Experiments conducted by Chang and Kommedahl (11) showed that *Fusarium* spp. growth was severely inhibited by *Chaetomium globosum* and *Bacillus subtilis*. Moreover, they found that *Fusarium roseum* growth was inhibited by both *Aspergillus flavus* and *Penicillium* spp., 2 prevalent fungi in this study.

Effect of Photoperiod Regime

Analysis of variance indicated that photoperiod did not affect general colony counts, counts from a specific fungus (photoperiod × species interaction), counts from a given medium (photoperiod × medium interaction), or a specific fungus growing on a certain medium (photoperiod × species × medium interaction) (Table 3). These results indicate that, for the species present, colony growth under a 12:12 (L:D) photoperiod is equivalent to that under a 24 hr scotophase and suggest that photoperiod may be unimportant to growth of fungi associated with stored maize. This was expected since fungi are achlorophyllus.

ACKNOWLEDGMENT

This investigation was supported in part by a USDA/CSRS grant to Kentucky State University under agreement KYX-10-87-06P.

LITERATURE CITED

1. Tuite, J. 1969. Plant pathological methods. Fungi and bacteria. Burgess, Minneapolis, Minnesota.
2. Mills, J. T., R. N. Sinha, and H. A. H. Wallace. 1978. Multivariate evaluation of isolation techniques for fungi associated with stored rapeseed. Phytopath. 68:1520–1525.
3. Bottomley, R. A., C. M. Christensen and W. F. Geddes. 1952. Grain storage studies. X. The influence of aeration, time, and moisture content on fat acidity, nonreducing sugars, and mold flora of stored yellow corn. Cereal Chem. 29:53–64.
4. Christensen, C. M. 1957. Deterioration of stored grains by fungi. Bot. Rev. 23:108–134.
5. Pixton, S. W., S. Warburton and S. T. Hill. 1975. Longterm storage of wheat—III: Some changes in the quality of wheat observed during 16 years of storage. J. Stored Prod. Res. 11:177–185.
6. Christensen, C. M. 1946. The quantitative determination of molds in flour. Cereal Chem. 23:322–329.
7. Snedecor, G. W. and W. G. Cochran. 1980. Statistical methods, 7th ed. Iowa State Univ., Ames, Iowa.
8. Neter, J. and W. Wasserman. 1974. Applied linear statistical models. Irwin, Homewood, Illinois.

9. Christensen, C. M. and H. K. Kaufmann. 1969. Grain storage, the role of fungi in quality loss. University of Minnesota Press, Minneapolis, Minnesota.

10. Christensen, C. M. 1982. Storage of cereal grains and their products. Amer. Assoc. Cereal Chem., St. Paul, Minnesota.

11. Chang, I-Pin and T. Kommedahl. 1972. Interaction among microorganisms occurring naturally and applied to pericarps of corn kernels. Plant and Disease Reporter 56:861–863.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 140–142

NOTES

Bat Notes from Eastern Kentucky—A fall mist-netting investigation in eastern Kentucky produced the following noteworthy results. Monofilament mist-nets were set at 2 sites over the Poor Fork of the Cumberland River: 1 in Harlan County 1.5 km north of Cumberland, the other site approximately 8 km upstream from the first in Letcher County. A set of 3 or 4 nets was placed at each station for 2 nights (14 and 15 October, 1987), and tended until midnight when temperatures dropped to about 4°C.

The 2 stations in 2 nights yielded 60 bats of 5 species. The majority of red bats, *Lasiurus borealis*, captured (29 of 31) were males, but 6 others escaped before their gender was identified. All bats were marked by placing a small nail-polish spot on a wing, but only 1 red bat was captured twice.

We also captured 20 silver-haired bats, *Lasionycteris noctivagans*; the sexes were equally represented. Unlike the ubiquitous red bat, the silver-haired bat is an uncommon species in Kentucky. One of us (H.D.B.) had previously collected over 200 bats, using mist-nets set over Commonwealth streams in summer, but had never collected a silver-haired bat until this study. Two previous nights of mist-netting in July 1987 at these same 2 sites on the Cumberland River did not disclose silver-haired bats. It is likely that the species was in migration from its northern breeding grounds to its winter range. We have found a few specimens hibernating in limestone caves in eastern Kentucky. Winter surveys by JRM recorded the species from caves in Carter, Jackson, Lee, Pulaski and Rockcastle counties, usually only a few individuals from crevices or found hanging in the cold areas of the caves.

Although there is evidence of sexual segregation during summer (Barbour and Davis, *Bats of America*, Univ. of Kentucky Press, 1969), the sexes apparently sometimes migrate together. At our upstream station on the second night of netting, we caught 15 silver-haired bats (8 females and 7 males). Multiple captures of 2 or 3 silver-haired bats occurred several times and both sexes were usually represented.

A single specimen of the federally endangered gray bat, *Myotis grisescens*, was also captured at the downstream site in Harlan County. This young male was taken in a net set at water level. This is only the third record of this species in eastern Kentucky and the first collected foraging over a stream. The other 2 were recorded in caves in Carter and Lee (Davis, Bat Res. News, V 10:29–30, 1969) counties almost 2 decades previously. Since *M. grisescens* uses caves in both summer and winter, this animal was probably enroute to its winter hibernaculum. The only gray bat hibernaculum known in Kentucky is in Edmonson County about 300 km west of our sites. However, several smaller colonies of gray bats are known to hibernate in abandoned mines and caves in eastern Tennessee (Currie, USFWS, pers. comm., 1987). There is a possibility that gray bat hibernacula remain undiscovered in caves of the Newman Limestone on Pine Mountain.

The other 2 species captured during the October netting study were the big brown bat, *Eptesicus fuscus*, and the little brown bat, *Myotis lucifugus*. Each species was represented by 2 males.

We increased our number of captures from 14 to 28 on the second night at the Letcher County station by moving several hundred meters upstream. Our nets at the Harlan County station, which remained at the same site both nights, caught only half as many bats the second night.

We appreciate the help of J. A. Roscher, R. M. Morris and W. D. Hendricks, who assisted with the difficult task of mist-netting on these cold evenings.—**Hal D. Bryan**, Division of Environmental Analysis, Kentucky Transportation Cabinet, 419 Ann Street, Frankfort, Kentucky 40622, and **John R. MacGregor**, Kentucky Department of Fish and Wildlife Resources, Nongame Wildlife Program, Frankfort, Kentucky 40601.

Alligatorweed, *Alternanthera philoxeroides* (Mart.) Griseb. in Kentucky—Alligatorweed (Amaranthaceae), a native flowering plant of eastern South America, was first reported in the southeastern United States from Florida in 1894 (Robertson, J. Arnold Arb. 62:267–313, 1981). Spreading rapidly over much of the southern Atlantic and Gulf Coastal plains, it has become a serious pest in many southern waterways from South Carolina to Texas (Mears, Proc. Acad. Nat. Sci. Phil. 129:1–21, 1977; Spencer and Coulson, Aquatic Bot. 2:177–190, 1976). Infestations have also been reported from Virginia, North Carolina, Tennessee, Arkansas, and California (Weldon, USDA–ARS, Crop Res. Div. Ser. 33–60, 41 pp., 1960). This note reports the species from the Tennessee River shoreline in western Kentucky and indicates its weedy potential there.

Alligatorweed is a perennial, aquatic herb with erect or prostrate stems and hollow, buoyant internodes (Fig. 1). It is primarily a floating plant but may be completely terrestrial in moist soil or rooted along watercourse margins with branches extending outward for 15 m or more on the water surface and for up to 1 m downward into the water; roots develop at most nodes and lateral shoots from many, resulting in extensive mats. The flowering head is a globose spike of 10–20 white flowers but viable seeds are rarely, if ever, produced in the United States. Instead, reproduction is vegetative, by fragmentation, and each node is capable of producing a new plant.

Classed as a weed because of its competitive advantage over native plants, few species can compete successfully with it. Also, it is extremely difficult to control due to high tolerance to herbicides and great reproductive capacity. Even mechanical destruction, without removal, results in proliferation; however, biological (insect) control is proving effective (Reimer, Introduction to Freshwater Vegetation, AVI Publ. Co., Westport, Conn., 1984).

The presence of Alligatorweed in most waterways is undesirable for a number of reasons. Mats impede water

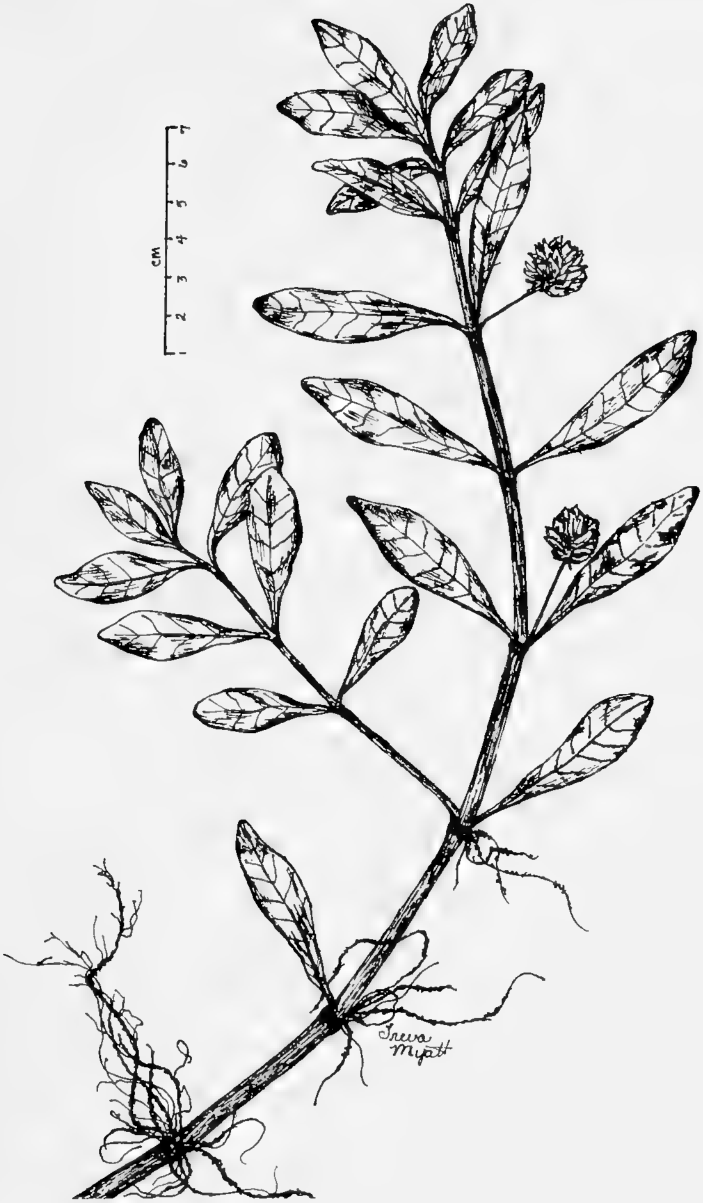


FIG. 1. Portion of an Alligatorweed plant, drawn by Treva Myatt from Chester 87-704, collected 25 August 1987, Trigg County, Kentucky (APSC).

movements, restrict traffic on navigable waterways, and hinder fishing and recreation. Also, they block drainage and irrigation channels, thus increasing the threat of flooding, and cause public health problems by increasing mosquito breeding areas and water pollution from decomposition. Alligatorweed is one of several aquatic pests in Tennessee River impoundments of northern Alabama, and that waterway has provided a migratory route northward. Wofford, Webb, and Dennis (Castanea 42:190–193) first reported the alligator weed from the lower Tennessee River drainage (Henry Co., Tennessee) in 1977 and herbarium specimens at APSC, TENN, and VDB, representing later collections, now voucher its presence from several sites and counties there.

The only mention of the species in Kentucky botanical literature is that of Beal and Thieret in their recent account of Kentucky wetland plants (Kentucky Nat. Pres. Comm., Sci. and Techn. Ser. 5, 1986). They reported a persisting stand in a Knox County (southeastern Ky.) ditch. However, I have found it to be well-established at several points along the eastern shoreline of Kentucky Lake, the most downstream impoundment of the Tennessee River, in Lyon and Trigg counties, mostly in shallow water or on mud along bays and inlets or in small, shoreline ponds resulting from wave-created dams.

Since Ellis, Wofford, and Chester did not include it in their list of area plants (Castanea 36:229–246, 1971), movement into western Kentucky may be recent. Extensive flooding of the lower Tennessee River basin during the spring of 1984 may well have accounted for this immigration. At this point, populations are not extensive enough to pose threats to lower Kentucky Lake water quality; however, based on the weedy nature of the species along the Tennessee River southward, alligatorweed is a potentially troublesome species for western Kentucky waterways. Voucher specimens for my collections are in the Austin Peay Herbarium (APSC).—**Edward W. Chester**, Austin Peay State University, Clarksville, Tennessee 37044.

CORRECTION

In the paper by Winstead and Strange, Vol. 49 (1–2), 1988, 29–31 the following corrections should be noted:

page 30, in Table 1, **Difference between control and test significant at 0.01 level

page 30, in Results, the last sentence of the first paragraph should read: Statistical analysis (Student's *t*-test) showed all the reduction highly significant at the 0.01 level.

The error was my fault and I appreciate your help in making the correction.—Joe E. Winstead.

ABSTRACT

Effects of Mg^{2+} and EDTA on microsomal UDP-glucuronosyltransferase activity. R. F. VOLP and CHARLES DIETSCH*, Chemistry Dept., Murray State University, Murray, KY 42071. The effects of UDP-glucuronic acid (UDPGA), EDTA, and Mg^{2+} concentrations on UDP-glucuronosyltransferase activity were studied in vitro. Incubations of rat liver microsomes with 0.5 mM 4-methylumbelliferone were conducted at 37°C for various times and stopped with 0.5 M $HClO_4$. The mixtures were centrifuged and the supernatant analyzed by high performance liquid chromatography (cyano column). The area of the 4-methylumbelliferyl glucuronide (MUG) peak was an index of enzyme activity. Rate of MUG production depended on UDPGA concentration (0.1–3.0 mM). Mg^{2+} (0–20 mM) and EDTA (0–10 mM) both affected the reaction rate. MUG production was highest at 5–10 mM Mg^{2+} and 1.0 mM EDTA. These results define incubation conditions for further studies of the Mg^{2+} dependence of the enzyme.

NEWS AND COMMENTS

New Section of Journal—At a recent meeting, the Governing Board voted approval for the establishment of a new section of the *Transactions.* This section, titled FORUM, will present scientifically oriented essays that are not the result of primary research but which are, instead, the result of synthesis, a position taken by a writer on some important scientific issue, or, perhaps, a private relationship between the writer and his/her science. One of these essays (when available) will be published per issue (after review by the Publications Committee) and will normally run between 5,000 and 6,000 words.

Regional Science Fair Winners—

KAS AWARDS
NOVEMBER 1987
Western Kentucky University, Bowling Green, Kentucky

Student Winner	**Sponsor/Teacher**
Northeast Kentucky Regional Science Fair Ron Fiel, (606) 783-2140 Morehead State University	
Suellen Hugen 1110 Park Drive Park Hills, KY 41011 (606) 291-4158	Sr. Mary Ethel Parrott Notre Dame Academy Hilton Drive Covington, KY 41011 (606) 261-4300
Southeast Regional Science Fair Blaine Early, (606) 549-2200 Biology, Cumberland College	
Mr. Clifton Johnston Laurel County High School 1705 S. Main St. London, KY 40741	Ms. Lawana Scoville Laurel County High School 1705 S. Main St. London, KY 40741
MSU Regional Science Fair Nick Gritt, (502) 762-2311 Math, Murray State University	
Ms. Darlene Keahey P.O. Box 749 Cadiz, KY 42211 Highway #68	Carol Alexander Trigg County High School P.O. Box 501-A Highway #68 Cadiz, KY 42211 (606) 522-6072
Louisville Regional Science Fair, Inc. Curtis H. Hannum 2013 Lauderdale Rd Louisville, KY 40205	
Ms. Rebecca Katherine Kelley Rte. 5, Box 326 Bardstown, KY 40004 (505) 348-4416	Miss Cari (Wilson) Small (Miss Williams' parents) 4 Chavalier Court Elizabethtown, KY 42701 (502) 765-2817

Southern Kentucky Regional Science Fair
Gail Miller, Director
(Warren Central High School)
559 Morgantown Rd
Bowling Green, KY 42101
(502) 842-7302

Elizabeth "Libby" Haines
Russelville High School
Russelville, KY
(502) 746-8421

Steve Meridith
Russelville High School
Russelville, KY
(512) 746-8421

Announcement of Kentucky EPSCoR 1988 Regional Universities Visiting Scholars—The review of proposals submitted for the 1988 Regional Universities Visiting Scholars Program is now complete. Of the 15 proposals submitted, eight awards have been offered and accepted:

—Dr. Karen R. H. Hackney and Dr. Richard L. Hackney, Physics and Astronomy, Western Kentucky University, "UBV Photometry of Very Young Stellar Objects Identified from the IRAS Survey" and "Spatially-Resolved CCD Photometry of Reflection Nebulae Accompanying Very Young Embedded Stars," $9,741. Host Faculty: Dr. Frank O. Clark, Physics and Astronomy, UK.

—Dr. Tom Morgan Hughes, Computer Science, Kentucky State University, "Application of Artificial Intelligence to Underground Mine Ventilation Management," $10,427. Host Faculty: Dr. Andrzej M. Wala, Mining Engineering, UK.

—Dr. Donald L. Jackson, Physics and Astronomy, Murray State University, "Resistance Changes in Necturus Antrum Due to Changes in Tonicity," $10,373. Host Faculty: Dr. Gasper Carrasquer, Medicine, U of L.

—Dr. Robin Kimmerer, Biology, Centre College, "Gynecological Differentiation in Reproductive Strategy of the Bryophyte *Tetraphis Pellucida*," $10,073. Host Faculty: Dr. David Wagner, Forestry, UK.

—Dr. James Ora Manning, Mathematical Sciences, Cumberland College, "Determination of Atmospheric Aerosol Properties," $9,128. Host Faculty: Dr. Frank O. Clark, Physics and Astronomy, UK.

—Dr. David L. McNeely, Biological and Environmental Science, Morehead State University, "The Effect of Predation by Smallmouth Bass on Shelter Use by Mottled Sculpins and Crayfish," $8,915. Host Faculty: Dr. Andrew Sih, School of Biological Sciences, UK.

—Dr. Clifford B. Sowell, Economics and Business, Berea College, "A Cost of Adjustment Model of Excess Reserve Accumulation," $9,324. Host Faculty: Dr. Frank Scott, Economics, UK.

—Dr. Brent C. White, Psychobiology, Centre College, "Urinary Cortisol Assessment and Social Behavior in Captive Woolly Monkeys," $10,421. Host Faculty: Dr. Joseph M. Steffen, Biology, U of L.

We look forward to working with this group of investigators during the coming summer and we are confident that the Kentucky EPSCoR Regional Visiting Scholars Program will continue to be a success.

Southeast Raptor Management Symposium—The meeting will be held in Blacksburg, Virginia, 14–16 September 1988. The Department of Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University is hosting this symposium. Proceedings of the symposium will be published as part of the Federation's Scientific and Technical Series.

For more information, contact the National Wildlife Federation, Institute for Wildlife Research, 1400 Sixteenth St., N.W., Washington, D.C. 20036-2266 or call (703) 790-4268.

Important Publication—White, K. D., J. L. Smoot, J. K. Jackson and A. F. Choquette. 1987. Surface water-quality assessment of the Kentucky River Basin, Kentucky: project description. U.S. Geol. Surv. Open-File Rept. 87-234: 39 pages.

Resignations from the Governing Board.—Two of our fine officers have recently resigned their positions because of excellent professional opportunities outside Kentucky. One of these is Dr. David E. Legg (Governing Board), and the other is Dr. Virginia Eaton (Secretary). We shall miss both of these fine professionals.

Editor Appointed Foundation Professor—Your editor was informed of this honor by President Hanley Funderburk, Eastern Kentucky University, in May 1988.

Trans. Ky. Acad. Sci., 49(3–4), 1988, 145–150

PRESIDENTIAL ADDRESS

WILLIAM HETTINGER

Dr. William Hettinger
1988, President, KAS

As has been pointed out by our Presidents over the years, it is customary for the incoming President to address the members in this first or spring newsletter of the Academy. Somehow this conjures up images of spring rites, flowers, new green grass and such other pleasant thoughts associated with springtime. However, as I sit here in my office on a cold, blustery, gray winter's day in January, with the temperature approaching 0 degrees Fahrenheit, I must confess, I have difficulty getting into the spirit of such thoughts. Only the pervading thought that perhaps I might somehow slip down to Florida for a few days in late February, helps me get into the proper frame of mind for this letter.

As is also customary for the President, this letter enables me to comment on the accomplishments of the Academy over the past year, the highlights of the annual meeting, to express appreciation for all of the many accomplishments and contributions of so many dedicated people, and especially your past President, Larry Giesmann, officers and board members of the Academy, and Joe Winstead and Charles Kupchella and co-workers who arranged for and provided such a fine outing for our annual meeting.

It also gives the incoming President the opportunity to set some new goals and objectives for the coming year.

The Academy continues to grow and prosper under the energetic leadership of a continuing string of most capable Presidents, stretching back, at least, as far as my memory serves me, over the almost eleven years of my residence in Kentucky, and membership in the Academy. These Presidents, without exception have been outstanding, and the growth in membership, the activities of the Academy, and its present financial status, all are testimony to their contributions.

Before I review the progress and accomplishments of the Academy for the past year, and the contribution of so many, however, I'd like to reflect a bit on the various goals, objctives and purposes of the Academy as they have been expressed over the years, as they are expressed today in these more recent accomplishments, and as they impact on my goals for the coming year, and those longer range goals which others coming after us will form and seek to achieve.

The Academy means many things to each of us, and undoubtedly each of these things may be more important to one individual member, and less to another, or be different, one from another.

The objectives and purpose of the Academy, as set forth in our Constitution in early discussions at the onset of the Academy, and even in our latest brochure, is as follows, and I quote: "The objectives of the Kentucky Academy of Science are to encourage scientific research, to promote the diffusion of scientific knowledge, and to unify the scientific interests of the Commonwealth of Kentucky. Note that scientific interests can be interpreted to encompass not only academic interests, but industrial and governmental interests as well.

The Kentucky Academy of Science appears to serve its members and the citizens of Kentucky through activities in harmony with its objectives. Specifically, its aims are: (1) to achieve effective and stimulating communication among all scientists within a discipline and between disciplines in the Commonwealth, (2) to provide a forum for the presentation and publication of scientific work, and which work may also be of specific significance to the Commonwealth, (3) to foster the interaction of science with other sectors in seeking solutions to major social, economic and environmental problems, (4) to interest the youth of the Commonwealth in science, to encourage them to consider science as a profession and hopefully to practice that profession within the Commonwealth, (5) to provide advisory assistance to the Commonwealth, as well as to local governments, in areas of science and technology.

The Academy certainly intends to recognize, encourage, honor and inspire scholarship, intellectual excellence and stimulating research in the pursuit and understanding of nature, and all of its ramifications. It also serves and seeks to encourage interaction of its members with their peers, in stimulating discussion, exchange of information and reporting of scientific information acquired by diligence, hard work, curiosity and dedicated research inquiry. This is accomplished in many ways, and including fellowship in the Academy and the establishment of close interaction with one's associates dedicated to the same area of inquiry. Hopefully, the Academy can also convey the spirit of adventure, the excitement of pioneering discovery, the stepping off into the unknown, all of which are associated with stimulating research, and professional involvement.

Fortunately, in an Academy such as ours, there is also great opportunity to become exposed and acquainted with other areas of interest and to gain a broader perspective and interaction with the world of science and technology. This is also how the Academy functions and can inspire. In this way, the Academy seeks to also encourage interaction of geologists with psychologists, biologists with physicists, botanists with chemists, anthropologists with mathematicians and combinations and permutations thereof.

Generally speaking, only in an Academy of Science, and in the smaller state organization, is such association and interaction possible, and we are all proud of this. For example, have you ever taken the time at an Academy annual meeting, to change your diet, so to speak, and attend some papers in an all together different field? This fall, I decided to do so. Not only did I attend some excellent papers in chemistry and the symposium on coal liquefaction, but I decided to also try to attend some others outside of my field. I had a perfectly delightful and scientifically stimulating time listening to several papers on anthropology, psychology, geology and biology. It seemed to me unfortunate that there was so little time to do this, but what time I did spend, was most stimulating, scientifically speaking, and I truly thirsted for more. I couldn't help but wish the annual meeting would last at least another day, so that I could do more of this.

The Academy also provides an opportunity to listen to speakers of national recognition, and by holding our meetings at a different university or college each year, it enables each of us to become better acquainted with the many excellent educational and research facilities of the state, and the professionals associated therewith. Industrial site visits are also possible, and enable the academic scientist to become acquainted with the world of industrial science and the industrial scientist, upon which so much economic progress depends. I still receive favorable comments on the meeting held at Ashland in 1982, when for the first time, many academic scientists had an opportunity to learn and observe how their industrial counterparts live. Perhaps we can do it again some time, or find another industrial site for a similar meeting.

The Academy has also clearly sensed the importance of recognizing the role of industrial science and technology in the Commonwealth and, therefore, the importance of encouraging participation by industry and industrial scientists. This is manifested in the encouragement I have received in becoming active in the Kentucky Academy, the visit to an industrial site for one of our annual meetings, and the continuing efforts in recent years by our presidents to introduce the industrial affiliate membership concept. Here again, we witness the Academy growing in stature and broadening its base and interests.

The Academy and the Junior Academy also stand for ecxellence in education, and here is another role and function of the Academy to encourage and provide leadership in the state in seeking, obtaining and maintaining excellence in advanced scientific education and research in our high schools, colleges and universities.

There is a tremendous role opportunity for the Junior Academy in promoting science in the state. Today we have 16 senior or junior high schools participating in the Junior Academy program, and another 68 have been active at one time or another. However, this is but a small fraction of 284 senior highs, 31 junior highs, and 118 non-public high schools in the state that could participate, and here is where our increased support of Pat Stewart and his committee could have great impact. Pat, and Herb Leopold before him, have had outstanding accomplishments with a minimum of resources and assistance. What an exciting opportunity exists here, if we can intensify their efforts by one means or another.

Herb is also drafting a plan and proposal for a Collegiate Academy, and informed me that he hopes to have it ready for presentation to the board sometime later in the spring, hopefully, before the April 29th board meeting.

Over the past recent years, the Academy has also begun to direct its attention to the welfare and health of science and science education, especially at the graduate level in Kentucky, both as they relate to education, and as they also relate to enhancing the social, economic and cultural welfare of the state by means of science and technology. This interest led our Academy to greater interaction at the top level of government in such activities as the Kentucky Tomorrow program and later the EPSCoR program. The EPSCoR program not only seeks to stimulate and enhance scientific effort at the level of graduate university research, but to a degree, has sought to tie elements of this basic research program to long-term implications for potential industrial spin off as well. Dr. Charles Kupchella has reviewed the history of the EPSCoR program in the 1986 spring newsletter.

By leadership from the Academy, including Kupchella, Boggess, Rodriguez, and Winstead, to name a few, a balanced ad hoc committee of governmental, academic and industrial representatives fashioned a program for the NSF EPSCoR challenge, with an eye to government support of sound and exciting basic academic research, but with at least a long-range, potential implication for industrial enhancement as well. Dr. Charles Kupchella has so eloquently reviewed the plight of science and technology in Kentucky on pages 59–62 of the Transactions, March 1986 (vol. 47), and the need for an effort such as the EPSCoR program to give the scientific community a much needed stimulus.

So we see an Academy gradually flexing its strength and injecting leadership into the mainstream of social and technical leadership in the Comonwealth. To a degree, this is a relatively new role for the Academy.

In the recent past, there has also been expressed the view that the Academy is made up, overwhelmingly, of biological scientists, although a review of the presidents of the past ten years tends to contradict that concern. Four of the last ten Presidents, myself included, have been from sections in the physical, mathematical and computer science division. Certainly the biological sciences are to be congratulated for their efforts to enhance and strengthen the growth of the Academy, but with the new constitution's emphasis on scientific balance, a new dedication to increase participation by members of the physical, mathematics and computer science division, and social sciences and science education division, should bring about an even stronger Academy.

With these comments as background, I'd like to now comment on some of the goals I outlined for this coming year and why I believe they are important and in harmony with the trends and direction in which the Academy appears to be heading.

(1) Greater Visibility for the Academy

To further assure that our voice may be heard at the level of government and industry as it relates to support of University Research, we need to achieve greater visibility. It is still surprising to me to note how little is known about the Academy by even those who might be expected to know.

In the past, for those dedicated to enhancing the role of science and technology in the state, there has generally been the belief and conviction that if the level of scientific activity and quality could be lifted, that economic development and growth would surely follow. It was and is believed that improved educational programs, both at the lower levels of education and at the college, university and graduate school levels, would result in producing a more highly trained and educated work force, making Kentucky more attractive to business and industry, and hopefully, high technology.

More recently, although it is still considered high priority to promote both education and economic development, the emphasis appears to be shifting, and to perceive that these objectives can better be achieved by stressing economic development, which in turn will generate funds by which to enhance education.

The problem is not unlike one that is so frequently also observed in industrial America. Corporations seeking to accelerate or assure growth have frequently introduced the so-called "corporate" research laboratory for the avowed purpose of generating new and more innovative products, no longer forthcoming from the "quick fix" approach found at the divisional level. Frequently, however, they have created this function without providing for a commercial development arm by which to exploit these developments.

Other firms have created the so-called "commercial development" department, in a technically based company, without providing for strong technical support. In either situation, the effort is usually doomed, unless both are created simultaneously, and further, that top management provides strong leadership and support over a long period of effort, preferably over several consecutive administrations.

So too in government, if a state is to grow and prosper in modern America, especially in the face of stiff competition from other states and nations, and long head starts of surrounding states, then strong economic and development leadership must be harnessed closely with outstanding scientific leadership, and with full support and encouragement of government, if it is to succeed in achieving some industrial impact. Playing "catch up" requires even greater effort than that required for just keeping even.

This seems to be the sum and substance of the situation in Kentucky, how to harness outstanding academic performance with economic development and government encouragement, so that they are all pulling together, and it is gratifying to note the zeal with which the Academy has sought to support such a troika concept of close interaction of government, industry and economic development, and academia over the past 15 years or so. Sometimes we have appeared to slide backward, only to pick ourselves up and again move forward. But the steadying gradual progress of the Academy in this endeavor is evident to any who would care to study it, and the EPSCoR program is the first symbolic small victory in this effort.

It is for this reason that many of us have concluded that if we are to make the next leap forward and make an even greater contribution, it is required that we achieve greater visibility in the community.

To my mind, to achieve greater visibility, and to assert our avowed role, we need a home, one that implies stability, strength and to a certain extent, power. Today the Academy is even hard to find, let alone be recognized. We are like a homeless waif. The records of the President, from one President to the next, can, and are often transferred in a cardboard box.

Several years ago, I reviewed information on the 44 academies that form the National Association of Academies of Science. Twenty-seven had a permanent address, most could be reached easily by phone or letter, and 21 had a permanent executive secretary, and/or executive-director. We have discussed the need for such a home for some time. Now is the time to act. To achieve such a goal requires financial support and a good location. By means of an increase in membership (target 1,000 members), and academic and industrial affiliate memberships, and a review of our projected income and budget for 1988, it is now possible to foresee that such a goal is attainable, and I and your officers will be giving this goal our attention this year.

We also are working hard on public relations. J. G. (Rod) Rodriguez, a former President of the Academy, has graciously and generously volunteered his services as executive secretary of the Academy, and the board has approved my nomination of him to that post. As you know, among many other improvements, the new constitution defines and creates the office of executive secretary, subject to appointment by the president, and approval by the board. Among his other responsibilities as executive secretary, the constitution appoints him Chair of Public Relations, and Rod will, therefore, also be working energetically on this assignment this year to improve our public image and relations. We badly need more and better press coverage, especially for the annual meeting.

The Academy has also sought to get the speakers bureau going to assist in bringing recognition to the Academy. However, to date it is stalled out, and needs rejuvenation. Can it be that no one has asked us to speak about the Academy? Again, we need a means to let the public know that we are here, and would like to talk about our efforts and interests.

Finally, with regard to this goal, I am pleased to inform you that one small step in our progress toward reaching the goal of a permanent site for the Academy has already been taken. The Academy, with the cooperation of the EPSCoR office, does now have a post office box address (P.O. Box 22313), a zip code (Lexington 40522), and a telephone number (606-257-4902). So you see, small but finite progress is being made.

(2) Broader Participation in the Transactions

In my discussions with both academic and industrial scientists, there has been skepticism expressed as it relates to the small number and quality of papers published in the Transactions, but even more importantly, the narrowness of coverage. This year we will seek your help to encourage greater participation by the physical science, mathematics and computer sciences division and the social science and science education division, not only at the annual meeting where it is already very good, but more importantly, in publishing in the Transactions. We need much better participation in order to achieve a balanced publication. Your President-elect, Mr. Richard Hannan, in his assignment as program chair, plans to encourage greater emphasis on publications by the secretary and chair of each section so as to help us encourage publication in the Transactions. Branley Branson and members of the editorial committee are also committed to seeking and encouraging broader publication participation in the Transactions.

(3) Greater Interaction with Industrial and Governmental Scientists

For the many reasons already discussed and for many other reasons which could be mentioned, I have also set as a goal to at least double the number of industrial and governmental scientist members, and to increase the number of industrial affiliates. There is a great disparity in the number of industrial and governmental scientists relative to academic scientist members, and this problem reflects either a disinterest or reluctance on the part of industrial scientists to become active, or more appropriately, and significantly, it bespeaks of the low level of industrial research in the Commonwealth, relative to other more technically successful states. Here we have again a reminder of our problem. Except for a few islands of excellence, we do not have a strong, high technology industrial sector, compared with surrounding states. As we seek to enlist industrial affiliates in this effort, perhaps this too will help enhance our upward struggle to enhance the welfare and economy of the state.

(4) Introducing the New Constitution

A final objective, as mentioned in my short acceptance speech last November, had to do with my concerns for implementing the new constitution. But this concern appears unfounded. The new Executive Committee and Governing Board met for our first business meeting of the year on January 23, and appears to be off to a great start. Everyone, and including committee chairs, have dug in with great enthusiasm, and give promise of leading the Academy to another great year.

Having said all of that, I would like to return to a review of progress and accomplishments over the past year and acknowledgment of all of those who were so intimately involved.

Our outgoing President, Larry Giesmann, is to be highly complimented for the many accomplishments of last year. His theme for the year, "Service to and Through the Academy", was most successful.

His goal to achieve approval for a revised constitution, which constitutional revision was undertaken by an ad hoc committee chaired by former Academy President, J. G. (Rod) Rodriguez, and including two other former Presidents, Ted George and Gary Boggess as committee members, was most successful, and is now in place. It is a significant improvement over the old constitution and provides the Academy with a document which the officers, governing board, and members can understand and follow. It also provides for a more understandable election procedure, and better distribution of scientific disciplines on the governing board. This achievement of a new constitution was a a most significant accomplishment of the ad hoc committee and of the many past presidents, as well as those who proposed and supported this effort.

A second most useful achievement of Larry's administration was the initiation and development of a membership database which provides the Academy with much needed information in a host of areas, including a member's areas of expertise, educational background and interest, interest in committee activities and much other valuable information for ready retrieval. This system is now up and operating, most of it due to personal effort on Larry's part. His wife confided to me the many nights when she looked for him at three in the morning, she found him intensely involved in incorporating this information into his computer. This database promises to become one of our most valuable assets.

Other activities and accomplishments of last year included a study to streamline accounting procedures by Paul Freytag, Alan Reed and Manuel Schwartz, and the formation of a committee to improve long-range planning for our annual meetings lead by Debra Pearce and assisted by Frank Howard, Gerrit Kloek and Joe Winstead. The handbook prepared by this committee should be most valuable for planning and hosting our annual meeting.

Membership again increased last year due to the efforts of Doug Dahlman and his committee. As of January 15 of this year, there were 573 members paid through 1987–88, 50 life members and 24 emeritus members, for a total of 647. There were an additional 179 members in arrears for two years or more, but very likely many of these will catch up on their dues this year. If half return, this could bring us to 736 by mid year. I have set as a challenge, membership goal of 1,000 for 1989, our 75th year.

The number of university affiliates remained steady at an impressive level of eight universities and fourteen colleges. Industrial affiliates have now risen from three to five and are targeted for additional increases. They represent a great long-range potential for increasing funding and support. Income from both of these sources continues to grow and represents a key base for financial soundness of the Academy.

Under the guidance of Branley Branson, Editor, and the Editorial Committee, our printing problems were finally resolved, and the Transactions are now also back on schedule and look very nice.

Overall, as noted in the treasurer's report presented at the Academy business meeting, the Academy has begun to achieve a sound financial position, and can begin to look forward to using this asset to further accelerate the activities and accomplish the goals set forth in our constitution. Because of this, the next few years show promise for exciting and significant contributions by the Academy to the scientific, educational and industrial climate in and for the Commonwealth.

Perhaps this letter could go on describing other progress during the year, and because so many people should and could be recognized for their many contributions. But because of space limitations, I'd like to express my thanks to all of you, both the named and the unnamed, the thanks and gratitude of your past President, Larry Giesmann, the entire executive committee and the governing board for all you have done.

In closing, I would also like to express my thanks to all of the individuals who have agreed to chair and/or serve in the coming year on the many committees and ad hoc committees defined and described by the new constitution. Your willingness to serve was most gratifying to me, and I am most grateful for it. I trust that in the days ahead, with your help and with the help, guidance and wisdom of the governing board and officers of the Academy, that we will not only keep this momentum going, but accelerate to even greater accomplishments. There is much to be done in the state and I am excited as to the ability of your Academy to make things happen.

My theme for the coming year is "Enhancing Academy of Science Recognition in the Commonwealth." I want you to know that I am very grateful for the honor bestowed upon me, and proud to be serving as your President. With your help and support, I look forward to another exciting and rewarding year, with a continuing escalation of accomplishments. Please plan to attend the annual meeting, November 4 and 5, at Eastern Kentucky University, Richmond, Kentucky, and please be thinking and planning for that big 75th annual meeting at the University of Kentucky in 1989.

Have a good spring and summer and see you at Eastern in the fall!

Trans. Ky. Acad. Sci., 49(3–4), 1988, 151–159

ACADEMY AFFAIRS

President Hettinger takes this opportunity to thank all the individuals listed below for unstintingly accepting the committee assignments. He especially thanks those individuals for shouldering chairperson responsibilities.

KENTUCKY ACADEMY OF SCIENCE
GOVERNING BOARD AND COMMITTEES—1988
DIRECTORY

GOVERNING BOARD

EXECUTIVE COMMITTEE

President
William P. Hettinger, Jr.
Ashland Petroleum Company
P.O. Box 391
Ashland, KY 41114
(606) 329-4650

President-Elect
Richard R. Hannan
Ky. Nature Preserves Commission
Rt. 4, Bald Knob Rd.
Frankfort, KY 40601
(502) 564-2886

Vice President
Debra K. Pearce
Dept. of Biological Science
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5362

Past President
Larry A. Giesmann
Dept. of Biological Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5110 or 572-5304

Treasurer
Paul H. Freytag
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-7452

Secretary
Varley E. Wiedeman
Dept. of Biology
University of Louisville
Louisville, KY 40292
502-588-5943

Editor—Ex Officio
Branley A. Branson
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1537

Executive Secretary—Ex Officio
J. G. Rodriguez
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4902

GOVERNING BOARD

William F. Beasley, Jr. (1988)
Dept. of Biology
Paducah Community College
Paducah, KY 42002
(502) 442-6131

William S. Bryant (1988)
Dept. of Biology
Thomas More College
Ft. Mitchell, KY 41017
(606) 341-5800

Douglas L. Dahlman (1989)
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4962

David E. Legg (1990)
Community Research Service
Kentucky State University
Frankfort, KY 40601
(502) 227-6582

Valgene L. Dunham (1991)
Dept. of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-3696

W. Blaine Early, III (1991)
Dept. of Biology
Cumberland College
Williamsburg, KY 40769
(606) 549-2200

Gordon K. Weddle (1989)
Dept. of Biology
Campbellsville College
Campbellsville, KY 42718
(502) 465-8158

Larry P. Elliott (1990)
Dept. of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6002

AAAS/NAAS Rep
William P. Hettinger, Jr.
Ashland Petroleum Company
P.O. Box 391
Ashland, KY 41114
(606) 329-4650

Director, KJAS
Warren Co. Board of Education
806 Kenton Street
Bowling Green, KY 42101
(502) 781-5150

MEMBERSHIP COMMITTEE

Chair
Douglas L. Dahlman
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4962

William R. Falls (1989)
Dept. of Physical Sciences
Morehead State University
Morehead, KY 40351
(606) 783-2913

Estel M. Hobbs (1990)
Ashland Petroleum Co.
P.O. Box 391
Ashland, KY 41114
(606) 329-5485

K. Grant Taylor (1990)
Dept. of Chemistry
University of Louisville
Louisville, KY 40292
(502) 588-6798

James Murray Walker (1988)
Dept. of Anthropology
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1648 or 622-1644

Richard R. Hannan (1991)
Ky. Nature Preserves Commission
Rt. 4, Bald Knob Rd.
Frankfort, KY 40601
(502) 564-2886

Burtron H. Davis (1991)
Ky. Energy Cabinet Lab
3572 Iron Works Pike
P.O. Box 13015
Lexington, KY 40512-3015
(606) 252-5535

COMMITTEE ON PUBLICATIONS

Editor and Chair
Branley A. Branson
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1537

Douglas L. Dahlman (1988)
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4962

Gerrit Kloek (1989)
Dept. of Biology
Kentucky State University
Frankfort, KY 40601
(502) 227-6066

Associate Editor
John T. Riley
Chemistry Dept.
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6020

Index Editor
Varley E. Wiedeman
Dept. of Biology
University of Louisville
(502) 588-5943

James E. O'Reilly (1990)
Dept. of Chemistry
University of Kentucky
Lexington, KY 40506
(606) 257-7077

Steven Falkenburg (1991)
Dept. of Psychology
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1105

Abstract Editor
John W. Thieret
Dept. of Biological Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-6390

President
William P. Hettinger, Jr.
Ashland Petroleum Company
P.O. Box 391
Ashland, KY 41114
(606) 329-4650

COMMITTEE ON LEGISLATION

Chair
Gary W. Boggess (1988)
College of Science
Murray State University
Murray, KY 42071
(502) 762-2886

Joe E. Winstead (1989)
Dept. of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6004

Charles E. Kupchella (1990)
Odgen College of Sci. & Tech.
Western Kentucky University
Bowling Green, KY 42101
(502) 745-4448

Leonard K. Peters (1991)
Graduate School Research Ofc.
University of Kentucky
105 Kinkaed Hall
Lexington, KY 40506-0057
(606) 257-8316

President
William P. Hettinger, Jr.
Ashland Petroleum Company
P.O. Box 391
Ashland, KY 41114
(606) 329-4650

President-Elect
Richard R. Hannan
Ky. Nature Preserves Com.
407 Broadway
Frankfort, KY 40601
(502) 564-2886

Past President Ex Officio
Larry A. Giesmann
Dept. of Biological Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5304 or 572-5110

PROGRAM COMMITTEE

Chair
President-elect
Richard R. Hannan
Rt. 4, Bald Knob Rd.
Frankfort, KY 40601
(502) 564-2886

Sectional Officers

ANTHROPOLOGY—A

John Hale, Chp.
Dept. of Anthropology
University of Louisville
Louisville, KY 40292
(502) 588-5555

James Murray Walker, Sec.
Dept. of Ant/Soc/Swk
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1648

BOTANY AND MICROBIOLOGY—B

James O. Luken, Chp.
Dept. of Biology
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5110

George P. Johnson, Sec.
Dept. of Biology
Lindsey Wilson College
Columbia, KY 42728
(502) 384-2126 Ext. 231

CHEMISTRY—C

Lowell Shank, Chp.
Dept. of Chemistry
Western Kentucky University
Bowling Green, KY 42101
(502) 745-4986

William D. Schulz, Sec.
Dept. of Chemistry
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1463

GEOGRAPHY—D

Wilma J. Walker, Chp.
Dept. of Geography
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1418

James L. Davis, Sec.
Dept. of Geography & Geology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-0111

GEOLOGY—E

Kenneth W. Kuehn, Chp.
Dept. of Geography & Geology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-3082

Charles T. Helfrich, Sec.
Dept. of Geology
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1277

PHYSICS—F

Raymond C. McNeil, Chp.
Dept. of Physical Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5100

Jack Wells, Sec.
Dept. of Physics
Thomas More College
Crestview Hills, KY 41017
(606) 344-3364

PHYSIOLOGY, BIOPHYSICS, BIOCHEMISTRY, AND PHARMACOLOGY—G

John J. Just, Chp.
Dept. of Biology
University of Kentucky
Lexington, KY 40506
(606) 257-8786

Ron Rosen, Sec.
Union College
Box 479
Barbourville, KY 40906
(606) 546-4151

SCIENCE EDUCATION—H

Curtis C. Wilkins, Chp.
Dept. of Chemistry
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6236

Michael N. Howard, Sec.
701 E. Main Street
Lexington, KY 40502
(606) 281-0100 Ext. 240

PSYCHOLOGY—I

Robert A. Adams, Chp.
Dept. of Psychology
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1105

Jack G. Thompson, Sec.
Dept. of Psychology
Centre College
Danville, KY 40422
(606) 236-5211

SOCIOLOGY—J

J. Allen Singleton, Chp. & Sec.
Political Science Dept.
Eastern Kentucky University
Richmond, KY 40475
(606) 622-2287

ZOOLOGY AND ENTOMOLOGY—K

Barbara A. Ramey, Chp.
Dept. of Biology
Eastern Kentucky Univ.
Richmond, KY 40475
(606) 622-1543

Robert Barney, Sec.
Plant & Soil Science
Comm. Research Service
Kentucky State Univ.
Frankfort, KY 40601
(502) 227-6000

COMPUTER SCIENCE—L

John H. Crenshaw, Chp.
Dept. of Computer Science
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6216

Richard Rink, Sec.
Dept. of Math, Stats, Com. Sci.
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1935

MATHEMATICS—M

Carroll G. Wells, Chp.
Dept. of Mathematics
Western Kentucky University
Bowling Green, KY 42101
(502) 745-0111, Ext. 6218

Russel M. Brengelman, Sec.
UPO 1222
Morehead State University
Morehead, KY 40351
(606) 783-2178

ENGINEERING—N

Dibakar Bhattacharyya, Chp.
Dept. of Chemical Engineering
University of Kentucky
Lexington, KY 40506
606-257-2794

Kimberly A. Ward, Sec.
Dept. of Chemical Engineering
University of Kentucky
Lexington, KY 40506
606-257-4956

COMMITTEE ON DISTRIBUTION OF RESEARCH FUNDS
KAS FOUNDATION BOTANY FUND
KAS FOUNDATION MARCIA ATHEY FUND

Chair
William S. Bryant (1988)
Dept. of Biology
Thomas More College
Ft. Mitchell, KY 41017
(606) 341-5800

Ralph L. Thompson (1988)
Dept. of Biology
Berea College
Berea, KY 40403
(606) 986-9341

William S. Davis (1988)
Dept. of Biology
University of Louisville
Louisville, KY 40292
(502) 588-5937

Paul H. Freytag (1989)
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-7452

William S. Wagner (1989)
Dept. of Physical Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5414

Ray K. Hammond (1990)
Division of Science
Centre College
Danville, KY 40422
(606) 236-5211

James O. Luken
Dept. of Biology
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5110

Mary Sue Coleman (1990)
Dept. of Biochemistry
University of Kentucky
Lexington, KY 40546-00840
(606) 233-5443

SCIENCE EDUCATION COMMITTEE

Chair
Ron Gardella (1988)
Dept. of Education
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5237 or 572-5229

Manuel Schwartz (1988)
Dept. of Physics
University of Louisville
Louisville, KY 40292
(502) 588-6787

Ted M. George (1989)
Dept. of Physics
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1521

W. Blaine Early, III (1989)
Dept. of Biology
Cumberland College
Williamsburg, KY 40769
(606) 549-2200, ext. 382

Jonathan Bushee (1990)
Dept. of Physical Science
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5405

James J. Dyar (1990)
Department of Biology
Bellarmine College
Louisville, KY 40205
(502) 452-8211

COMMITTEE ON AWARDS

Chair
Vice President
Debra K. Pearce
Dept. of Biological Science
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5362

Joseph P. "Pat" Stewart (1988)
Warren Co. Board of Education
806 Kenton Street
Bowling Green, KY 42101
(502) 781-5150

Douglas L. Dahlman (1990)
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4962

Valgene L. Dunham (1989)
Dept. of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-3696

COMMITTEE ON NOMINATIONS, ELECTIONS AND RESOLUTIONS

Chair (1988)
John C. Philley
College of Arts & Sciences
Radar Hall—212
Morehead State University
Morehead, KY 40351
(606) 783-2045

Manuel Schwartz (1989)
Dept. of Physics
University of Louisville
Louisville, KY 40292
(502) 588-6787

J. G. Rodriguez (1990)
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4902

AUDIT COMMITTEE

Chair (1988)
Alan W. Reed
East 80 Estates
Columbia, KY 42728
(502) 384-4555

Modesto del Castillo (1989)
Dept. of Science
Elizabethtown Comm. College
Elizabethtown, KY 42701
(502) 769-2371

Gordon K. Weddle (1990)
Dept. of Biology
Campbellsville College
Campbellsville, KY 42718
(502) 465-8158

FINANCE COMMITTEE

Chair
President
William P. Hettinger, Jr.
Ashland Petroleum Company
P.O. Box 391
Ashland, KY 41114
(606) 329-4650

President-Elect
Richard R. Hannan
Ky. Nature Preserves Commission
Rt. 4, Bald Knob Rd.
Frankfort, KY 40601
(502) 564-2886

Vice President
Debra K. Pearce
Dept. of Biological Science
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5362

Executive Secretary
J. G. Rodriguez
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4902

Treasurer
Paul H. Freytag
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-7452

PLANNING COMMITTEE

Chair
Debra K. Pearce (1988)
Dept. of Biological Sciences
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5362 or 572-5110

COMMITTEE ON PUBLIC RELATIONS

SEMI AD HOC COMMITTEE—JR. ACADEMY OF SCIENCE

AD HOC COMMITTEE ON RARE AND ENDANGERED SPECIES

Chair
John MacGregor
Ky. Fish and Wildlife Resources
Arnold L. Mitchell Building
#1 Game Farm Road
Frankfort, KY 40601
(502) 564-5448

Jerry M. Baskin
Dept. of Biological Sciences
University of Kentucky
Lexington, KY 40406-0225
(606) 257-8770

Donald L. Batch
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1818

Branley A. Branson
Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1537

Wayne H. Davis
Dept. of Biological Sciences
University of Kentucky
Lexington, KY 40506-0225
(606) 257-1828

Paul H. Freytag
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-7452

Richard R. Hannan
Ky. Nature Preserves Commission
407 Broadway
Frankfort, KY 40601
(502) 564-2886

Max Medley
1386 S. 3rd St.
Louisville, KY 40208
(502) 588-6771

Melvin Warren, Jr.
Dept. of Zoology
Southern Illinois University
Carbondale, IL 62901
(618) 536-2314

AD HOC COMMITTEE ON LONG RANGE ACADEMY SITE SELECTION AND IMPLEMENTATION COMMITTEE

Chair
Executive Secretary
J. G. Rodriguez
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4902

Joseph V. Swintosky
College of Pharmacy
University of Kentucky
Lexington, KY 40546-0091
(606) 257-1571

William P. Hettinger, Jr.
Ashland Petroleum Company
P.O. Box 391
Ashland, KY 41114
(606) 329-4650

Resource Members
Gary W. Boggess
Charles V. Covell, Jr.
Larry A. Giesmann
Charles E. Kupchella
Joe E. Winstead

Trans. Ky. Acad. Sci., 49(3–4), 1988, 160–164

INDEX TO VOLUME 49

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