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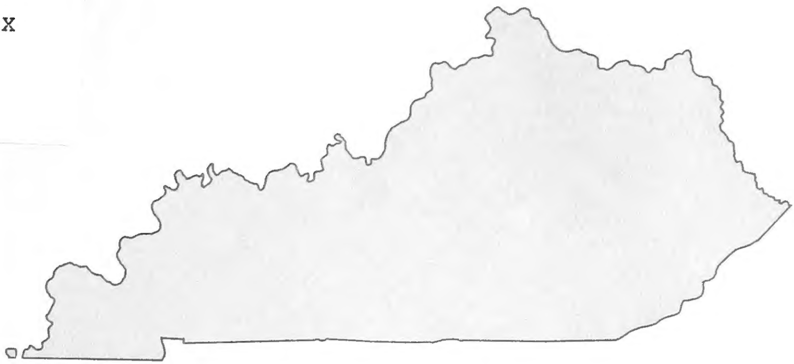

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Extended and Internal Commuting Change in the Intermetropolitan Periphery of Western Kentucky

ROBERT G. CROMLEY AND ROBERTA L. HAVEN

Department of Geography, University of Kentucky, Lexington, Kentucky 40506

ABSTRACT

One of the major development trends during recent times has been the economic and population growth of nonmetropolitan America. After years of decline, nonmetropolitan areas are experiencing unprecedented growth rates while major metropolitan areas are slowing down or losing population. The magnitude of this reversal of former trends has led several authors to speculate on the reasons and meaning of this turnaround for the changing urban system. A debate has ensued whether recent nonmetropolitan growth is merely the residual spread effects of metropolitan decentralization or if this growth represents a clean break with past urbanization processes. This paper examines the nature of these forces within the intermetropolitan periphery of western Kentucky, by comparing changes in the external and internal commuting fields of this region between 1960 and 1970.

INTRODUCTION

Although the population growth rate of nonmetropolitan areas during the 1970s has been impressive, the economic growth of these regions has been substantial since the early 1960s and can be explained within a regional development framework synthesizing elements of growth-center theory and the product-cycle model. Growth-center theory explains the spatial distribution of economic activity in terms of relationships between a growth center and its hinterland. Basic to the growth of a region is the capacity for attracting industries that produce goods for export to other regions. As foci for investment, growth centers first manifest polarization attracting the factors of production from peripheral areas and often accentuating spatial disparities in the economic development of a region (1). During the polarization stage, extended commuting is one mechanism by which a center extracts the labor pool it needs from the periphery. Holmes (2) suggested that extended commuting may in fact be a prelude to outmigration from rural areas to metropolitan areas and should continue to expand into nonmetro areas filling in the intermetropolitan periphery (3). However, because commuting is a spatial income redistribution mechanism, it has been proposed by Hansen (4) as a possible solution to the employment problems of economically depressed, rural areas. Thus, extended commuting also has the potential to transmit growth impulses back to the periphery through income multipliers.

Additionally, growth impulses are transmitted to nonmetro areas through the diffusion of mature industries from metropolitan centers. Between 1962 and 1978, 56 per cent of the total increase in

FIG. 1. The study area—the intermetropolitan periphery of western Kentucky.

U.S. manufacturing jobs were added to nonmetropolitan areas (5). The most frequent explanation for this shift has been the "filterdown" process or product-cycle model (6, 7). Large urban areas, with their external economies of scale, incubate new industry and enjoy the rapid growth associated with the early stages of an industry's life cycle. However, as the industry matures and the production process becomes standardized, increasing competition and high-wage rates in the metropolitan market may force the firm to relocate production in smaller settlements where cheaper labor can perform the simplified production process.

In time, as industries and retail activity relocate in the periphery, the need for extended commuting is reduced. In fact, extended commuting may accentuate the redistribution of economic activities to the hinterland by training the labor force in the necessary industrial skills. Thus, small centers within the periphery will emerge as foci for employment opportunities, manifesting polarization themselves, although at a lesser intensity than their larger metropolitan counterparts. The expansion of large urban commuting fields should slow down as internal commuting, commuting within the intermetropolitan periphery, becomes more important.

Any shifts occurring in the regional distribution of economic activity should be reflected in the extent and intensity of local commuting fields over time. A comparison of extended and internal commuting patterns should aid in ascertaining whether the residents of the intermetropolitan periphery are bound to metropolitan areas for employment opportunities or whether smaller intermetropolitan centers are emerging as foci for employment.

The area selected for the investigation of these trends comprises the 57 nonmetropolitan counties in Kentucky that lie west of the Appalachian Regional Commission's delineation of the Appalachian portion of Kentucky (Fig. 1). The development of the nonmetropolitan counties of these two regions has differed significantly. Eastern Kentucky has a long history of being a stagnant, economically depressed region tied to the boom and bust cycle of the coal industry, while western Kentucky has a more diversified economy with stronger ties to agriculture and industry.

Although western Kentucky had its highest population growth rate of recent times during the 1970s (12.6%), the major turnaround for this region occurred during the 1960s. After experiencing a population loss during the 1950s (−2.5%), the

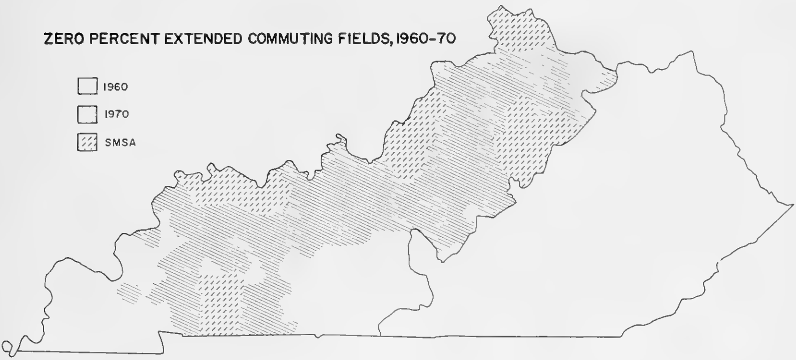

FIG. 2. Zero per cent extended commuting fields, 1960–70.

population of western Kentucky grew at a rate of 9.3% during the 1960s (8). This time period of turnaround is more relevant to the analysis of commuting changes within the region if population growth is indeed related to the provision of employment opportunities.

METHODS AND MATERIALS

Six Standard Metropolitan Statistical Areas (SMSAs) that lie adjacent to the study area—Cincinnati, Ohio; Louisville, Kentucky; Lexington, Kentucky; Evansville, Indiana; Owensboro, Kentucky; and Clarksville, Tennessee/Hopkinsville, Kentucky—provide the basis for examining extended commuting patterns for the region (Fig. 1). An earlier analysis of commuting destinations among the nonmetropolitan counties (9) identified 9 counties (with 9 associated centers)—Warren (Bowling Green), Hardin (Elizabethtown), Taylor (Campbellsville), Barren (Glasgow), Boyle (Danville), Franklin (Frankfort), Hancock (Hawesville), Hopkins (Madisonville), and McCracken (Paducah)—as major intermetropolitan destinations (Fig. 1).

The data were compiled from the Bureau of the Census 1960 and 1970 samples of commuting behavior (a 25% sample in 1960 and a 15% sample in 1970). The 260 census-county divisions (CCDs) in the 57 county region were used as the areal units for commuter origins. The 9 counties mentioned above were used as the destinations for all internal commuting; the central counties of the 6 contiguous SMSAs were used as the destination for the measure of extended commuting, except for the Clarksville, Tennessee/Hopkinsville, Kentucky SMSA. Because Christian County had a higher level of nonmetropolitan commuters from western Kentucky than did the central county of the SMSA, it was chosen as the destination for the measurement of extended commuting for this SMSA.

RESULTS

Both cartographic and regression analysis were performed to analyze any relevant changes in the commuting fields of SMSA and nonmetropolitan destinations between 1960 and 1970. Results suggest that the residents of western Kentucky are becoming less bound to metropolitan areas for employment opportunities. In fact, where commuting option zones exist residents may have several alternative workplace destinations to choose from within the intermetropolitan periphery along with the possibility of commuting to a metropolitan center.

DISCUSSION

A zero per cent isoline map enclosing all CCDs with any commuters to an SMSA

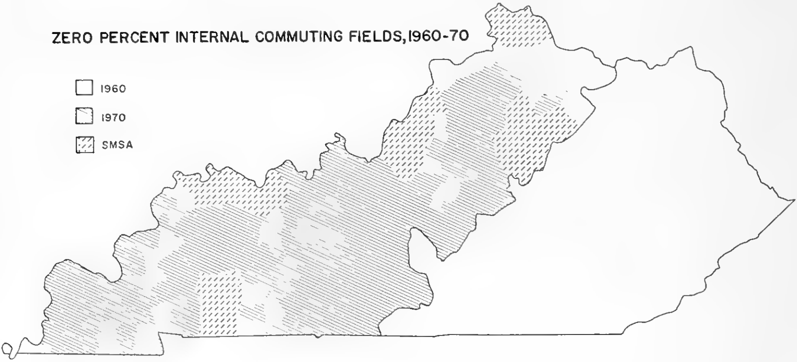

FIG. 3. Zero per cent internal commuting fields, 1960–70.

was used to analyze the expansion of extended commuting between 1960 and 1970 (Fig. 2). Although this measure has been criticized by Taaffe et al. (10) and Hansen (4) as a poor indicator of urban influence, it does denote the limit of extended commuting within the periphery. While the change in the expanse of extended commuting was minimal between 1960 and 1970, the overall number of CCDs within the zero per cent isoline declined from 163 in 1960 to 153 in 1970 (Table 1). With respect to individual destinations, Lexington was the only SMSA experiencing expansion at this time, while Evansville, Hopkinsville, and Louisville displayed diminishing commuting fields and Cincinnati and Owensboro remained unchanged.

The zero per cent isoline map defining the expanse of internal commuting fields for the 9 selected intermetropolitan centers, however, displays a clear expansion of internal commuting during this same

TABLE 1.—CHANGE IN EXPANSE OF EXTENDED COMMUTING BY DESTINATION UTILIZING THE ZERO PER CENT ISOLINE[1]

Destination	1960 Number of CCDs in commuting field	1970 Number of CCDs in commuting field	1960–1970 change	Percentage change
Cincinnati	20	20	0	0.0%
Evansville	36	21	−15	−41.7%
Hopkinsville	31	25	−6	−19.3%
Lexington	33	37	+4	+12.1%
Louisville	77	70	−7	−9.1%
Owensboro	28	28	0	0.0%
Total	163[a]	153[a]	−10	−6.1%

[a] These totals represent the actual number of CCDs contained within the zero per cent isoline for each year, not a summation of column values.

[1] Source: Compiled from U.S. Bureau of the Census, *Census of Population and Housing, 1960, Special Report, Ph-4*, and *Census of Population and Housing, 1970, Summary Tape, Fourth Count, File B, Table 35.*

TABLE 2.—CHANGE IN EXPANSE OF INTERNAL COMMUTING BY DESTINATION UTILIZING THE ZERO PER CENT ISOLINE[1]

Destination	1960 Number of CCDs in commuting field	1970 Number of CCDs in commuting field	1960–1970 change	Percentage change
Glasgow	14	19	+5	+35.7%
Elizabethtown	23	32	+9	+39.1%
Paducah	29	31	+2	+6.9%
Bowling Green	25	35	+10	+40.0%
Campbellsville	11	11	0	0.0%
Danville	8	12	+4	+50.0%
Frankfort	17	27	+10	+58.8%
Madisonville	28	34	+6	+21.4%
Hawesville	2	20	+18	+900.0%
Total	134[a]	162[a]	+28	+20.9%

[a] These totals represent the actual number of CCDs contained within the zero per cent isoline for each year not a summation of column totals.

[1] Source: Compiled from U.S. Bureau of the Census, *Census of Population and Housing, 1960, Special Report Ph-4*, and *Census of Population and Housing, 1970, Summary Tape, Fourth Count, File B, Table 35.*

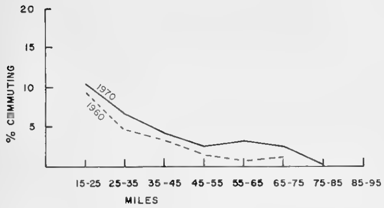

FIG. 4. The regional profile for extended commuting.

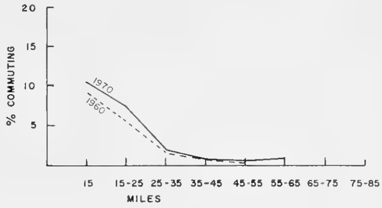

FIG. 5. The regional profile for internal commuting.

period (Fig. 3). In fact, the number of CCDs within the zero per cent isoline increased from 134 in 1960 to 162 in 1970, a 20.9% increase (Table 2). Each individual field also expanded except Campbellsville which stayed the same (Campbellsville expanded more in the intermetropolitan periphery of Kentucky outside the study area). Hawesville clearly displayed the greatest overall expansion.

To analyze the intensification of commuting during the 1960s, commuting profiles were constructed displaying the average commuting percentages of a given destination by distance bands. These percentages are based on the average of actual commuters for only those nonmetro CCDs representative of some degree of commuting. CCDs with no commuters to the central county were excluded.

A regional profile of extended commuting by distance bands displays a gradual distance decay, and an overall upward shift of commuting percentages from 1960 to 1970 is evident (Fig. 4). This intensification is occurring not only at distances close to the SMSAs but also at distances far from these destinations. In fact, the greatest percentage change in the intensification of extended commuting is at distances of 55–75 miles from the central SMSA county. The commuting profiles for individual SMSAs also display a greater intensity of commuting in 1970 as compared with 1960 with the exception of Owensboro.

The regional profile for internal commuting by distance bands displays an intensification of commuting similar to the regional profile for extended commuting (Fig. 5). Along with a gradual distance decay, there is also an overall upward shift of commuting percentages from 1960 to 1970. This intensification of internal commuting represents a 67.0 per cent increase in the overall percentage of internal commuters. As opposed to the regional profile of extended commuting, the intensification of internal commuting is occurring near the intermetropolitan centers especially at distances 15–25 miles away.

Likewise, the commuting profiles for the individual intermetropolitan centers display some degree of commuting intensification with Hawesville experiencing the greatest change in commuting intensification. Negative externalities associated with the numerous primary metal and wood pulp industries and a housing shortage in Hawesville may be facilitating the desire to live farther away from the job opportunities located there.

Finally, a series of forward stepwise regression analyses are employed to identify the significant factors that best explain the spatial patterns of nonmetropolitan commuting in western Kentucky between 1960 and 1970. Factors describing the accessibility of an origin CCD to respective destinations, factors describing the strength of smaller competing centers and factors describing the site characteristics of the origin CCD were used to measure the strength of both extended and internal commuting patterns. For this study a positive linear relationship is expected between the number of commuters to a given destination with:

TABLE 3.—FACTORS AFFECTING COMMUTING (STANDARDIZED BETA COEFFICIENTS[a])

Independent variables	Extended commuting 1960	Extended commuting 1970	Internal commuting 1960	Internal commuting 1970
1) Population of the origin			0.87	1.14
2) Distance to the destination	−0.62	−0.64	−0.24	0.40
3) Distance to the competing center				
4) Population of the competing center				
5) Total number employed in the origin	0.09	0.25	−0.21	−0.57
6) Population of the destination	3.29		0.24	
7) Total number employed in the competing center		−0.22		
8) Highway accessibility variable				
9) Total number employed in the destination	0.48			
10) Percentage unemployed in the origin				
11) Percentage unemployed in the competing center				
12) Percentage unemployed in the destination	0.20			
R^2	0.35	0.45	0.74	0.62
Sample size (N)	240	201	218	267

[a] Significant at .01 level.

(1) the population of the origin CCD; (2) the Euclidean distance from the center of the origin CCD to the nearest competing center; (3) the total number of the civilian labor force age 14 and over employed in the origin CCD; (4) the percentage of the civilian labor force age 14 and over unemployed in the origin CCD; (5) the percentage of the civilian labor force age 14 and over unemployed in the nearest competing center; (6) the population of the county of destination; (7) the total number of the civilian labor force age 14 and over employed in the destination county; and (8) access to an interstate highway. A negative linear relationship is expected between the number of commuters to a given destination with: (1) the Euclidean distance from the center of the origin CCD to the central city of the destination county; (2) the population of the competing center; (3) the total number of the civilian labor force age 14 and over employed in the nearest competing center; and (4) the percentage of the civilian labor force age 14 and over unemployed in the destination county.

Examining the correlates of extended commuting through a regional profile of the study area for 1960, the Euclidean distance from the origin to the destination, the population of the destination, the percentage unemployed in the destination, and the total number employed in the origin are significant variables (Table 3). These 4 variables accounted for 35.2 per cent of the variation in the number of extended commuters for the study area as a whole. The population of the destination is the most important variable. Destinations with larger populations and possibly a more diverse economic base, provide potential commuters with expanded employment opportunities. Furthermore, commuters may be taking jobs away from the local labor force, as the linear relationship between the dependent variable and the percentage unemployed in the destination is positive rather than negative.

In 1970, the distance variable, the total number employed in the origin, and the total number employed in the nearest competing center entered the regression equation significantly, accounting for 45.4 per cent of the explained variance. Although the distance variable exerts the most effect on the number of extended commuters within the study area for 1970, it must be noted that the role of competing centers within the intermetropolitan periphery was more significant in 1970 than in 1960.

Next, the correlates of internal commuting were determined by a regional analysis of the study area for 1960. During this time period, the population of the origin, the distance to the destination, the population of the destination, and the total number employed in the origin together accounted for 74.4 per cent of the explained variance (Table 3). The population of the origin is the most important.

In 1970, the population of the origin, the distance to the destination, and the total number employed in the origin account for 61.7 per cent of the explained variance. Not only is the population of the origin again the most important variable, but the increased magnitude of its beta coefficient displays the increased strength of this particular variable. This is an indication that the larger the origin population, the larger the potential number of commuters.

For both years, the relationship between the number of internal commuters and the total number employed in the origin is unexpectedly negative. This may be an indication that employment opportunities within the intermetropolitan periphery are increasing. As employment increases in many nonmetropolitan CCDs, the need to commute outside one's own community is diminished. Clearly, this intensification of employment opportunities and the growing population of many nonmetropolitan areas may be significant factors in the commuting process.

SUMMARY

Similar to studies done by Taaffe et al. (10) and Fisher and Mitchelson (11, 12), there is little evidence that the intermetropolitan periphery of western Kentucky counties is shrinking. While there is evidence of a diminishing intermetropolitan periphery as extended and internal commuting fields show some degree of expansion, the greatest change is in an intensification of commuting. Similarly, a regression analysis of extended commuting suggests that competing centers in nonmetropolitan counties are diverting a significant number of commuters away from metropolitan destinations by providing more employment opportunities closer to home.

The increased intensity of commuting to nonmetropolitan centers suggests that many of these smaller centers are indeed emerging as foci for employment. While the number of commuters to SMSAs increased 42.2 per cent over the ten-year period, the number of internal commuters to intermetropolitan centers increased 67.0 per cent. The growing importance of these intermetropolitan centers may be due in part to growth impulses being transmitted back to peripheral areas from metropolitan areas themselves. Filter-down effects may have reached into the intermetropolitan periphery as some of these smaller centers such as Bowling Green and Elizabethtown begin to manifest polarization characteristics themselves.

ACKNOWLEDGMENTS

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Gastropod and Sphaeriacean Clam Records for Streams West of the Kentucky River Drainage, Kentucky

BRANLEY A. BRANSON AND DONALD L. BATCH[1]

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

One genus and 3 species of sphaeriid clams and 6 families, 12 genera and 23 species of aquatic snails are reported from the Tradewater, Tennessee and Green river systems and from some small tributaries of the Ohio River in Kentucky.

INTRODUCTION

During our work on the rare and endangered species of Kentucky (1), it became obvious than many sections of Kentucky were poorly represented in the literature on aquatic snails and fingernail clams. Because of this, we recently generated a series of papers (2, 3, 4, 5) designed to alleviate the lack of information in those 2 groups of conspicuous aquatic organisms. This contribution, a continuation of that series, treats records gleaned from drainages west of the Kentucky River basin.

COLLECTING SITES

In the annotated list of species, collecting sites are indicated by the numbers listed below; the figures in parentheses indicate the number of specimens collected at each site.

1. Smith Creek at KSR 696, Clinton County, Cumberland River drainage; 13 June 1980.

Green River Drainage

2. Little Barren River at US 68, Green County; 6 May 1977.

3. Fallen Timbers Creek at SR 90, Barren County; 13 March 1974.

4. Small swampy creek at the junction of US 127 and SR 70, Casey County; 27 October 1979.

5. Green River at Butler-Warren county line, SR 195; 30 September 1980.

6. Green River at Mumfordville, Hart County; 16 July 1968.

7. Pond, 1.4 km east of Maysville, Mason County; 13 October 1980.

8. Rough River at Lock One, Ohio County; 26 August 1980.

9. North Fork of the Rough River at SR 690, Breckinridge County; 15 April 1970.

10. Green River at Greensburg, Green County; 6 May 1967.

11. Wolf Lick Creek, SR 107, Logan County; 19 April 1970.

12. Sinking Creek, SR 79, Breckinridge County; 18 April 1970.

13. Big Slough, SR 54, Grayson County; 29 July 1980.

14. Cave Springs, Edmonson County; 30 July 1981.

[1] Dean, College of Natural and Mathematical Sciences, Eastern Kentucky University, Richmond, Kentucky 40475.

15. Crane Pond, 1.5 km east of Green River Parkway, Daviess County; 22 July 1980.

16. Rockhouse Slough, Ohio County; 25 September 1980.

17. Muddy Creek at US 231, Ohio County; 9 September 1980.

18. Mud River at Muhlenberg-Todd county line; 23 September 1980.

Salt River Drainage

19. Otter Creek at US 60, Meade County; 11 October 1980.

20. Chaplin River at US 68, Boyle County; 6 September 1980.

21. Small creek, 9.4 km south of Shepardsville, SR 480, Bullitt County; 14 April 1966.

22. McCowans Pond, 1.6 km east of US 121, Mercer County; 10 July 1966.

23. Salt River near Shepardsville, Bullitt County; 11 October 1980.

24. Rolling Fork of Salt River at SR 527, Marion County; 13 October 1980.

25. Salt River at SR 208, Marion County; 4 October 1980.

Tradewater Drainage

26. Flat Creek just above mouth, Hopkins County; 6 August 1980.

Tennessee River Drainage

27. Kentucky Lake, Land Between the Lakes, 2.4 km west of Golden Pond, U.S. Route 68, Lyon County; 14 March 1981.

Ohio River Drainage

28. Ohio River opposite Portsmouth, Ohio, in Greenup County, Kentucky; 9 September 1980.

29. Beargrass Creek near mouth, Jefferson County; 11 September 1980.

30. Small unnamed creek, muddy banks, Cherokee Park, Louisville, Jefferson County; 13 November 1980.

31. Small swamp just west of Warden's Slough, Union County; 17 July 1980.

32. Richland Slough, Henderson County; 24 July 1980.

33. Bee Creek at SR 641, 0.7 km north of Murray, Calloway County (Clarks River); 3 December 1965.

ANNOTATED LIST

Voucher specimens of all species reported herein are in the Eastern Kentucky University Museum.

SPHAERIIDAE

Sphaerium fabale Prime

Collecting sites: 9 (1).

This habitat was muddy gravel and sand at the edge of a slow riffle.

Sphaerium similis (Say)

Collecting sites: 9 (2).

This heavy shelled species is adapted for life in backwaters and lakes with sandy, vegetated bottoms. It is mostly associated with streams in englaciated parts of America (6). However, the Green River was a refugium for northern species during Pleistocene times (7) so it is not surprising to find residual populations of species such as this one.

Sphaerium striatinum (Lamarck)

Collecting sites: 11 (5), 12 (2).

This is the most common stream sphaeriid in Kentucky.

PLEUROCERIDAE

Our collections contained representatives of 3 genera and 10 species of this taxonomically confusing family.

Lithasia verrucosa (Rafinesque)

Collecting sites: 27 (4).

This species is correctly considered as Endangered in Kentucky (1) and is being considered for federal listing (8).

Lithasia obovata (Say)

Collecting sites: 5 (1), 6 (9), 12 (1), 18 (2), 23 (14), 24 (8).

Lithasia obovata is listed as of Special Concern in Kentucky (1). However, in view of the large populations of the species in the Green, Rough, and Salt rivers, it probably should be delisted.

Pleurocera acuta Rafinesque

Collecting sites: 1 (2), 6 (1), 23 (5), 28 (1).

An uncommon species in the Kentucky River drainage (3, 5) and listed as of Special Concern in Kentucky (1), *P. acuta* appears to be thriving in the Green and Salt rivers.

Pleurocera canaliculatum (Say)
Collecting sites: 6 (6), 23 (5), 27 (2).
This species is likewise of Special Concern (1), particularly in the Kentucky River drainage.

Pleurocera alveare (Conrad)
Collecting sites: 3 (2).
There is a thriving community of this species in Fallen Timbers Creek.

Goniobasis semicarinata (Say)
Collecting sites: 21 (92), 24 (21), 25 (30), 29 (5).
This is the most common pleurocerid throughout the Kentucky River drainage (4) and, as indicated above, produces at least some populations in Salt River. It has been recently reported from the Little South Fork of the Cumberland River (5). The population discovered in Beargrass Creek in Jefferson County (Station 29), a tributary of the Ohio River, is an interesting one in relation to 2 sites from the Green River, Kentucky, and the Big Blue River, Indiana (9, 10), emphasizing the importance of the Ohio River and smaller tributaries that possibly functioned in tributary hopping during re-expansion migrations in post-glacial times.

Goniobasis costifera (Haldeman)
Collecting sites: 5 (1), 11 (19), 14 (9), 18 (11).
To our knowledge, this species has heretofore not been reported from Tennessee.

Goniobasis laqueata (Say).
Collecting sites: 2 (3), 3 (3), 9 (26), 12 (57).
This is the characteristic *Goniobasis* of the Middle and Lower Green River and its tributaries (9). It was the dominant species present in the Rough River (stations 9 and 12).

Goniobasis curreyana (Lea)
Collecting sites: 10 (1), 14 (4), 19 (2).
Bickel (11) also reported specimens from Otter Creek (near our Station 19) and suggested that the species would probably be found in other parts of the Green River. Our collections corroborate his prognostications.

VIVIPARIDAE

The principal references to this family were Clench (12), Clench and Fuller (13), and Clench and Turner (14).

Viviparus georgianus Lea
Collecting sites: 8 (8).
These are some of the few records for this large operculate from Kentucky.

HYDROBIIDAE

A very poorly understood family in Kentucky. Our collections contained specimens of one amphibious species.

Pomatiopsis cincinnatiensis (Lea)
Collecting sites: 30 (7).
Our specimens closely resemble those of van der Schalie and Dundee (15). The same authors (16) reported this species from a site in the Upper Cumberland River in Kentucky, and there are few additional known sites in the state.

LYMNAEIDAE

Our generic and species concept in this family follows Hubendick (17, 18). Three species are reported.

Lymnaea humilis Say
Collecting sites: 7 (2).
Lymnaea humilis is a highly variable species that is found in both standing and slowly running water.

Lymnaea palustris (Müller)
Collecting sites: 31 (1).
There are very few records for this species in Kentucky, and the ecology is poorly understood. It is often associated with bodies of water frequented by migratory birds.

Lymnaea (Pseudosuccinea) columella (Say)
Collecting sites: 4 (2), 7 (2), 16 (2).
Found mostly in stagnate ponds and backwaters, this snail is often heavily laden with fluke larvae.

PHYSIDAE

One of the most confusing and variable groups of aquatic snails in North America, the Physidae is represented in Kentucky by the genus *Physa*. Until the family is thoroughly studied and revised, any specific identification is tentative, as are the 4 species reported here, based entirely upon shell features.

Physa integra Haldeman

Collecting sites: 13 (4), 15 (3), 22 (8), 23 (1), 32 (7), 33 (35).

Typically with long spires and inflated body whorls, *Physa integra* is often found in flowing waters, although it also occupies backwaters and lentic waters.

Physa virgata Gould

Collecting sites: 31 (18).

The shell is usually slender with a long spire and a short, narrow aperture. The habitat is usually well-vegetated standing waters over mud bottoms.

Physa heterostropha (Say)

Collecting sites: 20 (1).

Physa heterostropha is a rather squat species with an inflated body whorl, a short spire, and a capacious, elongated aperture.

Physa gyrina Say

Collecting sites: 4 (5), 7 (1), 15 (2), 31 (1).

ANCYLOPLANORBIDAE

We follow Hubendick (17) in combining the Planorbidae and Ancylidae. Five genera and 6 species are reported here.

Ferrissia rivularis (Say)

Collecting sites: 24 (1), 25 (1).

Because of the clandestine habitat on stones, pelecypod valves, snail shells, and other objects in lotic situations, this and other members of the Tribe Physastrini are often overlooked in general collecting. Hence, published records for the Kentucky fauna are few.

Laevapex fuscus (C. B. Adams)

Collecting sites: 5 (2), 16 (5).

Mostly a lentic species, this snail is often found in backwaters on submerged limbs and rocks.

Gyraulus parvus (Say)

Collecting sites: 26 (2).

The scanty published Kentucky records for this and other minute Planorbinae reflect inadequate collecting rather than scarcity.

Planorbula (Menetus) sampsoni (Ancey)

Collecting sites: 17 (3).

This is one of three reported sites for this species in Kentucky. We follow Hubendick (17) in utilizing *Planorbula* rather than *Menetus*.

Helisoma trivolvis (Say)

Collecting sites: 4 (25), 11 (1), 31 (17).

Found in both lentic and lotic waters, *H. tribolvis* occurs statewide, as does the next species.

Helisoma anceps (Menke)

Collecting sites: 12 (2).

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Freshwater Naiads (Mussels) (Pelecypoda: Bivalvia) of Slate Creek, A Tributary of the Licking River, Kentucky

RALPH W. TAYLOR AND BEVERLY SPURLOCK

Department of Biological Sciences, Marshall University, Huntington, West Virginia 25701

ABSTRACT

During the summer and fall of 1981, collections of freshwater naiads (mussels) were made from 6 sites along Slate Creek, a tributary of the Licking River. Nineteen species of naiads were found. Two species, *Fusconaia maculata* and *Epioblasma triquetra,* are currently considered endangered, threatened, or rare in Kentucky. *Fusconaia maculata* is a rather rare shell in Slate Creek, but *Epioblasma triquetra* was extremely abundant throughout the stream. All other species reported are commonly found throughout Kentucky.

Slate Creek, a tributary of the South Fork of Licking River, is a rather short (approximate length 40 km) eastcentral Kentucky stream, but one which has a rich and diverse naiad fauna. The stream originates in the rolling hill region of Montgomery County, Kentucky approximately 12.8 km SE of Mount Sterling and meanders through Bath County to its confluence with the South Fork of the Licking River ca. 9.6 km E of Owingsville. Slate Creek rarely exceeds 2 m in depth and 10 m in width. The substrate is sand and cobble with an occasional stretch of exposed bedrock. The water quality is quite good as no industries or urban centers are located within the drainage.

During the summer and fall of 1981, collections of freshwater naiads (mussels) were made at irregular intervals from 6 stream sites, mostly by picking in shallow waters (Table 1). Other records were derived from bank shell debris. No live specimens were taken when fresh dead material of equivalent species could be found and used as voucher specimens. Reference specimens are housed in the Marshall University Malacological Col-

TABLE 1.—FRESHWATER MUSSELS FOUND AT EACH SITE

Species	Sites					
	1	2	3	4	5	6
Anodonta grandis (Say 1829)	X	X	X	X	X	
Anodontoides ferussacianus (Lea 1834)				X		
Strophitus u. undulatus (Say 1817)	X	X	X	X		X
Alasmidonta viridis (Rafinesque 1820) = *calceolus* (Lea 1830)	X	X	X	X	X	X
Lasmigona costata (Rafinesque 1820)	X	X	X	X	X	X
Tritogonia verrucosa (Rafinesque 1820)			X	X		
Quadrula quadrula (Rafinesque 1820)			X			
Quadrula pustulosa (Lea 1831)		X	X			
Amblema plicata (Say 1817)	X	X	X	X	X	X
Fusconaia maculata (Rafinesque 1820) = *subrotunda* (Lea 1831)			X		X	
Fusconaia flava (Rafinesque 1820)	X	X	X	X	X	X
Elliptio dilatata (Rafinesque 1820)	X	X	X	X	X	X
Ptychobranchus fasciolaris (Rafinesque 1820)		X	X	X	X	X
Actinonaias carinata (Barnes 1823)			X			
Potamilus alatus (Say 1817)			X			
Villosa iris (Lea 1829)	X	X		X		X
Lampsilis radiata luteola (Lamarck 1819) = *siliquoidea* (Barnes 1823)	X	X	X	X	X	X
Lampsilis ventricosa (Barnes 1823)	X	X	X	X		X
Epioblasma triquetra (Rafinesque 1820)	X	X	X	X		X
Corbicula fluminea (Müller) was found at all stations.						

lections and the Ohio State University Museum of Zoology. Scientific names are those in current usage by Stansbery (1).

Location of Collecting Sites

All sites are in Bath County, Kentucky.

1. Slate Creek at Stepstone Rd., 1.6 km S of intersection with US 60, 3.2 km W of Owingsville.
2. Slate Creek at Kendall Rd., 1.6 km W of KR 36.
3. Slate Creek at KR 36, 3.2 km S of Owingsville.
4. Slate Creek at I-64, 480 km E of Owingsville/Frenchburg exit on KR 36.
5. Slate Creek at bridge on US 60, 2.9 km E of Owingsville.
6. Slate Creek off KR 111, 8 km NE of Owingsville, 3.2 km from confluence of Slate Creek and South Fork of Licking River.

DISCUSSION

A total of 19 species of naiads was collected from Slate Creek. At all sites the number of mussels present was phenomenal considering the small size of the stream.

Fusconaia maculata and *Epioblasma triquetra* are currently on the list of (Endangered, Threatened, and Rare Animals and Plants of Kentucky) (2). *Fusconaia maculata* is a rather rare shell in Slate Creek, but *E. triquetra* was found to be extremely abundant throughout the stream. All other species reported are commonly found throughout Kentucky. The exotic Asian clam (*Corbicula fluminea*) was found at all stations in large numbers.

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The Ferns and Fern Allies of Pike County, Kentucky

FOSTER LEVY, VEDA KING, CLARA OUSLEY, TOM PHILLIPS, AND DAVID WHITE

Department of Biology, Pikeville College, Pikeville, Kentucky 41501

ABSTRACT

A total of 41 species of pteridophytes are reported from Pike County, Kentucky. This represents 16 new county records. Several reports extend the ranges of species into the eastern third of the state.

INTRODUCTION

Cranfill's (1) monograph summarized much of the information on the pteridophytes of Kentucky. However, distributional data is lacking for many of the easternmost counties. This study assesses the status and ecological relationships of pteridophytes in Pike County, Kentucky. Field work for this project was conducted from November 1980 to November 1981, throughout Pike County and adjacent areas.

Nomenclature and taxonomic treatment follow Cranfill (1). Voucher specimens were placed in the Pikeville College herbarium and duplicate specimens in the University of Kentucky herbarium.

Pike County, largest and easternmost county in Kentucky, lies within the Cumberland Mountain-Cumberland Plateau physiographic region (2) and within the Mixed Mesophytic Forest floristic province as delineated by Braun (3). Hills are steep throughout the county with little bottomland between. Elevations range from 183 m along the Big Sandy River to over 854 m on Pine Mountain and the Dorton Flatwoods. Most of the county has a local relief of 213–366 m. Forests in the county are mainly successional, composed of a mesophytic buckeye-basswood-tulip-maple association on north and lower south-facing slopes, beech-mixed oak on south-facing slopes, and oak-hickory on upper slopes and ridges. Oak-pine is found on the more sandy ridges and hemlock-rhododendron occurs in the cooler ravines, becoming most common on Pine Mountain.

Forty-one species are reported from Pike County, 16 of which are new county records, and 2, *Lygodium palmatum* and *Cystopteris bulbifera*, have been reported previously in the county but were not found in this study (Table 1).

DISCUSSION

LYCOPODIACEAE

Lycopodium digitatum is common in a variety of habitats, including cutover hillsides where successional processes have not produced a closed canopy. It also invades partly shaded roadsides and forest edges in addition to being common in more mature woods. *Lycopodium obscurum* has been found only in the vicinity of the highest peaks of the county.

OPHIOGLOSSACEAE

Ophioglossum pycnostichum is apparently more common in eastern Kentucky than present records indicate. Three scattered colonies were located, each occurring on level, but not flooded areas, such as wooded benches on hillsides. In one locality a colony was associated with black walnut-ash-buckeye on a mid-slope bench of a south-facing slope. In a second locality, *Ophioglossum pycnostichum* occupied a small bench on a west-facing slope under a stand of beech, and in a third site it was on a shaded lower slope under sycamore-hemlock. The common factors in each case were level, non-inundated habitats.

Botrychium dissectum is one of the most conspicuous fall and winter components of woodlands and successional edges. This highly variable species is represented by the common var. *obliquum* with occassional var. *dissectum* intermixed. In addition, all intermediate

TABLE 1.—LIST OF FERNS AND FERN ALLIES AND NEW RECORDS FROM PIKE COUNTY, KENTUCKY

Lycopodiaceae	
Lycopodium digitatum A. Braun	*
L. lucidulum Michx.	
L. obscurum L.	*
Equisetaceae	
Equisetum arvense L.	
E. hyemale L.	*
Ophioglossaceae	
Ophioglossum pycnostichum (Fern.) Love & Love	*
Botrychium dissectum Spreng.	
var. *dissectum*	*
var. *obliquum*	*
B. johnsonii	*
B. virginianum (L.) Sw.	
Osmundaceae	
Osmunda cinnamomea L.	
O. claytoniana L.	
O. regalis L.	
Schizaeaceae	
Lygodium palmatum (Bernh.) Sw.	p
Adiantaceae	
Cheilanthes lanosa (Michx.) D.C. Eaton	
Pellaea atropurpurea (L.) Link	*
Adiantum pedatum L.	
Polypodiaceae	
Polypodium polypodioides (L.) Watt	
P. virginianum L., diploid	*
P. virginianum L., tetraploid	
Dennstaedtiaceae	
Dennstaedtia punctilobula (Michx.) Moore	*
Pteridium aquilinum (L.) Kuhn	
Thelypteridaceae	
Thelypteris noveboracensis (L.) Nieuwland	*
Phegopteris hexagonoptera (Michx.) Fee	
Aspleniaceae	
Asplenium bradleyi D.C. Eaton	*
A. × *ebenoides* Scott	*
A. montanum Willd.	
A. pinnatifidum Nutt.	*
A. platyneuron (L.) Oakes	
A. resiliens Kunze	*
A. rhizophyllum L.	
A. trichomanes L.	
A. × *trudellii* Wherry	*
Onoclea sensibilis L.	
Athyrium asplenioides (Michx.) A.A. Eaton	*
A. pycnocarpon (Spreng.) Tidestrom	

TABLE 1.—CONTINUED

A. thelypterioides (Michx.) Desv.	
Cystopteris bulbifera (L.) Bernh.	p
C. protrusa (Weatherby) Blasdell	
Woodsia obtusa (Spreng.) Torrey	*
Polystichum acrostichoides (Michx.) Schott	
Dryopteris goldiana (Hook) Gray	*
D. intermedia (Muhl.) Gray	
D. marginalis (L.) Gray	

*—county record.
p—previous county record exists but not located during this study.

forms are present. Several populations of a very robust, lush *Botrychium* have been located on shaded, mesophytic lower slopes of ravines. It appears that this is the same plant referred to as *B. johnsonii* by Johnson (4), and collected by him in nearby Johnson County, Kentucky. We have located a site where *B. johnsonii* occurs mixed with typical *B. dissectum* and another site where *B. johnsonii* occurs in pure colonies. The specific status of this plant is currently under investigation by Dr. Warren H. Wagner and the senior author.

OSMUNDACEAE

The genus *Osmunda* is not common in Pike County although the county lies well within the range of all 3 species of the genus. Only on Pine Mountain are large populations encountered, and this was the only locality in which *O. regalis* and *O. claytoniana* were located in this study. *Osmunda regalis* requires constantly moist wetland conditions and its sparse distribution in the county reflects the paucity of undisturbed wetlands.

ASPLENIACEAE

The genus *Asplenium* is well represented in Pike County with 9 species. In the Appalachian *Asplenium* complex (5) the 3 parent species are found as well as 4 species of hybrid origin. *Asplenium rhizophyllum* is common on shaded, moss-covered sandstone boulders and outcrops, being distributed from creek bottoms to the shaded side of ridge outcrops. It should be emphasized that *A. rhizophyllum* is not a limestone species.

Asplenium platyneuron, abundant on south-facing slopes, successional woodlands, and rock outcrops, is infrequent on north-facing mesophytic slopes. At the base of a sandstone outcrop on the Pikeville College Farm, Johns' Creek, both *A. rhizophyllum* and *A. platyneuron* are found intermixed in a small colony. Approximately 1 m from this site, in a shaded crevice at the base of the outcrop, grows 1 tuft of *A.* × *ebenoides*.

The third parent species in the complex, *A. montanum*, is mainly found on cool, moist, sandstone outcrops and is thus more common on Pine Mountain than in other parts of the county. *Asplenium bradleyi* has been found in 3 localities and *A.* × *trudellii* in 1 locality near Caney Creek and 1 locality on the Virginia side of the Breaks Interstate Park. Due to the richness of the genus in the county, other members of the complex can be expected to be found in the future.

In the genus *Dryopteris*, *D. marginalis* is common in a variety of habitats and *D. intermedia* is usually found along the banks of shaded creeks and drainages becoming most common on Pine Mountain. *Dryopteris goldiana* is associated with rich, sometimes rocky draw slopes of hollows.

Also abundant on Pine Mountain and common locally in other parts of the county is *Cystopteris protrusa*, which is sparsely recorded in other areas of eastern Kentucky (1).

OTHER SPECIES OF NOTE

Cheilanthes lanosa and *Polypodium polypodioides* are species which increase in numbers to the west and south of the eastern plateaus of Kentucky (1, 6). In 1 locality, within the city limits of Pikeville, both are found on the same south-facing, exposed, sandstone-shale outcrop. While data are not available, Pikeville appears to be warmer than the outer parts of the county.

The bedrock of Pike County consists mainly of shales and sandstones with sandstone caps and outcrops forming the resistant mountain ridges. The only occurrence of limestone at the surface is on Pine Mountain where 2 major strata have been exposed due to faulting and uplift. Some species usually restricted to limestone have been found on sandstone substrates in the county. These include a colony of *Woodsia obtusa* approximately 10 m^2 in diameter. This extends the range of *Woodsia obtusa* into the eastern third of the state. Another limestone species, *Pellaea atropurpurea*, was found growing on sandstone rock. In addition, 2 tufts of *Asplenium resiliens* were found in Pikeville on a sandstone outcrop.

Approximately 300 m across the state line, in Dickenson County, Virginia, is a series of *Polystichum acrostichoides* which grades into a highly dissected *P. acrostichoides* f. *multifidum*. These plants were found in a mesophytic site.

Note: Since the preparation of this manuscript, two additional species have been found in Pike County. These species are *Selaginella apoda* (L.) Spring ex Mart. and *Trichomanes boschianum* Sturm ex Bosch. Both were located near the Russell Fork River of Breaks Interstate Park.

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Hypothesis Testing and Model Comparisons of Trend Surfaces

ALAN D. SMITH

Department of Geology, Eastern Kentucky University,
Richmond, Kentucky 40475

ABSTRACT

The use of trend-surface analyses is wide spread in many disciplines. However, researchers need to statistically justify their selection of the trend that best fits the data of study areas. A relatively simple computer program, written in APL language, is presented to accomplish this task. The program uses total variance and amount of variance explained by each order surface to complete an analysis of variance table for each trend surface. In addition, model comparison between successively higher trend surfaces is completed to determine the statistical best fit.

TREND-SURFACE ANALYSIS

A trend is a statistically derived surface to explain variations in a given set of values, known as Z-values, that have a given geographic position, either regularly or irregularly distributed in the x-y plane. The surface is the representation of an equation using the least-squares criterion. This means that the generated surface will be fitted to the input data in such a way that the sum of the squared deviations between the data at their particular locations and the corresponding value of the computed surface are minimized. Thus, the least-squares criterion calls for the surface to be laid down in such a way that the sum of the squares of these discrepancies is as small as possible, as indicated by: $d^2 = E$, where d^2 = deviation squared and E = minimum value.

The basic reasoning behind minimizing the sum of squares of the deviations, and not minimizing the sum of the absolute magnitudes of the discrepancies, are: 1. It is extremely difficult to mathematically deal with the absolute discrepancies or deviations; while the treatment of the squared deviations provides the method of practical mathematical developments in the interpretation of the regression equation. 2. Useful and desirable statistical properties follow from using the least-squares criterion (1, 2, 3).

The equation describing the surface can be linear (plane), quadratic (paraboloid), cubic (paraboloid with an additional point of inflection), to higher-order degree surfaces. In general, the higher order of the surface, the more the residuals, or individual deviations, will be minimized and the more computation will be required. The higher-order trend surfaces may reflect the variation in Z-values more accurately if the study area is complex, but lower-order surfaces may be more useful in the isolation of local trends. The filtering mechanism allows the upper limit of variability to be determined by the order of the surface. The equation for a linear trend surface, for example, is: $Y = b_0 + b_1X_1 + b_2X_2$, where Y = dependent variable, b_0 = constant value related to the mean of the observations, b_1b_2 = coefficients, X_1X_2 = geographic coordinates. This linear equation generates 3 unknowns and 3 equations are needed to determine a solution. These equations are:

$$(1) \quad \sum_{i=1}^{n} Y = b_0 n + b_1 \sum_{i=1}^{n} X_1 + b_2 \sum_{i=1}^{n},$$

$$(2) \quad \sum_{i=1}^{n} X_1Y = b_0 \sum_{i=1}^{n} X_1 + b_1 \sum_{i=1}^{n} X_1^2 + b_2 \sum_{i=1}^{n} X_1X_2, \quad \text{and}$$

$$(3) \quad \sum_{i=1}^{n} X_2Y = b_0 \sum_{i=1}^{n} X_2 + b_1 \sum_{i=1}^{n} X_1X_2 + b_2 \sum_{i=1}^{n} X_2^2,$$

where n = number of observations or data collected. Solving these equations simul-

TABLE 1.—TYPICAL ANALYSIS OF VARIANCE TABLE FOR POLYNOMIAL TREND SURFACES. (IN THE TABLE, M IS THE NUMBER OF COEFFICIENTS IN THE TREND-SURFACE EQUATION, NOT INCLUDING THE CONSTANT COEFFICIENT, B_0, AND N IS THE NUMBER OF DATA POINTS.)

Source of variation	Sum of squares	Degrees of freedom	Mean squares	F-ratio
Regression	SS_{Reg}	m	MS_{Reg}	MS_{Reg}/MS_{Res}
Residual	SS_{Res}	n − m − 1	MS_{Res}	
Total	SS_T	n − 1		

taneously will give the coefficients of the best-fitting linear surfaces, where best fit is defined by the least-square criterion (4). Of course, as the degree of the trend surface that is to be used increases, so does the number of equations that must be solved simultaneously.

STATISTICAL ANALYSIS OF TRENDS

According to Davis (4), the significance of a trend or regression may be tested by performing an analysis of variance, which deals with the separation of the total variance of a set of observations into components with defined sources of variation. In the case of trend-surface analysis, the total variance in an independent variable may be divided into the trend itself, which is determined by regression analysis, and the residuals, or error vector. An analysis of variance table can be calculated (Table 1). By reducing the sum of squares, which were derived from the least-square criterion, an estimate of the variance can be compared by using the F-distribution (4). The F-test, like a t-test, is a very robust test and relatively insensitive to violations of the assumptions of random selection of observations and normal distribution of the variables (5, 6). Newman and Fraas (7) and Nunnally (8) looked at a number of investigations that dealt with the F-distribution assumptions and their eventual violation, and summarized by suggesting that no appreciable effect on the accuracy of the F-test from non-normality of sample distribution occurred. In addition, if the sample sizes are equal, heterogeneity of variance has a negligible effect.

TABLE 2.—COMPUTER SOURCE PROGRAM FOR STATISTICALLY ANALYZING DATA FROM TREND SURFACE

```
 ∇ANOVA[⎕]∇
 ∇ ANOVA
 TS←⍳0
 EXP←⍳0
 UEXP←⍳0
 M1← 3 6 10 15 21 28
 'ENTER NUMBER OF DATA POINTS'
 N←⎕
 'ENTER THE TOTAL VARIATION FOR THE SURFACE'
 SST←⎕
BEG:'ENTER DEGREE OF SURFACE'
 '(ENTER 0 FOR TABLE)'
 X←⎕
 →BEG×⍳(X>6)
 →GO×⍳(X=0)
 TS←TS,X
 'ENTER VARIATION EXPLANED'
 EXP←EXP,TEXP←⎕
 UEXP←UEXP,SST-TEXP
 →BEG
GO:→0×⍳((⍴TS)<1)
 DF1←M1[TS]-1
 DF2←N-M1[TS]
 MSSR←EXP÷DF1
 MSSE←UEXP÷DF2
 F←MSSR÷MSSE
 REPORT1
 →0×⍳((⍴TS)=1)
 M2←¯1↓M1[TS]
 M1←1↓M1[TS]
 EXP1←1↓EXP
 EXP←¯1↓EXP
 DIF←EXP1-EXP
 UEXP←1↓UEXP
 DF1←M1-M2
 DF2←N-M1
 MSSR←DIF÷DF1
 MSSE←UEXP÷DF2
 F←MSSR÷MSSE
 REPORT2
 ∇

 ∇REPORT1[⎕]∇
 ∇ REPORT1
 I←0
LOOP:I←I+1
 (20⍴' '),'ANOVA FOR DEGREE ',⍕TS[I]
 ' '
 '              VARIATION         DF          MEAN SQ'
 'EXPLAINED  ',(10 2 ⍕EXP[I]),(10 0 ⍕DF1[I]), 15 2 ⍕MSSR[I]
 'UNEXPLAINED',(10 2 ⍕UEXP[I]),(10 0 ⍕DF2[I]), 15 2 ⍕MSSE[I]
 'TOTAL      ',(10 2 ⍕SST),(13⍴' '),'         FRATIO', 10 4 ⍕F[I]
 VACC←EXP[I]÷SST
 'VAR ACCT FOR',(9 4 ⍕VACC),(18⍴' '),
 2⍴⎕TC[2]
 →LOOP×⍳(I<⍴TS)
 ∇

 ∇REPORT2[⎕]∇
 ∇ REPORT2
 I←0
LOOP:I←I+1
 (20⍴' '),'MODEL COMPARISON FOR ',(⍕TS[I]),' VS ',⍕TS[I+1]
 ' '
 '               VARIATION          DF      MEAN  SQ'
 'EXPLAINED BY'
 '   DEGREE   ',(⍕TS[I+1]), 10 2 ⍕EXP1[I]
 'EXPLAINED BY'
 '   DEGREE   ',(⍕TS[I]), 10 2 ⍕EXP[I]
 'INCREASE    ',(10 2 ⍕DIF[I]),(10 0 ⍕DF1[I]), 15 2 ⍕MSSR[I]
 'UNEXPLAINED ',(10 2 ⍕UEXP[I]),(10 0 ⍕DF2[I]), 15 2 ⍕MSSE[I]
 (42⍴' '),'FRATIO', 10 4 ⍕F[I]
 FROB←(DF1[I],DF2[I]) B61 F[I]
 (42⍴' ')
 2⍴⎕TC[2]
 →LOOP×⍳((I+1)<⍴TS)
 ∇
```

The F-test for significance of fit is a test of the null hypothesis that the partial regression coefficients are equal to zero and, hence, there is no regression. If the computed F-value exceeds the F-value having a probability of a set alpha level, commonly, .01 to .05, then the null hypothesis is rejected and an alternative hypothesis is accepted. According to Davis (4), in polynomial trend-surface analysis, it is customary for investigators to fit a series of successively higher degrees to the data without statistically testing the higher order's contribution in additional variance. Davis further suggested that an analysis of variance table be expanded to analyze the contribution of the additional partial regression coefficients to give a measure of the appropriateness of increasing the order of the equations. However, a standardized statistical technique was not developed by Davis that can be readily used by the nonstatistician. Therefore, a computer program was devised to calculate and present recommended procedure for analyzing polynomial trend surfaces.

COMPUTER PROGRAM

Table 2 represents a listing of the program source deck to complete the analysis of data related to trend-surface analysis. The program, written in APL, can easily be adapted to almost any system with an APL compiler. The program was originally designed for an interactive mode, but with a few revisions in the program it can be adjusted to read in a batch mode. The required input is the total variation of the data, and the amount of variance accounted for by the order surface. This information is generated by most computer software packages that produce trend surfaces, such as SYMAP (9) and SURFACE II (10).

Table 3 illustrates the printed output of a successful execution of the program. The program not only completes an analysis of variance table for each trend surface, but also completes model comparison to determine if the use of a higher degree surface produces a statistically significant increase in amount of variance explained by the trend surface to warrant its use. Specifically, the example outlined in Table 3 shows that all 3 trends are not statistically significant at the .05 level, and no higher order trend is statistically better than its lower-order counterpart.

TABLE 3.—EXAMPLE INPUT AND OUTPUT OF AN ANALYSIS OF TREND-SURFACE DATA.

```
      ANOVA
ENTER NUMBER OF DATA POINTS
⎕:
      25
ENTER THE TOTAL VARIATION FOR THE SURFACE
⎕:
      2555546
ENTER DEGREE OF SURFACE
(ENTER 0 FOR TABLE)
⎕:
      1
ENTER VARIATION EXPLANED
⎕:
      23471
ENTER DEGREE OF SURFACE
(ENTER 0 FOR TABLE)
⎕:
      2
ENTER VARIATION EXPLANED
⎕:
      25792
ENTER DEGREE OF SURFACE
(ENTER 0 FOR TABLE)
⎕:
      3
ENTER VARIATION EXPLANED
⎕:
      42178
ENTER DEGREE OF SURFACE
(ENTER 0 FOR TABLE)
⎕:
      0
                        ANOVA FOR DEGREE 1

              VARIATION         DF        MEAN SQ
EXPLAINED      23471.00          2       11735.50
UNEXPLAINED2532075.00           22      115094.32
TOTAL        2555546.00                  FRATIO      .1020
VAR ACCT FOR      .0092

                   ANOVA FOR DEGREE 2

              VARIATION         DF        MEAN SQ
EXPLAINED      25792.00          5        5158.40
UNEXPLAINED2529754.00           19      133144.95
TOTAL        2555546.00                  FRATIO      .0387
VAR ACCT FOR      .0101


                   ANOVA FOR DEGREE 3

              VARIATION         DF        MEAN SQ
EXPLAINED      42178.00          9        4686.44
UNEXPLAINED2513368.00           15      167557.87
TOTAL        2555546.00                  FRATIO      .0280
VAR ACCT FOR      .0165


                   MODEL COMPARISON FOR 1 VS 2

                VARIATION          DF      MEAN  SQ
EXPLAINED BY
  DEGREE    2  25792.00
EXPLAINED BY
  DEGREE    1  23471.00
INCREASE        2321.00             3        773.67
UNEXPLAINED  2529754.00            19     133144.95
                                             FRATIO      .0058


                   MODEL COMPARISON FOR 2 VS 3

                VARIATION          DF      MEAN  SQ
EXPLAINED BY
  DEGREE    3  42178.00
EXPLAINED BY
  DEGREE    2  25792.00
INCREASE       16386.00             4       4096.50
UNEXPLAINED  2513368.00            15     167557.87
                                             FRATIO      .0244
```

Technically, the degrees of freedom used in the F-test utilizes the following: $df_1 = m_1 - m_2$, $df_2 = N - m_1$ where df_1 = degrees of freedom-numerator, df_2 = degrees of freedom-denominator, m_1 = number of coefficients, counting the constant coefficient, in the full model, m_2 = number of coefficients, counting the constant coefficient, in the restricted model, N = number of observations. These equations, determined by Newman and Thomas (11) are similar in function to those equations suggested by Davis (4), except the addition of the constant term, b_0. In the case of trend-surface analysis, m_1 corresponds to the number of coefficients, including the constant b_0 in the higher-order surface, while the term m_2 is associated with the number of coefficients, plus the constant term, in the lower-order surface. For example, in a second-order trend surface, the equation is represented by: $Y = b_0 + b_1X_1 + b_2X_2 + b_3X_1^2 + b_4X_2^2 + b_5X_1X_2$.

In hypothesis testing to determine if this second-order equation is statistically significant at a set alpha level, this equation becomes the full model, since it contains all the required terms and their coefficients. The restricted model is defined as no information, since an investigator is asking the question if the second-degree surface is predictive of the geographical distribution of the data over no other trend surface. Thus, m_1 equals 6 and m_2 equals 1, which is the constant term common in both models. If a sample size of 25 is assumed, the degrees of freedom-numerator are equal to 6 minus 1, or 5; and degrees of freedom-denominator are equal to 25 minus 6, or 19 (Table 3). The regression sum of squares term is calculated by the amount of variance explained by the trend surface, which is required as input into the program. The residual sum of squares term is calculated by substracting the variance explained from the total variance, which is also required as input, to arrive at the variance unaccounted for by the trend surface. The mean sum of squares for each term is, in turn, calculated by dividing the corresponding degrees of freedom, and the resulting ratio of these two mean sum of squares yields an F-value. By comparing this F-value with a tabulated F-ratio for a selected alpha level, found in most statistical tables, a decision on statistically accepting or rejecting the trend surface can be made. The completion of this analysis of variance in the format shown in Table 3 is the function of the subroutine, Report 1 (Table 2).

In addition, model comparison between trend surfaces is also completed by the function of subroutine, Report 2. The model comparison directly answers the major question of determining the order of best fit previously proposed by Davis (4). In the case of trend-surface analysis, the full model corresponds to the higher-order trend surface; and the restricted model corresponds to the lower-order trend surface, or 1 order less than the order in the full model. Again, the degrees of freedom and resultant F-value are reached as previously defined. Hence, an investigator can determine, by use of this computer program, the trend surface that statistically best fits geographically distributed data.

SUMMARY

The relatively simple computer program presented here utilizes ANOVA techniques to help researchers make a more effective and statistically sound decision in the selection process involved in trend-surface analyses. The author recommends that this test should be routinely used in geophysical and sociological surveys involving analyses of trends and their prediction.

ACKNOWLEDGMENTS

I appreciate the help and constructive criticism given in the development of the program by Gayle Seymour, systems analyst at the University of Akron.

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Additions to the Distributional List of Kentucky Trichoptera: Big Sandy River (Boyd County); Pond Creek and Scenic Lake (Henderson County)[1]

KIM H. HAAG AND PAUL L. HILL

Department of Biology, University of Louisville Louisville, Kentucky 40292

ABSTRACT

Adult caddisflies were collected from the Big Sandy River in Boyd County, and from Pond Creek and Scenic Lake in Henderson County, Kentucky. A total of 40 species in 7 families were identified, including 4 new state records: *Pycnopsyche indiana* (Ross), *P. luculenta* (Betten), *P. scabripennis* (Rambur), and *Ironoquia lyrata* (Ross). Occurrence of *I. lyrata* in Kentucky represents a southern range extension in North America.

INTRODUCTION

The caddisflies of Kentucky have been thoroughly examined in a few drainages only, and many areas remain unstudied in the state. Resh (1) compiled the first distributional list of Trichoptera in Kentucky, relying on his own collections as well as those from universities throughout the region. No species were listed from Boyd County, while only *Potamyia flava* and *Ceraclea maculata* were reported from Henderson County. This paper presents the results of collections of adult caddisflies from the Big Sandy River at Ashland, in Boyd County, and from Pond Creek and Scenic Lake, in Henderson County. A total of 40 species in 17 genera were identified, representing 7 families.

RESULTS

Big Sandy River

The Big Sandy River and its tributaries drain southeastern Kentucky and southwestern West Virginia. The stream joins the Ohio River at Ashland, Kentucky (ORM 322.6) and has a mean summer discharge of 1,965 cfs. Water-quality data were published by the U.S. Geological Survey (2). Caddisfly adults were collected qualitatively at several outdoor lights on the property of the Ashland Oil Company, from 14 June to 9 October 1973. A total of 350 specimens were taken during the summer, including 28 species referable to 5 families (Table 1). While most of the individuals taken represent county records, the species *Ironoquia lyrata*, *Pycnopsyche indiana*, *P. luculenta*, and *P. scabripennis* are new state records. The occurrence of *I. lyrata* (Ross) in Kentucky represents a southern range extension for the species, previously known only from Illinois and Pennsylvania (3), New Hampshire (4), Maine (5), and northern Ohio (6).

The family Hydropsychidae was numerically dominant, and emergence of adults spanned the entire season. *Cheumatopsyche pettiti*, the most abundant species, emerged throughout the sum-

[1] University of Louisville, Department of Biology Contribution No. 203.

TABLE 1.—LIST OF CADDISFLIES COLLECTED FROM BOYD AND HENDERSON COUNTIES, KENTUCKY

	Big Sandy River	Scenic Lake	Pond Creek
RHYACOPHILIDAE			
Rhyacophila fenestra Ross	3 m		
POLYCENTROPODIDAE			
Cyrnellus fraternus (Banks)	2 f, 1 m	1 f, 1 m	1 f, 1 m
Polycentropus sp.	1 f, 1 m		
Nyctiophylax affinis (Banks)		1 f, 3 m	
HYDROPSYCHIDAE			
Diplectrona modesta (Banks)	2 m		
Cheumatopsyche burksi Ross		1 f, 7 m	
C. harwoodi harwoodi Denning		2 f	14 f, 9 m
C. pettiti (Banks)	85 f, 92 m		2 f, 2 m
Hydropsyche betteni Ross	5 f, 1 m		
H. orris Ross	2 m	10 f, 11 m	
H. valanis Ross	1 f	3 f	
H. sp.	10 f		
Potamyia flava (Hagen)	4 f, 3 m	30 f, 81 m	
HYDROPTILIDAE			
Oxyethira pallida (Banks)		85 f, 20 m	
Orthotrichia aegerfasciella (Chambers)		2 f, 20 m	
Orthotrichia cristata Morton		3 f, 3 m	
PHRYGANEIDAE			
Phryganea sayi Milne		1 f	
LIMNEPHILIDAE			
***Ironoquia lyrata* (Ross)	1 f, 1 m		
I. punctatissima (Walker)	1 f, 2 m		
***Pycnopsyche indiana* (Ross)	1 m		
***P. luculenta* (Betten)	1 f, 1 m		
***P. scabripennis* (Rambur)	1 f		
LEPTOCERIDAE			
Ceraclea ancylus (Vorhies)		2 f	
C. cancellata (Betten)	10 f, 17 m	2 f	
C. maculata (Banks)	14 f, 6 m		
C. tarsipunctatus (Vorhies)	3 f, 1 m	2 f, 2 m	
Nectopsyche exquisita (Walker)	2 f, 3 m		
Nectopsyche sp.	5 f		
Triaenodes abus Milne			2 f, 6 m
T. connatus Ross	1 f, 2 m		
T. flavescens Banks	1 m		
T. ignitus (Walker)	1 f, 2 m		
T. injustus (Hagen)		1 f, 1 m	
T. tardus Milne			1 m
Oecetis cinerascens (Hagen)	1 f	1 m	
O. ditissa Ross	3 f, 3 m	2 f	1 f, 1 m
O. inconspicua (Walker)	1 f	9 f, 4 m	1 m
O. nocturna Ross	13 f, 30 m		
O. persimilis (Banks)	6 f, 3 m		

m = male; f = female; ** = State record.

mer, but was found in greatest numbers in June and early July, following a pattern seen in Salt River in 1971 (7). Members of the Leptoceridae also showed an emergence pattern which extended through the entire summer. Congeneric species in this family did not appear to show temporal segregation. Although limnephilids were found in low numbers, their emergence patterns did suggest temporal isolation of congeners. *Pycnopsyche indiana* was found only in mid-June while *P. scabripennis* was present in a late August collection, and *P. luculenta* was seen only in late September and early October. However, *Ironoquia lyrata* and *I. punctatissima* were found in low numbers in both mid-June and late September.

Scenic Lake, Audubon State Park

Blacklight trap collections were made on 14 June 1981 near a small unnamed creek which drains Scenic Lake. This man-made lake is the largest body of water within the John James Audubon State Park, just outside the city limits of Henderson, Kentucky. The small, woodland stream that drains Scenic Lake flows into the Ohio River approximately 2.4 km downstream from the collection site. A total of 294 specimens were collected, including 18 species in 5 families. *Potamyia flava*, commonly found in large rivers, was the most abundant species taken, suggesting that the light trap was attracting caddisflies emerging from the nearby Ohio River. *Oxyethira pallida*, the second most abundant species, is known to live in small lakes and ponds such as Scenic Lake (8).

Pond Creek, Jenny Hole Wildlife Area

Insects were collected from Pond Creek in the Jenny Hole Wildlife Area on 27 July 1981, using blacklight traps. Pond Creek is the primary drainage stream for the entire Henderson Sloughs Wetlands in western Henderson County. The undulating terrain of the area provides an unusual habitat of marshes, streams, and cypress swamps. Pond Creek is a sluggish, heavily silted tributary of Highland Creek that flows into the Ohio River at Uniontown, Kentucky. The small collection of 43 adults, including 8 species in 3 families, may reflect the high turbidity, low dissolved oxygen, and generally unfavorable conditions of surface waters in this area (9).

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Antibiotic Sensitivity in Group A Streptococci: Evidence for Chromosomal Resistance

JULIE C. CHRISTOPHER, JOAN S. MYLROIE, AND JAMES G. STUART
Department of Biological Sciences, Murray State University, Murray, Kentucky 42071

ABSTRACT

Two hundred ten clinical isolates of *Streptococcus pyogenes* were tested for constitutive and inducible resistance to penicillin, tetracycline, erythromycin, lincomycin, chloramphenicol, and gentamicin. Of the 210 isolates tested by the disc-plate method, 71 appeared resistant to at least 1 of the antibiotics although none of these isolates were resistant to chloramphenicol. Minimal inhibitory concentration testing revealed that 48 isolates were resistant to tetracycline (16.2%), lincomycin (1%), erythromycin (6.2%), gentamicin (2.4%). No isolates were resistant to penicillin or chloramphenicol. Also, no inducible antibiotic resistance was noted. Twenty of 210 isolates exhibited minimal inhibitory concentrations above the average serum level for tetracycline (15.7%), erythromycin (0.5%), lincomycin (1.0%), or gentamicin (2.8%). The clinically resistant isolates were screened for the presence of extrachromosomal DNA by gel electrophoresis but no plasmids were detected. Efforts to cure several antibiotic resistant strains were unsuccessful. The physical and genetic evidence indicated a chromosomal location for genes mediating antibiotic resistance of the isolates examined in this study.

INTRODUCTION

Surveys of antibiotic sensitivity of group A streptococci have been reported from the U.S. (1, 2) as well as from a number of other countries (3, 4, 5), with the most extensive work being done by Dixon and Lipinski (6) in Canada. In several instances (7, 8), antibiotic resistance in *Streptococcus pyogenes* has been shown to be a plasmid-mediated phenomenon. To date, 6 plasmids have been described (7, 8, 9, 10) which mediate macrolide, lincomycin and streptogramin B (MLS) resistance in this species.

Inducibility of antibiotic resistance in *S. pyogenes*, first reported by Hyder and Streitfeld (11), is a property associated with 5 of the 6 plasmids mentioned above. Thus, a pattern seems to be emerging whereby the MLS genotype is usually plasmid borne and inducibly expressed. A question which remains to be answered in *S. pyogenes* is: what is the incidence of plasmid-borne antibiotic resistance among clinical isolates resistant to one or more antibiotics? Data provided in this report indicate that plasmid-borne antibiotic resistance is uncommon among group A streptococci isolated in Kentucky.

MATERIALS AND METHODS

Bacterial Strains.—Clinical isolates of *Streptococcus pyogenes* were supplied by the Kentucky Bureau for Health Services (184 isolates) compliments of G. Kilgore and by the Student Health Service of Murray State University (26 isolates). All isolates were obtained from throat cultures processed from approximately Fall 1978 through January 1980. Streptococcal isolates were grouped by the fluorescent-antibody method at the Kentucky Bureau for Health and by the bacitracin-disc technique at Murray State University Student Health Service. Following identification of each isolate as a group A streptococcus, the culture was received and analyzed as described below. Antibiotic-sensitive control strains included 9440 and K56 (12). Plasmid-containing control strains included a group A strain, ACl, obtained from Clewell and Franke (8) and a group B strain MV154 described by Hershfield (13).

Media.—The standard (YTH) broth medium consisted of Todd Hewitt broth (Difco) supplemented with 0.6% Yeast Extract (Difco) plus 0.038% K_2HPO_4. YTH agar consisted of YTH broth with 1.5% agar.

Antibiotics.—These were obtained in powder form from Sigma except lincomycin which was obtained from Upjohn as the injectable hydrochloride.

Disc Plate Screening.—Two overnight cultures of each isolate were cultivated, one in YTH broth and one in YTH broth containing subinhibitory concentrations of the 6 antibiotics tested. One tenth ml aliquots from each overnight culture were spread on the surface of YTH agar plates. Paper discs (Difco) individually impregnated with penicillin (5 units), erythromycin (2 μg), lincomycin (2 μg), tetracycline (5 μg), chloramphenicol (5 μg), and gentamicin (10 μg) were applied to each agar plate. The agar plates were incubated at 37°C for 24 hours, and zones of growth inhibition measured and recorded in mm. The inhibitory zone diameters for each antibiotic against the control strains (K56 and 9440) were averaged, and those test isolates that had zones of inhibition less than ½ the control zone were considered presumptively resistant (pr).

Minimal Inhibitory Concentrations.—Each pr isolate was tested for the minimal inhibitory concentration (MIC) by a microtiter dilution technique adapted from Baker and Thornsberry (14). Each isolate was grown overnight as before in YTH broth and in YTH broth containing subinhibitory concentrations of the antibiotic(s) to be tested. Each overnight culture was diluted 1/100 in YTH broth, then distributed in 25 μl aliquots to wells of the microtiter dish. Previous to the inoculation of bacteria, 50 μl of YTH broth supplemented with the appropriate antibiotic were added to the first well and doubling dilutions were made. Strains K56 and 9440 served as sensitive controls and the average MIC for each antibiotic was determined. Test isolates with MICs 16 times the control average were considered resistant. Criteria for inducibility were set at the same level (i.e., inducibly resistant strains showed at least 16-fold difference between pre-induced and non-induced cultures). Clinically resistant strains possessed MIC values higher than the average human serum level for that antibiotic.

DNA Isolation.—Cell lysis was accomplished by a procedure described by Forbes and Ferretti (pers. comm.). Antibiotic resistant strains were cultivated at 37 C in 200 ml of YTH broth containing antibiotics to which each strain was resistant at a concentration of ½ the MIC value. Penicillin G (110 units/ml) was added to late log-phase cells and incubation continued for 2 hours. Cells were then harvested by centrifugation and the pellet frozen before use. The pellet was resuspended in 5 ml of 0.15 M Trizma (Sigma) base-HCl at pH 6.4 containing 4 mg of lysozyme (Natl. Biochem. Corp.) and 5 ml of 0.25 M EDTA and the suspension was incubated at 37°C for 3.5 hr. The cells were then pelleted and resuspended in 10 ml of 0.1 M sodium citrate, plus 0.8 ml of a 5% solution of protease (Sigma type V) with overnight incubation degraded the remaining proteins and enhanced cell lysis.

The method of separation of chromosomal DNA from plasmid DNA was essentially that described by Currier and Nester (15).

Gel Electrophoresis.—Gel electrophoresis of the experimental and control (ACl and MV154) DNA was accomplished by the method of Sharp et al. (16). Both tube gels (Buchler) and slab gels (Savant) were used for the separation and visualization of plasmid DNA. Ten or 20 μg of each DNA preparation was layered on the slab and tube gels, respectively.

Curing Methods.—Four plasmid curing methods were utilized: (a) storage of the isolates on blood agar slants at 4°C for at least 6 mo., (b) incubation of isolates with subinhibitory concentrations of ethidium bromide in YTH broth at 37°C for 24 hr, (c) incubation of the isolate at an elevated temperature (42°C) in YTH broth for 18 hr (13, 8) and (d) incubation at a high temperature (45°C) for an extended period (2–3 weeks) according to Clewell et al. (17).

RESULTS

Disc Plate Screening.—Of the 210 isolates tested, 71 exhibited presumptive resistance to at least one antibiotic by this

TABLE 1.—PERCENTAGES OF ANTIBIOTIC RESISTANT GROUP A ISOLATES DETERMINED BY THE MINIMAL INHIBITORY CONCENTRATION METHOD

Antibiotic	%* Resistance	r/pr × 100
Penicillin	0%	0%
Erythromycin	6.2%	86.7%
Lincomycin	1.0%	40.0%
Tetracycline	16.2%	70.8%
Gentamicin	2.4%	29.4%
Percentages of Multiply Resistant Group A Isolates		
Antibiotics	% Resistant	r/pr × 100
Gentamicin, Tetracycline	1.0%	33.3%
Erythromycin, Lincomycin	1.0%	100%
Erythromycin, Tetracycline	0.5%	100%
Erythromycin, Gentamicin, Tetracycline	0.5%	100%

* Per cent based on 210 isolates tested.

method. No isolates demonstrated resistance to chloramphenicol. Resistance to penicillin, erythromycin, lincomycin, tetracycline, and gentamicin was demonstrated by 3, 15, 5, 48, and 18 isolates, respectively.

MIC Testing.—Seventy of the pr isolates (1 stock was lost) were quantitated for antibiotic sensitivity. Although no pr isolates were noted exhibiting chloramphenicol resistance, 24 isolates were chosen for MIC testing. Percentages of resistant isolates are presented in Table 1. No inducible resistance was exhibited by any isolate tested by the MIC method. The largest category of resistance included those isolates resistant to tetracycline (16.2%), whereas no pr isolates were found to be resistant to penicillin by this method. The best agreement between disc-screened resistance (pr) and MIC testing (r) was observed with erythromycin testing.

Multiple resistance was confirmed in 6 isolates with the MIC procedure (Table 1). Five of the isolates were doubly resistant, whereas 1 isolate exhibited resistance to 3 antibiotics.

Table 2 presents MIC ranges and medians compared to average serum levels of the 6 antibiotics tested. The highest level of clinical resistance (15.7%) was noted among the tetracycline resistant isolates. No strains were clinically resistant to chloramphenicol or penicillin, although 1 strain exhibited clinical resistance to erythromycin.

Gel Electrophoresis.—With the exception of 6 strains lost from culture, the clinically resistant strains plus 12 additional erythromycin resistant strains were subjected to DNA isolation procedures and gel electrophoresis. Figure 1 shows the control strains ACl and MV154 with the characteristic chromosomal and plasmid bands of DNA compared to 8 experimental strains and plasmid negative 9440. No plasmids were detected in any of the clinical isolates tested with tube or slab gels.

Curing.—Several clinical isolates and the positive plasmid control strain ACl were subjected to a variety of curing procedures shown in Table 3. Curing frequencies in strain ACl varied from 0.5%–98.8% depending upon the curing regi-

TABLE 2.—ANTIOBIOTIC RESISTANCE LEVELS DETERMINED BY THE MINIMAL INHIBITORY CONCENTRATION METHOD

Antibiotic	Number of strains tested	Range (μg/ml)	Median (μg/ml)	Average serum[c] level (μg/ml)	Percent[a] clinically resistant
Penicillin[b]	3	0.00–0.1	0.01	11.5	0%
Erythromycin	15	0.01–10.0	1.56	6.0	0.5% (1)
Lincomycin	5	0.01–125.0	0.08	11.0	1.0% (2)
Tetracycline	48	0.31–125.0	11.25	3.0	15.7% (32)
Gentamicin	17	0.12–38.6	1.21	4.5	2.9% (6)
Chloramphenicol	24	0.62–2.5	1.25	7.5	0%

[a] Percent based on 210 isolates tested.
[b] The penicillin used in this survey contained 1.675 units/μg.
[c] From Lennett et al. (20).

FIG. 1. Slab Gel Electrophoresis (1.0% agarose). Slots #1, #2, and #3 are control strains. Slot #1 contains strain 9440 which possesses only chromosomal (chr) DNA. Slots #2 and #3 contain MV154 and ACl, respectively and both possess chromosomal and plasmid (pl) DNA. Clinical isolates are located in slots 4–11 and reveal only chromosomal DNA.

men utilized. No curing was observed among the selected clinical isolates with any of the procedures employed.

TABLE 3.—CURING OF SELECTED CLINICAL ISOLATES

Strain	Antibiotic resistance selected*	Agent†	% Curing
AC1	Ery	Control + Anti	0
AC1	Ery	EB	0.5
AC1	Ery	NS	97.7
AC1	Ery	NS + EB	98.1
AC1	Ery	NS + 42°C	98.8
25	Tet	NS + 42°C	0
154	Tet	NS + 42°C	0
1148	Tet, Gm	NS + 42°C	0, 0
2372	Ery	NS	0
2372	Ery	NS + EB	0
2372	Ery	NS + 42°C	0
2566	Ery	NS + 42°C	0
2566	Ery	NS + 45°C	0
2628	Ery	NS + 42°C	0
2723	Ery	NS + 42°C	0
2723	Ery	NS + EB	0
3017	Ery	NS + 42°C	0
3017	Ery	NS + EB	0
3019	Lin	NS + 42°C	0
3019	Lin, Ery	NS + 42°C	0, 0
3052	Lin, Ery	NS + 42°C	0, 0
3052	Lin, Ery	NS + 42°C + EB	0, 0
6003	Tet	NS	0
6028	Gm	NS + 42°C	0

* Tet (tetracycline), Ery (erythromycin), Lin (lincomycin), and Gm (gentamycin).

† NS (natural segregation of cells following refrigeration for at least six months), EB (ethidium bromide), 42 C (temperature at which cells were incubated prior to plating), and Control + Anti (the control experiment whereby the cells were grown in the presence of the antibiotic to which they were resistant).

DISCUSSION

The result of the antibiotic disc plate and MIC testing are comparable to reports of Dixon and Lipinski (18). However, our data showed higher incidences with higher MICs for tetracycline, erythromycin, and lincomycin resistance than other reports from this country (1, 2). This study indicates a continuing sensitivity of group A strains to penicillin, although as suggested earlier by Dixon and Lipinski (18) sensitivity testing should be performed when administering an alternative drug for penicillin-allergic patients.

The plasmid survey produced a surprising lack of data in comparison to reports concerning plasmids in other streptococcal species (19, 13). This is the first study to our knowledge which attempts to correlate antibiotic resistance with the presence or absence of plasmids in a population of clinical isolates. The physical evidence and curing data suggest that antibiotic resistance plasmids are rare in group A streptococci. This is further supported by the fact that only 6 plasmids from *S. pyogenes* have been described and all confer the MLS phenotype (7, 8, 9, 10). Interestingly all 6 of the plasmids are derived from a survey by Dixon and Lipinski (6) of 18,628 *S. pyogenes* isolates. Five of the 6 plasmids conferred inducible resistance, and all 5 exhibited high level resistance to erythromycin (200 μg/ml) and lincomycin (200 μg/ml). Notably, none of the isolates tested in this study exhibited inducible resistance nor MICs of this magnitude. Curing rates of 0.5% for ACl using ethidium bromide were comparable with those reported by Clewell using acridine orange (8). Additionally, excellent curing (98%) was obtained by storage at 4°C. This represents the most effective method yet reported for curing plasmids in this species.

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Terrestrial Beetles (Coleoptera) of Bat Cave, Carter County, Kentucky

David Bruce Conn[1] and Gerald L. DeMoss

Department of Biological and Environmental Sciences,
Morehead State University, Morehead, Kentucky 40351

Abstract

A survey of cavernicolous beetles in Bat Cave, Carter County, Kentucky was made using pitfall trapping, Berlése extraction and visual census. Distribution observations revealed relative proximity of beetles to *Myotis sodalis* Miller and Allen guano deposits in the cave's upper level or stream-bank detritus deposits in the lower level. Of 26 beetle taxa collected, only 4 were common. Of these, 3 were associated primarily with bat guano deposits. *Aglenus brunneus* (Gyllenhal) and *Prionochaeta opaca* (Say) were restricted to a single upper-level room containing large guano deposits. *Echochara lucifuga* Casey occurred throughout the cave, but was more common in the upper level. *Atheta* sp. occurred throughout the cave with approximately equal numbers in the upper and lower levels. The other 22 taxa were found less frequently and were associated primarily with stream-bank detritus in the lower level; most were considered to be accidental in Bat Cave.

Introduction

Bat Cave in Carter County, Kentucky is one of the world's largest hibernacula for the endangered Indiana Bat, *Myotis sodalis* Miller and Allen, an estimated 40,000 of which hibernate in the cave (1) along with fewer individuals of other species (2, 3). Several studies of bats have been made in Bat Cave, but other fauna largely has been ignored, despite the fact that bats, through guano deposition, provide a food supply which is not available in most eastern Nearctic caves, where bats rarely occur in such large numbers.

Several references have been made to beetles from Carter County caves, but only 10 species have been reported, including 7 from Bat Cave (4–13). None of those reports examined intra-cave distribution patterns; all were parts of studies covering a wider geographic area. In each of the previous studies, Carter County caves were mentioned only as related to general collection locality.

The present study was initiated to catalog the terrestrial coleopteran fauna of Bat Cave and to determine its basic distributional patterns, especially with regard to the occurrence of *M. sodalis* guano deposits. This provides a basis for further studies on the dynamics of the Bat Cave ecosystem and an insight into the role of *M. sodalis* in that system.

Materials and Methods

Bat Cave is approximately 1,030 m long and has over 2,100 m of accessible passageway with 2 entrances and 2 main levels (Fig. 1). The upper level is dry and has a clay loam floor with some rimstone pools and flowstone. Approximately 3 m below this, the lower level is primarily a stream channel for Cave Branch which flows year-round. Bat guano is the primary food souce in the upper level and stream-deposited plant detritus is the primary food source in the lower level.

Weekly visits to Bat Cave were made between 11 July 1979 and 29 March 1980. Three methods were used to collect beetles. Endogenous and cursorial beetles were collected by visual survey and capture, including searching under rocks, logs and detritus. Edaphic beetles were collected by Berlése extraction, as were some vagile forms. For extraction, each substrate sample (approximately 1 liter) collected at various points in the cave throughout the study period, was placed in an 18-cm plastic funnel supplied with

[1] Present address: Department of Biological Sciences, University of Cincinnati, Cincinnati, Ohio 45221.

TABLE 1.—IDENTIFICATIONS, FREQUENCY OF OCCURRENCE, DEVELOPMENTAL STAGES AND DISTRIBUTION OF BEETLES COLLECTED FROM BAT CAVE, CARTER COUNTY, KENTUCKY (A = ADULT, L = LARVA, * = FIRST REPORT FROM CARTER COUNTY CAVES)

	Number collected	Distribution
Brathinidae		
Brathinus nitidus	2 (A)	stream-bank detritus
Cantharidae		
*Cantharid larvae	3 (L)	Traps 3, 6, 9
Carabidae		
Carabid larvae	4 (L)	stream-bank detritus
Agonum sp. #1	8 (A)	Traps 1, 4, 6; stream-bank detritus
Agonum sp. #2	1 (A)	stream-bank detritus
Bembidion wingatei	9 (A)	stream-bank detritus
**Clivina* sp.	1 (A)	stream-bank detritus
**Dyschirius* sp.	1 (A)	stream-bank detritus
**Omophron americanus*	1 (A)	Trap 6
Pterostichus sp.	1 (A)	Trap 4
Colydiidae		
**Aglenus brunneus*	88 (A)	summer guano piles
	40 (L)	near Trap 1
Histeridae		
**Dendrophilus* sp.	1 (A)	Trap 3
Leptodiridae		
**Nemadus horni*	3 (A)	Traps 3, 5
Prionochaeta opaca	116 (A)	Traps 1, 2; summer bat room
Nitidulidae		
**Glischrochilus fasciatus*	3 (A)	Traps 3, 5
Pselaphidae		
**Batrisodes* sp.	4 (A)	stream-bank detritus
Ptiliidae		
**Ptenidium* sp.	7 (A)	Traps 3, 4; stream-bank detritus
Scydmaenidae		
**Scydmaenus* sp.	1 (A)	stream-bank detritus
Staphylinidae		
*Staphylinid larvae	170 (L)	Trap 8
**Echochara lucifuga*	56 (A)	Traps 1, 2, 4, 5, 6, 7, 8, 9; summer bat room
**Atheta* sp.	213 (A)	Traps 1, 2, 3, 4, 5, 6, 8, 9, winter guano deposits; stream-bank detritus; bat carcasses in lower level
**Homaeotarsus* sp.	1 (A)	Trap 4
**Psephidonus* sp.	1 (A)	Trap 6
**Quedius* sp. #1	1 (A)	Trap 7
**Quedius* sp. #2	3 (A)	Traps 7, 9; stream-bank detritus
**Stenus* sp.	2 (A)	stream-bank detritus
**Tachinus* sp. #1	4 (A)	Traps 3, 5, 7; stream-bank detritus
**Tachinus* sp. #2	1 (A)	Trap 5

a 60-w incandescent bulb. Because many cavernicoles are cryptic in habit, pitfall traps similar to those described by Barber (7) were used primarily to attract scavengers. Each trap was set by burying a 4-cm × 10-cm glass vial in the cave floor, leaving the rim flush with ground level. Approximately 5 g of spoiled pork liver bait was wrapped in cheesecloth and hung into the vial from 6-mm mesh hard-

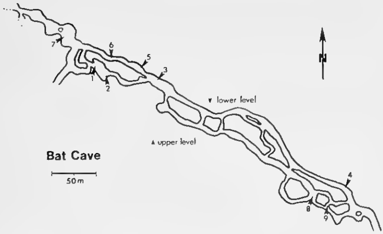

FIG. 1. Map of Bat Cave, Carter County, Kentucky showing locations of pitfall traps.

ware cloth. Galt's solution, a non-repellent narcotizing and temporary preserving agent, was poured into each vial to a depth of 2 cm. Nine traps were set at various points throughout the cave (4 upper, 4 lower, and 1 between levels) with different physical and biotic features. Sites were as follows (see 14 for more detailed descriptions): *Trap 1:* upper level; clay loam and breakdown block substrate; wet-weather seepage; as in previous years (2), several hundred bats occurred here throughout summer, leaving large guano deposits. *Trap 2:* upper level; clay and breakdown block substrate; wet-weather seepage; approximately 9 m from guano beds at *Trap 1*. *Trap 3:* lower level; thick piles of plant detritus atop breakdown blocks. *Trap 4:* lower level; small stones and streambed gravel substrate; in main hibernation room, but little guano or detritus. *Trap 5:* lower level; clay loam and breakdown block substrate; thin layer of plant detritus. *Trap 6:* lower level; alluvial sand substrate; periodic flooding left little guano or detritus. *Trap 7:* upper level; clay substrate; intermittent trickle; some wood planks and guano. *Trap 8:* upper level; clay loam substrate; small trickles during heavy rainfall; thin layer of guano deposited during winter bat activity. *Trap 9:* passage connecting levels; clay substrate; shallow pools; no guano or detritus.

All collecting was restricted to the aphotic zone and great care was taken at all times to avoid disturbing the bats.

Beetles were preserved in 70% ethanol. Some small forms were bleached in 30% NaOH, cleared in clove oil and mounted in Kleermount for compound microscopy.

RESULTS

A total of 746 beetles, representing 11 families and at least 26 species, was collected (Table 1). Only *Echochara lucifuga* Casey and *Atheta* sp. were distributed widely in the cave. Among most traps, *E. lucifuga* was collected more often in the upper level and *Atheta* sp. in the lower level. However, both species had highest densities at Trap 8, an upper-level trap.

DISCUSSION

Of the 26 taxa collected, 19 were found less than 5 times, making their status in Bat Cave difficult to determine. Most of these were collected in the lower level within short periods following flooding of Cave Branch and thus are considered to be accidental wash-in victims.

Six of the species collected less than 5 times in this study are reported to be common in caves by other authors. *Brathinus nitidus* LeConte was collected only twice, but often has been found in caves throughout the southeastern United States (15) and has been collected in Bat Cave previously (9, 13). As an epigean riparian insect, *B. nitidus* is probably subject to frequent transport into Bat Cave by flood waters of Cave Branch; but repeated occurrence of this species in caves may indicate a trogloxenous (periodically cavernicolous) habit.

Pterostichus sp. was collected only once, but some members of this genus are found often in Nearctic caves (16). Bolivar and Jeannel (8) found *P. honestus* in Bat Cave. Though common in epigean habitats, *Pterostichus* is probably a threshold trogloxene.

Batrisodes sp. was collected 4 times, always by Berlése extraction from streambank detritus. This species may be more common in Bat Cave than these data indicate. The genus is common in caves and includes many troglophilic (facultatively cavernicolous) and troglobitic (obligately cavernicolous) species (17).

Quedius spp. were collected only 4 times, but some species of this genus are common in caves throughout the eastern United States (13). Some species are considered to be successful troglophiles, but the present report is the first for *Quedius* in an eastern Kentucky cave.

Cantharid larvae, collected only 3 times in this study, are encountered frequently in North American caves and are considered by Peck (18) to be important trogloxenous predators.

Seven species were collected more than 5 times and thus show more certain distributional trends. *Ptenidium* sp. was collected only near stream-bank detritus in the lower level. The genus is a common epigean group and generally inhabits decaying plant material. The regular occurrence of *Ptenidium* sp. in Bat Cave throughout the study period and the fact that 2 of those collected were tenerals, suggests that this species is an occasional troglophile, although the genus has never been reported as such.

Agonum sp. #1 was collected in the upper and lower levels, and usually was close to large organic deposits. *Agonum* is common in eastern Nearctic caves and some species are considered to be habitual trogloxenes (16) or troglophiles (13). Prior to the present study, *A. angustatus* and *A. tenuicollis* were collected in Cascade and Bat caves, respectively (13).

Bembidion wingatei Bland was associated with stream-bank detritus throughout the study period. Harker and Barr (13) reported this species to be common in Bat Cave. Barr (16) concluded that *B. wingatei* is a troglophile. The collection of a teneral in the present study supports that opinion.

Prionochaeta opaca (Say), *Aglenus brunneus* (Gyllenhal), *Echochara lucifuga* and *Atheta* sp. occurred in Bat Cave as well-established troglophilic populations. This is the first report of such populations of the latter 3 species in eastern Kentucky caves. Peck (12) reported such populations of *P. opaca* from several eastern Nearctic caves and collected specimens in Bat Cave. In the present study, *P. opaca* was collected only in the summer bat room and only in the fall. Similarly, *A. brunneus* was collected only in the summer bat room. Berlése extraction was the only method by which *A. brunneus* was collected. To avoid possible population depletion, no samples were taken in this area after October. However, presence of all life cycle stages in fall samples suggests lack of seasonality. This species is blind and depigmented, but is found in epigean habitats and is thus not truly troglobitic.

Atheta sp. and *E. lucifuga* were abundant in Bat Cave during the entire study period, occurring in highest densities near Trap 8. Large numbers of staphylinid larvae were collected only in Trap 8 and may have represented one or both species. Despite the lack of reports of these genera from eastern Kentucky caves, both are known to be successful troglophiles in other areas (15, 19).

One beetle not collected in the present study deserves special mention. The troglobitic trechine carabid, *Pseudanophthalmus packardi* Barr, is a very rare riparian species which is known to occur only in caves of Carter County (10, 13).

Myotis sodalis guano deposits appear to influence distribution of beetles in Bat Cave. Most species in this study were associated with stream-bank detritus, but the more common species were found predominantly or completely in the upper level close to major guano deposits. Further studies are needed to elucidate the relationships between *M. sodalis* and cavernicolous invertebrates in Bat Cave, especially regarding the bat's role as a nutrient supplier.

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Ethanol and Acetylsalicylic Acid Effects on *in vitro* Incorporation of C-14 Phenylalanine in Rat Spleen Cells[1]

Gertrude C. Ridgel

Department of Biology, Kentucky State University, Frankfort, Kentucky 40601

Abstract

Experimental data indicated that ethanol-treated rat spleen cells may be inhibited in their ability to incorporate L-phenyl-[U-^{14}C]alanine. Summarized data demonstrated that a 0.4 mM ethanol concentration had little or no inhibitory effect while 1.5 mM and 3 mM ethanol concentrations significantly inhibited phenylalanine incorporation. In an experimental series investigating the effects of acetylsalicylic acid on phenylalanine incorporation, data indicated that there was little or no inhibition with concentrations of 1.2 mM, 0.6 mM and 0.3 mM. A third series of experiments showed that 3 mM ethanol strongly inhibited while 1.2 mM acetylsalicylic acid did not inhibit the ability of rat spleen cells to incorporate phenylalanine. No synergistic effect was observed when 3 mM ethanol and 1.2 mM acetylsalicylic acid were applied simultaneously.

Introduction

A popular mood-altering and medicinal drug in almost every human society has been, and is, alcohol. Its overconsumption produces pathological changes in tissues, especially liver tissue, and functional changes that may cause disability and death. Leiber (1) reviewed research reports on the hepatic and metabolic effects of alcohol in man and other mammals. Although there was much research verifying previous observations of interactions of ethanol and drug metabolism, and the elucidation of new microsomal pathways for ethanol oxidation, understanding the pathogenesis of alcohol hepatitis and cirrhosis remained unresolved.

A biophasic effect on aminotransferase activity was observed by Badawy (2) in liver extracts from rats that had been administered interperitoneal doses of ethanol. He suggested that the biophasic effect of ethanol was probably due to the release of adrenal components.

Morland and Bessesen (3) pointed out the difficulties of properly assaying *in vivo* results of alcohol effects on liver tissue because hormones and other extrahepatic factors can not be excluded. Using hepatocytes isolated from perfused liver tissue, they demonstrated that ethanol (50 mM) exposed cells were inhibited in the incorporation of valine by about 70%. They suggested that ethanol primarily affected the protein-synthesizing machinery of the cell.

Islam (4) showed that the presence of ethanol (40 mg %) in the incubation medium adversely affected the respiratory activity of rat leucocytes *in vitro*. He compared the respiration rates of nonphagocytizing leucocytes with phagocytizing leucocytes (heat-killed *E. coli*) after treatment with ethanol.

Using cells derived from Rueher hepatoma (H_4), Shields et al. (5) found that when these cells were exposed to ethanol (0.1 vol % and 1.0 vol %) they grew as well as untreated cells. Shields demonstrated that the level of alcohol dehydrogenase within the cell had no bearing on the ability of the cells to tolerate ethanol.

Ridgel et al. (6) demonstrated that crude preparations of spleen and liver cells were inhibited in the incorporation of leucine and phenylalanine after exposure to various concentrations of ethanol. They reported that phenylalanine incorporation was significantly higher than leucine in the system employed.

Aspirin, a common analgesic, is widely used to relieve human discomforts. The

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TABLE 1.—PROTOCOL

Groups	Reagents				
	MEM	Ethanol	Aspirin	Tissue-MEM	Radioactivity
Control(s)	.6 ml	0	0	2.2 ml	.2 ml
Killed (K)	.6 ml	0	0	2.2 ml	.2 ml
Killed spiked (2K)	.6 ml	0	0	2.2 ml	.2 ml
3 mM Ethanol	.4 ml	.2 ml	0	2.2 ml	.2 ml
1.5 mM Ethanol	.4 ml	.2 ml	0	2.2 ml	.2 ml
0.6 mM Ethanol	.4 ml	.2 ml	0	2.2 ml	.2 ml
1.23 mM Aspirin	.4 ml	0	.2 ml	2.2 ml	.2 ml
0.61 mM Aspirin	.4 ml	0	.2 ml	2.2 ml	.2 ml
0.30 mM Aspirin	.4 ml	0	.2 ml	2.2 ml	.2 ml
3 mM Ethanol + 1.23 mM Aspirin	.2 ml	.2 ml	.2 ml	2.2 ml	.2 ml

major side effects of aspirin treatment in humans have been tinnitus and gastrointestinal disturbances (7). Clinical research in humans gave evidence that salicylic acid provided more effective and safer treatment than did acetylsalicylic acid (8). These results showed that fecal blood loss after prolonged treatment with aspirin was greatly increased. Other side effects observed included headache, heartburn, nausea, emesis, and stomach upset. Kimerly and Platz (9) observed that human patients given anti-inflammatory dose levels of aspirin had elevated serum creatinine and blood urea nitrogen and decreased creatinine clearance. In patients with systemic lupus erythematosus, renal disease was elevated after aspirin treatment.

Studying the effect of acetylsalicylic acid on pain, Inoki et al. (10) reported that 200 mg/kg of aspirin administered into the intraperitoneal space of rats resulted in an inhibition of the release of kinen-forming enzyme following paw pricking and sciatic-nerve stimulation. Bowers et al. (11) reported aspirin administered intravenously to sheep appeared to cause increases in lung lymph flow and a higher lymph-protein clearance. Monolayer cultures of rat aorta smooth muscle cells exposed to 0.2 mM of aspirin for 30 minutes did not synthesize prostacyclins, but this synthesis was restored within an hour after removal of the aspirin (12). Vaughn and coworkers (13) investigated the effect of aspirin feeding in simulated altitudes on carbohydrate metabolism in rats. Their results demonstrated that aspirin treatment increased the activity of glutamic, oxalacetic, and glutamic pyruvate transaminases in the rat liver.

A review of the above suggests that aspirin and ethanol may have some effect on enzyme activity and perhaps protein synthesis. The present report gives results of investigations designed to validate earlier results in our laboratory on alcohol effects and to determine the ability of rat spleen cells to incorporate amino acid after treatment with aspirin alone and with aspirin and ethanol administered simultaneously.

MATERIALS AND METHODS

Sprague Dawley male rats weighing 150 to 200 grams were sacrificed by cervical dislocation after fasting for 24 h. The spleen was quickly removed, weighed, and pressed through a wire strainer into 30 ml of ice-cold Earle's Minimum Essential Media (MEM) pH 7.4 containing penicillin and streptomycin. After careful agitation to suspend cells, the cell mixture was allowed to stand in an ice-cold bath and decanted from the residue. The cell mixture was centrifuged at 2,000 rpm for 10 minutes and the pellet suspended in 30 ml of fresh MEM and strained through cheese cloth and centrifuged again. After a second resuspension and centrifugation, the pellet was suspended in 50 ml of MEM; this cell-mixture was used to establish the experimental groups according to the protocol (Table 1). Each

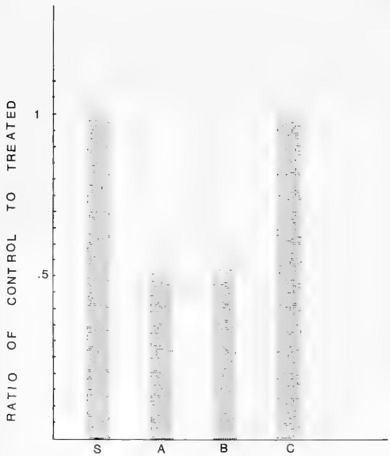

FIG. 1. The *in vitro* incorporation of L-[^{14}C] phenylalanine in rat spleen cells. Comparison of control (S) with experimental samples treated with 3 mM (A), 1.5 mM (B), and 0.4 mM (C) ethanol.

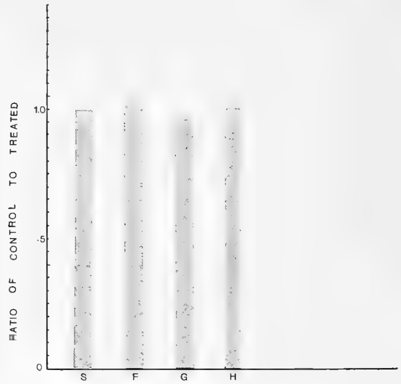

FIG. 2. The *in vitro* incorporation of L-[^{14}C] phenylalaine in rat spleen cells. Comparison of control (S) with experimental samples treated with 1.2 mM (F), 0.6 mM (G) and 0.3 mM (H) aspirin.

experimental group was set up in duplicate and some were triplicated.

All reagents were dissolved in MEM at the concentrations indicated in the protocol. Cell samples labeled K and 2K were killed by adding 3 ml of trichloracetic acid (TCA) and to the 2K sample was added a known concentration of radioactive phenylalanine to be used to determine the amount of quenching in the liquid scintillation system.

L-^{14}C-phenylalanine (513 mCu/m mol) at a concentration of 50 μci/ml was obtained from Amersham Corp. This amino acid was diluted with MEM so that each 0.1 ml contained 5.55×10^4 dpm. After incubation at 37°C for 50 min in a water bath shaker, 3 ml of ice-cold 20% TCA was added to each sample except the K and 2K. All samples were allowed to stand in the cold bath for 30 min and centrifuged at 5,000 rpm for ten min. Each pellet was washed in two changes each of TCA, absolute alcohol and distilled deionized water. Following each wash the samples were centrifuged at 5,000 rpm for ten min. The final pellets were treated as previously outlined (6) and counted on a Searle Model 6868A Isocap/200 Temperature Compensated Liquid Scintillation System.

The number of spleen cells in the experimental samples were determined by the standard procedures for leucocyte counting and the viability of cells was approximated by the exclusion of 0.4% trypan blue.

RESULTS

Figure 1 represents the results of summary data obtained from 10 rat spleens. It can be seen clearly that, at concentrations of 3 mM and 1.5 mM of ethanol, inhibition of the incorporation of phenylanine was nearly 50% of the control. However, the amino acid incorporation in spleen cells treated with 0.4 mM ethanol was no different from that of the control.

The results of phenylalanine incorporation obtained from rat spleen cells treated with 1.2 mM, 0.6 mM and 0.3 mM of aspirin were not significantly different from the results of nontreated preparations. Summary data of the 5 rat spleens are illustrated in Figure 2.

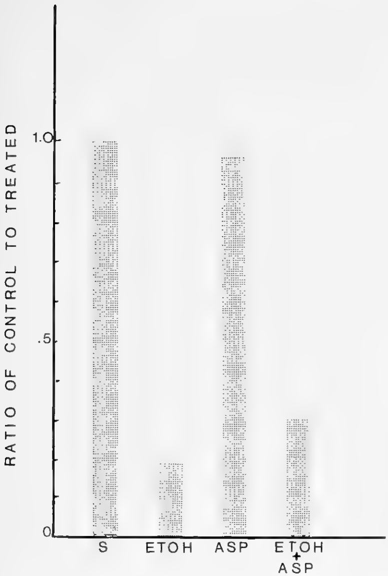

FIG. 3. The *in vitro* incorporation of L-[^{14}C] phenylalanine in rat spleen cells. Comparison of control (S) with experimental samples treated with 3 mM ethanol (ETOH), 1.2 mM aspirin (ASP) and 3 mM ETOH + 1.2 mM ASP.

In another series of experiments utilizing 4 rat spleens, 3 aliquots of a cell preparation from each spleen cell preparation were exposed to either 3 mM ethanol, 1.23 mM aspirin or a combined dose of ethanol (3 mM) and aspirin (1.23 mM). Figure 3 illustrates that 3 mM ethanol-treated cells had an 80% inhibition of incorporation when compared with controls; whereas a 1.23 mM aspirin-treated cell preparation had 3% inhibition. The latter results were shown not to be significantly different from those of the control using t-test for significant (0.05 level) differences of means. When 3 mM ethanol and 1.23 mM aspirin were added at the same time to spleen cell samples, the inhibition of radioactive phenylalanine was 70%.

TABLE 3.—RATIO OF TREATED/CONTROL IN INDIVIDUAL EXPERIMENTAL SERIES

Experimental series	3 mM ethanol	1.2 mM aspirin	3 mM ethanol + 1.2 mM aspirin
1	0.104	0.72	0.45
2	0.072	1.36	0.37
3	0.224	0.81	0.26
4	0.330	1.03	0.23

Tables 2 and 3 show the data of the experimental series mentioned in the above paragraph. A considerable amount of variation was observed between the individual series but there was clear indication that a dose of 3 mM ethanol inhibited the incorporation of phenylanine from 67 to 93%. In series 2 and 4, the phenylalanine incorporation was somewhat higher than that of the control in spleen cells exposed to 1.2 mM aspirin. Series 1 and 3 of the aspirin-treated cells incorporated phenylalanine at 72% and 81%, respectively. When 1.23 mM of aspirin and 3 mM of alcohol were administered at the same time to spleen cells,

TABLE 2.—COMPARISON OF ASPIRIN AND ALCOHOL EFFECTS ON THE UPTAKE OF [^{14}C] PHENYLALANINE BY SPLEEN CELLS

Experimental series	Control	3 mM ethanol	1.2 mM aspirin	3 mM ETOH + 1.2 mM aspirin
1	1,184 ± 34	123 ± 11	860 ± 29	534 ± 23
2	1,734 ± 42	125 ± 11	2,359 ± 49	649 ± 25
3	3,068 ± 55	688 ± 25	2,486 ± 50	787 ± 28
4	1,746 ± 48	576 ± 24	1,791 ± 42	409 ± 20
Average	1,933 ± 44	378 ± 19	1,874 ± 43	595 ± 21
Treated / Control		0.196	0.970	0.308
% inhibition		80.4	3	69.2

the incorporation of phenylalanine in the individual series ranged from 23% to 45%. These data suggest no synergistic effects between aspirin and alcohol.

DISCUSSION

Rat spleen cell preparations, by the technique employed in this investigation, can be used to study the effects of certain chemicals on the ability of the cells to incorporate amino acids. At doses of 3 mM ethanol and 1.2 mM aspirin, the highest concentrations used in these experiments, spleen cells remained adequately viable as determined by standard procedures for leucocyte counting and the trypan blue viability test. Perin et al. (14) and Morland and Bessesen (3) employed up to 150 mM of ethanol without serious lethality in their experimental systems with liver slices and hepatocytes, respectively.

The current results in our laboratory verify previous findings that certain concentrations of ethanol inhibit the ability of rat spleen cells to incorporate radioactive phenylalanine. Perin et al. (14) applied several amino acids, leucine, glycine, lysine, and theronine to their liver slices; however, they did not use phenylalanine. Their data demonstrated that inhibition in amino-acid incorporation was increased with increased doses from 0.5 mM to 150 mM. The data of Perin et al. (14) showed inhibition of 24% in leucine incorporation when liver slices were exposed to 1 mM ethanol. Previous results in our laboratory (6) from spleen cells treated with the equivalent of 1.5 mM ethanol showed 29% incorporation of leucine. Morland and Bessesen (3) demonstrate that the addition of 50 mM ethanol to liver cell preparations reduced incorporation to about 70%. If different systems react similarly, this would suggest that with increased dose of ethanol there would be increased inhibition in amino-acid incorporation.

Figure 1 demonstrates little difference between the inhibitory effects of 1.5 mM and 3 mM ethanol treatment and no effect with a dose as low as 0.4 mM. These results might suggest that there is a threshold level for ethanol effects and increased doses would not further affect the incorporation of the amino acid. However, based on the reports of Perin et al. (14) and Morland and Bessesen (3), who used higher concentrations of ethanol with increased inhibition, other factors must be responsible for the results obtained in our experiments. The difference observed in the summary data on incorporation of phenylalanine on 3 mM ethanol-treated cells between the 10 spleens (Fig. 1), 51%, and that of the 4 spleens (Fig. 3), 19.6%, demonstrate a significant variation. This type of variation in individual experiments cannot be explained. Preliminary results, data not included here, of recent experiments performed in our laboratory, suggested that 100 mM ethanol inhibited spleen-cell phenylalanine incorporation to over 80%. This latter report appears to argue against the threshold dose but more data must be amassed before a conclusion can be reached.

Spleen-cell preparations treated with 0.3 mM, 0.6 mM and 1.2 mM aspirin solutions incorporated radioactive phenylalanine at levels not significantly different from those of control preparations. Our interpretations of these results are contrary to those of other workers (10, 13), who showed increases and decreases in protein synthesis following aspirin administration. Whiting et al. (12) demonstrated that exposure of rat smooth muscle cells to 0.2 mM aspirin for 30 minutes completely inhibited the synthesis of 6-keto-prostacyclin from exogenous arachidonic acid. The fact that we observed incorporation of an amino acid and total protein synthesis rather than the synthesis of a specific protein, as was investigated by the Whiting team (12), may account for some of the differences in results.

When data from individual experiments on aspirin were reviewed, Series 1 and 2 (Table 3) showed the greatest departure from a 1:1 ratio between treatments and controls. Analyzing data from the individual series (Fig. 2), we found that in 4 of the 5 series of cell preparations treated with 1.2 mM aspirin the ratio of experimental : control ranged from 1.01 to 1.15. In the fifth series, the ratio was 0.65, although other dose treatments of aspirin in that series were at more expected levels. The 5 series of cell preparations treated with 0.6 mM aspirin gave experimental : control ratios ranging from 1.03 to 1.10, and with 0.3 mM aspirin from 0.86 to 1.27. Although the overall summary ratios for these doses in decreasing concentrations were 1.08, 0.96, and 0.99 respectively, the analysis of individual experiments might suggest a slight increase in total protein synthesis at the doses applied in our experiments.

When 3 mM ethanol and 1.2 mM aspirin were administered at the same time to a given spleen-cell preparation in four series of experiments, the experimental : control ratios ranged from 0.23 to 0.45. This variation reflected the type observed in other experiments. Apparently the effect of the ethanol on the cells was more dominant than that of aspirin, with an average inhibition of amino acid incorporation at 69%.

Further investigations are underway in our laboratory to quantify the synthesized protein and to determine if there are any differences in electrophoretic protein separations between treated and non-treated cell preparations.

ACKNOWLEDGMENTS

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Spider Fauna of Alfalfa and Soybean in Central Kentucky[1]

Joseph D. Culin and Kenneth V. Yeargan

Department of Entomology, University of Kentucky, Lexington, Kentucky 40546

Abstract

A 3-year study of spider communities in 4 alfalfa and 4 soybean plots (each 15 m × 30 m) resulted in the collecting of 42,671 spiders representing 21 families, 86 identified genera, and 143 identified species. Three families, Amaurobiidae, Oecobiidae, and Segestriidae, were collected in alfalfa only.

Tetragnatha laboriosa Hentz was the most abundant foliage-dwelling species in both crops. On the ground surface, *Grammonota inornata* Emerton and *Meioneta unimaculata* (Banks) were the most common species in alfalfa, while *Erigone autumnalis* Emerton and *G. inornata* were the most abundant species in soybean.

Introduction

Surveys of the spider fauna of alfalfa were presented by Howell and Pienkowski (1), Wheeler (2), and Yeargan and Dondale (3). Only 2 studies (4, 5) have presented lists of spider species found in soybeans.

In connection with a study of spider-community structure and population dynamics in alfalfa and soybean (6), an extensive survey of the spider fauna of these 2 crops in central Kentucky was undertaken.

Methods and Materials

This study was conducted during 1978–1980 on a University of Kentucky Agricultural Experiment Station research farm located in Lexington, Kentucky. Collections were made in 4 plots each of 'Buffalo'-variety alfalfa and 'Williams'-variety soybean. Each plot measured 15 m × 30 m.

In alfalfa, spider populations were surveyed using both a carriage-mounted D-VAC suction sampler (7), and pitfall traps having V-shaped drift fences (8, 9). Spiders in soybean were sampled using both the shake-cloth method (10) and pitfall traps. The sampling schedule is presented in Table 1.

On each sampling date, 4 D-VAC samples were taken in each alfalfa plot. During 1978 a sample consisted of the organisms vacuumed from an area 0.25 m^2, while in 1979 and 1980 a sample consisted of a transect of 10 0.09 m^2 sub-samples. In soybean 4 shake-cloth samples were taken in each plot on each sampling date during all 3 growing seasons. A shake-cloth sample consisted of the organisms shaken from a 1 m portion of a single row. Pitfall traps consisted of a 12 cm dia. trap located at the apex of a V-shaped drift fence measuring 10 cm × 60 cm on a side. In both crops, 4 traps were used with each placed approximately 3 m from the edge. Further details of the sampling methods can be found in Culin (6).

The use of different sampling methods in each crop was based on published reports and the availability of equipment. To date, no studies have been reported that compare sampling methods for spiders in alfalfa. However, Dietrick et al. (11) and Callahan et al. (12), comparing sweep-net and D-VAC methods, found that most insect species in alfalfa were better sampled by the D-VAC method. Shepard et al. (13) compared the D-VAC and shake-cloth methods in soybean and found that the latter yielded the greater number of spiders. On the other hand, Marston et al. (14) and LeSar and Unzicker (4) reported that a back-pack-mounted D-VAC collected more spiders in soybean than the shake-cloth method.

[1] This paper (82-7-65) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with the approval of the Director. Received for publication 20 April 1982.

TABLE 1.—SAMPLING SCHEDULE USED IN COLLECTING SPIDERS FROM ALFALFA AND SOYBEANS IN CENTRAL KENTUCKY

Crop	Year	D-VAC[1]	Shake-cloth[2]	Pitfall[3]
Alfalfa	1978	weekly 25 May–14 Dec	—	weekly 24 Apr–24 Nov
	1979	weekly 6 Apr–10 Dec	—	weekly 22 Mar–24 Nov
	1980	bi-weekly 7 Apr–4 Nov	—	bi-weekly 17 Apr–29 Nov
Soybean	1979	—	weekly 29 Jun–17 Oct	weekly 5 Jun–24 Nov
	1979	—	weekly 11 Jun–29 Oct	weekly 22 Mar–24 Nov
	1980	—	bi-weekly 19 Jun–5 Nov	bi-weekly 17 Apr–8 Nov

[1] Samples both foliage and ground surface.
[2] Samples only foliage.
[3] Samples only ground surface.

RESULTS AND DISCUSSION

There were 42,671 spiders collected during this study (35,171 in alfalfa D-VAC samples; 3,084 in soybean shake-cloth samples; 3,136 in pitfall traps in alfalfa; 1,280 in pitfall traps in soybean). The greater number of spiders collected in the D-VAC, compared to the shake-cloth samples, was probably due in part to differences in sample size caused by using different methods. In addition, the D-VAC method samples spiders from both the foliage and ground-surface, while the shake-cloth samples only the foliage. In the pitfall trap samples, the greater number of spiders collected in alfalfa may have been in part due to the more moderate environment caused by the relatively dense ground cover.

Collected spiders represented 21 families, 86 identified genera, and 143 identified species (Table 2). Additional morpho-species (small numbers of individuals appearing morphologically distinct) were occasionally collected (6); however, this paper presents only those identified at least to the generic level. Two taxa, *Misumenops* spp. and *Xysticus* spp., are presented in Table 2 as representing multiple species. Both of these consisted of large numbers of immature individuals that could not be positively identified beyond the generic level.

The families Oecobiidae, Amaurobiidae, and Segestriidae were rarely collected and only in alfalfa. The remaining families were collected in both crops, although not all species were found in both.

Tetragnatha laboriosa Hentz was the most abundant species collected in both D-VAC and shake-cloth samples. Other studies have also reported *T. laboriosa* as being the most abundant species collected from the foliage in these 2 crops (alfalfa, 1, 2; soybean, 4, 15). *Misumenops* spp. immatures were the second most abundant foliage taxa collected in soybeans. Population trends and densities were similar to those reported for *Misumenops* sp. in soybean fields in Delaware (15). In pitfall traps, *Grammonota inornata* Emerton and *Meioneta unimaculata* (Banks) were the 2 most commonly collected species in alfalfa, while *Erigone autumnalis* Emerton and *G. inornata* were the 2 most abundant ground-surface species in soybeans. Of the most abundant ground-surface species in this study, only *M. unimaculata* has been reported previously as being commonly collected in either of these crops. Yeargan and Dondale (3) found that *Pardosa ramulosa* (McCook) was the most abundant spider species collected in pitfall traps in alfalfa in California, while Culin and Rust (15) commonly collected *Par-*

TABLE 2.—SPIDERS IDENTIFIED TO GENUS OR SPECIES COLLECTED FROM ALFALFA AND SOYBEAN

Taxa[a]	Crop and collection method[b]	
	Alfalfa	Soybean
Oecobiidae		
Oecobius sp.	D	
Dictynidae		
Dictyna sp.	P	S
Amaurobiidae		
Titanoeca sp.	P	
Segestriidae		
Ariadna sp.	P	
Theridiidae		
Achaearanea sp.	D	S
Argyrodes fictilium (Hentz)		S
Dipoena sp.	D	
Euryopis funebris (Hentz)	D, P	S[g], P
Latrodectus mactans (Fabricus)		P
Steatoda americana (Emerton)	D, P	S, P[g]
Theridion albidium Banks	D	S
Theridion australe Banks	D, P	S, P
Theridion cheimatus Gertsch & Archer	D	
Theridion differens Emerton		S, P
Theridion frondeum Hentz	D	S
Theridion lyricum Walckenaer		S
Theridion neshamini Levi	D[g], P	S[g], P
Theridion sexpunctatum Emerton		S
Theridion sp. A	D, P	P
Theridion sp. B	D	
Theridion sp. C	D	S
Theridion sp. D	D	
Theridion sp. E	D	
Theridion sp. F	D	
Theridion sp. G	D	
Theridion sp. H	D	
Theridion sp. I		S
Theridion sp. J		S
Theridion sp. K		S
Theridion sp. L		S
Theridula emertoni Levi	D	S
Theridula opulenta (Walckenaer)	D	S
Linyphiidae		
Bathyphantes pallida (Banks)	D, P[g]	S, P[f]
Florinda coccinea (Hentz)	D	S
Frontinella pyramitela (Walckenaer)	D	S
Meioneta dactylata Chamberlin & Ivie	D, P	S, P
Meioneta micaria (Emerton)	D, P	S, P
Meioneta unimaculata (Banks)	D[g], P[f]	S, P[f]
Microlinyphia pusilla (Sundevall)	D[g]	S[g]
Pimoa sp.	D	
Tennesseellum formicum (Emerton)	D[g], P[g]	S, P[f]
Erigonidae		
Ceratinella placida Banks	D, P	S, P
Ceratinopsis laticeps Emerton	D[g], P	S, P
Eperigone tridentata (Emerton)	D, P	
Eperigone trilobata (Emerton)	D, P	S, P
Eridantes erigonoides (Emerton)	D	S, P
Erigone autumnalis Emerton	D[f], P[f]	S, P[d]
Erigone blaesa Crosby & Bishop	D, P	P

TABLE 2.—CONTINUED

Taxa[a]	Crop and collection method[b]	
	Alfalfa	Soybean
Grammonota capitata Emerton	D, P	S
Grammonota inornata Emerton	D[f], P[d]	S, P[d]
Walckenaeria spiralis (Emerton)	D, P	S, P
Araneidae		
Acanthepeira stellata (Marx)	D, P	S, P
Araneus sp.	D	S
Argiope aurantia Lucas		S
Argiope trifasciata (Forskal)	D	S
Cyclosa turbinata (Walckenaer)	D	S
Eustala sp.		S
Gea heptagon (Hentz)	D, P	S
Leucauge sp.	D	S
Mangora sp.		S
Micrathena sagittata (Walckenaer)		S
Neoscona arabesca (Walckenaer)	D	S[g], P
Nuctenea spp.	D	S[g]
Tetragnathidae		
Mimognatha foxi (McCook)	D[g], P	S
Pachygnatha autumnalis Keyserling	D, P	S, P
Pachygnatha tristriata C. L. Koch	D[g], P[g]	S, P
Tetragnatha laboriosa Hentz	D[d], P[g]	S[c], P
Agelenidae		
Agelenopsis pennsylvanica (C. L. Koch)	P	P
Cicurina sp.	P[g]	P[g]
Coras sp.	P	
Cybaeus sp.		P
Hahniidae		
Neoantistea agilis (Keyserling)	D, P	P
Mimetidae		
Mimetus eperioides Emerton	D, P	S, P
Pisauridae		
Dolomedes sp.	P	
Pisaurina sp. prob. *mira* (Walckenaer)	D	S[g]
Pisaurina sp.		P
Lycosidae		
Allocosa funerea (Hentz)	D, P[g]	P[g]
Lycosa avida Walckenaer	D, P[g]	P
Lycosa carolinensis Walckenaer	P	P
Lycosa frondicola Emerton	P[g]	P[g]
Lycosa helluo Walckenaer	D, P[g]	P[g]
Lycosa modesta (Keyserling)	P	
Lycosa punctulata Hentz	D	
Lycosa rabida Walckenaer	D, P	P
Lycosa ripariola Bonnet	P	P[g]
Lycosa sp.	P	P
Pardosa milvina (Hentz)	D, P[g]	S, P[g]
Pardosa saxatilis (Hentz)	D, P[f]	P[g]
Pirata arenicola Emerton	D, P[g]	P
Pirata sp. A	D, P	
Pirata sp. B	D, P	
Schizocosa bilineata (Emerton)	P	P
Schizocosa crassipes (Walckenaer)	P	P
Oxyopidae		
Oxyopes salticus Hentz	D	S

TABLE 2.—CONTINUED

Taxa[a]	Crop and collection method[b]	
	Alfalfa	Soybean
Gnaphosidae		
Drassodes sp.	P	P[g]
Drassylus depressus (Emerton)	D, P	P
Gnaphosa sericata (L. Koch)		P
Sergiolus sp.	D	
Zelotes sp.		P
Clubionidae		
Agroeca sp.		P
Castianeira sp.	D, P	P
Chiracanthium inclusum (Hentz)		S
Clubiona abboti L. Koch	D, P	S[g], P
Clubiona sp. A	D	
Clubiona sp. B	P	P
Phrurotimpus sp.	D	
Scotinella sp.	P	P
Trachelas tranquillus (Hentz)	D	S
Trachelas sp.	P	P
Anyphaenidae		
Anyphaena celer (Hentz)		S
Aysha sp.		S
Wulfila sp.	D	S
Thomisidae		
Misumena vatia (Clerck)		S
Misumenoides formosipes (Walckenaer)		S
Misumenops asperatis (Hentz)	D	S
Misumenops spp. immature	D	S[e]
Oxyptila sp.		P
Synema parvula (Hentz)		S
Xysticus auctificus Keyserling	D, P[g]	P[g]
Xysticus discursans Keyserling	D, P	S, P
Xysticus ferox (Hentz)	D, P	P
Xysticus funestus Keyserling	P	S, P
Xysticus texanus Banks	D, P	S, P
Xysticus triguttatus Keyserling	P	P
Xysticus sp. A	P	P
Xysticus sp. B	P	P
Xysticus spp. immature	D[g], P	S, P
Philodromidae		
Ebo sp.	D	S
Philodromus sp.	D	S[g], P
Tibellus oblongus (Walckenaer)	D	S, P
Salticidae		
Eris marginata (Walckenaer)		S[g]
Eris sp.	D	
Habronattus sp.	D	
Hentzia sp.		S
Metacyrba sp.	D	
Metaphidippus galathea (Walckenaer)		S
Metaphidippus sp. A		S
Metaphidippus sp. B		S
Peckhamia sp.	D	P
Phidippus audax (Hentz)	D, P	S, P
Phidippus sp.	D	
Sarinda hentzi (Banks)	D	
Sitticus floridanus Gertsch and Mulaik		P
Sitticus sp.	D	

dosa milvina (Hentz), *Erigone blasea* Crosby & Bishop, *Tennesseellum formicum* (Emerton) and *M. unimaculata* using pitfall traps in soybean fields in Delaware. However, compared with studies dealing with foliage spiders in crops, very few have dealt with the ground-surface fauna.

There were 112 species collected in alfalfa in the present study. Howell and Pienkowski (1) and Yeargan and Dondale (3), who also sampled using the D-VAC and pitfall trap methods, reported 112 species in Virginia and 34 species in California alfalfa fields, respectively. Wheeler (2), sampling only alfalfa foliage, reported 78 species from New York.

Eighty species were collected from the soybean foliage in this study using the shake-cloth method. LeSar and Unzicker (4) found 77 species in soybean foliage in Illinois using a D-VAC sampler, while Culin (5) found 105 species in soybean shake-cloth samples in Delaware.

Sixty-eight species were collected in pitfall traps in alfalfa in this study, much greater than the 19 spider species collected in pitfall traps by Yeargan and Dondale (3) during a 3-year study of ground spiders in California alfalfa fields. Soybean ground spider species richness in this study (67 species) was greater than that reported by Culin (5), who listed 48 species from pitfall traps during a 1-year study of soybean fields in Delaware.

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←

[a] Family names arranged according to Kaston (16, 17); generic names listed alphabetically.
[b] D indicates species collected in D-VAC samples; S indicates shake-cloth samples; P indicates pitfall trap samples.
[c] Taxon representing at least 20% of the total individuals for the collection method.
[d] Taxon representing between 15% and 19.9% of the total individuals for the collection method.
[e] Taxon representing between 10% and 14.9% of the total individuals for the collection method.
[f] Taxon representing between 5% and 9.9% of the total individuals for the collection method.
[g] Taxon representing between 1% and 4.9% of the total individuals for the collection method.

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Savanna-Woodland in the Outer Bluegrass of Kentucky

WILLIAM S. BRYANT
Thomas More College, Ft. Mitchell, Kentucky 41017

ABSTRACT

Remnant stands of old trees comparable in structure, composition and physiognomy to the presettlement savanna-woodland of the Inner Bluegrass occur in the Outer Bluegrass in Mason and Shelby counties. They occur on sites similar to those of the Inner Bluegrass. The dominant trees and their importance values in the Mason County stands are *Fraxinus quadrangulata* (86.88), *Quercus macrocarpa* (51.29), *Q. muehlenbergii* (17.29); in the Shelby County stands, they are *Q. muehlenbergii* (66.76), *F. quadrangulata* (40.09), *Acer saccharum* (21.37), *F. americana* (13.50), and *Q. alba* (12.79). Coefficients of similarity for the Inner Bluegrass remnants and those in Mason and Shelby counties were 80.12% and 46.73%, respectively.

Trees are over 200 years old at all sites. Size-class distribution curves for all stands are bell-shaped, which is typical of even-aged stands. Reproduction is poor and the stands are disappearing. Fire and grazing probably were important in maintaining the savanna-woodland vegetation in presettlement times.

INTRODUCTION

According to Braun (1) the vegetation of the Outer Bluegrass of Kentucky is very similar to that of the Inner Bluegrass. Braun cited an 1857 Kentucky Geological survey report that, "locust, black walnut, black and blue ash, wild cherry, and some white oak; undergrowth of cane," were present in the Outer Bluegrass portion of Bath County. This combination of species, especially the occurrence of blue ash with cane, suggests some similarity to the blue ash-oak savanna-woodland of the Inner Bluegrass (2). Stands of widely spaced trees, whose dominants included *Fraxinus quadrangulata* (blue ash), *Quercus macrocarpa* (bur oak), *Q. muehlenbergii* (chinquapin oak), and *Q. shumardii* (Shumard oak), occupied large areas of the rolling landscape of the Inner Bluegrass during presettlement times and remnants have persisted to the present (2). Cane (*Arundinaria gigantea*) was probably a common understory member of that community, but it is now absent from the remnants.

Because of Braun's (1) statements concerning the vegetational similarities between the Inner and Outer Bluegrass, a search was made in most of the Outer Bluegrass counties for extant stands of old trees whose physiognomy and/or dominants fit the savanna-woodland description. As a result of the search, large areas of savanna-woodland were located in Mason County and less extensive stands were found in Shelby County. This report gives quantitative descriptions of the savanna-woodland in these two counties and compares them to the savanna-woodland of the Inner Bluegrass.

The Environment

Geologically, the Outer Bluegrass is the region where the Maysville, Richmond, and younger formations of Ordovician age outcrop. Topographically, it is a gently rolling plain similar to the Inner Bluegrass, but the soils are of somewhat lower fertility (3). Although McFarlan (3) mentions that underground drainage is less pronounced than in the Inner Bluegrass and that sinks are few, all savanna-woodland stands studied in both regions were on gently undulating sites with sinks and springs present consistently. Soils at all sites were well-drained. Lowell silt loam, a soil with high available water capacity and medium natural fertility, is dominant at the Mason County sites (4). In Shelby County, Lowell silt loam and Shelbyville silt loam are dominant (5). The Shelbyville silt loam also has a high available water capacity and is medium in natural fertility. Both soils are often associated with karsted areas (5). The climate of the

Outer Bluegrass is of the humid continental type typical of the entire state. The annual temperature averages about 13°C and the mean annual precipitation of 109 cm is evenly distributed throughout the year (6).

METHODS OF STUDY

Except for trees within 10 m of the edge (fence rows) or groves of small trees on disturbed sites, the diameters of all trees 20 cm and greater in diameter at 1.37 m above ground level were measured. The diameter measurements were converted to basal area and summed for each species. Tree numbers and basal areas were analyzed to Relative Density (RD) and Relative Dominance (RDo), respectively, and those values were summed to produce an Importance Value (IV) for each species. Five sites were sampled in Mason County and 2 in Shelby County. Because of the close proximity of the stands in each county it was assumed that they were formerly continuous. For that reason, individual stand data were lumped to give a composite for each county.

The Similarity Coefficient (C) as used by Bray and Curtis (7) was used to compare the similarities between stands in the Outer and Inner Bluegrass. The equation for calculating the coefficient is $C = (2w)/(a + b)$, where $a =$ the sum of importance values of all tree species in one stand, $b =$ the sum of importance values for the second stand, and $w =$ the sum of the lower values for the species that occur in both stands. The value for C was multiplied by 100 to give a percentage.

Ring counts of 16 trees recently cut for fire wood were made to determine age structure. Additionally, a Swedish increment borer was used to obtain core samples from 8 trees for age analysis.

RESULTS AND DISCUSSION

A total of 408 trees was measured in the Mason County stands. As observed in the Inner Bluegrass (2), blue ash (IV 86.88) was the most important member of the savanna-woodland (Table 1). Bur, chinquapin, and Shumard oaks had a collective IV of 73.04; thus, they were more prominent here than in the Inner Bluegrass. It should be emphasized that the importance values for the species in these and other remnants are not necessarily the same as they would have been in the presettlement communities. Some species may not have the longevity of the oaks, and at the time of settlement some trees in the savanna-woodland were probably removed for special uses. However, the fact that 14 tree species occur in common with the Inner Bluegrass and the high coefficient of similarity of 80.12% point to a strong resemblance between the Mason County stands and those of the Inner Bluegrass. Additionally, other similarities between the Mason County stands and those of the Inner Bluegrass, respectively, are 17.1 trees/hectare (t/ha) vs. 12.35–17.34 t/ha; and basal area of 11.35 meters^2/hectare (m^2/ha) vs. 9.24–10.74 m^2/ha.

A total of 112 trees was sampled in Shelby County. The structure of these stands, 15.5 t/ha and 10.2 m^2/ha, was similar to the savanna-woodland of Mason County and the Inner Bluegrass. Although there were 12 tree species present that also occurred in the Inner Bluegrass stands, the coefficient of similarity of 46.73% was low. This is attributed to a difference in dominants. Chinquapin oak (IV 66.76) ranked first with blue ash (IV 40.09) second (Table 1). Additionally, sugar maple (*Acer saccharum*) was an important member with white oak (*Q. alba*), black cherry (*Prunus serotina*), and Ohio buckeye (*Aesculus glabra*) being minor components. Bur oak was of minor importance.

Tree size-class distributions for the savanna-woodland communities in Mason and Shelby counties, as well as those in the Inner Bluegrass, followed bell-shaped curves (Figure 1) as observed by Anderson and Anderson (8) for presettlement oak savannas of Williamson County, Illinois. Such curves are indicative of even-aged stands (9). Ring counts of trees in Mason County showed the dominant members to be consistently over 200 years old, with several in the 300-year range.

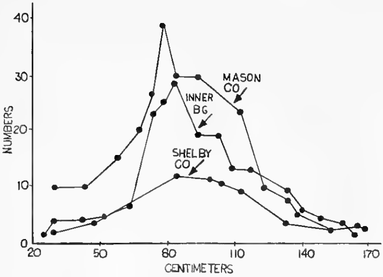

FIG. 1. The size-class distributions of all trees in the savanna-woodlands of Mason and Shelby counties, and the Inner Bluegrass. Curves have been smoothed by connecting maximum numbers but not all size classes.

These ages agree with the findings of Bryant et al. (2) for the Inner Bluegrass, indicating that many of the trees date from presettlement times. A total of 23 oak seedlings was observed in Mason County, but reproduction was almost nonexistent because of grazing, mowing of pastures, cultivation, and perhaps fruit and seed mortality.

The interaction of past climatic conditions, chemical nature of the rocks, underground drainage, soil character, fire, and grazing were suggested as factors responsible for the maintenance of savanna-woodland in the Inner Bluegrass (2). Undoubtedly some, if not all, of those factors were involved in the maintenance of the Outer Bluegrass communities. The physical environments, including undulating topography with sinks and springs at most sampling sites, and the climatic history of the two regions are nearly identical. Although of different types, the soils are deep and well-drained in both regions.

Fires and grazing probably exerted major influences in keeping the savanna-woodland open during presettlement times. Portions of Mason County were once occupied by the Fort Ancient culture, especially Fox Field (10) in the vicinity of Mays Lick where the savanna-woodland is well-developed. The Fort

TABLE 1.—THE NUMBER (N), RELATIVE DENSITY (RD), RELATIVE DOMINANCE (RDo), AND IMPORTANCE VALUE (IV) OF TREE SPECIES IN THE SAVANNA-WOODLANDS OF MASON AND SHELBY COUNTIES OF THE OUTER BLUEGRASS COMPARED WITH THE INNER BLUEGRASS

	Mason County				Shelby County				Inner Bluegrass
Species	N	RD	RDo	IV	N	RD	RDo	IV	$\bar{x}$ IV
Fraxinus quadrangulata	188	46.08	40.80	86.88	21	18.75	21.34	40.09	107.97
Quercus macrocarpa	79	19.36	31.93	51.29	2	1.79	2.63	4.42	19.37
Quercus muehlenbergii	32	7.84	9.48	17.32	34	30.36	36.40	66.76	17.60
Juglans nigra	32	7.84	1.97	9.81	6	5.36	3.31	8.67	5.96
Carya laciniosa	24	5.88	3.85	9.73	2	1.79	1.18	2.97	7.99
Gymnocladus dioicus	15	3.68	1.87	5.55	5	4.46	1.45	5.91	4.02
Ulmus americana	10	2.45	2.25	4.70	—	—	—	—	5.83
Quercus shumardii	5	1.23	3.20	4.43	2	1.79	2.45	4.24	8.49
Celtis occidentalis	7	1.72	1.35	3.07	4	3.57	2.69	6.26	4.83
Fraxinus americana	6	1.47	1.42	2.89	9	8.04	5.46	13.50	4.94
Acer saccharum	4	0.98	0.96	1.94	13	11.61	9.76	21.37	2.74
Carya ovata	2	0.49	0.41	0.90	—	—	—	—	5.20
Platanus occidentalis	1	0.25	0.24	0.49	1	0.89	0.24	1.13	3.25
Carya cordiformis	1	0.25	0.20	0.45	—	—	—	—	—
Morus rubra	1	0.25	0.05	0.30	—	—	—	—	0.28
Ulmus rubra	1	0.25	0.02	0.27	—	—	—	—	—
Quercus alba	—	—	—	—	6	5.36	7.43	12.79	—
Prunus serotina	—	—	—	—	3	2.68	2.15	4.83	—
Liriodendron tulipifera	—	—	—	—	2	1.79	2.72	4.51	0.52
Diospyros virginiana	—	—	—	—	1	0.89	0.63	1.52	—
Aesculus glabra	—	—	—	—	1	0.89	0.16	1.05	—
Robinia pseudo-acacia	—	—	—	—	—	—	—	—	1.02

Ancient culture had an agricultural base and fire may have been used as a means for keeping the forest open or as a technique in hunting. Lightning scars are prominent on the majority of large trees. In earlier times, when the original ground cover was composed of cane and warm-season grasses, lightning fires were probably common. The fire resistance of bur oak is well known (11). Filson (12) showed "fine caneland" in Mason County and it is well known that the large herds of buffalo grazed on cane (13). The Great Buffalo Trace passed through Mason County and the cane and scattered springs may have attracted herds of grazing animals. According to Clark (14), the buffalo came to drink at the saline springs at Blue Licks just south of the Mason County line and their appetites were sharpened to eat every green thing in sight.

Based on the patterns of settlement, it would seem that the early pioneers entering Kentucky from the east showed a definite preference for the open savanna-woodlands. The first major settlements in Kentucky were in the Inner Bluegrass (1775), centering around Lexington, and in Mason County of the Outer Bluegrass (1784), centering around Mays Lick and Washington. According to Shaler (15), "The early settlers chose their places of settlement by the nature of the timber. Where blue ash, black walnut, or coffee trees abounded, they knew that they had the most fertile soils." Additionally, the open savanna-woodlands required little clearing to convert to agriculture.

For the two centuries following settlement, the savanna-woodland of Mason and Shelby counties has remained in agricultural use, especially livestock raising. Changes in land use have caused many of these farms to be lost to urban expansion, as in the Inner Bluegrass. Reproduction or replacement of the old trees is low. The trees are easy targets for lightning, as indicated by the numerous scars. Additionally, woodchucks have undermined the root systems of many of them, thus encouraging windthrow. The disappearance of the blue ash-oak savanna-woodland as a distinct community type in Kentucky may be drawing near.

The similarities regarding habitat and certain aspects of stand structure in the remnant stands of the savanna-woodland vegetation type of the Outer and Inner Bluegrass make it apparent that savanna-woodland was a distinct component of the landscape of the Bluegrass region during presettlement times. As stated by Bryant et al. (2), "The high incidence of blue ash distinguishes the Kentucky savanna-woodlands from all other savanna types or prairie groves in the eastern deciduous forest."

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The Effects of Topography on Kentucky Tornadoes

L. Michael Trapasso and Robert R. Mattingly

Department of Geography and Geology, Western Kentucky University, Bowling Green, Kentucky 42101

Abstract

The relationship between tornadoes within Kentucky and the topography over which they track is investigated. Previous studies of this type have offered numerous methods and varied conclusions. In this study, 50 counties throughout the Commonwealth were chosen to attain a variety of topographic characteristics. Topographic quadrangles were utilized to extract a mean slope, a mean vertical relief and a mean ruggedness factor. These terrain variables were correlated with tornado number per 1,000 miles^2 (1,600 km^2), mean (Fujita) intensity, mean (Pearson) path length, and mean (Pearson) path width.

The analysis resulted in negative correlations for all the relationships, suggesting that a rugged topography experiences fewer and weaker tornadoes. The analysis further shows that topography exerts a rather small influence on tornadoes.

Introduction

It has long been considered that tornado incidence is less frequent over mountainous terrain. Proponents of this concept maintain that surface topography may affect the development and propagation of tornadoes by influencing inflow of air to the storm, angular and linear momentum, vertical shear, vertical motion fields, and flow patterns aloft (1, 2, 3, 4). Topography-tornado relationships have been researched and varied conclusions have been reached. Research of this type has taken place in Indiana (5), Michigan (6), Arkansas (5, 7), Wisconsin (7), Missouri (2), the Southern Rockies (8), the Ozarks and Appalachians (9), and the Boston Mountains (4, 9).

The present study examines this relationship in Kentucky. A map of tornado incidence by county (Fig. 1) seemed to suggest topographic influence. It is hypothesized that an increase in topographic slope, vertical relief and ruggedness is accompanied by decrease in tornado number per 1,000 miles^2 (1,600 km^2), mean intensity ($\bar{F}$), mean path length ($\bar{P}_l$), and mean path width ($\bar{P}_w$). Though the topographic variables may be similar to those used in previous studies, the use of these 4 variables to quantify the tornado phenomena constitutes a significant difference in methodological approach.

Tornado-Topography Studies

A number of researchers using various methodologies have explored the effects of topography on tornadoes. The use of laboratory tornado simulators has shown that an increase in surface roughness can decrease tornado damage (10, 11) and inhibit the transition from a single vortex to the more destructive multiple vortex tornado (12). However, laboratory simulations are not real-world situations and conclusions drawn from such studies should be taken with care (13).

Photogrammetric analysis was used by Forbes (5) who noted changes in tornado appearance with changes in the underlying surface. The vortex was visibly altered as it passed over a grassy field to a plowed filed, and then to a residential area.

Statistical techniques were utilized by several authors. Safford (1) correlated tornado incidence with a roughness factor and found no correlation coefficient stronger than −0.6. Multiple regression was used by Schroeder (2) to relate tornado occurrence to a multivariate environment. He found that correlations between tornado numbers and population density and economic levels of the population overshadowed correlations with topography. Fujita (8), however, correlated mean topographic height and height

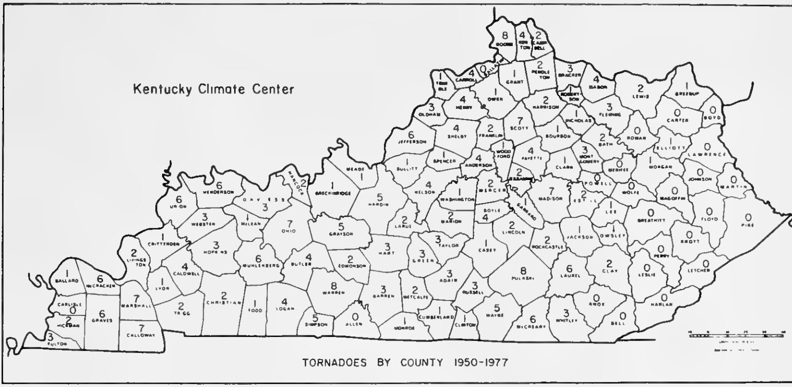

FIG. 1.

variance to tornado incidence and found both variables to be significant.

Topographic influences were further viewed by Galimore and Lettau (7) who employed spectral curves to reconstruct landscape profiles. Areas of higher than normal tornado occurrence (tornado alleys) were found in areas of smoother terrain while areas of lower than normal tornado numbers (shunt regions) were coincident with rougher terrain.

STUDY AREA

Fifty counties were chosen to investigate the response of tornadoes to Kentucky topography (Fig. 2). The counties were selected primarily on the basis of population density. When investigating the regionalization of tornado reports, a population bias must be considered (14), especially when comparing low elevations to mountainous regions (9), grass-

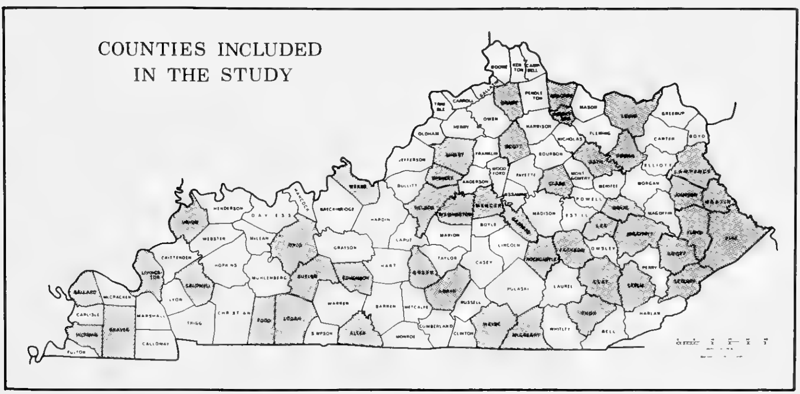

FIG. 2.

lands to forested areas (6) or rural to urban areas (8).

Researchers have addressed the problem of populaiton bias in a variety of ways. Galimore and Lettau (7) chose to ignore population bias, contending that tornado damage left behind would, in time, be discovered and reported regardless of the population density of the region. Safford (1) used partial correlation techniques to remove the effect of population density from his analysis. A "tornado index" was established by Schroeder (2) to eliminate large urban populations and ensure a more homogeneous population density, while Kelley et al. (15) suggested that present-day tornado data are collected with meticulous cross-referencing of many sources thus reducing the importance of population bias.

In this research, attempts are made to hold population bias in Kentucky to a minimum. This is accomplished by choosing counties in the western, less mountainous regions, whose population density ranged from 30 to 40 persons per square mile. In the eastern mountainous regions (characteristically sparse in population density), data were collected from counties with population densities of 40 to 50 persons per square mile (16).

Population-density values may be offset by counties containing large urban areas (2). Taking this into consideration, only 4 of the 50 counties chosen for analysis include communities with populations greater than or equal to 10,000. The most populated community in the study area was Winchester, Clark County, with a population of 15,700 (17).

TABLE 1.—RANGES OF VARIABLES

I. TORNADO VARIABLES (DEPENDENT VARIABLES)		
(1) Number of Tornadoes/1,000 sq. mi. (1,600 sq. km) 0 to 30.77		
(2) Intensity (Fujita Scale)		
	0: Light Damage	(less than 120 km/hr)
	1: Moderate Damage	(121 to 180 km/hr)
	2: Considerable Damage	(181 to 250 km/hr)
	3: Severe Damage	(251 to 330 km/hr)
	4: Devastating Damage	(331 to 420 km/hr)
	5: Incredible Damage	(421 to 510 km/hr)
(3) Path Length (Pearson Scale)		
	0: Less than 1.6 km	
	1: 1.6 to 5.0 km	
	2: 5.1 to 16.0 km	
	3: 16.1 to 50.0 km	
	4: 51.0 to 16.0 km	
	5: 161 km or greater	
(4) Path Width (Pearson Scale)		
	0: Less than 0.016 km	
	1: 0.016 to 0.048 km	
	2: 0.049 to 0.145 km	
	3: 0.150 to 0.500 km	
	4: 0.510 to 1.600 km	
	5: 1.610 or greater	
II. TOPOGRAPHIC VARIABLES (INDEPENDENT VARIABLE)		
(1) Mean Slope (in degrees) 3.15° to 28.28°		
(2) Mean Relative Relief (in m) 19.82 m to 276.83 m		
(3) Mean Roughness Factor (dimensionless) 0.029 to 0.341		

MATERIALS AND METHODS

The completion of this research required the extraction of two distinct data sets. The first set describes, in numerical form, tornadoes in Kentucky; the second set quantifies the terrain over which these tornadoes were reported.

Tornado Variables.—Four variables were utilized to describe the characteristics of Kentucky tornadoes. These were obtained from the National Severe Storm Forecast Center, published in *Compiled Tornado Statistics of Kentucky* 1950 through 1979.

The first variable used values of the incidence per county to derive the number of tornadoes per 1,000 miles^2 (1,600 km^2). The second variable utilized the Fujita intensity (F) scale (Table 1) to derive a mean intensity value per county ($\bar{F}$). Tabulated values of Pearson tornado path length (P_l) and path width (P_w) were the basis from which mean path length ($\bar{P}_l$) and mean path width ($\bar{P}_w$) were derived. These 2 quantities comprised the third and fourth tornado variables (Table 1).

Topographic Variables.—The 50 counties chosen for analysis were selected from various regions around the Commonwealth to display a variety of landscapes. The topographic variables used to describe these landscapes were derived from U.S. Geological Survey 1: 24,000 scale topographic quadrangles. Contour-line intervals and spacing patterns were applied in conjunction with slope-indicator templates (18) to derive the slope of the terrain in degrees. Vertical relief was derived using contour lines to find the distance between the highest and lowest points in the area where slope was determined. Lastly, a ruggedness factor (19) was calculated using the following ratio: (Vr/Hd) where Vr equals vertical relief and Hd equals the horizontal distance between the points used to determine vertical relief.

A minimum of 5 target areas were quantified upon each topographic quadrangle from which mean values were derived. (Three topographic quadrangles equals approximately one county area.) Thus, the topography of each county was typified by a mean slope, mean vertical relief and a mean ruggedness factor, the ranges of which are indicated in Table 1.

During the data collection phase of this research, the counties containing the weakest tornadoes (F0 and F1 intensity) and the strongest tornadoes (F4 and F5 intensity) were noted. This was done to reveal the existence of spatial patterns where weaker or stronger tornadoes may tend to persist. No significant patterns were discovered. In fact, several counties had experienced both F1 and F4 intensity tornadoes through the period of data record.

Graphic Appearance.—When topographic variables were graphed west to east across the Commonwealth (Fig. 3) a "ramp-like" appearance of Kentucky terrain becomes visible. An eastward traverse is accompanied by a movement upslope into rougher terrain. The three topographic variables graphed in Figure 3 show general agreement with this trend. Comparing this trend with that found in Figure 4, the tornado variables sampled across the Commonwealth show an inverse relationship with topographic variables especially at the foothills of the Appalachians where the tornado frequency drops to zero.

Statistical Analysis.—When all the data sets were tabulated, 2 problems became evident. First, all 7 sets of data (3 topographic and 4 tornado variables) violated

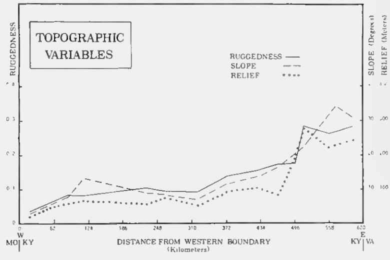

FIG. 3.

the assumption of a normal distribution, an essential consideration when applying parametric statistics. Secondly, 3 distinct types of variables are represented in the data. The rank order of $\bar{F}$, $\bar{P}_l$, and $\bar{P}_w$ distinguish them as ordinal variables. While tornado number, slope, and vertical relief are examples of interval data, the ruggedness factors stand out as the only ratio variable in the series. Again, the heterogeneity of the data precludes the use of parametric statistics. It is the opinion of these authors that the results of previous or future tornado/topography research must be examined carefully for violations of assumptions that may render a parametric statistical analysis invalid.

The nature of the data sets was such that a non-parametric statistical approach was sought. Spearman (ρ) rank correlation coefficients assume freedom from population distribution and can be used with nominal, ordinal, interval or ratio

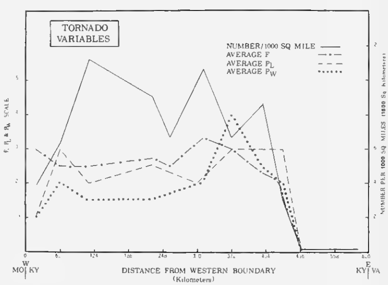

FIG. 4.

TABLE 2.—CORRELATION MATRIX, SPEARMAN RANK CORRELATION COEFFICIENT

	Ruggedness	Relief	Scope
No./1,600 km^2	−0.57	−0.56	−0.52
$\bar{F}$	−0.43	−0.39	−0.37
$\bar{P}_l$	−0.32	−0.34	−0.13
$\bar{P}_w$	−0.48	−0.46	−0.39

data (20). Spearman coefficients (ρ) were used to relate each (dependent) tornado variable to each (independent) topographic variable. The resulting correlation matrix is shown in Table 2.

RESULTS AND DISCUSSION

A number of conclusions can be drawn from the correlation matrix. Primarily, all relationships, regardless of their strength, show a consistent negative correlation. These correlations support the inverse relationship between tornado characteristics and topography suggested in previous research. However, the strength of the correlations (−0.13 to −0.57) indicates that only a small amount of the variance in Kentucky tornadoes is accounted for by local topography.

Of the relationships presented, the number of tornadoes is most affected by topography, followed by mean path width ($\bar{P}_w$). Mean intensity ($\bar{F}$) and mean path length ($\bar{P}_l$) were the least affected by terrain. Of the topographic variables ruggedness followed closely by relief exerts the greatest influence on tornado existence and maintenance. The slope of a surface appears to have less effect.

SUMMARY

Tornado statistics for 50 Kentucky counties were correlated with the quantitative topographic variables for those counties, disclosing that an inverse relationship exists. Tornadoes tend to be less abundant, have shorter tracks, are narrower and less intense in more rugged, mountainous terrain. The findings support similar results in previous research. However, the correlations between topography and the incidence and average characteristics of tornadoes in Kentucky are rather weak. The highest Spearman (ρ) value for these correlations was −0.57. Though topography has its influence, the key to understanding these violent and sporadic storms still lies elsewhere.

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Amphiachyris dracunculoides (DC.) Nutt. (Common Broomweed) in Kentucky: A Potentially Weedy Pest in Overgrazed Pastures?

JERRY M. BASKIN AND CAROL C. BASKIN

School of Bological Sciences, University of Kentucky, Lexington, Kentucky 40506

ABSTRACT

Amphiachyris dracunculoides (DC.) Nutt. (Common broomweed) is an annual composite that was introduced into Kentucky and other eastern states from its native habitat farther west and southwest. In Kentucky, it is presently known from rocky roadsides or badly overgrazed pastures in 6 counties: Anderson, Madison, Meade, Simpson, Todd, and Washington. This unpalatable weed may have the potential of becoming a serious pest in overgrazed Kentucky pastures.

INTRODUCTION

Amphiachyris dracunculoides (DC.) Nutt. (*Gutierrezia dracunculoides* (DC.) S. F. Blake; *Xanthocephalum dracunculoides* (DC.) Shinners), a member of the family Compositae (or Asteraceae) is an annual herbaceous plant native to the western United States. Solbrig (1) gives its native habitat as Oklahoma and Texas, but, according to Jones and Fuller (2), the natural range of *A. dracunculoides* extends from western Missouri and Kansas thru Oklahoma, Texas, eastern New Mexico into Mexico. The species is an adventive eastward (1, 2), and it has been collected in several states east of the Mississippi River (3).

Baskin and Baskin (4) reported *A. dracunculoides* (as *Gutierrezia dracunculoides*) from Washington and Anderson counties, Kentucky. This was thought to be the first report of the species in Kentucky, although Solbrig (1) stated that it had spread as far eastward as Kentucky. In her taxonomic treatment of *Amphiachyris*, Lane (3) has only one dot on the distribution map for *A. dracunculoides* in Kentucky. The Kentucky distribution of this species is based upon an Anderson County specimen (cited above) collected by J. & C. Baskin (M. Lane, pers. comm.). It should be pointed out, however, that although Lane (3) used the specimen from Anderson County to construct her distribution map, the dot appears to be in Pendleton County. The only other known report of this species from Kentucky is that of Cranfill and Medley (5) who reported it from Todd County.

RESULTS AND DISCUSSION

Field observations on Common broomweed in Tennessee and Kentucky and greenhouse studies on plants grown from seeds collected in middle Tennessee show that this species behaves both as a winter and as a summer annual. Seeds are nondormant at maturity in late September and October. Those that fall off the plant in early autumn germinate soon after dispersal and form an overwinter rosette. Those that are dispersed in mid- to late autumn do not germinate until the following spring; these do not form a rosette. Shoot elongation begins in spring (soon after germination for those plants

FIG. 1. Flowering plant of *Amphiachyris dracunculoides* grown in a greenhouse. Seed germinated in early spring 1981, and photograph was taken on 8 September 1981.

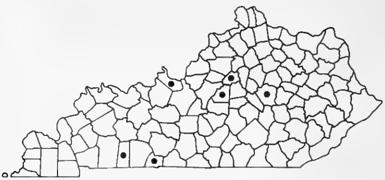

FIG. 2. Counties in Kentucky where authors have collected *Amphiachryis dracunculoides.*

that germinate in spring) and continues until about mid-summer; some plants may grow to a height of 1.0 meter. During this stage of vegetative growth, many branches are produced on the upper one-third of the plant. Flowering occurs from late July to early October (Fig. 1), and the seeds are mature in October. The ecological life cycle of A. *dracunculoides* in Texas is almost identical to that reported above (6, 7, 8).

Over the past several years of fieldwork in Kentucky, *A. dracunculoides* has been collected from 6 counties. The collection data are: ANDERSON CO.: Bluegrass Pkwy, roadside, 6.4 km E of Co. Rd. 555 (J. & C. Baskin #1130, Sept. 17, 1971). MADISON CO.: Interstate 75, roadside 1.6 km S of St. Rd. 876 (J. & C. Baskin #1966, Oct. 11, 1979). MEADE CO.: Jct. of US 60 and St. Rd. 448, roadside (J. & C. Baskin #1796, Sept. 12, 1976). SIMPSON CO.: Interstate 75, pasture, 1.6 km S of St. Rd. 100 (J. & C. Baskin #1550, Aug. 20, 1972). TODD CO.: St. Rd. 171, pasture, 8.0 km S of Allegre (J. & C. Baskin #1946, Sept. 5, 1977). WASHINGTON CO.: Bluegrass Pkwy., roadside, 3.7 km E of St. Rd. 555 (J. & C. Baskin #1129, Sept. 18, 1971). A county dot-distribution map is shown in Figure 2. We expect that the species eventually will be found in a number of additional counties in the state.

In the 6 localities where *A. dracunculoides* was collected, the bedrock is either limestone or calcareous shale. Soil from the Anderson and Washington county sites had a pH of 8.0 and 8.2, respectively (4). The collections from Anderson, Madison, Meade, and Todd counties are from rocky roadsides, and those from Simpson and Todd counties are from badly overgrazed pastures. All of these sites have at least 3 things in common: (1) the bedrock is calcareous, (2) they have been badly disturbed by man and/or his livestock, and (3) competition on *A. dracunculoides* from other plants is minimal. We have observed this species in habitats with these same characteristics in Missouri, Kansas, Oklahoma, and in the Nashville Basin of Tennessee. Warner (9) reported that in east Texas *A. dracunculoides* is an indicator of calcium carbonate in the soil and that non-acid soils may be mapped by its distribution.

Amphiachyris dracunculoides is not presently a serious weedy pest in Kentucky, except, perhaps, in a few local areas such as the Todd County site, but it may have the potential to become one. According to Solbrig (1), *A. dracunculoides* is a weed of only secondary importance.

However, Scifres et al. (8) stated that this species can become a serious problem on ranges where the grass cover has been reduced by overgrazing or drought. The invasion of *A. dracunculoides* in overgrazed range land in Kansas (10, 11), Oklahoma (12, 13, 14, 15, 16), and Texas (17, 18, 19) is well documented.

Amphiachyris dracunculoides is very drought tolerant, and thus during the great drought of the 1930s its numbers greatly increased in its native geographical range. In the eastern third of Kansas, Gates (20) observed that prior to the droughts the species was found occasionally in open woods, on rocky hillsides, along roadsides, and in prairies, but during the droughts it became abundant in abandoned fields, pastures, and prairies.

Heavy infestations of common broomweed can reduce forage production and utilization by cattle (L. R. Rittenhouse, unpubl. ms.), and the plants can cause gastro-enteritis, an eye infection (similar to pinkeye) in cattle, and skin irritation (dermatitis) in cattle and in humans (20). Although the plant is distasteful to cattle, they will eat it when other forage is not available (21). Thus, this unpalatable annual weed appears to have the potential to cause economic losses to cattle farmers in Kentucky.

Common broomweed can be controlled effectively by herbicides (7, 8, 22) or by mowing before the plants set seeds (23). The most desirable way of controlling it on grazing land seems to be the maintenance of a good cover of perennial grasses with which common broomweed is a poor competitor. In western Kansas the species is a principal forb on heavily grazed prairie but is only sparingly present on non-grazed sites (11), and in Oklahoma it is absent from ungrazed grassland but invades and increases in number as heavy grazing or overgrazing occurs (13, 16).

In the tobosa grasslands of Texas, fire is used to control *A. dracunculoides* (24, 25). It is the major winter annual in this plant community, and spring burning will control it for two years following the burn (25). However, common broomweed soon re-establishes on burned areas and in the fourth growing season following a fire it was slightly more important in the burned than in the unburned sites (24).

Few values have been attributed to *A. dracunculoides* in the literature. Lehman (26) and Chenault (27) indicated that it served as a good cover for quail on farms in central Texas; Parks (28) thought that it had some value as a soil cover in stopping wind erosion and in beautifying the landscape with its numerous small yellow flowers; and Oertel (29) included it in his list of important honey and pollen plants in Kansas.

ACKNOWLEDGMENTS

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Computer Mapping and Trend-surface Analysis of Selected Controls of Hydrocarbon Occurrence in the Berea Sandstone, Lawrence County, Kentucky

ALAN D. SMITH

Department of Geology, Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

Computer-generated contour maps were utilized in mapping parameters associated with oil and gas production of wells that penetrate the Berea Sandstone, Lawrence County, Kentucky. In addition, trend-surface analysis techniques, hypothesis testing, and model comparisons of these trends were completed for the following variables: elevation of the top of the Berea Sandstone, Sunbury Shale thickness, oil production, gas production, and 5 lithologic characteristics of the Berea. Therefore, for each variable studied, the spatial distribution was mapped and the best-fit trend-surface for predictive purposes was determined. An F-test for significance of fit of polynomial trend surface was used. The results illustrate that the first degree surface is the best fit for gas production; fifth order for oil production; third degree for Berea Sandstone thickness; first order for Sunbury Shale thickness; sixth degree for elevation of top of Berea Sandstone; first order for sand per cent from cuttings number one; and no trend surface accounted for enough explained variance for sand per cent from cuttings number 2, 3, 4, or 5.

INTRODUCTION

A recent study by Smith and Morgan (1) concerning hydrocarbon occurrence in the Berea Sandstone, in Lawrence County, Kentucky (Fig. 1) was completed. Information from 354 wells (Fig. 2) was used in a statistical search for factors influencing hydrocarbon occurrence. The variables studied were: elevation of the top of the Berea Sandstone, Sunbury Shale thickness, oil production, gas production, Berea Sandstone thickness, and 5 lithologic characteristics of the Berea Sandstone. In this statistical study by Smith and Morgan (1), another problem presented itself: finding statistical relationships was not adequate to make the study useful in a practical sense. The information in this study needed to be mapped to provide visual information. In addition, statistical relationships needed to be spatially quantified to be useful.

METHODS

The Kentucky Department of Mines and Minerals supplies the Kentucky Geological Survey with location plots for all oil and gas wells that are permitted within the state. An inventory was made of every well on file at the Geological Survey that penetrated the Berea Sandstone in Lawrence County, since this county has been in the forefront of Berea-oriented oil and gas exploration. Information was collected for 354 wells concerning a variety of Berea Sandstone, related lithologic characteristics, and hydrocarbon occurrence. Geophysical logs and cutting samples were used to estimate depths to the top and bottom of the Berea Sandstone and Sunbury Shale. Cuttings were studied using a binocular microscope and per cent sand present in each sample was calculated using charts by Compton (2). In addition, to gain more stratigraphic control within the Berea, the formation was vertically divided in 20-foot intervals and the per cent sand was averaged for each of these intervals (referred to as sand per cent from cuttings number 1 through 5).

Computer mapping techniques using SURFACE II (3) via an incremental drum plotter located at the University of Kentucky were utilized to visually display spatial variations throughout the county. In addition, trend surface analysis techniques using SYMAP (4) were completed to arrive at predictive relationships of the variables studied with spatial orientation. A computer program developed by Smith (5), using concepts

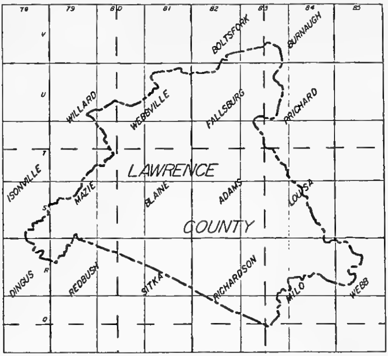

FIG. 1. Carter coordinates and geological quadrangles of Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

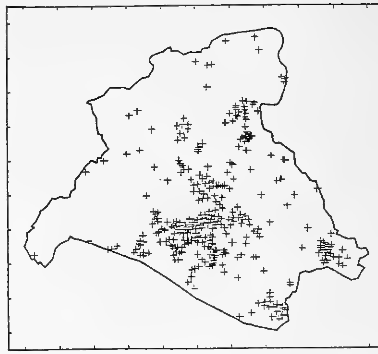

FIG. 2. Well locations, Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

suggested by Davis (6) was employed to statistically discriminate among trend surfaces by model comparison and, hence, to determine what degree equation could best be used to spatially describe the variables.

The basic form of graphic display produced by SURFACE II is the contour map. In general, the sequence of three basic operations performed by SURFACE II to create a map from data is: (1) input irregularly spaced data; (2) construct a matrix or regular grid of estimated surface values; (3) plot a map from the grid matrix. Commands by the user implement the various routines in the program to perform each of the basic operations. These commands specify which plot option to perform, how large to make the display, how to calculate values in the grid matrix, where to find the input data, and the format to read the data.

Trend-surface analysis techniques were applied to the various parameters studied to arrive at spatially predictive relationships. SYMAP program, using elective 38, performed the actual regression analysis. Unlike SYMAP's standard interpolation procedure for contouring, trend-surface

TABLE 1.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE VARIABLE GAS PRODUCTION

Order of trend surface	R^2_f	R^2_r	df	F	Probability	Sign.
1	0.0462	0.0	2/297	7.1910	0.0009	S
2	0.0698	0.0	5/294	4.4142	0.0007	S
3	0.0920	0.0	9/290	3.2637	0.0008	S
4	0.1210	0.0	14/285	2.8014	0.0006	S
5	0.1607	0.0	20/279	2.6714	0.0002	S
6	0.1975	0.0	27/272	2.4787	0.0001	S
1 vs 2	0.0698	0.0462	3/294	2.4908	0.0604	NS
2 vs 3	0.0920	0.0698	4/290	1.7678	0.1353	NS
3 vs 4	0.1210	0.0928	5/285	1.8803	0.0977	NS
4 vs 5	0.1607	0.1210	6/279	2.2025	0.0430	S
5 vs 6	0.1975	0.1607	7/272	1.7791	0.0915	NS

(N = 300)

Note. An alpha level of 0.05 was employed before each hypothesis was considered statistically valid.

TABLE 2.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE VARIABLE OIL PRODUCTION

Order of trend surface	R^2_f	R^2_r	df	F	Probability	Sign.
1	0.0928	0.0	2/295	15.0849	0.0000	S
2	0.1240	0.0	5/292	8.2667	0.0000	S
3	0.2307	0.0	9/288	9.5950	0.0000	S
4	0.3083	0.0	14/283	9.0107	0.0000	S
5	0.3736	0.0	20/277	8.2589	0.0000	S
6	0.3973	0.0	27/270	6.5926	0.0000	S
1 vs 2	0.1240	0.0928	3/292	3.4688	0.0166	S
2 vs 3	0.2307	0.1240	4/288	9.9837	0.0000	S
3 vs 4	0.3083	0.2307	5/283	6.3537	0.0000	S
4 vs 5	0.3736	0.3083	6/277	4.8076	0.0001	S
5 vs 6	0.3973	0.3736	7/270	1.5211	0.1600	NS

(N = 298)
Note. An alpha level of 0.05 was employed before each hypothesis was considered statistically valid.

TABLE 3.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE VARIABLE BEREA SANDSTONE THICKNESS

Order of trend surface	R^2_f	R^2_r	df	F	Probability	Sign.
1	0.0067	0.0	2/165	0.5557	0.5748	NS
2	0.1206	0.0	5/162	4.4425	0.0008	S
3	0.1850	0.0	9/158	3.9860	0.0001	S
4	0.1957	0.0	14/153	2.6591	0.0017	S
5	0.2699	0.0	20/147	2.7171	0.0003	S
6	0.3227	0.0	27/140	2.4703	0.0003	S
1 vs 2	0.1206	0.0067	3/162	6.9934	0.0002	S
2 vs 3	0.1850	0.1206	4/158	3.1241	0.0166	S
3 vs 4	0.1957	0.1850	5/153	0.4056	0.8444	NS
4 vs 5	0.2699	0.1957	6/147	2.4899	0.0253	S
5 vs 6	0.3227	0.2699	7/140	1.5587	0.1526	NS

(N = 168)
Note. An alpha level of 0.05 was employed before each hypothesis was considered statistically valid.

TABLE 4.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE VARIABLE SUNBURY SHALE THICKNESS

Order of trend surface	R^2_f	R^2_r	df	F	Probability	Sign.
1	0.0903	0.0	2/307	15.2310	0.0000	S
2	0.1043	0.0	5/304	7.0811	0.0000	S
3	0.1326	0.0	9/300	5.0967	0.0000	S
4	0.1688	0.0	14/295	4.2803	0.0000	S
5	0.1967	0.0	20/289	3.5383	0.0000	S
6	0.2493	0.0	27/282	3.4693	0.0000	S
1 vs 2	0.1043	0.0903	3/304	1.5893	0.1920	NS
2 vs 3	0.1326	0.1043	4/300	2.4477	0.0464	S
3 vs 4	0.1688	0.1326	5/295	2.5707	0.0269	S
4 vs 5	0.1967	0.1688	6/289	1.6707	0.1280	NS
5 vs 6	0.2493	0.1967	7/282	2.8251	0.0074	S

(N = 310)
Note. An alpha level of 0.05 was employed before each hypothesis was considered statistically valid.

TABLE 5.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE VARIABLE ELEVATION OF TOP OF BEREA SANDSTONE

Order of trend surface	R^2_f	R^2_r	df	F	Probability	Sign.
1	0.7801	0.0	2/350	620.7875	0.0000	S
2	0.8331	0.0	5/347	346.3073	0.0000	S
3	0.8875	0.0	9/343	300.5669	0.0000	S
4	0.9083	0.0	14/338	239.2048	0.0000	S
5	0.9167	0.0	20/332	182.6278	0.0000	S
6	0.9358	0.0	27/325	175.5181	0.0000	S
1 vs 2	0.8331	0.7801	3/347	36.6956	0.0000	S
2 vs 3	0.8875	0.8331	4/343	41.4659	0.0000	S
3 vs 4	0.9083	0.8875	5/338	15.3759	0.0000	S
4 vs 5	0.9167	0.9083	6/332	5.5485	0.0000	S
5 vs 6	0.9358	0.9167	7/325	13.8486	0.0000	S

(N = 353)
Note. An alpha level of 0.05 was employed before each hypothesis was considered statistically valid.

TABLE 6.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE VARIABLE SAND PER CENT CUTTINGS NUMBER ONE

Order of trend surface	R^2_f	R^2_r	df	F	Probability	Sign.
1	0.0833	0.0	2/48	2.1808	0.1240	NS
2	0.1033	0.0	5/45	1.0368	0.4078	NS
3	0.2842	0.0	9/41	1.8090	0.0959	NS
4	0.4212	0.0	14/36	1.8710	0.0652	NS
5	0.5524	0.0	20/30	1.8512	0.0618	NS
6	0.6595	0.0	27/23	1.6497	0.1131	NS
1 vs 2	0.1033	0.0833	3/45	0.3346	0.8004	NS
2 vs 3	0.2842	0.1033	4/41	2.5911	0.0506	NS
3 vs 4	0.4212	0.2842	5/36	1.7032	0.1589	NS
4 vs 5	0.5524	0.4212	6/30	1.4660	0.2234	NS
5 vs 6	0.6595	0.5524	7/23	1.0331	0.4356	NS

(N = 51)
Note. An alpha level of 0.05 was employed before each hypothesis was considered statistically valid.

TABLE 7.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE VARIABLE SAND PER CENT CUTTINGS NUMBER TWO

Order of trend surface	R^2_f	R^2_r	df	F	Probability	Sign.
1	0.0811	0.0	2/48	2.1186	0.1313	NS
2	0.0871	0.0	5/45	0.8583	0.5164	NS
3	0.1245	0.0	9/41	0.6480	0.7495	NS
4	0.3049	0.0	14/36	1.1281	0.3686	NS
5	0.4778	0.0	20/30	1.3723	0.2115	NS
6	NA	0.0				
1 vs 2	0.0871	0.0811	3/45	0.9770	0.9609	NS
2 vs 3	0.1245	0.0871	4/41	0.4386	0.7799	NS
3 vs 4	0.3049	0.1245	5/36	1.8687	0.1243	NS
4 vs 5	0.4778	0.3049	6/30	1.6549	0.1667	NS
5 vs 6	NA					

(N = 51)
Note. An alpha level of 0.05 was employed before each hypothesis was considered statistically valid.

TABLE 8.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE VARIABLE SAND PER CENT CUTTINGS NUMBER THREE

Order of trend surface	R^2_f	R^2_r	df	F	Probability	Sign.
1	0.0408	0.0	2/46	0.9784	0.3836	NS
2	0.0933	0.0	5/43	0.8852	0.4993	NS
3	0.2053	0.0	9/39	1.1192	0.3726	NS
4	0.3897	0.0	14/34	1.5506	0.1457	NS
5	0.4625	0.0	20/28	1.2046	0.3192	NS
6	0.5013	0.0	27/21	0.7819	0.7295	NS
1 vs 2	0.0933	0.0408	3/43	0.8303	0.4845	NS
2 vs 3	0.2053	0.0933	4/39	1.3734	0.2609	NS
3 vs 4	0.3897	0.2053	5/34	2.0547	0.0956	NS
4 vs 5	0.4625	0.3897	6/28	0.6322	0.7033	NS
5 vs 6	0.5013	0.4625	7/21	0.2336	0.9722	NS

(N = 49)
Note. An alpha level of 0.05 was employed before each hypothesis was considered statistically valid.

TABLE 9.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE VARIABLE SAND PER CENT CUTTINGS NUMBER FOUR

Order of trend surface	R^2_f	R^2_r	df	F	Probability	Sign.
1	0.1671	0.0	2/35	3.5108	0.0408	S
2	0.2965	0.0	5/32	2.6970	0.0383	S
3	0.4168	0.0	9/28	2.2236	0.0512	NS
4	0.5108	0.0	14/23	1.7151	0.1216	NS
5	0.5463	0.0	20/17	1.0235	0.4855	NS
6	0.6547	0.0	27/10	0.7022	0.7773	NS
1 vs 2	0.2965	0.1671	3/32	1.9616	0.1396	NS
2 vs 3	0.4168	0.2965	4/28	1.4445	0.2455	NS
3 vs 4	0.5108	0.4168	5/23	0.8833	0.5080	NS
4 vs 5	0.5463	0.5108	6/17	0.2219	0.9642	NS
5 vs 6	0.6547	0.5463	7/10	0.4484	0.8503	NS

(N = 38)
Note. An alpha level of 0.05 was employed before each hypothesis was considered statistically valid.

TABLE 10.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE VARIABLE SAND PER CENT CUTTINGS NUMBER FIVE

Order of trend surface	R^2_f	R^2_r	df	F	Probability	Sign.
1	0.1690	0.0	2/18	1.8307	0.1889	NS
2	0.3576	0.0	5/15	1.6698	0.2025	NS
3	0.4496	0.0	9/11	0.9985	0.4924	NS
4	0.8073	0.0	14/6	1.7955	0.2427	NS
5	NA	0.0				
6	NA	0.0				
1 vs 2	0.3576	0.1690	3/15	1.4675	0.2633	NS
2 vs 3	0.4496	0.3576	4/11	0.4599	0.7638	NS
3 vs 4	0.8073	0.4496	5/6	2.2273	0.1789	NS
4 vs 5	NA					
5 vs 6	NA					

(N = 21)
Note. An alpha level of 0.05 was employed before each hypothesis was considered statistically valid.

FIG. 3. Elevation contour of the top of the Berea Sandstone (feet), Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

FIG. 4. Thickness contour of Berea Sandstone (feet), Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

analysis does not fit a surface so that it passes through each point value. The surface will be fitted to the data values in such a way that the sum of the squared deviations between the given values at data points and the value of the computed surface is minimized. In the fitting of a polynomial trend surface, the higher the order of the surface, the more the residuals will be minimized, resulting in greater computation time and cost. Lower-order surfaces may be quite useful in isolating important local trends from those that exist over larger areas, even though higher order surfaces may reflect the variation in the input values more accurately. Thus, as suggested by Davis (6) and implemented by Smith (5), statistical testing using the F-distribution should be performed to determine the order of the sur-

TABLE 11.—MODEL COMPARISON OF THE THIRD DEGREE POLYNOMIAL TREND SURFACE WITH SECOND DEGREE SURFACE FOR THE VARIABLE BEREA SANDSTONE THICKNESS

Explanation of models	Models	df	R^2	Alpha	F-ratio	Probability	Sign.
Model 3:							
$Z = a_0U + a_1X + a_2Y + a_3X^2 + a_4XY + a_5Y^2 + a_6X^3 + a_7X^2Y + a_8XY^2 + a_9Y^3 + E$	Full		0.1850				
		4/158		0.05	3.1241	0.0166	
Model 2:							S
$Z = a_0U + a_1X + a_2Y + a_3X^2 + a_4XY + a_5Y^2 + E$	Restricted (covaried)		0.1206				

Where:
- Z = Berea Sandstone thickness measured in feet
- U = unit vector
- a_0 = constant term
- a_1–a_9 = partial regression coefficients in double precision
- X,Y = geographical coordinates converted to SYMAP system
- E = error vector (residuals) containing the difference between the actual and predicted values for measured values of Berea Sandstone thickness

Hypothesis:

Does the third degree trend surface for Measured Values of Berea Sandstone Thickness account for a significant amount of variance in predicting actual thickness values over and above that which can be accounted for by the lower second order trend surface equation.

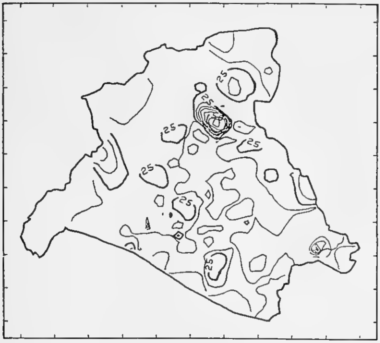

FIG. 5. Thickness contour of Sunbury Shale (feet), Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

FIG. 6. Production of oil (barrels/day), Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

face which best describes the spatial distributions of the variables studied.

The F-test, like the t-test, is a very robust test and relatively insensitive to violations of the assumptions of random selection of observations and normal distribution of the variables (7, 8, 9). The F-test for significance of fit is a test of the null hypothesis that the partial regression coefficients are equal to zero and, hence, there is no regression. If the computed F-value exceeds the F-value having a probability of a set alpha level, then the null hypothesis is rejected and the alternative hypothesis is accepted. The required input into the program is the total variation of the data, and the amount of variance accounted for by the order of the surface. This information is generated by most computer software packages that produce trend surfaces.

RESULTS

As shown in Tables 1–10, a regression analysis of testing the null hypothesis of each trend surface is represented by the first 6 entries. For example, in Table 1, each surface was found to be statistically significant at the assigned alpha level of 0.05. The R^2 terms in the table, multiplied by 100%, reflect the per cent of the variance in the data explained by the trend surface equation. R^2_f denotes the full model, or model with all the terms being tested, and the R^2_r represents the restricted model, or the terms being held constant or covaried. When testing the null hypothesis, all the R^2_r terms are zero, since a test of the trend over no regression is being performed. Model comparisons are completed in the last 6 entries of each of the tables, and the R^2_r term is the variance accounted for by the lower order surface. Table 11 illustrates a model comparison of trend order second and third for the variable Berea Sandstone thickness. Therefore, a significance test is used to determine the contribution to explained variance in the prediction by the higher order surface. As shown in Table 1, the first degree surface is the best fit for gas production; fifth order for oil production (Table 2); third degree for Berea Sandstone thickness (Table 3); first order for Sunbury Shale thickness (Table 4); sixth degree for elevation of top of Berea Sandstone (Table 5); first order for sand per cent from cuttings number one (Table 6); and no trend surface accounted for enough explained variance for sand per cent from cuttings number 2 (Table 7), number 3 (Table 8), number 4 (Table 9), or number 5 (Table 10).

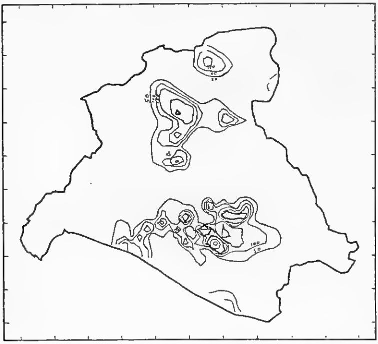

FIG. 7. Production of gas (1,000 ft³/day), Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

FIG. 9. Contour of sand per cent from cuttings number two, or second 20-foot interval, Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

Figures 3 through 12 are computer-generated contour maps of the various parameters associated with hydrocarbon occurrence studied in Lawrence County. An option that calculates the element-by-element difference between a grid matrix and a matrix stored on an external file (ISOPACH) was used to produce the computer-generated maps. Figure 3 represents the SURFACE II computer plot of elevation contour of the top of the Berea Sandstone; Figure 4 illustrates the contour map of the thickness of the Berea Sandstone; Figure 5 displays the thickness contour of the Sunbury Shale; Figure 6 is a graphic depiction of production of oil, contoured in barrels per day; Figure 7 depicts the computer-generated contour map of gas production in 1,000 ft³ per day; Figures 8 through 12 represent contours of five lithological parameters of the Berea Sandstone from cuttings. Figure 8 displays the spatial re-

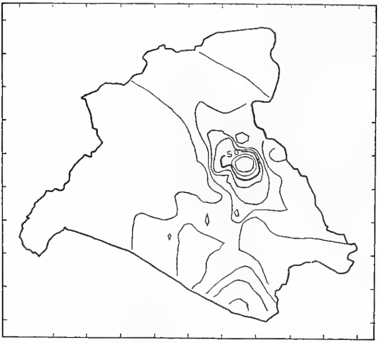

FIG. 8. Contour of sand per cent from cuttings number one, or first 20-foot interval, Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

FIG. 10. Contour of sand per cent from cuttings number three, or third 20-foot interval, Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

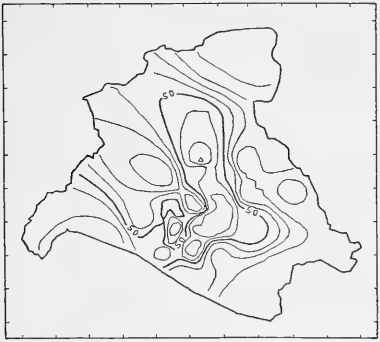

FIG. 11. Contour of sand per cent from cuttings number four, or fourth 20-foot interval, Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

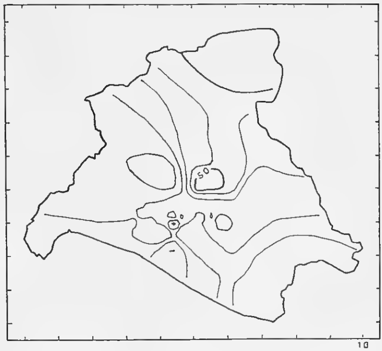

FIG. 12. Contour of sand per cent from cuttings number five, or fifth 20-foot interval, Lawrence County, Kentucky (from in-progress thesis by Morgan (10)).

lationship of per cent sand from the first 20 feet or cuttings number 1, Figure 9 for cuttings number 2, Figure 10 for cuttings number 3, Figure 11 for cuttings number 4, and Figure 12 for cuttings number 5, or the last 20-foot interval of the Berea Sandstone.

SUMMARY

The use of computer graphics, trend surface analyses, and significance testing of trend surfaces can greatly aid the scientist in the examination of spatially oriented data. The author recommends that these techniques, which are readily available, be routinely used in determing trends and their prediction.

ACKNOWLEDGMENTS

I appreciate the help in compiling and executing the computer graphics offered by Baylus Morgan, a former graduate student at Eastern Kentucky University, and Brandon C. Nuttall of the Kentucky Geological Survey. In addition, the figures used in this study were derived from an in-progress thesis by Baylus Morgan, Department of Geology at Eastern Kentucky University, for whom I was major advisor. I extend my gratitude to Gayle Seymour, Academic Programmer Analyst at The University of Akron, for assistance in developing the trend-surface model comparisons, which aided in the development of Tables 1 through 11.

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Trans. Ky. Acad. Sci., 44(1–2), 1983, 68–73

Habitat Selection by Small Mammals in an Urban Woodlot[1]

MARK A. MCPEEK[2], BARBARA L. COOK[3], AND WILLIAM C. MCCOMB[4]
University of Kentucky, Lexington, Kentucky 40546

ABSTRACT

Removal trapping was used to identify which of 27 habitat variables were important to each of 5 small mammal species inhabiting an urban woodlot and an adjacent field. *Microtus pinetorum* selected wooded areas with high vertical vegetative stratification, with an abundance of evergreen shrubs and ground cover, and with many long logs. *Microtus pennsylvanicus* and *M. ochrogaster* selected areas dominated by grass and sedge vegetation. *Peromyscus leucopus* was captured in close proximity to trees in both wooded and field habitats. Logs were habitat characteristics important to *Blarina brevicauda* captures.

INTRODUCTION

Many techniques have been employed to study segregation of small mammal species within an environment. Hamilton (1) tried to describe habitats of small mammals by indigenous plant taxa. Ambrose (2) studied movements of *M. pennsylvanicus* in pens that simulated their natural habitat. His studies indicated that flexibility in habitat utilization would allow modification in the animal's behavior according to local environmental conditions (2).

Recent studies have shifted emphasis to the determination of structure and composition of microhabitats. Dueser and Shugart (3, 4) employed statistical analysis of structural variables to determine microhabitats and niche overlap among small mammal species. The distribution of vegetative strata was used to describe the distribution of *Peromyscus leucopus* (5). Food abundance, nesting sites, and complexity of escape routes also acted as deterministic factors in the distribution of *P. leucopus* (5). Stages and growth forms of vegetation have been considered to be of primary importance in determining small mammal distribution and density (6, 7, 8, 9).

The objective of our study was to quantify microhabitat differences among small mammal species in an urban woodlot and in an adjacent field, and to identify the environmental variables that would distinguish among the preferred microhabitats for species within the small mammal community.

MATERIALS AND METHODS

The study area was Shady Lane Woods, a 6-ha undisturbed tract in the southwest section of the University of Kentucky campus, Lexington. The area consists of two adjacent but different habitats: one dominated by *Poa pratensis*, *Festuca* spp., *Carex* spp. with a partial *Juglans nigra* overstory, and another of mixed hardwoods (*J. nigra*, *Celtis occidentalis*, and *Gymnocladus dioicus*) with ground cover ranging from sparse herbs to dense *Euonymus fortunei*, *E. americanus* and *Symphoricarpos orbiculatus*.

A grid system of 50 points (5 rows of 10 points) was established to equally sample both the field and the forest. Intersection points on the grid were 8 m apart. One tree was present in the field portion of the study area, and the field was partially covered by the canopies of 2 adjacent trees as well as by the trees at the wood's edge.

Following unacceptable capture efficiency with pitfall traps and live traps, 4

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[1] This investigation (No. 82-8-78) was in connection with Kentucky Agricultural Experiment Station No. 624. It is published with approval of the Director.

[2] School of Biological Sciences.

[3] Present address: School of Forestry, Yale University, New Haven, Connecticut.

[4] Department of Forestry.

snap traps (2 mouse traps, 2 Museum Specials) were distributed per grid point, with emphasis on placing the traps on existing mammal runs within 1.5 m of the plot point. Peanut butter and cotton were used as bait.

Trapping was conducted for 3 periods during 1981: 24 May to 5 June, 21 July to 23 July, and 11 September to 14 September. For purposes of calculation, the second and third capture periods were combined into 1 period since they were each of short duration; the periods were similar in weather, and summer herbaceous vegetation dominated during that time. The traps were checked twice a day: 0700 and 1900 hours.

Habitat characteristics that do not vary seasonally (tree, log, snag and stump characteristics) were measured at each grid point in March and April, 1981. Vegetative cover, stem density, and leaf cover were measured in May 1981 and were used to describe the first trapping period. The characteristics that changed seasonally were remeasured in July and considered representative of the habitat during the second and third trapping periods. A detailed description of habitat variables and measurement techniques is found in Table 3.

Linear correlation was used to determine association of habitat variables with the number of small mammal captures. A t-test was used to compare mean habitat variables for plots where captures were made with means for plots where captures were not made.

RESULTS

During the 2 trapping periods, 99 captures were made: 37 *Microtus pinetorum*, 8 *Blarina brevicauda*, and 6 *Peromyscus leucopus* during the first period and 23 *M. pinetorum*, 10 *M. pennsylvanicus*, 9 *P. leucopus*, 3 *B. brevicauda*, and 3 *M. ochrogaster* during the second period. Captures were made on 41 of the 50 grid points. Multiple captures were made on 15 grid points. Animals were captured on 27 of the 50 plots during the first trapping period, and on 16 plots in the second period.

Microtus pinetorum.—*Microtus pinetorum* was captured more often in the woods (44) than in the field (16) ($P < 0.05$) but 11 were caught in the field and 13 in the woods during the second trapping period. *Microtus pinetorum* was trapped at 20 of the 25 points in the woods with a maximum of 6 captures made at each of 2 woods points. In the field, *M. pinetorum* was taken at 10 points with multiple captures at 4 points.

Of 27 habitat variables considered for *M. pinetorum*, 15 showed significant correlation to capture site during the first trapping period, but no variable showed significant correlation during the second trapping period due to randomness of *M. pinetorum* captures. Of the variables that showed correlation during the first period, tree characteristics dominated (Table 1). Positive correlations were obtained for height of overstory ($P < 0.01$), midstory ($P < 0.01$), and understory trees ($P < 0.05$); per cent of canopy cover ($P < 0.05$); and foliage height diversity ($P < 0.05$). Captures were negatively correlated ($P < 0.05$) with distance to the nearest tree. Results of the t-tests on these variables yielded similar results (Table 1). *Microtus pinetorum* showed its preference for the woods by its negative correlation with major field variables: per cent of grass cover ($P < 0.1$), density of herbaceous cover ($P < 0.1$), and number of herb species ($P < 0.01$) (Table 1). Percentage of non-deciduous plant cover influenced the distribution of *M. pinetorum*; evergreenness of shrubs ($P < 0.001$), ground cover ($P < 0.01$), and herbs ($P < 0.05$) were positively correlated with captures of *M. pinetorum*. The t-test results indicate that a preponderance of evergreen ground cover (*E. fortunei*, *E. americanus*, and *S. orbiculatus*) was the most influential variable of the 3.

Finally, *M. pinetorum* showed preference for logs in the environment. Captures showed positive correlation with log diameter ($P < 0.001$) and log density ($P < 0.001$), and negative correlation with distance to the nearest log ($P < 0.001$).

Microtus pennsylvanicus.—*Microtus pennsylvanicus* exhibited a preference for

TABLE 1.—MEANS AND STANDARD DEVIATIONS FOR POINTS WITHOUT CAPTURES VERSUS POINTS WITH CAPTURES, $P > (t)$, AND COEFFICIENTS OF CORRELATION (r) FOR HABITAT VARIABLES OF *Microtus pinetorum*

Variable	Non-captures (N = 20) ($\bar{x} \pm s$)	Capture (N = 30) ($\bar{x} \pm s$)	$P > (t)$	r
Overstory tree height (m)	7.2 ± 11.0	14.3 ± 11.8	0.04	0.373*
Midstory tree height (m)	3.3 ± 4.9	6.8 ± 4.9	0.02	0.420*
Understory tree height (m)	1.0 ± 1.3	2.5 ± 1.8	0.002	0.323*
Canopy cover (%)	62.8 ± 36.9	82.4 ± 27.2	0.05	0.300*
Foliage height diversity	1.0 ± 0.4	1.2 ± 0.3	0.04	0.302*
Tree distance (m)	8.2 ± 7.4	2.5 ± 2.5	0.0004	−0.349*
Grass cover (%)	52.7 ± 34.0	26.1 ± 32.6	0.009	−0.436*
Number of herb species	16.0 ± 5.7	11.4 ± 3.2	0.0007	−0.368*
Herb stem density/4 m^2	385.6 ± 217.8	177.8 ± 189.4	0.002	−0.427*
Evergreenness of shrubs (%)	1.1 ± 2.4	4.2 ± 4.7	0.02	0.480**
Evergreenness of herbs (%)	23.8 ± 28.9	48.8 ± 35.8	0.01	0.281*
Evergreenness of ground cover (%)	47.4 ± 35.8	78.1 ± 32.3	0.004	0.444*
Log diameter (cm)	4.4 ± 6.5	11.6 ± 6.2	0.0003	0.462**
Log density/4 m^2	0.6 ± 1.0	1.8 ± 1.4	0.0007	0.454**
Log distance (m)	13.8 ± 8.6	6.4 ± 6.7	0.003	−0.424*

* $P < 0.05$.
** $P < 0.001$.

the field in this study. Ten *M. pennsylvanicus* were taken at 5 of the 25 field-points. Capture points had a lesser per cent canopy cover ($P < 0.001$), and they were farther from trees ($P < 0.005$) than points without captures. Capture points also had lower evergreen ground cover ($P < 0.0001$), and denser herbaceous ground cover ($P < 0.001$) than non-capture points.

Correlations between the number of captures per point and habitat variables influencing captures were more difficult to make because of the small sample size and the positions of points where captures were made (Table 2). Variables measuring stratification of vegetation at the points, canopy cover ($P < 0.001$) and foliage height diversity ($P < 0.001$), were negatively correlated with *M. pennsylvanicus* captures. Captures were also negatively correlated with the following variables characteristic of woods: density of woody stems ($P < 0.05$), number of woody stems ($P < 0.05$), percentage of evergreen herbs ($P < 0.05$), and ground cover ($P < 0.01$).

Other Species.—Three other species of small mammals were captured during this study: *P. leucopus*, *B. brevicauda*, and *M.*

TABLE 2.—MEANS AND STANDARD DEVIATIONS FOR POINTS WITHOUT CAPTURES VERSUS POINTS WITH CAPTURES, $P > (t)$, AND COEFFICIENTS OF CORRELATION (r) FOR HABITAT VARIABLES OF *Microtus pennsylvanicus*

Variable	Non-captures (N = 45) ($\bar{x} \pm s$)	Capture (N = 5) ($\bar{x} \pm s$)	$P > (t)$	r
Canopy cover (%)	75.6 ± 31.4	17.8 ± 22.0	0.0001	−0.465**
Foliage height diversity	1.1 ± 0.3	0.5 ± 0.3	0.0003	−0.430*
Tree distance (m)	5.4 ± 6.3	12.8 ± 7.9	0.02	0.242
Number of woody species	5.4 ± 3.7	0.3 ± 0.5	0.0001	−0.356*
Woody stem density/4 m^2	22.4 ± 19.9	4.2 ± 10.2	0.04	−0.270*
Evergreenness of herbs (%)	36.8 ± 33.7	1.7 ± 1.6	0.0001	−0.270*
Evergreenness of ground cover (%)	63.8 ± 36.1	13.3 ± 12.2	0.0001	−0.435*
Ground cover (%)	74.1 ± 30.0	98.3 ± 4.1	0.0001	−0.227

* $P < 0.05$.
** $P < 0.001$.

TABLE 3.—DESIGNATION, DESCRIPTIONS, AND SAMPLING METHODS OF 27 VARIABLES MEASURING FOREST HABITAT STRUCTURE

Variable	Methods
1) Per cent canopy cover	Per cent of overstory vegetation coverage above a 1.0 m radius circle around plot center.
2) Per cent ground cover	Percentage of soil covered by vegetation within a 1.0 m radius circle around plot center.
3) Per cent shrub cover	Same as (1) for shrub-level vegetation.
4) Overstory tree height	Height in m of the nearest overstory tree.
5) Midstory tree height	Height in m of the nearest midstory tree.
6) Understory tree height	Height in m of the nearest understory tree.
7) Number of woody species	Woody species count within a 1.0 m radius circle around point center.
8) Number of herbaceous species	Same as (7) for herbaceous species.
9) Woody stem density	Live woody stem count within a 1.0 m radius circle around point center.
10) Herbaceous stem density	Same as (9) for herbaceous stems.
11) Tree stump density	Largest diameter in cm of the nearest tree stump.
12) Tree stump distance	Distance in m to the nearest tree stump.
13) Log diameter	Largest diameter in cm of the nearest fallen log (>10.0 cm diameter).
14) Log length	Length in m of the nearest fallen log (>10.0 cm diameter).
15) Log density	Same as (9) for fallen logs (≥10.0 cm diameter).
16) Log distance	Distance in m to the nearest fallen log (≥10.0 cm diameter).
17) Snag diameter	Diameter in cm at breast height of the nearest dead tree (>10.0 cm).
18) Snag distance	Distance in m to the nearest dead tree.
19) Tree diameter	Diameter in cm at breast height of the nearest tree (≥10.0 cm diameter).
20) Tree distance	Same as (18) for distance to the nearest tree.
21) Number of tree species	Same as (7) for tree species.
22) Leaf litter	Greatest depth in cm of leaf litter within a 1.0 m radius circle around plot center.
23) Per cent of grass cover	Same as (2) for grasses.
24) Evergreenness of shrubs	Same as (1) for evergreen shrub-level vegetation.
25) Evergreenness of herbs	Same as (2) for herbaceous vegetation.
26) Evergreenness of ground cover	Same as (2) for ground cover.
27) Foliage height diversity	Foliage height diversity index (19) calculated from the following formula: $FHD = 3.3219(\log N-(1/N(n_o \log n_o + n_m \log n_m + n_u \log n_u)))$ where n_o = per cent overstory cover, n_m = per cent midstory cover, n_u = per cent understory cover, and $N = n_o + n_m + n_u$.

ochrogaster. *Peromyscus leucopus* was captured 15 times during the study, 6 times during the first capture period and 9 times during the second period. *Blarina brevicauda* was taken 11 times, 8 during the first sample period and 3 in the second period. Only 3 *M. ochrogaster* were captured, all during the second period, and all were taken in the field.

Peromyscus leucopus has been characterized as a species preferring a shrubland-woodland habitat (5, 10), but we caught more *P. leucopus* in the field than in the woods. The per cent canopy cover was the only variable that showed correlation with capture ($P < 0.05$) in both sample periods. The points where *P. leucopus* were taken in the field indicated its preference for trees since every capture site was within 8 m of a tree.

Blarina brevicauda was an ubiquitous species that showed no preference for a specific type of vegetation. They have been taken in vegetation types ranging from grasslike to forested (11, 12). Captures of *B. brevicauda* were positively correlated with log length ($P < 0.05$), probably because invertebrates could be found in greater numbers there.

Only 3 *M. ochrogaster* were taken during the study. However, these 3 captures substantiated the available literature on the prairie vole; it is a species of grassy fields (7, 13, 14).

DISCUSSION

Microtus pinetorum captures were correlated with tree variables, reflecting the predominance of captures in the woods. They occurred at sites with thick canopy cover, adjacent trees, and high tree species diversity and showed preference for sites of vegetative strata diversity. Life forms of vegetation influenced selection of habitat by *M. pinetorum*. Variables that consider life forms rather than taxa have been shown to be most important in *M. pinetorum* habitat selection (8). This species preferred sites with a preponderance of evergreen vegetation. Woody and herbaceous plants have more water available during the growing season than grasses. Benton (15) reported that *M. pinetorum* is not dependent on water to any degree in nature; the species thrives in captivity without water if succulent food is supplied. It is reported to feed on succulent roots and tubers in nature (1). *Microtus pinetorum* also occurred at sites with fallen logs. Log diameter, density, and distance were important habitat features. Microtine runs were observed along fallen logs; *M. pinetorum* will nest under fallen logs (13).

Microtus pennsylvanicus segregated itself from *M. pinetorum* by its selection of field characteristics, occurring at sites with dense grass. Many studies have shown *M. pennsylvanicus* to prefer grass-like herbaceous cover (6, 9, 16, 17), while avoiding areas where woody plants predominate (18).

The number of captures of other species was low, but general trends were discerned. *Peromyscus leucopus* showed a preference for points with trees in the vicinity, *Blarina brevicauda* showed a preference for long logs; and *M. ochrogaster* preferred grassy habitats.

The results of this study indicate that habitat characteristics selected by small mammals in an urban woodlot were similar to characteristics reported in previous studies for each species in rural areas. The location of the woodlot in an urban environment had no obvious effect on habitat selection by indigenous small mammals. Shady Lane Woods offers unique opportunities to study sympatric small mammal species in an urban setting because of its diverse habitats and high species richness of small mammals.

ACKNOWLEDGMENTS

We thank Wayne H. Davis, Bart A. Thielges, and Robert N. Muller for a critical review of an early draft of the manuscript; Gail A. McPeek for assistance with field-data collecting; and Charles Rowell for assistance with statistical analysis.

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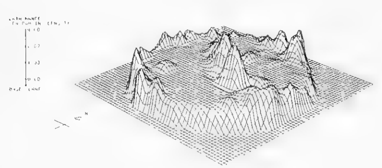
Trans. Ky. Acad. Sci., 44(1–2), 1983, 74–77

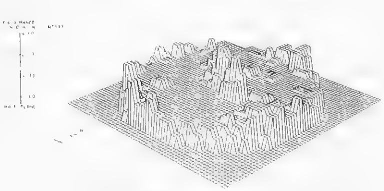
NOTES

Three-dimensional Plotting of Schmidt Nets.—Problems involving angular relationships of lines and planes can be solved with descriptive geometry methods. However, if certain complex problems, such as the 3-dimensional geometry of a rock mass, are to be solved graphically, then the use of the stereographic projection or stereonet is essential (Ragan, Structural geology: An introduction to geometrical techniques, 2nd ed., John Wiley & Sons, 1973). With a large number of scattered points, the problem of treating and evaluating the data arises. Thus, the statistical evaluation of orientational data with the aid of a digital computer is certainly destined to be an increasingly important approach (Cruden and Charlesworth, G.S.A. Bull. 83:2019–2024, 1972; Watson, Bull. Geol. Inst. 2:73–83, 1970). The evaluation of plotted data requires a special type of net, since the resulting distribution plotted on the usual Wulff net would not be statistically random. To overcome this difficulty, an equal area of the Schmidt net is used, since, for many applications in structural geology, it is convenient to use a projection that does not distort area. Once the point diagram is prepared, the densities are counted out. A wide range of graphical counting methods have been developed (Denness, Geol. Mag. 109:157–163, 1972; Hobbs, Means, and Williams, An outline of structural geology, John Wiley & Sons, 1976; Stauffer, Canadian Jour. Earth Sci. 3:474–498, 1966).

In an attempt to illustrate a graphical counting method, approximately 400 stike and dip readings were taken in an area of the Shenandoah Valley region, Virginia, and plotted on an equal area projection. SYMAP (Dougenik and Sheehan, SYMAP users reference manual, Harvard Univ., 1979), which is a computer package designed for the purpose of producing line-printer maps to depict spatially distributed data, was used to contour the point densities and create an 89 × 89 digital data matrix of this information on a tape file. This data file was then fed into a three-dimensional plotting program using the following options: QUSMO2, which performs a 9-point quadratic interpolation between points to give a smooth appearance (Fig. 1); and QUTAB, which produces a plot similar to a three-dimensional histogram (Fig. 2) (Sawan and Nash, Three-dimensional mapping programs user manual, Univ. of Akron, 1974). Both figures display the same information, and the plots can be rotated in 8 directions; this more dramatically presents structural information than the traditional 2-dimensional contour diagram.



PARTIAL PLOT OF SHENANDOAH VALLEY



SYMAP, QUSMO2, and QUTAB are commercially available and require no previous programming experience or knowledge. Both SYMAP and SURFACE II (Sampson, Surface II graphics system, Kan. Geol. Survey, 1979), the counterpart to QUSMO2, are presently available to interested persons through the University of Kentucky as well as several other academic computing centers.—Alan D. Smith, Dept. Geol., East. Ky. Univ., Richmond, Kentucky 40475.

New Species Records of Caddisflies (Trichoptera: Hydropsychidae) in Kentucky.—Two species of caddisflies are added to the list of species known from Kentucky: *Hydropsyche frisoni* Ross and *Symphitopsyche slossonae* (Banks). *Hydropsyche frisoni* larvae were collected on 6 June 1979 from Crooked Creek, 3 August 1979 from Browne Fork of Skeggs Creek, and on 14 August 1979 from the Rockcastle River in Rockcastle County. *Symphitopsyche slossonae* larvae were collected on 5 September 1979 from Horse Lick Creek and from Clover Bottom Creek, and again on 6 June 1979 from Horse Lick Creek in Jackson County.

Specimens were identified by means of the keys and species descriptions provided by Schuster and Etnier (USEPA Publ., EPA 600/4-78-060, 129 pp., 1978) and were confirmed by Dr. G. A. Schuster, Eastern Kentucky University. These records supplement the list of Kentucky Trichoptera (Resh, Trans. Ky. Acad. Sci. 36:6–16, 1975), and bring the current Commonwealth total to 177 species.

Hydropsyche frisoni is known from Illinois, Michigan, Tennessee, Alabama, and Minnesota (Ross, Bull. Ill. Nat. Hist. Surv. 21:101–183, 1938; Ross, Bull. Ill. Nat. Hist. Surv. 23, 326 pp., 1944; Leonard and Leonard, Occ. Pap. Mus. Zool. Mich. 522:1–35, 1949; Etnier, J. Ga. Ent. Soc. 8:272–274, 1973; Schuster and Etnier, 1978). *Symphitopsyche slossonae* has a much broader known range, extending over the northeastern sections of the United States and Canada. The discovery of these 2 species in Kentucky was not surprising considering their known distributional ranges, and more intensive collecting in the area would probably increase the total for Trichoptera in Kentucky.

We thank Dr. G. A. Schuster for confirming the identification of the specimens.—William T. Thoeny, Dept. Entomol., Univ. Ky., Lexington, Kentucky 40506 and Donald L. Batch, College Nat. and Math. Sci., East. Ky. Univ., Richmond, Kentucky 40475.

Suggested Format for Presenting Hypothesis Testing and Model Comparisons of Trend Surfaces.—Trend-surface analysis is the term for a mathematical method of separating map data into two components, regional and local (Davis, Statistics and data analysis in geology, John Wiley and Sons, Inc., New York, 1973). Hypothesis testing and model comparisons of successively higher order trends are important in this process. The significance of a trend, or regression, may be tested through the analysis of variance, which separates variance into components with defined sources, or through the F-test which explores the null hypothesis that partial regression coefficients are equal to zero and, hence, there is no regression. In polynomial trend-surface analysis, it is customary for investigators to fit a series of successively higher polynomials to the data without justifying their contribution of additional explained variance over the previous lower order trend. As demonstrated elsewhere (Smith, Trans. Ky. Acad. Sci. (abs.) 43(1–2):93, 1982), an analysis of variance table should be expanded to analyze the contribution of the additional partial regression coefficients to give a measure of the appropriateness of increasing the order of the equation.

Hypothesis testing and model comparisons to evaluate higher order trends are relatively recent statistical procedures, not fully practiced by researchers using trend surface analysis techniques. A standardized format to present the data generated from these procedures is needed. Table 1 illustrates data for a fourth-degree polynomial trend surface with random variation. The terms in the table are esential to the development and understanding of the statistical results to evaluate the explained variance of the additional partial regression weights. Model 4 represents the fourth-degree surface with its related statistics: degrees of freedom, both in the numerator and denominator (df); amount of variance accounted for by the regression equation (R^2); set decision criterion (alpha); F-ratio; probability of the F-ratio (*P*); and significance (NS or S). Model 99 shows a restricted model displaying simple random variation, noted by the constant term, a_0U, and residual vector, E. Table 2 illustrates the results of determining if additional variance accounted for by a third-degree surface trend is significant enough to warrant its use over and above the variance accounted for by a second-degree surface. Lastly, Table 3 lists a summary of F ratios, probability levels, R^2 for both the full and restricted models, degrees of freedom for both numerator and denominator, and significance for each trend surface. This table condenses 11 separate tables in the hypothesis testing and model comparisons process.

The tables presented here are an attempt to display, in an organized and selective fashion, the relatively large amount of information associated with a detailed statistical analysis of trend surfaces. The suggested format, similar in nature to the related statistical format frequently used with multiple lin-

TABLE 1.—MODEL COMPARISON OF FOURTH DEGREE POLYNOMIAL TREND SURFACE WITH RANDOM VARIATION FOR THE SPATIALLY DISTRIBUTED FREE-AIR GRAVITY (HENNING AND SMITH, TRANS. KY. ACAD. SCI. (ABS.) 43(1–2):92, 1982)

Explanation of models	Models	df	R^2	Alpha	F	*P*	Sign.
Model 4:							
$Z = a_0U + a_1X + a_2Y + a_3X^2 + a_4XY + a_5Y^2 + a_6X^3 + a_7X^2Y + a_8XY^2 + a_9Y^3 + a_{10}X^4 + a_{11}X^3Y + a_{12}X^2Y^2 + a_{13}XY^3 + a_{14}Y^4 + E$	Full	14/193	0.8767	0.05	98.0220	0.0000	S
Model 99:							
$Z = a_0U + E$	Restricted		0.0000				
Where: Z = free-air gravity; U = unit vector; a_0–a_{14} = regression coefficients; X,Y = geographical coordinates (SYMAP); E = error vector (residuals)							

Hypothesis:

The fourth degree trend surface of free-air gravity accounts for a significant amount of variance in predicting values over and above that which can be accounted for by random variation.

Note. The term "Full Model" denotes the trend equation with all the higher order coefficients and the equation that is being tested for its contribution of additional variance. The term "Restricted Model" denotes the trend equation with the lower order coefficients and the equation that is being held constant in terms of its contribution of explained variance.

TABLE 2.—MODEL COMPARISON OF THIRD DEGREE POLYNOMIAL TREND SURFACE WITH SECOND DEGREE SURFACE FOR ELEVATION DATA (SMITH AND TIMMERMAN 1982, UNPUBLISHED STUDY).

Explanation of models	Models	df	R^2	Alpha	F	*P*	Sign.
Model 3:							
$Z = a_0U + a_1X + a_2Y + a_3X^2 + a_4XY + a_5Y^2 + a_6X^3 + a_7X^2Y + a_8XY^2 + a_9Y^3 + E$	Full	4/129	0.2773	0.05	6.4249	0.0001	S
Model 2:							
$Z = a_0U + a_1X + a_2Y + a_3X^2 + a_4XY + a_5Y^2 + E$	Restricted		0.1333				

Where: Z = elevation of bedrock (feet)
U = unit vector
a_0–a_9 = regression coefficients
XY = geographical coordinates
E = error vector (residuals)

Hypothesis:

The third degree trend surface accounts for a significant amount of variance in predicting bedrock elevation over and above that which can be accounted for by the second degree surface.

Note. For definitions of "Full Model" and "Restricted Model," see Table 1.

TABLE 3.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE VARIABLE BEDROCK DEPTH (SMITH AND TIMMERMAN 1982, UNPUBLISHED STUDY)

Order of trend surface	R^2_f	R^2_r	df	F	Probability	Sign.
1	0.0202	0.0	2/135	1.3931	0.2518	NS
2	0.4766	0.0	5/132	24.0416	0.0000	S
3	0.4947	0.0	9/128	13.9529	0.0000	S
4	0.6026	0.0	14/123	13.3231	0.0000	S
5	0.7146	0.0	20/117	14.6456	0.0000	S
6	0.7807	0.0	27/110	14.5010	0.0000	S
1 vs 2	0.4766	0.0202	3/132	38.3693	0.0000	S
2 vs 3	0.4947	0.4766	4/128	1.1472	0.3374	NS
3 vs 4	0.6026	0.4947	5/123	6.6782	0.0000	S
4 vs 5	0.7146	0.6026	6/117	7.6488	0.0000	S
5 vs 6	0.7807	0.7146	7/110	4.7356	0.0001	S

(N = 138)

Note. An alpha level of 0.05 for a two-tailed, nondirectional test was employed before a hypothesis was considered statistically valid.

ear regression, is designed to maximize clarity of information to aid the potential user in the interpretation of trends. The author recommends this format for routine use in all analyses of geographical trends that have representative sample locations.—Alan D. Smith, Dept. Geol., East. Ky. Univ., Richmond, Kentucky 40475.

Some Observations on the Egg String of a Nematomorph Worm, *Paragordius* sp.—On 12 September 1981 J. D. Jarnette, a graduate student in the Biology Dept., Univ. of Louisville, brought to one of our offices (F.H.W.) 2 living female specimens of *Paragordius* sp., 1 of which was ovipositing. The worms and egg string were placed in a container with aquarium water and observed for about 5 weeks, until the worms died. The adults were preserved in 70% ethanol, and the egg string was refrigerated at 4°C. The egg mass was subsequently examined on 4 occasions over 11 weeks for emerging and motile larvae.

At no time was there any detectable swelling of the egg string. During the fourth week, before refrigeration of the egg string, thousands of hatched larvae were observed on the bottom of the culture dish. Very few of these showed any movement. Although not motile, some larvae were in the process of emerging from the eggs (Fig. 1). Terminology of Fig. 1 is of Dorier (Trav. Lab. Hydrobiol. Piscicult.

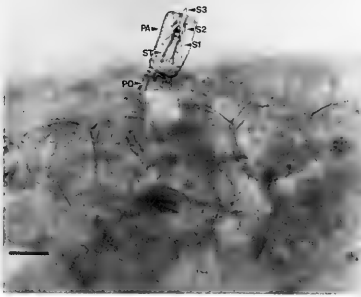


FIG. 1. Larva of *Paragordius* sp. in egg string. A part of the postseptum is visible. Retracted within the annulated postacanthal region of the preseptum can be seen the stylets of the proboscis and some spines of all 3 rows. Abbreviations: PA, postacanthal region; PO, postseptum; S1, spines of row 1; S2, spines of row 2; S3, spines of row 3; ST, stylets of proboscis. Bar equals 0.0058 mm.

Grenoble 22:1–183, 1930, and adopted from Muldorf, Z. Wiss. Zool. 111:1–75, 1914 by Zapotosky, Proc. Helminthol. Soc. Wash. 41:209–221, 1974). At no time was any larva observed to be encysted. The most signicant results of this study were observations of larval movement and emergence during each of the 4 times the egg mass was examined following the latter's refrigeration for 11 weeks.

There was no information from the available literature regarding the length of time larvae continue to hatch from eggs. The 11 weeks we recorded for the larvae of *Paragordius* sp. are probably not unusual for nematomorphs. Such extended hatching in nature would more effectively ensure the presence of infective larvae whenever hosts become available in the immediate area. This spatial and temporal relationship would have definite survival value for the nematomorphan species, since the larva probably does not survive long after hatching.

Basically, the larva is the infective stage for the arthropod host in which it transforms to the parasitic juvenile. Upon emergence, the juveniles rapidly mature to free-living adults which mate. From one to several million eggs are eventually deposited by each female (Cheng, Gen. Parasitol., Academic Press, 965 pp., 1973). Various modifications of how the larva enters the host exist; for example, larvae of *Gordius aquaticus* encyst and are perhaps ingested (Dorier, 1930), while larvae of *G. robustus* and *Paragordius varius* penetrate the host (May, Ill. Biol. Monogr. 5:1–118, 1919). A third condition is the larva of *Chordodes japonensis* which emerges from the egg, does not encyst, but must be ingested by the host (Inoue, Jap. J. Zool. 12:203–218, 1958).—Fred H. Whittaker and Robert L. Barker, Dept. Biol., Belknap Campus, Univ. of Louisville, Louisville, Kentucky 40292.

Note on Kentucky Riffle Beetles.—Distribution of the 3 families of aquatic insect usually called riffle beetles, i.e., Dryopidae, Psephenidae, and Elmidae, is very poorly known in Kentucky, hence the reason for this note. The following specimens were collected from Mud Creek, 4 km above the mouth, Madison County, Kentucky; 17 September 1970: 1 adult female *Helichus lithophilus* (Dryopidae), 12 immature *Psephenus herricki* (Psephenidae), 8 adult *Stenelmis sexlineata* (Elmidae). Dr. Harley P. Brown, foremost American authority on riffle beetles, diagnosed the specimens. He is anxious to obtain specimens from Kentucky and is willing to provide specific diagnoses. His address is: Dept. of Zoology, University of Oklahoma, Norman, Oklahoma 73069.—B. A. Branson, Dept. Biol., East. Ky. Univ., Richmond, Kentucky 40475.

Trans. Ky. Acad. Sci., 44(1–2), 1983, 78–90

ACADEMY AFFAIRS

The Sixty-Eighth Annual Business Meeting of the Kentucky Academy of Science

Ashland Oil, Inc., Ashland, Kentucky

4–6 November 1982

Host: Dr. William Hettinger, Jr.

Minutes of the Annual Business Meeting

The meeting was called to order by President George at 0930, 6 November in the Auditorium of the Petroleum Building with approximately 85 members in attendance.

After a motion by Secretary Creek and a second from the floor, the minutes of the 1981 annual business meeting at Murray State University, as recorded in the *Transactions* Vol. 43(1-2), were approved. Secretary Creek made a motion that all new members for 1982 be accepted by the Academy. Following a second from the floor the motion passed. Dr. Creek said that only about 50 percent of the membership had paid their 1982 dues and thus received the September issue of the *Transactions*. He pointed out that in order to receive the 1983 *Transactions* the 1983 dues must be paid by February 1, 1983.

The Treasurer's report was made by Dr. Taylor.

Treasurer's Report to Audit Committee

Kentucky Academy of Science

November 5, 1981–November 1, 1982

Cash in Madison National Bank, Richmond, Kentucky 1 November 1981		$ 7,684.33
RECEIPTS:		
Registration—Fall Meeting	$ 2,698.00	
Membership Dues	6,407.00	
Transactions Subscriptions	1,400.00	
Institutional Affiliations	250.00	
Page Charges	1,245.00	
Miscellaneous	950.18	
	$12,950.18	
Total Cash and Receipts—1981–82		20,634.51
DISBURSEMENTS:		
Transfers (Floristic Grant)	$ 1,024.83	
Operating Expenses	1,673.43	
Junior Academy of Science	500.00	
Publication of *Transactions* (Volume 42, No. 3–4, (Vol. 43, No. 1–4)	17,313.17	
Total Disbursements—1981–82		20,511.43
Cash on Hand—1 November 1982		123.08
Cash on Hand and Disbursements		20,634.51
BALANCE:		
Cash on Hand—1 November 1982 for FY 81–82		123.08
Prepaid 1983 Membership Dues		1,737.00
Total Cash on Hand		1,860.08
Maria Athey Memorial Fund (CD)		$40,000.00
Interest (Reinvested in Repurchase Agreements)		3,878.49
Total Reserves		$43,878.49
Botany Foundation (CD)		$10,000.00
Interest		757.32
Savings Account (1982) Working		1,079.94
Total in Savings Account (Renewal)		1,066.72
Total Reserves Before Grants		12,904.20
Grants (2)		1,050.00
Balance		11,854.20
Floristic Grant Fund—1981–82		1,524.83
Grants (1)		500.00
Balance		1,024.83

Following a motion and a second from the floor the report was approved. The report was audited by Allen Singleton, Charles Helfrich and William Watkins and found to be in order.

1. **BOARD OF DIRECTORS.** Ms. Mary McGlasson presented the following report.

The Board of Directors met twice this year and was primarily concerned with revising the By-laws of the Foundation. It was decided to merge the Floristic Survey Grant with the Botany Foundation after dispersement of the Grant's current funds. The Botany Foundation will be changed to the Botany Research Fund in order to prevent confusion with the K.A.S. Foundation.

The possibility of hiring an Executive Secretary to handle the financial matters of the Foundation was discussed by the Board. Although it was considered to be a good idea the Board decided it was not feasible at this time due to inadequate funds but should be reconsidered as funds became available.

A committee composed of Joe Winstead, Herb Leopold, and William Baker is in the process of developing guidelines for handling the foundation funds. When these and the By-law revisions are finalized, a copy will be sent to K.A.S. members.

Also under consideration are ways to obtain donations for the Foundation. One suggestion is to develop a brochure that would show what the academy is, what it has accomplished, and what it proposes to do with money donated to the Foundation.

Another consideration is the possibility of requesting from the state legislature a large one time donation which would be invested in the money market, the interest of which would be used in various ways such as employing an Executive Secretary or toward publishing the Transactions.

The other remaining business transacted by the Board was the selection of the recipient of the Distinguished Scientist Award for the current year.

2. **COMMITTEE ON PUBLICATIONS.** Dr. Branley Branson made the following report.

1. Volume 43(1–2), March 1982, consisted of 96 pages that included 12 papers, Academy Affairs, Program, Abstracts of some of the papers presented at the 1981 annual meeting of the Academy, and News and Comments. Volume 43(3–4), 97 pages, included 16 papers, Guidelines for Preparation of Abstracts, Format Changes for the *Transactions*, Academy Affairs, and the Annual Index. The cost for printing 43(1–2) was $5,998.09 and that for 43(3–4) was 5,490.39 for an annual total of $11,488.48, an increase of $913.17 (7.95%) over the cost for Volume 42. The percentage increase was roughly 7.5% less than that of the previous year, mostly because of a $446.87 savings in labor charges, materials costs, and mailing associated with revision of the mailing list. The actual increase was associated with the publication of a few more papers than in 1981. Additional savings are anticipated because of the recently applied format changes (see *Transactions* 43(3–4) and the elimination of blank pages in the journal; the effect of these changes will not become obvious until publication of 44(1–2). There was an actual decrease in cost of printing per page from 1981 to 1982 amounting to approximately $1.50. However, Volume 43 was 20 pages longer than Volume 42.

The subjects of the 28 papers in Volume 43 were distributed among 4 disciplines as follows: General, 1 paper; Zoology and Entomology, 17 papers; Botany and Microbiology, 9 papers; Geology and Geography, 1 paper.

2. Because of the precarious financial situation now extant, the Editor has recently entered into a discussion with the Allen Press, and he has successfully convinced the press of our problem. Allen Press has agreed to bill us for the production of the journal in 1983 at the same price they charged us in 1981, thus giving us a degree of price stability. However, I have been informed that we should plan for a price increase in 1984.

In view of this, I have conducted a brief survey of other academies of science with regard to financial plights and their dues structure. The Kentucky Academy of Science is at present charging members far less than many other academies of comparable size and quality. For example, the Kansas Academy of Science charges members $16.00, students $10.00, and libraries $20.00. The North Carolina Academy of Science charges members $16.00 and libraries $30.00 with no special class for students ($16.00). The Oklahoma Academy of Science changes members $20.00, students $10.00, and libraries $30.00. We must increase our dues by $5.00 in order to bring our dues structure in line with those charged by other organizations in order to partially ameliorate our financial problems.

As mentioned previously, the format changes, the installation of a note format, and the publication of abstracts of papers presented at the annual meetings will help our income picture somewhat. However, this is only a partial solution.

3. As reported by the research section of the Allen Press to your Editor, before a society can have a stable or growing membership structure, six to twelve per cent new members must be added each year. Not only are we not accomplishing that, we have actually been losing membership. We must make a intensive attempt to pull all the scientific forces of Kentucky into the Academy of Science. If we could accomplish that goal most of our financial problems would virtually vanish. It is pathetic to realize that the Academy membership includes such a small percentage of Kentucky scientists.

3. **COMMITTEE ON LEGISLATION.** Dr. Charles Kupchella presented the report.

Dr. Kupchella said that the committee had no formal action upon which to report. There was concern, however, about the formula for funding of higher education being considered by the Council of Higher Education. He said that this was an area that should be followed closely because of the possible implications it would have in the science field.

4. **COMMITTEES ON DISTRIBUTION OF RESEARCH FUNDS.**

(1) The Botany Research Fund report was made by Dr. Joe Winstead.

Applications are being received for the 1983–84 year with the deadline for funding requests being 1 April, 1983.

Since the inception of the $10,000 endowment in 1978 six student research proposals have been funded with a total expediture of $2,043 from the earnings.

It is anticipated that available funding for 1982–83 will exceed $1,400.

(2) Floristic fund—No report.

5. **SCIENCE EDUCATION ADVISORY COMMITTEE.** Ms. Anna Neal made the following report.

Ms. Neal reported that the brochure concerning careers in science which was being developed by the committee had been put on hold this past year due to the involvement of the committee in the crisis developing in teacher education in science. She reported that as a result of attending the AAAS meeting in Washington D.C. on science and mathematics education she felt more positive toward the future of science education. She said she has been contacted by Auburn University about the possibility of the Academy participating in a southeastern regional conference to further discuss the problem. She reported that following her AAAS meeting she has had many inquiries about the scholarship-loan program that Kentucky has recently made available. Ms. Neal also reported that the State Science Advisory Board was being reformed which was the result of action taken by Raymond Barber. The council will report directly to Mr. Barber.

6. **KENTUCKY JUNIOR ACADEMY OF SCIENCE.** Mr. Herb Leopold made the following report.

Our annual symposium was held at Western Kentucky University on April 23–24, 1982. Thirty-one papers were entered from 8 schools. Our speaker was Dr. Thomas Coohill, who spoke on "Sunlight and Cancer." Also included were the Science Bowl and Lab Skills Competitions. Clubs represented were from as far away as Ashland and Murray.

Of major importance were two $1,000 scholarships, awarded for study in the sciences or mathematics at Ogden College. The scholarships were made possible through efforts of Dr. Earl Pearson and Dr. Gray Dillard who brought our Outstanding Science Student program to the attention of Mr. Al Temple of the Ogden Foundation, an independent philanthropic organization. The two scholarships were reserved for recipients of the K.J.A.S. Outstanding Science Student program. Final selections were made by the Foundation, assisted by Dr. Dillard, based on our list of Outstanding Science Student awards. These scholarships are often renewable if the recipients perform up to expectation. It is our hope that we will again have these scholarships available and that other foundations will earmark some scholarships for similar use.

Our regionalization effort has progressed, but not as rapidly as anticipated. Currently, we have a number of individuals who have agreed to serve as board members in the various regions.

Murray, Arvin Crafton—Jane Sisk
Bowling Green, Mr. Jeff Richardson—C. Meredith, Donna Chapin
Campbellsville, Dr. Tom Jeffries—Carol Nally, Sister Jane Hancock
Covington, Sister Ethel Parrott—Names not submitted as of this date
Williamsburg, Dr. Ann Hoffelder—Mary Lane, Charles Phelps, Lawana Scofield
Lexington-Richmond, Dr. Truman Stevens—Dr. Don Birdd, Linda Grant, Phil Jones
Bullitt-Jefferson County, Mr. Chris Allen—Names not submitted as of this date.

As you will note, the regions are being completed and several have said they will be in operation this year.

7. **RESOLUTION COMMITTEE.** Dr. Paul Freytag presented the following resolutions.

Resolution No. 1:

Whereas, Ashland Oil, a major international oil company which is incorporated in the commonwealth of Kentucky, and

Whereas, Ashland Oil has graciously served as the host for the sixty-eighth Annual Meeting of the Kentucky Academy of Science, and

Whereas, Dr. William Hettinger, Jr., Mr. Tony Berry, Dr. Tom Bean, Mr. William Sutton and many others of Ashland Oil have worked diligently to make this meeting a great success, and

Whereas, Ashland Oil has been a leader in many scientific areas, such as synthetic fuel and petroleum extraction technology,

Therefore, be it resolved: that the Kentucky Academy of Science expresses its sincere appreciation to Ashland Oil, and the above individuals, and that the secretary of the Kentucky Academy of Science be instructed to so inform them.

A motion was made and seconded from the floor to accept the resolution. Motion was passed.

Resolution No. 2:

Whereas, admission to Kentucky's public colleges and universities has traditionally been open to any high school graduate who is a native of Kentucky, and

Whereas, The Council of Higher Education in Kentucky has been studying the problem of quality of higher education in Kentucky, and

Whereas, The Council on Higher Education has concluded that one of the problems in higher education is that many do not use their opportunities to the fullest that are available to them in high school, and

Whereas, the Council has proposed that there be certain minimum high school requirements for *unconditional* admission to Kentucky's public universities, and

Whereas, the Council has suggested that each public college and university set up some provision for the admission, on appropriate and specified conditions, of otherwise qualified applicants who do not meet the specified minimum conditions,

Be it therefore resolved: That the Kentucky Academy of Science approve, in principle, the efforts of the Council on Higher Education to improve the scholarship of Kentucky students who plan to enter college.

A motion was made and seconded from the floor to accept the resolution. Motion was passed.

8. **AD HOC COMMITTEES**

A. Rare and Endangered Species Committee. The report presented by Dr. Branley Branson.

The committee respectfully submits the following revisions, including several changes in status, of the original list of Endangered, Threatened, and Rare animals and plants of Kentucky (Endangered, Threatened, and Rare animals and plants of Kentucky, Trans. Ky. Acad. Sci. 42:77–89, 1981, Branson et al.):

PAGE 80

Epioblasma florentina should read *Epioblasma florentina florentina*
Epioblasma lewisi E [E] should read *Epioblasma lewisi* E
Epioblasma sampsoni E should read *Epioblasma sampsoni* E [E]
Lasmigona subviridis U should read *Lasmigona subviridis* T
Pegias fabula E should read *Pegias fabula* T
Pleurobema rubrum E should read *Pleurobema rubrum* T
Anculosa praerosa T [CL] should read *Anculosa praerosa* T
Lithasia armigera E [CL] should read *Lithasia armigera* E
Lithasia geniculata E [CL] should read *Lithasia geniculata* E
Lithasia salebrosa T [CL] should read *Lithasia salebrosa* T
Lithasia verrucosa E [CL] should read *Lithasia verrucosa* E
Rhodacmea elaitor should read *Rhodacmea elatior*
Cambarus bouchardi E [CL] should read *Cambarus bouchardi* E
Orconectes jeffersoni E(e) [CL] should read *Orconectes jeffersoni* E(e)

PAGE 81

Sticklefin chub should read Sicklefin chub
mountain brook lamprey should read Mountain brook lamprey

PAGE 82

Accipiter cooperi should read *Accipiter cooperii*
Accipter striatus should read *Accipiter striatus*
Backman's Sparrow should read Bachman's Sparrow
Ammodramus savannarum II(b) T should read *Ammodramus savannarum* II S

PAGE 84

Cystopteris fragilis var. *Mackayi* should read *Cystopteris fragilis* var. *mackayi*
Calamogrostis porteri should read *Calamagrostis porteri*
White Ladyslipper should read White Lady's Slipper
Lady's slipper (undescribed) should read Lady's Slipper (undescribed)

PAGE 86

Drosera brevifolia Sundew should read *Drosera brevifolia* Dwarf Sundew

PAGE 87

Eupatorium rugosum var. *roanensis* should read *Eupatorium rugosum* var. *roanense*
Hedyotis michauxii T Thyme-leaved Bluets should be inserted following *Hedeoma hispidum* U Hairy Pennyroyal

PAGE 88

Plantago cordata E should read *Plantago cordata* E [CL]
Silphium terebinthinaceum var. *Lucy-brauniae* should read *Silphium terebinthinaceum* var. *lucy-brauniae*

PAGE 89

Viola lanceolata S should read *Viola lanceolata* T

In addition, we include the longnose dace, *Rhinichthys cataractae* (Valenciennes), as of Special Concern based upon the recent discovery of this species in Eastern Kentucky (Dr. Robert Kuehne, pers. comm.).

Dr. Jerry Baskin and Max Medley are continuing their work on the endangered plants of Kentucky. They will publish a completely revised list in a future issue of the *Transactions*.

The Lady's Slipper (see previous page) listed as *Cypripedium* sp. T. has been officially described by Clyde Reed (*Phytologia* 48:426–428, 1981) as *C. kentuckiense* Reed. The species continues to be listed as Threatened.

The committee expresses its appreciation to the Kentucky Nature Preserves Commission for its continued cooperation and assistance.

B. Committee to Study Legislatively Mandated Educational Programs. Dr. Wallace Dixon made the report.

Dr. Dixon said that the committee had nothing significant to report concerning the mandated teaching of scientific creationism. Since its defeat in Lexington the issue of scientific creationism has died down. Dr. Dixon said that the committee would continue to watch this issue and any others that involved mandated educational programs.

9. **UNFINISHED BUSINESS.** There was no unfinished business.

10. **NEW BUSINESS.**

A. Dr. Taylor reported that the Academy had been operating at a deficit during the past few years with the deficit being made up from a contribution from the State some years ago. The last year for state contributions was 1979. This grant has carried us through two budget years but will not be available in the future. In order to partly alleviate this problem Dr. Taylor moved that the dues be raised to $15.00. He pointed out that an increase in dues would not totally solve the problem as reflected by the following proposed budget for 1983 which assumes the proposed increase in dues.

Kentucky Academy of Science

Proposed Budget for 1983

RECEIPTS:	
Individual Membership (400 @ $15.00)	$ 6,000.00
Institutional Memberships	1,700.00
Library Subscriptions	1,400.00
Page Charges	1,400.00
Miscellaneous (Registration, etc.)	1,000.00
	$11,500.00
DISBURSEMENTS:	
KAS Transactions	$12,000.00
Operating Expenses	1,400.00
Junior Academy of Science	500.00
	$13,900.00
Deficit	$ 2,400.00

Following a second from the floor a discussion followed concerning the feasibility of raising the dues and other possible means of raising revenues. The following were the main points discussed:

(1) Library subscriptions would have to be raised in the near future.
(2) An increase in the life membership dues would have to be considered.
(3) The possibility of raising page charges was another suggestion.
(4) The possibility of separating the *Transactions* from the dues and give the member the option of receiving the *Transactions* at a cost over and above the dues.

The motion was voted upon and passed effective for the 1983 fiscal year.

B. Dr. George made the following proposal for a second area of institutional affiliations.

For several years, we have had a class of Institutional Affiliates who have helped support KAS by donations. We have applied a rule of thumb in which we ask each college or university to donate $50 for each 1,000 full-time students. But there does not seem to exist any such rule of thumb for industrial and commerical concerns. At the August meeting of the Board of Directors, it was voted to propose to the membership that there be two areas of Institutional Affiliation which would be called (1) Academic Affiliate and (2) Industrial Affiliate. There would be four categories of Industrial Affiliate:

Associate Member
Member
Sustaining Member
Patron

The cost of each category of membership would be set by the Executive Committee and adjusted from time to time as they saw fit. The costs would be adjusted on a sliding scale with Associate Member least expensive and increasing in each category. The other area, Academic Affiliates, would operate as we are now doing; we suggest $50 for 1,000 full-time students. Both classes of affiliates would be published annually in the *Transactions*, in order that they might receive recognition for their contributions.

Dr. George made a motion to accept the proposal which was seconded from the floor. A suggestion was made, and accepted, to change the Industrial Affiliation to a Commercial and Industrial Affiliation. The motion was voted upon and passed.

11. **NOMINATING COMMITTEE.** Dr. Charles Covell, Jr. offered the following nominations and moved their acceptance.

Joe Winstead	Vice President
Robert Creek	Secretary
Morris Taylor	Treasurer
Gerrit Kloek	Board of Directors
Manual Schwartz	Board of Directors

The motion was seconded from the floor and passed unanimously, there having been no further nominations.

President George then presented President-elect Dr. J. G. Rodriguez who addressed the Academy.

Following his remarks, the meeting was adjourned at 1030.

Robert Creek, Secretary
Kentucky Academy of Science

KENTUCKY ACADEMY OF SCIENCE
68th ANNUAL MEETING
PROGRAM

Thursday, November 4, 1982

1900–2100 *Buffet*—Cafeteria, Ground Floor, Petroleum Bldg.

Friday, November 5, 1982

0830–1100 Tour of Coal Liquefaction (H-Coal) Plant; Reduced Crude Conversion (RCC) Process and R & D Laboratory
1100–1300 *Executive Committee Luncheon*—Conference Rm A, Petroleum Bldg.
1200–1600 Registration—Foyer, Petroleum Bldg.
1200–1700 *Scientific Exhibits*—Ground Floor, Petroleum Bldg.
1300–1500 *Sectional Meetings*—(see following pages)
1500–1530 *Coffee Break*—First Floor, Petroleum Bldg.
1530–1700 *Plenary Section*—Auditorium, Petroleum Bldg.
1730–1845 *Hospitality Hour*—Foyer, Petroleum Bldg.
1900–? *KAS Annual Banquet*—Cafeteria, Ground Floor, Petroleum Bldg.

Saturday, November 6, 1982

0800–1000 *Registration*—Foyer, Petroleum Bldg.
0800–1200 *Scientific Exhibits*—Ground Floor, Petroleum Bldg.
0800–0900 *Sectional Meetings*—(see following pages)
0900–0915 *Coffee Break*—First Floor, Petroleum Bldg.
0915–1015 *Annual Business Meeting*—Auditorium, Petroleum Bldg.
1030–1200 *Sectional Meetings*—(see following pages)
1300–? *Sectional Meetings*—(as needed)

THURSDAY NIGHT BUFFET

1900 Cafeteria, Ground Floor, Petroleum Bldg.
Speaker: Mr. Oliver J. Zandona
Senior Vice-President of Research and Development Activities and Overseas OPNS.
Ashland Petroleum Co.

PLENARY SESSION

Auditorium—Petroleum Bldg.

Friday, November 5

1530 "SYNFUEL IN KENTUCKY"
Speakers: Mr. Charles D. Hoertz, Jr.
President
Ashland Synthetic Fuels, Inc.

Dr. Jim Funk
Professor of Mechanical Engineering
University of Kentucky

ANNUAL BANQUET

Friday, November 5

1900 Cafeteria, Ground Floor, Petroleum Bldg.
Speaker: Mr. Charles J. Luellen
Senior Vice-President and Group Operating Officer, Ashland Oil, Inc. and President, Ashland Petroleum Co.
"THE PETROLEUM INDUSTRY IN THE 1990's"

BOTANY AND MICROBIOLOGY SECTION
Session I—Room G-1—Executive Bldg.
Marian Fuller, Chairman, Presiding
Harold E. Eversmeyer, Secretary

Friday, November 5, 1982

1500 Coffee Break
1530 Plenary Session

Saturday, November 6, 1982

0800 Vascular Plants of Lily Surface Mine Experimental Area, Laurel County, Kentucky. *Ralph L. Thompson*, Berea College.
0815 Seasonal Phytoplankton Succession in an Urban Reservior. *Stephen D. Porter*, Natural Resources and Environmental Protection Cabinet, Division of Water.
0830 Differential Deer Browsing on Ferns. *Foster Levy*, Lisa Barnett, Robin Moran, Warren H. Wagner, Pikeville College.
0845 Analysis of Vegetation Changes on an Ohio Strip Mine at Three, Thirteen, and Twenty-three Year Intervals. *Joe E. Winstead*, Western Kentucky University.
0900 Coffee Break
0915 Annual Business Meeting
1030 Trophic State Analyses and Use Impairment of Selected Public Lakes in Kentucky. *Terry P. Anderson* and L. Giles Miller, Natural Resources and Environmental Protection Cabinet, Division of Water.
1045 The Distribution of Aster Phlogifolium Muhl. ex Willd. (Asteraceae) in Kentucky. *Ronald L. Jones*, Eastern Kentucky University.
1100 Vegetative Pattern and Life Forms on a Kentucky River Rock Bar. *Hal Bryan*, Kentucky Department of Transportation, Division of Environmental Analysis.
1115 The Role of Vegetation Mapping in Environmental Assessment. *William H. Martin*, Eastern Kentucky University: H. L. Ragsdale, Emory University.
1130 Prairie Patches on Shale Barrens in Lewis County. *William Meijer*, University of Kentucky; Ray Cranfill, University of California at Berkeley.
1145 Two New Orchid Records from Harlan County, Kentucky. *John R. MacGregor*, Non-game

Wildlife Program, Kentucky Department of Fish and Wildlife Resources.

1200 A Preliminary Investigation of the Vascular Plants of Calloway County, Kentucky. *Michael Woods*, Marian Fuller, Murray State University.

1215 Data Banking of Species Records of Kentucky. *Marian Fuller*, Murray State University.

1230 Election of Section Officers

Session II—Room G-2—Executive Bldg.

Saturday, November 6, 1982—Harold E. Eversmeyer, Presiding

0900 Coffee Break

0915 Annual Business Meeting

1030 The Effect of Temperature on *Epichloe typhina* in Tall Fescue Seed. *D. R. Varney*, Eastern Kentucky University; M. R. Siegel, M. C. Johnson, L. P. Bush, R. C. Buckner, University of Kentucky.

1045 The Fescue Endophyte in Kentucky. D. R. Varney, *T. Meredith*, S. Ballard, R. Ross, H. Koury, Eastern Kentucky University; M. R. Siegel, W. Nesmith, University of Kentucky.

1100 Cation Analyses of Burley Tobacco During Induced Manganese Toxicity. *F. R. Toman*, Western Kentucky University; Everett Leggett, John Sims, University of Kentucky.

1115 Comparison of 5-hour Disc Susceptibility Test with Standard Kirby-Bauer Technique. *L. P. Elliott*, Western Kentucky University.

1130 The Bacterial Sulfur Cycle: Why Marshes Smell Like Yellowstone Park Hot Springs. *David J. Minter*, Berea College.

1145 Establishment of Tissue Culture of White Pine. *Karan Kaul*, Kentucky State University CRS/Biology.

1200 Rejoin other session for election of section officers.

CHEMISTRY SECTION

Auditorium—Petroleum Bldg.

John Reasoner—Chairman
Sam Cooke—Secretary

Session I, John Reasoner, Presiding

Friday, November 5, 1982

1300 DMF Extractability as a Predictor for Plasticity in Bituminous Coals. *Jana M. Whitt*, John W. Reasoner, and William G. Lloyd, Department of Chemistry, Western Kentucky University.

1315 Particulate Pollution and Energy Development. *Wm. D. Schulz*, Eastern Kentucky University, and Kent J. Voorhees, Colorado School of Mines.

1330 A Comparison of Simulated Distillation to True Boiling Point Distillation of H-Coal Distillates. *M. D. Kiser* and D. P. Malone, Research and Development Department, Ashland Petroleum Company. (Sponsored by W. P. Hettinger, Jr.)

1345 Correlation of H-Coal Recycle Solvent Quality with Various Physical Properties. Joe T. Collins and *Laurence J. Boucher*, Department of Chemistry, Western Kentucky University, and Howard Moore, Ashland Petroleum Company.

1400 Microautoclave Testing of H-Coal Liquefaction Recycle Solvents. *D. C. Boyer* and H. F. Moore, Research and Development Department, Ashland Petroleum Company. (Sponsored by W. P. Hettinger, Jr.)

1415 Bacterial Degradation and Chemical Glass Analysis of a Coal Liquid. *Randall Salley* and Norman Holy, Department of Chemistry, Western Kentucky University.

1430 Coal Liquids Distillation Tower Corrosion. Mechanism of Inhibition by Strongly Basic Amines. *Diane E. Riley*, Alberto A. Sagues and Burtron H. Davis, Institute for Mining and Minerals Research, University of Kentucky.

1445 The Anodic Stripping Voltammetric Determination of Trace Elements in Coal Ash. *John T. Riley* and J. Alvaro Jimenez Montoya, Department of Chemistry, Western Kentucky University.

1500 Coffee Break

1530 Plenary Session

Session II, Sam Cooke, Presiding
Room 1–4, Executive Bldg.

Friday, November 5, 1982

1300 A Data Acquisition System Based on an Apple II Plus Computer and a Heath 6800 Microcompressor. *Carl D. Slater* and William S. Wagner, Department of Physical Sciences, Northern Kentucky University.

1315 Limited Data Acquistion and Laboratory Control with Built-in Features of Personal Computers. *S. L. Cooke* and Charles Hunt, Department of Chemistry, University of Louisville.

1330 Methyl Viologen Radical Cation Reactions with Persulfate Ion and with Hydrogen Peroxide. *G. Levey* and T. Ebbeson, Department of Chemistry, Berea College.

1345 Measurement of Mo Dispersion in Mo/Al_2O_3 Catalysts by ESCA and Model Compound Reactions. *Bruce Adkins*, Burt Davis, and Garrett Cawthon, Institute for Mining and Minerals Research, University of Kentucky.

1400 UO_2F_2 Particle Size Analysis by Coulter Counter Method. *Harry Conley*, Murray State University, and M. G. Otey, Union Carbide Corporation.

1415 Preparation and Cloning of EcoRI Generated Fragments from *E. coli* and *Strep. fecalis*. *M. Ruth Clark*, Ricky Jackson, and Vaughn Vandergrift, Department of Chemistry, Murray State University.

1430 Oxidations of Organic Compounds in Pressed Discs of KBr. *Rita K. Hessley*, Department of Chemistry, Western Kentucky University.
1445 Preparation and Evaluation of Mixed Transition Metal Catalysts for High Yield Syngas Methanation. M. A. Takassi and *D. A. Owen*, Department of Chemistry, Murray State University.
1500 Coffee Break
1530 Plenary Session

Session III, William Hettinger, Jr., Presiding
Auditorium—Petroleum Bldg.

Saturday, November 6, 1982

0800 Hydrogenation of Aryl Nitro Compounds with a Polymer Bound Catalyst. *Edwardo Boralt* and Norman Holy, Department of Chemistry, Western Kentucky University.
0815 Kinetic and Spectral Studies of Cobalt(II)–4,4′,4″,4‴-Tetrasulfophthalocyanane in Various Media. *Maria Torres* and Robert Farina, Department of Chemistry, Western Kentucky University.
0830 Catalytic Hydrogenation of Nitrogen Containing Heterocycles. *D. Ross Spears* and Laurence J. Boucher, Department of Chemistry, Western Kentucky University.
0845 Structure and Characteristics of Palladium(II) Bis(phenylthio)methane. *Gary B. Kaufman* and P. E. Fanwick, Department of Chemistry, University of Kentucky.
0900 Coffee Break
0915 Annual Business Meeting
1030 The Use of Blended Fuels in Diesel Engine Applications. *C. H. Jewitt* and L. M. Ferguson, Automobile and Product Application Laboratories, Ashland Petroleum Company. (Sponsored by W. P. Hettinger, Jr.)
1045 Ethanol-Extended Motor Fuels—A 50,000-Mile Test. G. L. Bostick and *V. L. Kersey*, Automotive and Product Application Laboratories, Ashland Petroleum Company. (Sponsored by W. P. Hettinger, Jr.)
1100 Coal/Oil Mixtures and Coal/Water Mixtures: Industrial Fuels of the Future. G. F. Felton and *A. J. Schmutz*, Automotive and Product Application Laboratories, Ashland Petroleum Company. (Sponsored by W. P. Hettinger, Jr.)
1115 Heavy Hydrocarbon Analysis in Petroleum Refining. *Robert H. Wombles* and David P. Wesley, Ashland Petroleum Company. (Sponsored by W. P. Hettinger, Jr.)
1130 Combustion Calorimetry on Eastern Oil Shales. *Gerald Thomas*, D. W. Koppenaal, and William C. Jones, Institute for Mining and Minerals Research. (Sponsored by Burtron David)
1145 Density Versus Chemical Composition and Physical Properties of Kentucky Coal and Oil Shales. *William C. Jones*, D. W. Koppenaal and Gerald Thomas, Institute for Mining and Minerals Research. (Sponsored by Burtron David)
1200 Election of Sectional Officers

GEOGRAPHY SECTION
Fifth Floor—Executive Bldg.

Gary C. Cox, Chairman, Presiding
William A. Withington, Secretary

Friday, November 5, 1982

1300 The Effectiveness of Spatial Solutions to the School Desegregation Problem. *Robert G. Cromley* and Mark Woodall, University of Kentucky.
1315 The Human Ecosystem: A Conceptual Framework for Geography. *E. E. Hegen*, Western Kentucky University.
1330 Visitation Patterns to Kentucky Resort Parks. *John L. Anderson*, University of Louisville.
1345 Kentucky County Government Expenditures, 1957–1977. *Jerry Webster*, University of Kentucky.
1400 Alternative Work Schedules and Journey to Work. *Paul Schoniger*, University of Kentucky.
1415 The Effects of Topography on Kentucky Tornadoes. *Michael Trepasso*, Western Kentucky University.
1430 Precipitation Distribution in Kentucky. *D. Glenn Conner*, Kentucky State Climatologist, Western Kentucky University.
1445 Mennonite Settlement in Allen County, Kentucky: A Case Study. *Albert Petersen*, Western Kentucky University.
1500 Geography Section Business Meeting
1515 Coffee Break
1530 Plenary Session

Saturday, November 6, 1982

0800 Muldraugh or a Safe Place to Live: Perceived Impacts of the 1979 Train Derailment. *Stanley D. Brunn*, University of Kentucky.
0815 Wildlife Management in Northeastern Kentucky: A Bright Future. *Roland L. Burns*, Morehead State University.
0830 Migration Selectivity of College Graduates in Northeastern Kentucky. *Wilma J. Walker*, Eastern Kentucky University.
0845 Ethnic Patterns in a New York Village. *Mark Lowry*, Western Kentucky University.
0900 Coffee Break
0915 Annual Business Meeting
1030 Coal Slurry Pipelines: Possible Implications for Kentucky. *Dennis E. Quillen*, Eastern Kentucky University.
1045 Havana: Colonial Spaces Forgotten and Failing. *L. H. Kubiak*, Eastern Kentucky University.
1100 Changing Patterns of Land Use in the Big Sandy Basin of Eastern Kentucky. *Gary C. Cox*, Morehead State University.
1115 The Black Population of Kentucky in 1980. *Dinker Patel*, Kentucky State University.

GEOLOGY

Room A—Petroleum Bldg.

Graham Hunt, Chairman, Presiding
Roy VanArsdale, Secretary, Presiding

Friday, November 5, 1982

1300 The Stratigraphic Framework of the Western Kentucky Coal Field. *David A. Williams*, Kentucky Geological Survey.
1315 The Nomenclature of Some Lower Carbondale Coal Beds in Western Kentucky. *Allen D. Williamson*, Kentucky Geological Survey.
1330 Geology of Lake Malone and Lake Malone State Park. *Gail S. Stamper*, James X. Corgan, Department of Geology, Austin Peay State University.
1345 Pore Pressure Determination Derived from Drill Data Ratios and Electric Log Correlation. *H. Hull Rush*, Department of Geology, Austin Peay State University. Sponsored by James Corgan.
1400 Stratigraphy and Petrology of the Laurel Dolomite (Silurian) on the Western Flank of the Cincinnati Arch, Kentucky. *James Webb* and Wm. C. MacQuown, Department of Geology, University of Kentucky.
1415 Rare and Unique Mineral Replacement of Fossils from the Lower and Middle Parts of the Borden Formation, Northeastern Kentucky. *Charles E. Mason*, Department of Physical Sciences, Morehead State University and Joseph H. Gilbert, Lewis County School System. Sponsored by Roy VanArsdale.
1430 Geophysical Applications of Hypothesis Testing and Model Comparisons of Trend Surfaces. *Alan D. Smith*, Department of Geology, Eastern Kentucky University.
1445 Distribution of the Flint Clay Parting of the Fire Clay Coal and its Implications. *Don Chestnut* and Anne Schreiber, Department of Geology, University of Kentucky.
1500 Coffee Break
1530 Plenary Session

Saturday, November 6, 1982

0800 Initial Analysis of Mine Roof Fall Data in Coal Mines of Eastern Kentucky. *Alan D. Smith*, Department of Geology, Eastern Kentucky University and A. B. Szwilski, Department of Mining Engineering, University of Kentucky.
0815 Discriminative Relationships Among Basic Lithologies and Engineering Parameters Obtained from the Point Load and Slake Durability Tests. *Richard A. Smath* and Alan D. Smith, Department of Geology, Eastern Kentucky University and James C. Cobb, Kentucky Geological Survey.
0830 Regression Analysis Techniques Applied to Petrographic Studies. *Alan D. Smith* and Gary L. Kuhnhenn, Department of Geology, Eastern Kentucky University.
0845 The Drought Problem: An Attempt at the Development of a Water-Retaining Soil. *Pam Rust*, Notre Dame Academy. Sponsored by H. A. Leopold.
0900 Coffee Break
0915 Annual Business Meeting
1030 Palynology of Eastern Kentucky Coals—New Directions. *Charles T. Helfrich*, Department of Geology, Eastern Kentucky University.
1045 The Foerstia Zone—A Key to Late Devonian Stratigraphy in Kentucky. *Roy C. Kepferle*, Department of Geology, Eastern Kentucky University and James D. Pollock, Institue for Mining and Minerals Research, University of Kentucky.
1100 Distribution of Salines in Kentucky. *Richard Boisvert*, Department of Anthropology, University of Kentucky and Steven Cordiviola, Kentucky Geological Survey.
1115 Election of Officers

PHYSIOLOGY, BIOPHYSICS, AND PHARMACOLOGY SECTION

Room 1–3, Executive Bldg.

Robert E. Daniel, Chairman
Thomas E. Bennett, Secretary

Thomas E. Bennett, Presiding

Friday, November 5, 1982

1300 The effect of long distance running on serum cholesterol and triglyceride levels. *Mark Smith* and Ray K. Hammond, Department of Biology and Biochemistry, Centre College.
1315 The influence of exercise on hypertension in experimental animals. *Charles H. Bennett*, Department of Biology, Kentucky State University and T. A. Kotchen, Department of Medicine, University of Kentucky.
1330 *In vivo* study of the effects of danazol on cytoplasmic receptors in the female rat. *Debbie Spencer* and David Magrane, Department of Biological and Environmental Sciences, Morehead State University.
1345 Characterization of danazol binding to specific cytosol receptors *in vitro*. *Gail Russell* and David Magrane, Department of Biological and Environmental Sciences, Morehead State University.
1400 A new column perfusion technique using isolated rat adrenal cells to study ACTH and danazol. *Diane Johnson* and David Magrane, Department of Biological and Environmental Sciences, Morehead State University.
1500 Coffee Break
1530 Plenary Session

Robert E. Daniel, Presiding

Saturday, November 6, 1982

0900 Coffee Break
0915 Annual Business Meeting
1030 Colorectal cancer incidence in Campbell County, Kentucky. *Raymond E. Richmond*, Department of Biological Sciences, Northern Kentucky University.

1045 Glyosaminoglycan patterns in 8 lines of transplantable hepatomas having different growth rates and metastatic potentials. *Saeid Baki-Hashemi* and Charles E. Kupchella, Department of Biological Sciences, Murray State University.

1100 Glyosaminoglycan changes in normal tissue adjacent to implanted hepatomas. *Maryjane Estes*, Saeid Baki-Hashemi, and Charles E. Kupchella, Department of Biological Sciences, Murray State University.

1115 Differential glycosaminoglycan infiltration in human cutaneous mucinoses. *Branley T. Bryan*, Charles E. Kupchella (Department of Biological Sciences, Murray State University), Lois Matsuoka, Jacobo Wortsman (Department of Medicine, Southern Illinois University School of Medicine), and John Dietrich (Department of Pathology, Southern Illinois University School of Medicine).

1130 Election of Officers

PHYSICS

Room 1–4, Executive Bldg.

P. J. Ouseph, Chairman, Presiding
Raymond McNeil, Secretary

Friday, November 5, 1982

1500 Coffee Break
1530 Plenary Session

Saturday, November 6, 1982

0800 Asymmetry Potential for Sub-Coulomb-Protons Interacting with ^{90}Zr. *D. S. Flynn*, University of Kentucky.

0815 Edwin Hubble in Kentucky. *Joel Gwinn*, University of Louisville.

0830 Magnetic Dimensional Resonance of Indium Antimonide at Room Temperature. *Raymond Enzweiler* and Donald E. Munninghoff, Thomas More College.

0845 Using the SiO Maser as a Near Stellar Probe. *F. O. Clark*, University of Kentucky.

0900 Coffee Break

0915 Annual Business Meeting

1030 Wigner Cusps Observed in Proton Radiative Capture on ^{92}Zr, ^{51}V, ^{67}Zn, and ^{64}Ni. *C. E. Laird* and B. S. Finch, Eastern Kentucky University; D. S. Flynn, R. L. Hershberger, and F. Gabbard, University of Kentucky.

1045 Temperature Dependence of Velocity of Sound: An Experimental Determination. *James Link* and P. J. Ouseph, University of Louisville.

1100 The Parabolic Rule—Application to Energy Levels of ^{96}Nb. *Bernard D. Kern*, University of Kentucky.

1115 Comments on High School Physics Teaching in Kentucky. *Donald Esbenshade*, St. Francis High School.

1130 Physics Section Meeting

SCIENCE EDUCATION

Room 1–2, Executive Bldg.

Dan Ochs, Chairman
Jane Sisk, Secretary, Presiding

Friday, November 5, 1982

1500 Coffee Break
1530 Plenary Session

Saturday, November 6, 1982

0830 The Tree-hole Mosquito as a Classroom Organism. *David R. Bezanson* and Thomas C. Rambo, Department of Biological Sciences, Northern Kentucky University.

0845 Arson Investigations in the Laboratory: Classroom Applications. *Robert E. Fraas*, Forensic Science Program, Eastern Kentucky University.

0900 Coffee Break

0915 Annual Business Meeting

1030 Stated Reasons for Withdrawal and Degrees of Satisfaction Among College Persisters and Nonpersisters. *Alan D. Smith*, Department of Geology, Eastern Kentucky University.

1045 A Microcomputer Exercise on Genetic Transcription-Translation. *John L. Meisenheimer*, Department of Chemistry, Eastern Kentucky University.

1100 Election of Sectional Officers

PSYCHOLOGY

Fifth Floor—Petroleum Bldg.

Frank Kodman, Presiding
James A. Lee, Secretary

Friday, November 5, 1982

1300 The Effect of Friday Afternoon Class Attendance on Grades. *John C. Parkhurst*, Steven D. Falkenberg, Eastern Kentucky University.

1310 Pregnancy Symptoms and Mood Changes in Expectant Fathers and Factors Relating to these Experiences. *Debbie Champion*, Murray State University. Sponsored by Terry Barrett.

1320 The Effect of Sex of the Victim on the Eyewitness Accounts of Males and Females. *John E. Story*, Murray State University. Sponsored by Terry Barrett.

1330 Amount of Eye Contact as a Predictor of Personal Space. *Tanas Ball*, Murray State University. Sponsored by Terry Barrett.

1340 Cue Effectiveness in Facilitating Recall of a Word in the "Tip-of-the-Tongue" State. *Susan Parrish*, Murray State University. Sponsored by Terry Barrett.

1350 The Effects of Contextual Selectivity on Ambiguous Words. *Jeff Johnston*, Murray State University. Sponsored by Terry Barrett.

1400 Automatic and Effortful Processes and the Recall of Spatial Location. *Shari A. Shields*, Murray State University. Sponsored by Terry Barrett.

1410 The Effects of Stimulus Screening on Cognitive and Motor Performance. *Steven M. Peaugh,* Murray State University. Sponsored by Terry Barrett.

1420 Brainstorming: The Effectiveness of Deferred Judgment and Idea Quantity. *Penny Tucker Hailey,* Murray State University. Sponsored by Terry Barrett.

1430 The Relation of Memory Distortion to Intelligence. *Glen Crouch,* Murray State University. Sponsored by Terry Barrett.

1440 Mental Activity and Memory in the Young and Old. *Terry R. Barrett* and Louanne Yarbro, Murray State University.

1450 Alleviation of Learned Helplessness Effects in an Academic Setting. *Deborah A. Otto,* Murray State University. Sponsored by Terry Barrett.

1500 Coffee Break

1530 Plenary Session

Saturday, November 6, 1982

0800 Teacher-Child Interactions and the Relation to Performance. *Barbara J. Smith,* Murray State University. Sponsored by Terry Barrett.

0810 The Effects of Father-Daughter Relationships on the Daughter's Later Willingness Towards Touching and Being Touched. *Jacqueline R. Pope,* Murray State University. Sponsored by Terry Barrett.

0820 Effects of Modeling and Selective Attention on Anxiety Reduction. *Sherry Mayfield,* Murray State University. Sponsored by Terry Barrett.

0830 Self-Regulation of Digital Skin Temperature as Affected by Music. *Sara C. Keeling,* Murray State University. Sponsored by Terry Barrett.

0840 Coping Strategies of Normal Bereavement. *Karen W. Dodson,* Murray State University. Sponsored by Terry Barrett.

0850 Are Males Really More Agressive than Females? *Teresa Davis,* Murray State University. Sponsored by Terry Barrett.

0900 Coffee Break

0915 Annual Business Meeting

1030 Attitude Differences Among Males and Females in Intercollegiate Athletics. *Virginia P. Falkenberg* and Scott Quesnel, Eastern Kentucky University.

1040 Attitudes of College Students toward Conjugal/Romatic Love Relationships. Vivian L. Pyles and *Steven D. Falkenberg,* Eastern Kentucky University.

1050 A Study of Sex Differences among Student Persisters and Nonpersisters Enrolled in the Community and Technical College. *Alan D. Smith,* Department of Geology, Eastern Kentucky University. Sponsored by William H. Watkins.

1100 Inferential Statistical Techniques Commonly Employed in Contemporary Life Science Journals. Francis H. Osborne, Jeanne S. Osborne, *Katherine E. Koch,* and Malcolm P. Graham, Morehead State University.

1110 Cross Validation and Discriminative Analysis Techniques to Estimate the Stability of Partial Regression Weights for Predictive Purposes. *Alan D. Smith,* Department of Geology, Eastern Kentucky University. Sponsored by William H. Watkins.

1120 Aggression Behavior in Planaria. *Jenny Fry.* Notre Dame Academy. WINNER: Kentucky Junior Academy of Science Symposium, 1982. Sponsored by H. A. Leopold.

1130 Dual Coding Mechanisms in Implicit Learning. *Barney Beins* and Gary Beatrice. Thomas More College. Sponsored by William H. Watkins.

1140 Effect of Background Color on Recall of Randomly Positioned Symbols. *Thomas D. Robbins* and William H. Watkins, Eastern Kentucky University.

1150 Recall of Stimuli from Auditory vs. Visual vs. Pictorial Displays with Rehearsal Prevented. *Jane T. Riley* and William H. Watkins, Eastern Kentucky University.

1200 Lunch Break

1300 Visual Perception: A Comparison between the Deaf and Hearing. *Jim A. Herrell.* Eastern Kentucky University. Sponsored by William H. Watkins.

1310 Are the "Blue" and "Seven" Phenomena Genuine? *Terry Lee Miller* and William H. Watkins, Eastern Kentucky University.

1320 Altruistic Behavior of Local Residents and EKU Faculty Members of Richmond, Kentucky toward Students and Non-Students. Debi Smith and *Steve Falkenberg,* Eastern Kentucky University.

1330 Name Stereotypes and Appearance Rankings: An Empirical Study. *Robin Kim Boggs,* Eastern Kentucky University. Sponsored by William H. Watkins.

1340 Affectionate Responding as a Function of Success Experiences. *Brian A. Keith,* Steven D. Falkenberg, and Richard J. Shuntich, Eastern Kentucky University.

1350 Use of the Observation Rating Scale in Screening for Hyperactive Child Syndrome (HCS) in the General Grade School Population. *Patricia Tobin,* Eastern Kentucky University. Sponsored by William H. Watkins.

1400 Affective Disorders in College Students: Are New Theoretical Constructs Needed? *Jack G. Thompson,* Donald H. Brown and Angela Kirkland, Centre College of Kentucky.

1410 Steepness of Approach and Avoidance Gradients in Humans as a Function of Experience. *Anthony Howard,* Virginia P. Falkenberg and Steven D. Falkenberg, Eastern Kentucky University.

1420 The Effects of Personality Moderator Variables in the Efficacy of EMG-Biofeedback Relaxation Training: The Search for the Holy Grail. *Jack G. Thompson* and Nora Meadows, Centre College of Kentucky.

1430 Election of Section Officers.

SOCIOLOGY SECTION
Room C—Petroleum Bldg.

John Curra, Chairman, Presiding
Steve Savage, Secretary

Friday, November 5, 1982

The Program for the Sociology Section will be Available at the Annual Meeting.

ZOOLOGY AND ENTOMOLOGY
Session I—Room G-1, Executive Bldg.

Charles V. Covell, Jr., Chairman
Gerritt Kloek, Acting Secretary

Friday, November 5, 1982—Gerrit Kloek, Presiding

1315 Freshwater Mussels of Elkhorn Creek, Kentucky (UNIONIDAE). *Ralph W. Taylor,* Department of Biological Sciences, Marshall University, Huntington, West Virgina.
1330 The Influence of Temperature on Testicular Photosensitivity in the White-throated Sparrow (*Zonotrichia albicollis*). *Laurel Prinz* and Blaine R. Ferrell, Department of Biology, Western Kentucky University.
1345 You are Where You Eat—Influence of Substrate Type on the Comparative Feeding Strategies of Two Species of Estuarine Fishes. *Michael Barton*, Division of Science and Mathematics, Centre College of Kentucky.
1400 The Prevalence of Heartworm Infection in East-Central Kentucky Dogs. *Allen L. Lake* and Hoy Miller, Jr., Morehead State University.
1415 Status Signaling in House Sparrows, *Passer domesticus. Gary Ritchison*, Department of Biological Sciences, Eastern Kentucky University.
1430 The Fishes of Buck Creek, Upper Cumberland River System, Kentucky. Ronald R. Cicerello, Kentucky Nature Preserves Commission and *Robert S. Butler,* Department of Biological Sciences, Eastern Kentucky University.
1445 Distribution of Two Treehole Mosquitos, *Aedes triseriatus* Say and *Aedes hendersoni* Cockerelle (Diptera: Culicidae) in Berea, Kentucky. *Jerome H. Waller,* Department of Biology, Berea College and Ellen M. Ballard, Department of Entomology, University of Kentucky.
1500 Coffee Break
1530 Plenary Session

ZOOLOGY AND ENTOMOLOGY
Session II—Room G-2, Executive Bldg.

Friday, November 6, 1982—Charles V. Covell, Jr., Presiding

1315 Field Biology of the Blackfaced Leafhopper, *Graminella nigrifrons* (Forbes), in Kentucky. *John D. Sedlacek* and Paul H. Freytag, Department of Entomology, University of Kentucky.
1330 Effect of Parasitism on the Development of Fourth and Fifth Instar *Heliothis virescens. Bruce Webb* and D. L. Dahlman, Department of Entomology, University of Kentucky.
1345 Pest Interactions in the Alfalfa Ecosystem *Sitona hispidulus, Hypera postica* and Soil-Borne Root Rot Fungi. *L. D. Godfrey* and K. V. Yeargan, Department of Entomology, University of Kentucky.
1400 Seasonal Abundance and Impact of the Locust Twig Borer on Black Locust on a Surface-Mine Reclamation Site. *William T. Thoeny* and Gerald L. Nordin, Department of Entomology, University of Kentucky.
1415 L-Canavanine: Synergistic Effects with Carbamate Insecticides in *Heliothis virescens* and *Manduca sexta. G. W. Felton* and D. L. Dahlman, Department of Entomology, University of Kentucky.
1430 Physical Characteristics of Corn Kernel Pericarp and Resistance Against the Rice Weevil. *D. F. Blake* and L. A. Gomez, Division of Science, Math & Nursing, Kentucky State University and J. G. Rodriguez, Department of Entomology, University of Kentucky.
1445 Utilization of Maize Endosperm by the Rice Weevil. *L. A. Gomez* and D. F. Blake, Division of Science, Math & Nursing, Kentucky State University and J. G. Rodriguez and C. G. Poneleit, Department of Entomology, University of Kentucky.
1500 Coffee Break
1530 Plenary Session

ZOOLOGY AND ENTOMOLOGY
Candlelight Room—Petroleum Bldg.

Saturday, November 6, 1982—Charles V. Covell, Jr., Presiding

0800 *Rhopalosoma nearcticum* Brues in Kentucky. Paul H. Freytag, Department of Entomology, University of Kentucky.
0815 State Records of Stoneflies (Plecoptera) in Kentucky. *Donald C. Tarter* and Dean A. Adkins, Department of Biological Sciences, Marshall University, Huntington, West Virginia and Charles V. Covell, Jr., Department of Biology, University of Louisville.
0830 The Effect of Malathion on Larval *Xenopus laepis.* Sharon Just, Lexington Catholic High School, First Place Winner, Jr. KAS.
0845 The Effects of Testosterone on the Sexual Differentiation of *Lebistes reticulatus. Jeffrey D. Smith,* North Bullitt High School, First Place Winner, Jr. KAS.
0900 Break
0915 Annual Business Meeting
1030 Effect of Chlorpyrifos, Bendiocarb, Trichlorfon, and Isofenphos on a Kentucky Bluegrass Turf Arthropod Community. *Stephen D. Cockfield* and Daniel A. Potter, Department of Entomology, University of Kentucky.
1045 Effects of Intensive Turf Management on Pests and Non-target Invertbrates in Kentucky Bluegrass. *Daniel A. Potter* and Terry B. Ar-

nold, Department of Entomology, University of Kentucky.

1100 Reproductive Behavior in the Praying Mantis: A Sequential Analysis and Comparison of Two Species (*Tenodera aridifolia sinensis* and *Stagmomantis carolina*). *Michael Poston*, Stephen Hirsch, J. William Porter, Melissa Morehead, and Timothy Meier, Department of Psychology and Biology, Thomas More College.

1115 Notes on the Lepidoptera Fauna of the Vicinity of Tingo Maria, Peru. *Charles V. Covell, Jr.*, Department of Biology, University of Louisville.

1130 Influence of Selected Leguminous Hosts on Development and Potential Progeny of Potato Leafhopper. *Alvin M. Simmons*, Bobby C. Pass, and Kenneth V. Yeargan. Department of Entomology, University of Kentucky.

1145 Election of Sectional Officers

Trans. Ky. Acad. Sci., 44(1–2), 1983, 90–93

ABSTRACTS OF SOME PAPERS PRESENTED AT THE ANNUAL MEETING

BOTANY AND MICROBIOLOGY

Two new orchid records from Harlan County, Kentucky. JOHN R. MACGREGOR, Nongame Wildlife Program, Kentucky Department of Fish and Wildlife Resources, Frankfort, KY 40601.

In July 1982 I discovered colonies of *Liparis loeselii* (L.) L. C. Rich. (Loesel's twayblade) and *Corallorhiza maculata* (Raf.) Raf. (spotted coral-root) in Harlan County, Kentucky. There are no previous records for *L. loeselii* in Kentucky. Earlier reports for *C. maculata* in Kentucky have been based on robust specimens of the closely-related *C. wisteriana* or are unsupported by available voucher material. Photographs of both of these orchids, brief descriptions of the sites in which each was found, and speculations concerning the existence of additional unreported species of orchids in the mountains of southeastern Kentucky were presented.

Trophic State Analyses and Use Impairment of Selected Public Lakes in Kentucky. TERRY P. ANDERSON* and L. GILES MILLER. Natural Resources and Environmental Protection Cabinet, Division of Water, Frankfort 40601.

The Divison of Water surveyed forty-seven publicly owned lakes in Kentucky to determine their trophic state. Trophic status was assessed by the Carlson Trophic State Index (TSI). Three lakes were determined to be hypereutrophic, twenty-six were eutrophic, fifteen were mesotrophic and three were oligotrophic. Selected parameter ranges between the hypereutrophic and oligotrophic lakes were, respectively: TSI (Chlorophyll), 74–34; maximum chlorophyll-a, 198–3 μg/l; total phosphorus, 840–7 μg/l; conductivity, 512–55 μS/cm; euphotic zone depth, 1.2–18.6 m; secchi depth, .3–8.8 m.

An impaired use assessment was conducted for eight lakes. Causes of the impairments were attributed to shallow lake basins, excessive nutrient contributions from cultural and agricultural sources, acid mine drainage, and hypolimnetic discharges.

Vascular plants of Lily Surface Mine Experimental Area, Laurel County, Kentucky. RALPH L. THOMPSON, Department of Biology, Berea College, Berea, KY 40404.

The Lily Surface Mine Experimental Area, a 14.5-hectare abandoned stripmine, was planted with 110 herbaceous and woody species by the U.S. Forest Service in 1965–1966 and then allowed to progress through natural plant succession. Floristic study in 1981–1982 disclosed 341 taxa from 86 families, including 68 introduced species persisting from the original plantings. Thirty 2 m × 100 m belt transects indicated important trees were *Pinus virginiana, Liquidambar styraciflua, Acer rubrum, Betula nigra, Cornus florida, Nyssa sylvatica,* and *Oxydendrum arboreum*. Important shrubs and vines were *Rhus copallina, Smilax glauca, Rhus radicans, Rubus* spp., *Lonicera japonica, Spireae tomentosa,* and *Rosa multiflora*. Sixty 1 m × 1 m quadrats revealed that the Poaceae, Asteraceae, and Fabaceae were the most important families of the herbaceous layer.

GEOGRAPHY

Visitation patterns of Kentucky resort parks. JOHN L. ANDERSON, Department of Geography, University of Louisville, Louisville, KY 40292.

Changes in overnight attendance and average distance traveled by visitors from the largest recreational markets to Kentucky's resort parks were examined, revealing an increasing interest in taking advantage of close-to-home opportunities. Recreational hinterlands contracted and vistation decreased for most of the parks during the recent decade. Lakes Cumberland and Barkley provided noteworthy exceptions by registering outstanding growth and hinterland expansion. Numerous and complex reasons enter into travel decisions, but emphasis was given to accessibility, quality of environments, and state of the economy.

GEOLOGY

The distribution and volcanic source area for the flint clay parting of the Fire Clay Coal. DONALD R. CHESNUT and ANNE M. SCHREIBER*, Kentucky Geological Survey, Lexington, KY 40506.

To support the volcanic origin for the flint clay parting of the Fire Clay coal bed, an isopach of the parting was constructed. It shows a pronounced decrease in thickness to the north. Paleogeographic reconstruction of the Middle Pennsylvanian, the isopach of the flint clay parting, the global wind patterns, and the isomass map of the Mt. Saint Helens ash fall pointed to a source in the south-central Appalachians coinciding with a portion of the Hercynian magmatic arc from Maryland to Georgia.

Rare and unique mineral replacement of fossils from the lower and middle parts of the Borden Formation, northeastern Kentucky. CHARLES E. MASON*, Department of Physical Sciences, Morehead State University, Morehead, KY 40351 and JOSEPH H. GILBERT, Lewis County School System, Vanceburg, KY 41179.

The mineralization is restricted to invertebrate fossils found in the Farmers, Nancy, and Cowbell members of the Borden Formation. In lateral extent this mineralization has been observed from Scioto County, Ohio, south to Rockcastle County, Kentucky. The fossils are found in siderite nodules, lenses, and beds preserved as molds and casts with the internal mode dominating. Barite, in a colorless form, is the most common mineral. Other associated minerals in order of decreasing abundance are sphalerite, pyrite, galena, and calcite. Pyrite commonly replaces areas of original shell whereas the remaining minerals infill voids. Reports of barite and sphalerite replacing or infilling fossils are rare and this report of galena is unique.

Pore pressure determination derived from drill data ratios and electric log correlation. H. HULL RUSH, Department of Geology, Austin Peay State University, Clarksville, TN 37040.

Data collected from nearby wells can provide information for predicting and determining pressures in oil and gas exploration wells. Data correlation with "E"-long conductivity is often used to predict pressures and dictate drilling fluid weights. A formula for determining pressures based on porosity (Boone 1968) is:

$$\text{Pressure}_2 = \text{Pressure}_1 \pm \frac{\Delta\ \text{Porosity}}{5} \pm \text{Mud Weight}$$

$$\left(P_2 = P_1 \pm \frac{\Delta\theta}{5} \pm \text{MW}\right)$$

When porosity is undetermined, a proposed empirical formula based on rate of penetration (ROP) in unrelieved shale sequences is:

$$\text{Porosity}_2 = \text{Porosity}_1 \pm (\Delta\text{ROP} \times .2) \pm \Delta\text{MW}$$

$$(\theta_2 - \theta_1 \pm (\Delta\text{ROP} \times .2) \pm \Delta\text{MW})$$

and: $P_2 = P_1 \pm \Delta\theta \pm \text{MW}$

The results of these formulae are of value since they are independent of surface physical data.

Geophysical applications of hypothesis testing and model comparisons of trend surfaces. ALAN D. SMITH, Department of Geology, Eastern Kentucky University, Richmond, KY 40475.

The significance of a trend or regression may be tested by performing an analysis of variance, which deals with separation of the total variance of a set of observations into components with defined sources of variation. In the case of trend surface analysis, total variance in an independent variable may be divided into the trend itself, which is determined by regression analysis, and the residuals, or error vector. By reducing the sum of squares, which were derived from the least-square criterion, an estimate of variance can be compared by using the F-distribution. Applications of the full and restricted models in regression analysis were utilized in determining the highest degree polynomial surface for selected geotechnical borehole data, gravity anomalies, oil and gas production, and stratigraphic mapping examples.

Regression-analysis techniques applied to petrographic studies. ALAN D. SMITH* and GARY L. KUHNHENN, Department of Geology, Eastern Kentucky University, Richmond, KY 40475.

Field observations and study of 98 polished slabs and 113 thin sections were used in order to study the depositional environment of the Strodes Creek Member and its relationship to the enclosing Millersburg Member and Tanglewood Limestone Member in north-central Kentucky. The Strodes Creek Member consists of eight microfacies—an algal boundstone, a claystone, a dolomitic ostracod packstone, a dolomitic packstone, a dolomitic wackestone, a dolomitic carbonate mudstone, a *Tetradium* packstone, and a skeletal grainstone—representing various sub-environments within a shallow water, slightly restricted and sheltered depositional framework. Regression-analysis techniques and a detailed description of the steps involved, including hypothesis testing and stepwise regression, were used to statistically verify the microfacies classification.

Initial analysis of mine roof fall data in coal mines of eastern Kentucky. ALAN D. SMITH*, Department of Geology, Eastern Kentucky University, Richmond, KY 40475 and A. B. SZWILSKI, Department of Mining Engineering, University of Kentucky, Lexington, KY 40506.

Roof falls are so common a problem that many consider them to be a part of mining operations. The purpose of this study was to develop a survey instrument and resultant pilot study capable of systematically documenting the basic characteristics of roof falls in eastern Kentucky. A statistical study using Pearson correlations, multiple linear regression corrected for multiple comparisons, and frequencies was completed for selected variables, e.g., depth, location, span, orientation, pillar dimensions, seam and roof fall characteristics, geology of the first four immediate roof beds, water, time, floor heave, roof bolting, and various production parameters. Although only 13 cases were analyzed in the pilot study, definitive relationships between roof fall, water, and bolting characteristics were established.

Discriminative relationships among basic lithologies and engineering parameters obtained from the point load and slake durability tests. RICHARD A. SMATH* and ALAN D. SMITH, Department of Geology, Eastern Kentucky University, Richmond, KY 40475 and JAMES C. COBB, Kentucky Geological Survey, Lexington, KY 40506.

A great need exists for information that allows for the prediction of rock behavior as a function of lithology. A study to investigate this was based on four cores derived from the eastern Kentucky coal field, sampled at 5-foot intervals for slake durability and point load tests. Twenty-seven research hypotheses were tested using multiple linear regression, with 15 hypotheses found to be significant at the alpha level of 0.05. Several relationships were established among three basic lithologies of mudstone, siltstone, and sandstone and their engineering tests for predictive purposes.

Geology of Lake Malone and Lake Malone State Park. GAIL S. STAMPER* and JAMES X. CORGAN, Department of Geology, Austin Peay State University, Clarksville, TN 37040.

Massive Caseyville sandstones crop out along the shores of Lake Malone, forming joint-controlled cliffs, locally over 200 feet high. Within cliffs, weathering along joints and along crossbeds has created over 30 small natural bridges, the largest 9 meters in span. Caseyville cliffs also display abundant honeycomb weathering. This phenomenon is rarely described from nonmarine, temperate settings. Natural bridges and honeycomb make Lake Malone a near classic area for study of differential weathering. The park draws over 400,000 visitors every year, and over 600,000 in good years. Much of its aesthetic appeal is geological in origin.

Stratigraphy and petrology of the Laurel Dolomite (Silurian) on the western flank of the Cincinnati Arch, Kentucky. JAMES WEBB* and W. C. MacQUOWN, Department of Geology, University of Kentucky, Lexington, KY 40506.

The Laurel Dolomite was deposited on a marine shelf west of an exposed Cincinnati Arch in the Illinois Basin. Five subsurface units consist of secondary dolomite formed by fresh/marine water mixing (Dorag model). Structural and stratigraphic hinge-lines separate the shallow shelf from the deeper basin to the west. Petroleum occurs on the shelf in structural, stratigraphic, and unconformity traps. Dominant lithologies consist of two hypidiotopic early dolomite mosaics: fine crystalline (after micrite) and medium crystalline (after biogenic limestone). Early to late zoned dolomite rhombs and late euhedral poikilotopic dolomite occur in both fine and medium crystalline lithologies.

PHYSICS

Magnetic dimensional resonance of indium antimonide at room temperature. RAYMOND ENZWEILER* and DONALD MUNNINGHOFF, Department of Physics, Thomas More College, Crestview Hills, KY 41017.

We are studying microwave resonances in spheres of indium antimonide. We are particularly concerned with magnetic dimensional resonances, from which the carrier concentration can be calculated. We found the magnetic fields at which resonances occur to be about 1,000 gauss higher than that predicted by theory. However, the known carrier concentration is within the error range of the measured carrier concentration. Thus, we conclude the theory may need slight adjustment but has the potential for providing an effective method of measuring carrier concentration.

PHYSIOLOGY, BIOPHYSICS, AND PHARMACOLOGY

Effects of adrenocorticotrophin and danazol on isolated rat adrenal cells by column perfusion. DIANE JOHNSON and DAVID MAGRANE*, Department of Biological and Environmental Sciences, Morehead State University, Morehead, KY 40351.

Collagenase isolated rat adrenal cells were suspended in columns with Bio-Gel P-2 and perfused with either Krebs ringers (KRBG) or KRBG plus adrenocorticotrophin (ACTH), danazol, or both. Hemocytometer cell counts of viable cells, checked by trypan blue exclusion after isolation, were $364{,}000/mm^3$ and $303{,}000/mm^3$ after perfusion, indicating only a 16.8% cell loss by continuous perfusion. Fluorometrically measured corticosterone was stimulated within 5 minutes by 100 μU ACTH ($P < .02$), and basal release was inhibited by 100 μM danazol within 30 minutes ($P < .01$). Danazol (100 μM) inhibited 100 μU ACTH stimulated corticosteroidogenesis for 20 minutes with simultaneous perfusion ($P < .02$), indicating direct inhibition of steroidogenesis.

In vitro characterization of danazol binding to specific cytosol receptors. GAIL RUSSELL* and DAVID MAGRANE, Department of Biological and Environmental Science, Morehead State University, Morehead, KY 40351.

The synthetic steroid danazol was investigated for its dose responsiveness, specificity of binding to cytosol receptors, and ability to translocate cytosol receptors to the nucleus. Receptors for estradiol (E_2), dihydrotestosterone (DHT), progesterone (P), and corticosterone (B) were evaluated in uterine, mammary, adrenal, and hypothalamic tissues, using the hydroxyapatite assay. Dose responsiveness was shown in increased competition from physiological doses (10^{-9} M) to pharmacological doses (10^{-5} M). At 10^{-9} M, the androgen receptor (DHT) was bound and translocated most efficiently in all tissues studied, followed by P, E_2, and B respectively. These data support the current literature and extend the understanding of danazol's action to mammary tissue *in vitro*.

Effect of running on serum triglyceride and cholesterol. MARK SMITH* and RAY HAMMOND, Division of Science, Centre College of Kentucky, Danville, KY 40422.

Serum levels of several enzymes, triglyceride, and cholesterol in two male runners, age 21 and 38, were substantially influenced by running 7–10 miles. There were age related differences both in pre-run levels and extent of post-run change. Triglyceride decreased 62%, total cholesterol decreased 23%, and high density lipoprotein increased 47% in the older subject (18% and 10% decrease, and 64% increase respectively in the younger subject). These changes persist substantially longer in the older subject. Running appears to keep high density lipoprotein levels in older males at "younger" levels.

In vivo study of the effects of danazol on cytoplasmic receptors in the female rat. DEBBIE SPENCER* and DAVID MAGRANE, Department of Biological and Environmental Sciences, Morehead State University, Morehead, KY 40351.

Effects of the synthetic steroid antigonadotrophin danazol on cytoplasmic receptors were studied *in vivo* in adult female rats. Competition with estrogen (E_2), progesterone, dihydrotestosterone, and corticosterone receptors in uterine, mammarian, adrenal, hypothalamic, and ovarian tissues were evaluated by hydroxyapatite micromethod. Long term, low dose (4 mg/kg/14 days) of danazol resulted in significant reduction of E_2 receptors ($P < .05$) and a non-significant reduction of other receptors in both intact and ovariectomized rats. Uterine, adrenal, and ovarian weights were significantly reduced by danazol injections ($P < .02$). Short term, high dose (8 mg/kg/3 days) demonstrated no reduction of organ weights and showed a non-significant reduction of all receptors.

PSYCHOLOGY

Inferential statistical techniques commonly employed in comtemporary life science journals. FRANCIS H. OSBORNE, JEANNE S. OSBORNE, KATHERINE E. KOCH*, and MALCOLM P. GRAHAM, Morehead State University, Morehead, KY 40351.

The purpose of this study was to determine the incidence and type of inferential statistics employed in several disciplines and to use this information to make recommendations for content in an interdisciplinary statistics course. Seven psychology journals were surveyed for frequency of occurrence of statistical procedures in 1981. APA journals included were those examined in Edington's (1964, 1974) tabulations. Three journals were selected on the basis of "impact factor" in each of three additional fields frequently served by introductory statistics courses: biology, education, and sociology. Contingency table analysis indicated substantial overlap in statistical techniques employed in these disciplines as well as differences in emphasis specific to disciplines. For example, over 70% of psychology articles surveyed used analysis of variance techniques. The other disciplines surveyed tended to use multiple regression techniques substantially more than did psychology.

SCIENCE EDUCATION

Arson investigations in the laboratory: classroom applications. ROBERT E. FRAAS, Forensic Science Program, Eastern Kentucky University, Richmond, KY 40475.

In response to increased emphasis on arson detection, a special topics course on arson evidence analysis has been developed. Topics included the chemistry and physics of fire, heats of combustion, petroleum refining processes, methods of analysis, and report writing/courtroom testimony. Several different extraction procedures were used in analysis of unknown arson residue samples. Laboratory experiments also included gas chromatographic analysis of common accelerants, analysis of dye additives by thin layer chromatography, and analysis of lead additives by gas chromatography/mass spectrometry.

Stated reasons for withdrawal and degrees of satisfaction among college persisters and nonpersisters. ALAN D. SMITH, Department of Geology, Eastern Kentucky University, Richmond, KY 40475.

Revised questionnaire forms by the National Center for Higher Education Management Systems were given to students enrolled in the Community and Technical College and the General College in academic year 1978–1979 at The University of Akron. The response rate of usable questionnaires varied from 22% of nonreturning students (485) to 28% of the continuing student population (2,995). Discriminative analysis of demographic variables was completed to assess selection bias. Conflict with job and studies, not enough money for school, and needed temporary break from school were reasons for withdrawal cited by more than 20% of the student nonpersisters. Nonpersisters listed counseling and advising services, financial aid opportunities, and quality of instruction more frequently as the first factors to be changed. Persisters listed registration processing, parking availability, and television courses as the more frequent items to be changed.

ZOOLOGY AND ENTOMOLOGY

Distribution of two treehole mosquitoes, *Aedes triseriatus* Say and *A. hendersoni* Cockerelle (Diptera: Culicidae) in Berea, Kentucky. JEROME H. WALLER, Department of Biology, Berea College, Berea, KY 40404, and ELLEN M. BALLARD*, Department of Entomology, University of Kentucky, Lexington, KY 40506.

Four line transects and three area plots were used to determine the occurrence of *Aedes triseriatus* Say and *A. hendersoni* Cockerelle in the Berea College Forest in Madison County, Kentucky. Effects of altitude, tree species, sampling date, and climatic conditions were examined. Sampling was conducted with the use of ovitraps, and two additional mosquito species were also found: *Anopheles barberi* and *Toxorhynchites* sp. The protozoan parasite *Ascogregarina barretii* was identified in field-collected larvae of *Aedes triseriatus* but not in *A. hendersoni*. In late summer sampling, the effect of transmittance of light in water from the traps was compared with number of eggs collected.

NEWS AND COMMENTS

North American Benthological Society The North American Benthological Society (NABS) is seeking new members. NABS is an international organization whose purpose is to promote better understanding of the biotic communities of stream and lake bottoms and their role in aquatic ecosystems by providing media for disseminating new investigation results, new interpretations, and other benthological information to the scientific community at large. Membership is open to anyone interested in the Society's purpose. Currently the membership includes those in education, business and government. Graduate student participation is encouraged at all levels. NABS has a 3-day annual meeting, to be held this year on April 27–29, in La Crosse, Wisconsin. Included in the program are both verbal and poster presentations of scientific papers, symposia, workshops and several social events. The Society publishes the *Current and Selected Bibliography of Benthic Biology,* The Bulletin of the North American Benthological Society, and a membership directory, all of which are included in the low membership fee (regular—$10; student—$5). Send your check, payable to NABS, along with your name, address, zip code and professional affiliation to: Dr. A. C. Hendricks, University Center for Environmental Studies and Biology Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

* * * * *

69th Meeting of the Kentucky Academy of Science The 69th annual meeting of the Kentucky Academy of Science will be held at the University of Louisville, Belknap Campus, in November 1983. The exact dates will be announced in the Newsletter and in 44(3–4) of the *Transactions.*

* * * * *

A Drive for Membership Membership in the Kentucky Academy of Science is at an all time post-war low. There is an urgent need for all active members to thoroughly and strongly solicit new members and to urge old members who have allowed membership to lapse to rejoin the ranks. Please contact all the members of your departments or companies and urge them to pay their dues.

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 Indian 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.

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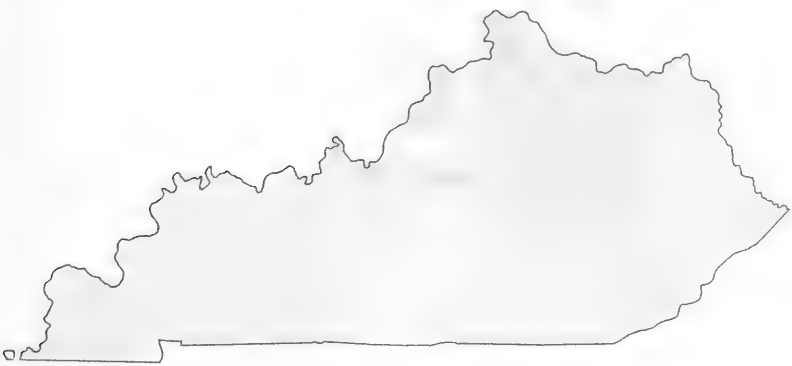

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September 1983

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Hydrocarbon Occurrence in the Berea Sandstone, Lawrence County, Kentucky

ALAN D. SMITH AND BAYLUS K. MORGAN

Department of Geology, Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

Since 1918, approximately 1,100 oil and gas wells have been drilled into the Berea Sandstone of Lawrence County, Kentucky. Information from 354 of these wells was used in a statistical search for factors influencing hydrocarbon occurrence. Variables studied are elevation of the top of the Berea Sandstone, Sunbury Shale thickness, oil production, gas production, Berea thickness and five lithologic characteristics. Of the 2 general and 18 specific hypotheses tested, only 2 were found significant. Elevation of the Berea accounted for 4.9 per cent of the common variance in oil production and 8.9 per cent of the common variance in gas production. Unstudied factors account for the majority of the variance in hydrocarbon occurrence.

INTRODUCTION

The first well to penetrate oil bearing sediments in Kentucky was drilled in 1819. Since that time, over 200,000 oil and/or gas wells have been drilled (1, 2, 3). One of the most important producing formations in the state is the early Mississippian Berea Sandstone. This formation extends from its type locality in northern Ohio into eastern Kentucky and western West Virginia. In general, the Berea in Kentucky is composed of light to medium gray sandstones, siltstones, and shales. The underlying Bedford formation is so similar that many researchers find it difficult to separate the 2 units (4, 5, 6, 7, 8, 9).

Since the turn of the century, Lawrence County, Kentucky (Fig. 1), has been in the forefront of Berea-oriented oil and gas exploration, with approximately 1,100 wells drilled. Almost 17 million barrels of oil have been produced since 1918 (1) and 23 hydrcarbon pools are recognized (Fig. 2). The first 2 pools were discovered in 1912: the Fallsburg Pool, producing from the Berea Sandstone and Ohio Shale, and the Busseyville Pool, producing from the Berea and Clinton Sandstones. The Redbush Pool, discovered in 1912, has the largest number of producing formations; 8 including the Berea (1, 3). In 1978, two new Berea pools were discovered: Webbville South and Jobe Branch (Nuttall, Kentucky Geol. Survey, Lexington, Kentucky, personal communication).

The purpose of this paper is to examine within Lawrence County, factors that are thought to be associated with hydrocarbon occurrences in the Berea Sandstone.

METHOD

The Kentucky Department of Mines and Minerals supplies the Kentucky Geological Survey with location plots for all oil and gas wells that are permitted within the state. Upon completion of the well, the operator is required to supply the

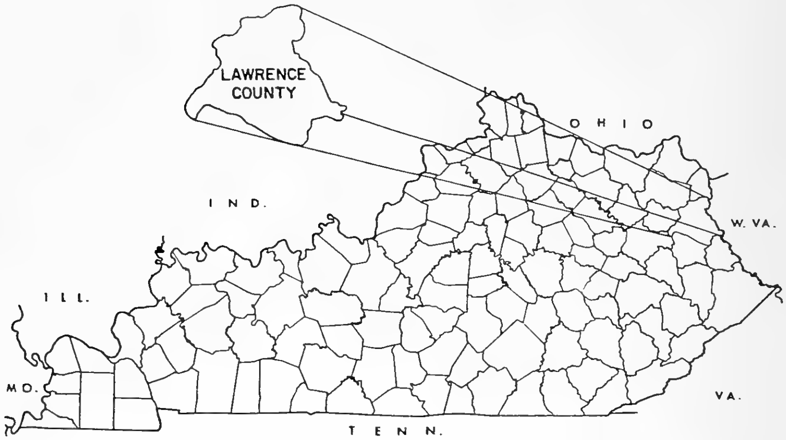

FIG. 1. Location of the study area.

Kentucky Geological Survey with copies of the drillers' log and geophysical logs, if any. This material is stored in Lexington at the Geological Survey and is open for public inspection.

An inventory was made of every well on file at the Geological Survey that penetrated the Berea Sandstone in Lawrence County. Each well was given an identification number and plotted on the appropriate seven and one-half minute topographic map. As each well was plotted, a list of all the pertinent data contained in the well envelope was compiled. The operator, farm name, Carter Coordinate location, quadrangle, date drilled, elevation, and total depth were recorded. The production status of the well was listed, and if there was production, the amount of production, producing formation, and producing interval were also noted. The type and quality of geophysical logs, if any, were listed as was the availability of well cuttings. Depths to the top and bottom of the Sunbury Shale and Berea Sandstone were also recorded (Fig. 3).

Cuttings were studied using a binocular microscope. The per cent of sand present in each sample was calculated using charts published by Compton (10). Siltstone was grouped with shale because their gamma ray curves are similar (11) and because neither is favorable for petroleum accumulation. In an attempt to gain more stratigraphic control, the Berea was divided, vertically, into 20-foot intervals. Per cent sand was averaged for each interval and will be referred as sand

FIG. 2. Hydrocarbon pools in Lawrence County, Kentucky from Wilson and Sutton (3).

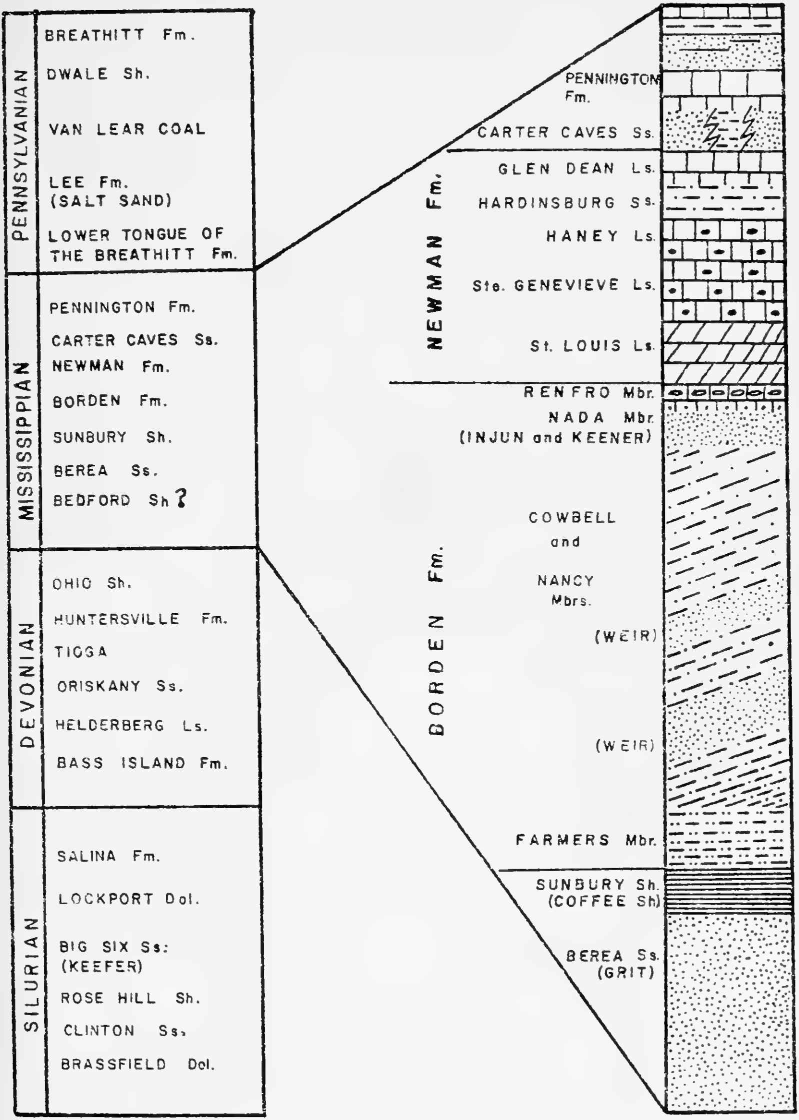

FIG. 3. Stratigraphic relationships in eastern Kentucky from Wilson and Sutton (3).

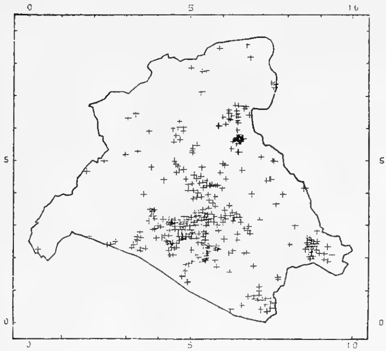

FIG. 4. Well locations.

FIG. 5. Elevation contour of the top of the Berea Sandstone. (Contour interval = 100 feet.)

per cent from cuttings number 1–5. Each good quality geophysical log was analyzed to establish formation boundaries and thickness.

Data developed were analyzed using multiple linear regression, a long-used approach to statistical evaluation that is related to the analysis of variance techniques which analyses estimate population variance and yield an F-statistic (12). By allowing the selected predictor variables to enter into a multiple regression equation with either gas or oil production as the criterion, R^2 values were obtained. An R^2 value in linear regression is the amount or per cent of the variance in the criterion variable which is accounted for the predictor variables; another term describing this is common variance. The R^2 value indicates to what extent the selected variables are predictable of the observed variance in oil and gas production. If one subtracts the amount of common variance from both the full and restricted models, a figure for the per cent of the common variance can be found for the predictor variables not covaried or accounted for in the model. Variables used in the study are elevation of the top of the Berea Sandstone, Sunbury Shale thickness, oil production, gas production, Berea thickness, and sand per cent cuttings number 1–5. For purpose of this study, the entire lithologic interval between the Ohio and Sunbury Shale was considered to be the Berea Sandstone. This removed uncertainty about recognition of the Bedford Shale.

In order to test for significant relationships among these variables, a series of hypotheses were developed. The .05 level of significance was considered sufficient to reject the nondirectional two-tailed hypotheses. When appropriate, a modification for multiple comparisons was made (13). Hypotheses tested are:

G_1: Do the variables Elevation of the Top of the Berea Sandstone, Sunbury Shale Thickness, Gas Production, Berea Thickness, and Sand Per Cent Cuttings 1–5 account for a significant amount of variance in predicting Oil Production?

- H_1: Does the variable Elevation of the Top of the Berea Sandstone account for a significant amount of variance in predicting Oil Production?
- H_2: Does the variable Sunbury Shale Thickness account for a significant amount of variance in predicting Oil Production?
- H_3: Does the variable Gas Production account for a significant amount of variance in predicting Oil Production?

TABLE 1.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH RESEARCH HYPOTHESIS TESTING PREDICTIVE RELATIONSHIPS AMONG OIL AND GAS PRODUCTION AND VARIOUS PARAMETERS ASSOCIATED WITH THE BEREA SANDSTONE

Hypothesis number	R^2 full	R^2 restr.	df	F	Probability	Sign.
G1	0.7103	0.0	9/4*	1.0899	0.5057	NS
H1	0.0489	0.0	1/295	15.1499	0.0001	S
H2	0.0130	0.0	1/257	3.3919	0.0667	NS
H3	0.0162	0.0	1/271	4.4698	0.0354	NS
H4	0.0010	0.0	1/156	0.1557	0.6937	NS
H5	0.0537	0.0	1/43	2.4423	0.1254	NS
H6	0.0229	0.0	1/43	1.0078	0.3210	NS
H7	0.0005	0.0	1/41	0.0184	0.8928	NS
H8	0.0381	0.0	1/34	1.3474	0.2538	NS
H9	0.1000	0.0	1/17	1.8891	0.1871	NS
G2	0.5900	0.0	9/4*	0.6396	0.7352	NS
H10	0.0888	0.0	1/297	28.9524	0.0000	S
H11	0.0026	0.0	1/263	0.6798	0.4104	NS
H12	0.0162	0.0	1/371	4.4698	0.0352	NS
H13	0.0282	0.0	1/144	4.1789	0.0428	NS
H14	0.0010	0.0	1/42	0.0412	0.8401	NS
H15	0.0122	0.0	1/42	0.5181	0.4756	NS
H16	0.0331	0.0	1/40	1.3678	0.2491	NS
H17	0.0373	0.0	1/31	1.1998	0.2818	NS
H18	0.2239	0.0	1/16	4.6147	0.0439	NS

Note. An F-test was utilized to test for significant relationships between oil and gas production and various parameters associated with the Berea Sandstone. The assigned alpha level of .05 for a two-tailed, nondirectional test was considered statistically significant. However, the employment of a correction for multiple comparisons was necessary, using the Newman and Fry (13) method. The corrected alpha level of .006 was used before the research hypothesis was considered significant.

* This statistic is not valid, due to the large number of missing cases.

H_4: Does the variable Berea Thickness account for a significant amount of variance in predicting Oil Production?

H_5: Does the variable Sand Per Cent From Cuttings Number 1 account for a significant amount of variance in predicting Oil Production?

H_6: Does the variable Sand Per Cent From Cuttings Number 2 account for a significant amount of variance in predicting Oil Production?

H_7: Does the variable Sand Per Cent From Cuttings Number 3 account for a significant amount of variance in predicting Oil Production?

H_8: Does the variable Sand Per Cent From Cuttings Number 4 account for a significant amount of variance in predicting Oil Production?

H_9: Does the variable Sand Per Cent From Cuttings Number 5 account for a significant amount of variance in predicting Oil Production?

G_2: Do the variables Elevation of the Top of the Berea Sandstone, Sunbury Shale Thickness, Oil Production, Berea Thickness, Sand Per Cent From Cuttings Number 1 through Sand Per Cent From Cuttings Number 5 account for a significant amount of variance in predicting Gas Production?

H_{10}: Does the variable Elevation of the Top of the Berea Sandstone account for a significant amount of variance in predicting Gas Production?

H_{11}: Does the variable Sunbury Shale Thickness account for a significant amount of variance in predicting Gas Production?

H_{12}: Does the variable Oil Production account for a significant

TABLE 2.—SIGNIFICANT CORRELATIONS AMONG OIL AND GAS PRODUCTION, BEREA SANDSTONE PARAMETERS, AND RELATED VARIABLES

Variable	Correlation	Variable
Elevation of the Top of the Berea Sandstone	0.2989	Gas Production
	−0.2210	Oil Production
	0.3242	Sand Per Cent from Cuttings Number One
	0.4614	Sand Per Cent from Cuttings Number Four
Berea Thickness	0.5968	Sand Per Cent from Cuttings Number One
	0.4097	Sand Per Cent from Cuttings Number Four
	−0.1679	Gas Production
Gas Production	−0.1274	Oil Production
	−0.4731	Sand Per Cent from Cuttings Number Five
Oil Production	0.1141	Sunbury Thickness
Sand Per Cent from Cuttings Number One	0.3130	Sand Per Cent from Cuttings Number Four

amount of variance in predicting Gas Production?

H_{13}: Does the variable Berea Thickness account for a significant amount of variance in predicting Gas Production?

H_{14}: Does the variable Sand Per Cent From Cuttings Number 1 account for a significant amount of variance in predicting Gas Production?

H_{15}: Does the variable Sand Per Cent From Cuttings Number 2 account for a significant amount of variance in predicting Gas Production?

H_{16}: Does the variable Sand Per Cent From Cuttings Number 3 account for a significant amount of variance in predicting Gas Production?

H_{17}: Does the variable Sand Per Cent From Cuttings Number 4 account for a significant amount of variance in predicting Gas Production?

H_{18}: Does the variable Sand Per Cent From Cuttings Number 5 account for a significant amount of variance in predicting Gas Production?

The testing of hypotheses involved the use of the following hardware and software: the University of Kentucky's IBM 370 with the statistical packages DPLINEAR (Double Precision Multiple Linear Regression program) and SPSS (Statistical Package for the Social Sciences) from the University of Southern Illinois at Carbondale.

RESULTS

Data from 354 wells, which penetrate the Berea Sandstone, were analyzed. Well locations are shown in Fig. 4. Of these wells, 57 were dry holes, 46 were oil wells, 98 were gas wells, 8 were oil and gas wells, 32 were wells with oil shows, 26 were wells with gas shows, 27 were wells with oil shows and gas shows, 6 were oil wells with gas shows, 28 were gas wells with oil shows, and 26 were unclassified.

Table 1 summarizes significance testing. Only the hypotheses H_1 and H_{10},

TABLE 3.—DESCRIPTIVE STATISTICS OF OIL AND GAS PRODUCTION, BEREA SANDSTONE PARAMETERS, AND RELATED VARIABLES

Variable	Valid cases	Mean	Standard deviation	Variance	Skewness	Kurtosis
Elevation of the top of the Berea Sandstone (m)	353	−203.9	94.1	29,048.1	0.1	−1.2
Sunbury Shale Thickness (m)	310	6.2	2.0	12.8	1.4	6.7
Gas Production (1,000 ft³/day)	300	58.8	114.2	13,043.1	3.2	16.7
Oil Production (barrels/day)	298	7.0	2.5	6.2	5.4	37.6
Berea Thickness (m)	168	31.7	7.1	164.6	0.1	3.3
Sand Per Cent from Cuttings Number One	51	83.7	16.2	261.3	−2.0	4.5
Sand Per Cent from Cuttings Number Two	51	73.3	22.2	494.9	−1.0	0.2
Sand Per Cent from Cuttings Number Three	49	52.9	27.3	744.0	−0.2	−1.2
Sand Per Cent from Cuttings Number Four	38	44.7	25.3	641.1	0.1	−1.5
Sand Per Cent from Cuttings Number Five	21	26.9	17.1	292.6	0.5	−1.1

which dealt with the elevation of the top of the Berea Sandstone (Fig. 5), were significant. The R_2 term in Table 1 indicates the extent to which a variable is predictive of the observed variance in oil and gas production. The maximum value of $R^2 = 1.0$ for continuous values. Of the significant relationships found, the highest R^2 was 8.88 per cent and the lowest was 4.89 per cent. Thus, the other 91–95 per cent of the variance in gas and oil production is unaccounted for, even though the hypotheses were significant. Table 2 represents the significant correlation coefficients of the variables studied. The ability of the test to detect a difference when it does exist for a medium-effect size was over 95 per cent. Since some of the independent variables have correlations significantly greater than zero, care must be taken when interpreting the regression weights, due to multicolinearity. Table 3 summarizes the descriptive statistics for both the criteria and predictor variables.

CONCLUSIONS

Data may be biased as a result of geological exploration programs designed to enhance oil and gas discovery. In addition, because of the age of many of the wells, since operators are not required by the state to provide production statistics, data acquired for some of the variables may be poor. However, the F-test is a very robust statistical technique and is relatively insensitive to violations of random selection and normality of distributions.

Testing of the 2 general and 18 specific hypothese yielded only 2 hypotheses that are significant. Elevation of the top of the Berea Sandstone was significant ($P = .0001$) in predicting oil production, but it only accounted for 4.89 per cent of the variance in oil production. In addition, this variable was significant ($P = .0000$) in predicting gas production, accounting for 8.88 per cent of the common variance in gas production.

Many of the correlation values were significant, suggesting that a wide range of geological conditions may explain these results since only a small amount of variance in oil and gas production was explained by the two significant hypotheses. Other factors clearly account for the majority of the variance in hydrocarbon occurrence.

A greater understanding of the geology of eastern Kentucky and of the Berea

Sandstone is needed to help understand factors associated with hydrocarbon occurrence. The refinement of relationships among the different structural elements of the region is greatly needed. Analysis of the Berea-Bedford interval with emphasis on the Berea-Bedford boundary and the sources of their clastics merits study. Further analysis of hydrocarbon occurrences in the Berea Sandstone using oriented cores, if they become available, would be useful in delineating the effects of fracturing, mica content and orientation, variations in cementation, and many other variables that may be important.

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Observations on the Palezone and Sawfin Shiners, Two Undescribed Cyprinid Fishes from Kentucky

BRANLEY ALLAN BRANSON

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

Variation in 11 mensurable and 4 enumeration characters are presented for the sawfin (*Notropis* sp. cf. *spectrunculus*) and palezone (*Notropis* sp. cf. *procne*) shiners from the Little South Fork of the Cumberland River in Kentucky. Notes on the coloration and pigment distribution in these two undescribed species are included.

INTRODUCTION

It has been known since the 1960's that the Cumberland River drainage below the falls and portions of the Tennessee River drainage contain two undescribed cyprinid fish species, the putative palezone and sawfin shiners (1), in Kentucky principally in the Little South Fork of the Cumberland River (2, 3). The palezone shiner, *Notropis* sp. cf. *procne* is being considered by Robert E. Jenkins, Roanoke College, Virginia, and the sawfin shiner, *Notropis* sp. cf. *spectrunculus*, is being studied by John S. Ramsey, Auburn University (4). Both species are of considerable environmental concern (5), and very little is known about the biology, variability, or total geographic distribution of either species.

This contribution presents information on the variability of several proportional measurements and counts in these two species of minnows in Kentucky.

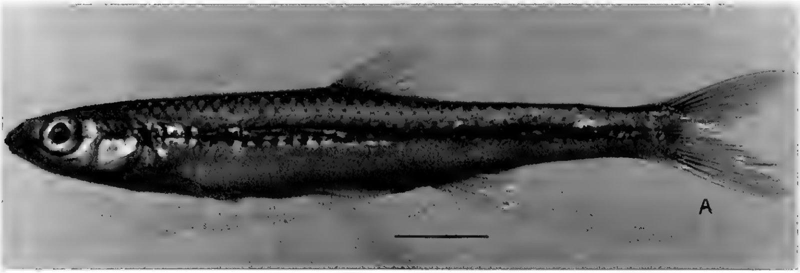
OBSERVATIONS

Both species of minnows are still relatively abundant in the high-quality waters of the Little South Fork of the Cumberland River in Kentucky, where the sawfin shiner ranks seventh and the palezone shiner second in relative abundance behind *Notropis telescopus* (3). Warren (6) recently reported sawfin shiners from Rock Creek (Big South Fork of the Cumberland River) in McCreary County, and from Pitman Creek, a Cumberland River tributary in Pulaski County, but the paleozone shiner seems to be restricted to the Little South Fork within the Cumberland drainage.

Because most field biologists and ichthyologists are not familiar with these species, the following general descriptions are presented.

The palezone shiner (Fig. 1a) is a slender, slab-sided minnow with (in life) nearly transparent flesh and a complete lateral line. Proportional measurements and counts are presented in Tables 1–3. The color pattern is somewhat reminiscent of that in the swallowtail shiner. Large melanophores line the upper lip and there are a few scattered ones on the lower lip; otherwise, the venter of the head and most of the belly are nearly immaculate. There is a very narrow black streak on the venter behind the anal fin and a very black streak occurs along the base of that fin. A narrow, dusky band suffused by silver (in life) follows the lateral line and a black triangle (apex forward) is associated with each lateral-line pore. The sides below and immediately above the lateral line are essentially pigmentless. Above the pale zone, the scales are outlined with small melanophores. A small black blotch occurs just in front of the dorsal fin and there is a second blotch on the back near the middle of the dorsal fin. A dusky streak extends through the eye, and the uppermost and lowermost rays of the caudal fin are streaked with black.

By contrast, the sawfin shiner (Fig. 1b), presumed to be most closely related to the mirror shiner (3, 4), is not so distinc-



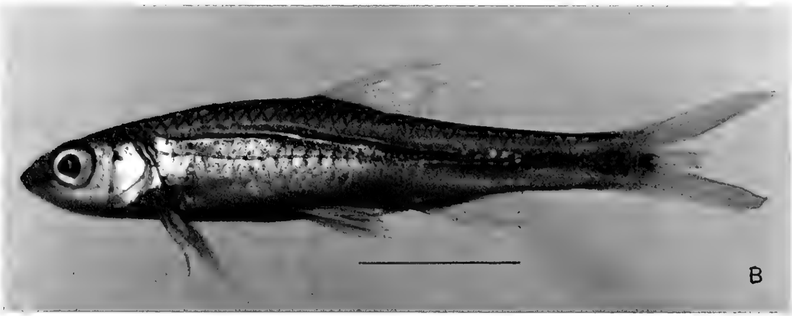


FIG. 1a. The palezone shiner from the Little South Fork of the Cumberland River, Kentucky. Scale = 18.0 mm (57.0 mm SL).

FIG. 1b. The sawfin shiner from the Little South Fork of the Cumberland River, Kentucky. Scale = 12.5 mm (49.5 mm SL).

TABLE 1.—PROPORTIONAL MEASUREMENTS (MEAN AND RANGE) OF PALEZONE AND SAWFIN SHINERS FROM THE LITTLE SOUTH FORK OF THE CUMBERLAND RIVER, KENTUCKY (n = 100)

Characteristic	Palezone	Sawfin
Size range and mean standard length	46.2 (35.2–58.0)	42.3 (31.5–50.1)
In standard length		
Body depth	5.98 (5.3–8.0)	5.36 (3.7–6.2)
Predorsal length	2.0 (1.7–2.2)	2.0 (1.6–2.2)
Caudal peduncle length	3.7 (2.8–4.3)	4.0 (3.1–4.7)
Head length	4.2 (3.7–4.6)	3.8 (3.8–4.7)
In head length		
Dorsal origin to lateral line	2.2 (1.8–2.6)	2.1 (1.6–2.4)
Orbit length	3.1 (2.6–3.5)	2.8 (2.4–3.3)
Upper jaw length	3.6 (3.2–4.6)	3.3 (2.8–3.8)
Body width	1.9 (1.7–2.3)	2.1 (1.5–2.4)
Snout length	2.9 (2.4–4.0)	3.2 (2.4–3.6)
In caudal peduncle length		
Caudal peduncle depth	3.2 (2.6–4.4)	2.7 (2.1–3.3)

TABLE 2.—FREQUENCY DISTRIBUTIONS OF FIN-RAY NUMBERS IN THE PALEZONE AND SAWFIN SHINERS FROM THE LITTLE SOUTH FORK OF THE CUMBERLAND RIVER, KENTUCKY

	Anal Rays				
	6	7	8	9	Mean
Palezone	3	93	4		7.01
Sawfin		1	97	2	8.01
	Pectoral Rays				
	12	13	14	15	Mean
Palezone		12	63	25	14.1
Sawfin	1	34	59	6	13.7
	Pelvic Rays				
	7	8	9		Mean
Palezone	5	89	6		8.0
Sawfin	2	85	13		8.1

tive; in fact, it bears a strong resemblance to *Notropis volucellus,* the mimic shiner, a common species in Kentucky. The lateral line is complete, the anteriormost scales being somewhat higher than wide. The supratemporal lateral-line canal is narrowly to widely interrupted and the infraorbital canal is narrowly interrupted in a few specimens. Proportional measurements and counts are presented in Tables 1–3.

In coloration, the sawfin shiner resembles the mimic shiner. Each pectoral fin ray, but not those of the pelvics, bears a row of very fine melanophores. There is an indistinct black blotch at the base of the caudal fin from which streaks extend out onto the membranes. A distinct black spot occurs on the belly immediately in front of the anal fin and there is a dark midventral streak behind that fin. A black streak is obvious on the back in the base of the dorsal fin.

In life, the general coloration is silvery. The scales above the complete lateral line are outlined with melanophores and the sides below the midline, the belly behind the pelvic and anal fins, and the sides of the caudal peduncle bear scattered and indistinct brownish freckles. The upper lip is lined with enlarged melanophores. A dusky band suffused with silver extends from head to tail, becoming slightly enlarged at the base of the caudal peduncle. The lateral-line pores are outlined with small black blotches bearing vertically elongated and thin black streaks.

TABLE 3.—FREQUENCY OF LATERAL-LINE SCALES IN THE PALEZONE AND SAWFIN SHINERS FROM THE LITTLE SOUTH FORK OF THE CUMBERLAND RIVER, KENTUCKY

	34	35	36	37	38	39	40	Mean
Palezone	1	13	28	31	18	6	1	36.8
Sawfin	5	27	34	33	1			36

CONCLUDING REMARKS

The palezone shiner is a rather distinctive minnow that should not be confused with any other species in Kentucky. The pigmentless, virtually transparent stripe above the lateral line is diagnostic. The only other minnow in Kentucky waters having a similar trait is the Tennessee shiner, *Notropis leuciodus,* which is separable by other features. By contrast, the sawfin shiner may be easily confused with *Notropis volucellus,* the mimic shiner. However, the last-named species has all the rays of the dorsal fin lined with melanophores whereas in the sawfin shiner only the first four rays are marked in that manner. Both species, and their closest relatives, have the pharyngeal teeth arranged in a single row (4-4).

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Wildlife Information Needs of Kentucky County Extension Agents[1]

WILLIAM C. MCCOMB AND STEPHEN A. BONNEY

Department of Forestry, University of Kentucky, Lexington, Kentucky 40546-0073

ABSTRACT

A questionnaire was mailed to 120 county extension agents in February 1981. The questionnaire was used to identify their needs for information on various fish and wildlife topics, to estimate the number of requests they received for fish and wildlife information, and to determine the best means of information dissemination. The 80 respondents indicated they most needed aquaculture information for warm-water species; animal damage control information for blackbirds, moles, woodchucks, pigeons, house sparrows, and rodents; and habitat management information on bobwhite quail, white-tailed deer, cottontail rabbits, and squirrels. This information could best be provided through publications, workshops, and 4-H projects.

INTRODUCTION

County agricultural extension agents are employed through the Cooperative Extension Service (CES) stationed at Land Grant Universities in each state. The CES involves cooperation among federal (USDA), state (university), county, and private people and funds (1). County extension agents are responsible for providing fish and wildlife information to the public via 4-H, workshops, phone conversations, and on-site visits. Wildlife and fisheries extension specialists work with the county agents to provide a variety of educational programs (publications, workshops, 4-H projects, and demonstrations) but identification of the everyday information needs of county agents is essential before a prioritized list of goals can be developed by personnel providing information to the public via county extension agents. Identification needs also may provide wildlife professionals with an indication of the public's views on fish and wildlife importance, particularly for those residing in rural vs urban environments.

The objectives of this study were to identify the important fish and wildlife information needs of county extension agents in Kentucky, and to compare information needs among 3 levels of human population density and among 4 geographic areas.

METHODS

A questionnaire was developed which addressed 4 broad topical areas: (1) the absolute and proportional number of requests made of a county agent for fish and wildlife information in 1980, (2) ranking of 13 broad categories of fish and wildlife topics based on the number of requests received in 1980 for each topic, (3) iden-

[1] The information reported in this article (82-8-251) is in connection with Agricultural Experiment Station Project No. 624 and is published with the approval of the Director.

tification of desirable information transfer techniques (field days, publications, etc.), and (4) determination of the degree of interaction with conservation officers and wildlife biologists of the Department of Fish and Wildlife Resources during 1980. Within 5 of the 13 broad categories of fish and wildlife topics, a list of 8 to 11 wildlife or fish taxa were listed and ranked based on number of requests received for each taxa within that wildlife topic. Questionnaires were mailed during February 1981 to the county agent for agriculture in each of the 120 counties in Kentucky. Geographic and demographic strata were developed at the county level to identify differences in responses among eastern, central, Bluegrass, and Purchase physiographic regions in Kentucky and among high (>20 people/km²), medium (≤20 people/km², ≥10 people/km²), and low (<10 people/km²) human population densities (Fig. 1). Mean number of requests, mean contacts, and mean ranks were compared among geographic and demographic strata using an analysis of variance with Duncan's multiple range test.

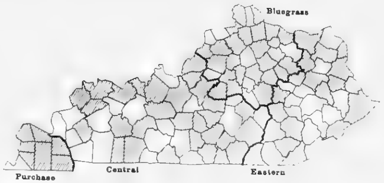

FIG. 1. Counties (darkened) from which county agents responded to the fish and wildlife questionnaire, 1981.

RESULTS

Eighty of 120 county agents responded to the questionnaire. Respondents were uniformly located across the state (Fig. 1).

Information Requests.—Respondents received an average of 65 requests for wildlife information and 35 requests for fish information, but the requests per county agent varied widely (SD = 231; 89.8, respectively) (Table 1). This represented 1.8% and 0.9% of the total requests each year. The number of wildlife and fish information requests did not vary geographically ($P > 0.05$) but did vary demographically. An average of 4.0% of all urban contacts dealt with wildlife, while 1.3% and 0.7% were wildlife oriented in medium- and low-population areas, respectively. Similarly there was a larger proportion of fish-oriented contacts in high population areas than in medium- and low-population areas. There are a greater number of potential contacts in densely populated areas than in sparsely populated areas, but total (all subject areas) county extension agent contacts did not differ significantly among demographic strata.

Total agent contacts concerning all types of agricultural information were higher in central Kentucky ($\bar{x} = 5{,}148$) than in eastern Kentucky ($\bar{x} = 1{,}600$) ($P < 0.05$).

Important Fish and Wildlife Topics.—Management of fish ponds and animal damage control (ADC, including control of undesirable species) had the lowest mean ranks (highest priority) of 13 fish and wildlife topics (Table 2). This trend was consistent over population and geographic strata. Game management information was more important in eastern Kentucky ($\bar{x}_R = 3.6$) than in the Bluegrass Area ($\bar{x}_R = 6.0$) ($P < 0.05$). Information on management of nongame species was more important in urban ($\bar{x}_R = 6.1$) than rural ($\bar{x}_R = 9.0$) areas ($P < 0.05$). Information on hunting, fishing, trapping, wildlife diseases, and wildlife food consistently received low priority.

Important Fish and Wildlife Taxa.—Fish species for which high information priority was given were warm-water species that may be found in farm ponds: largemouth bass (*Micropterus salmoides*), catfish (*Ictalurus* sp.), and crappie (*Pomoxis* spp.). Cold-water species (trout (*Salmo* spp.), smallmouth bass (*Micropterus dolomieui*), and rock bass (*Ambloplites rupestris*)) and bluegill (*Lepomis macrochirus*) received lower priority. Frogs

TABLE 1.—MEAN RESPONSES TO GENERAL FISH AND WILDLIFE QUESTIONS, KENTUCKY COUNTY EXTENSION AGENT QUESTIONNAIRE, FEBRUARY 1981

Question	N[1]	Response
How many contacts with the local Conservation Officer in 1980?	79	8.24 (20.2)[2]
How many contacts with the local Wildlife Biologist in 1980?	78	0.7 (1.3)
How many requests did you receive in 1980 for wildlife information?	78	64.9 (231.3)
How many requests did you receive in 1980 for fish information?	80	34.6 (89.8)
How many requests did you receive in 1980 for information about all agricultural subjects?	70	3,667 (4,282)
Would the following programs be well received in your county?		
4-H Wildlife	79	50.6%[3]
Short courses or seminars in wildlife	79	45.6%
Organization of a sportsman's club	79	7.6%
Organization of a birdwatching club	79	16.5%
Development of hunting lease	78	20.5%
Newsletter in wildlife and forestry from U.K.	79	63.3%

[1] N = number of respondents.
[2] Standard deviations indicated parenthetically.
[3] Per cent of "yes" responses.

(*Rana* spp.) and crayfish (*Cambarus* spp.), associated with farm ponds, received very low priority. Mean ranks for importance of aquatic taxa did not differ among demographic or geographic strata.

Information on control of blackbirds (Icteridae) and moles (*Scalopus aquaticus* and *Parascalops breweri*) received the highest priority among pest species. Control of woodchucks (*Marmota monax*), pigeons (*Columba livia*), house sparrows (*Passer domesticus*), rats, and mice also received high priority. Rat and mouse control was more important in mid-population areas than in urban or rural areas ($P < 0.05$). Fewer requests were made for woodchuck control information in the Purchase Area than elsewhere ($P < 0.05$), possibly because they are less numerous in the Purchase Area than in the rest of the state (4). Information on control of pigeons and house sparrows was more important in the Purchase Area than in the rest of the state. Information requests for other taxa—snakes (Colubridae), squirrels (Sciuridae), bats (Vespertilionidae), woodpeckers (Picidae), chipmunks (*Tamias striatus*), beavers (*Castor canadensis*) and raccoons (*Procyon lotor*)—were low and consistent over geographic and demographic strata.

Management information for bobwhite quail (*Colinus virginianus*), white-tailed deer (*Odocoileus virginianus*), cottontail rabbits (*Sylvilagus floridanus*), and squirrels received the highest priority among game animals. Rabbit management information was more important in urban and mid-population areas than in rural areas ($P < 0.05$). Information on mourning dove (*Zenaidura macroura*) management was important in central and eastern Kentucky. Management information for raccoons, foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*), ducks, geese, wild turkeys (*Meleagris gallopavo*), and woodcocks (*Philohela minor*) received low priority and was consistent over geographic and demographic strata.

Information needs on nongame management, particularly desirable in urban areas, focused on snakes, bats, small mammals, songbirds, and raptors. The importance of snake information was higher ($P < 0.005$) in urban and mid-population areas than rural areas. Informa-

TABLE 2.—MEAN RANKS[1] GIVEN TO FISH AND WILDLIFE RELATED PROBLEMS BASED UPON THE NUMBER OF REQUESTS FOR INFORMATION IN 1980, KENTUCKY COUNTY AGENT QUESTIONNAIRE, FEBRUARY 1981

Subject	N[2]	Mean rank
1. Mangement of fish ponds	76	3.00 (2.28)[3]
2. Control of undesirable species	77	3.10 (2.22)
3. Control of wildlife damage	75	3.45 (3.06)
4. Habitat management for game	65	4.94 (3.06)
5. Management of lakes and streams for game fish	60	6.00 (3.19)
6. Hunting in the county	60	7.37 (3.27)
7. Fishing in the county	62	7.58 (3.28)
8. Bird watching, bird house construction, etc.	61	8.11 (3.30)
9. Nongame management	58	8.12 (3.48)
10. Harvest regulations and game laws	56	8.43 (2.92)
11. Preparation of game for food	55	9.85 (3.58)
12. Wildlife diseases	54	9.94 (3.19)
13. Trapping in your county	54	10.13 (2.32)
14. Other subjects	18	11.20 (4.7)

[1] Rank of 1 = most important, rank of 14 = least important.
[2] N = number of respondents.
[3] Standard deviations indicated parenthetically.

tion requests for amphibians, turtles, endangered species, lizards, bobcats (*Lynx rufus*), and coyotes (*Canis latrans*) were consistently low over geographic and demographic strata.

Respondents ranked foxes, muskrats (*Ondatra zibethicus*), raccoons, and minks (*Mustela vison*) the important furbearers for which information is needed. Information needs for opossums (*Didelphis virginianus*), skunks (*Mephitis mephitis* and *Spilogale putorius*), and beavers were consistently low.

Information Transfer Techniques.—Over 60% of the respondents indicated that an extension newsletter from the University of Kentucky would be a desirable method of informing them and the public on fish, wildlife, and forestry topics (Table 1). Short courses and 4-H programs were also considered important methods. Development of clubs or leases was not considered a desirable means of informing the public about fish and wildlife (Table 1).

DISCUSSION

Several state and federal agencies are at least in part responsible for providing fish and wildlife information needs to the public. In addition to the Cooperative Extension Service, the Soil Conservation Service, U.S. Fish and Wildlife Service, and the Kentucky Department of Fish and Wildlife Resources provide written information and consultation with the public regarding fish and wildlife information. Our results may be biased toward information needs associated with agricultural situations because county agents most frequently have training in agriculture, but we think that our results provide prioritized guidelines for preparation of written materials and short courses to best meet the needs of the public.

Of highest priority is aquaculture information for warm-water fish production. County agents and landowners must rely on aquaculture advice from the Department of Fish and Wildlife Resources and from federal agencies since there is currently no designated aquaculture specialist in the Kentucky CES. An aquaculture program is being developed at Kentucky State University to meet this need. It is imperative that these agencies cooperate among themselves and especially with CES personnel if we are to provide this information.

Animal damage control has long been recognized as an important information need of the public (5, 6). In Kentucky, information on blackbird control is needed and since the U.S. Fish and Wildlife Service is currently conducting research on blackbird control in this state, we encourage their cooperation with county agents in disseminating the most current techniques for blackbird control. Information on control of other species such as moles, woodchucks, pigeons, house sparrows, and rodents is also needed. A handbook on Prevention and Control of Wildlife Damage is available (7), but it is not specific to Kentucky. A handbook of animal damage control in Kentucky, based on information from a variety of sources, was prepared (8), but additional information must be supplied to county agents as new techniques become available. Finally, short courses and workshops on ADC, similar to those currently conducted by the Fish and Wildlife Service, should be scheduled on a regular basis throughout the state and with inter-agency coordination.

Information on management of quail, deer, rabbits, and squirrels is widely available (9, 10), but little information is specific to Kentucky. Publications dealing with these topics as they apply to Kentucky, in combination with workshops or field days are needed to make landowners, especially farmland owners, aware of the benefits of maintaining a diversity of habitats for these species.

Nongame management techniques for reptiles, birds, and mammals should be made available to the public, particularly in urban areas. As urban areas expand, the need for this information will likely increase (11). Projects through the 4-H system would greatly enhance educational efforts in habitat management for nongame and game species. New and updated projects are needed similar to those developed by the Kentucky Nature Preserves Commission (12). A coordinated effort among agencies is essential if we are to maximize our educational efforts in fish and wildlife.

ACKNOWLEDGMENTS

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Correlation of Fish Distribution and Stream Order in the Upper Cumberland and Upper Kentucky Rivers Based Upon an Information Retrieval System

David A. Dixon, Branley A. Branson, and Donald L. Batch

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

This article demonstrates some of the capabilities of a computerized information/retrieval system designed to store distribution and ecological data of the lotic organisms of Kentucky. Data for 152 species of fishes correlated with stream-order occurrence in the Upper Kentucky and Upper Cumberland river systems are presented.

Introduction

Numerous reports on the fishes of the Upper Cumberland and Upper Kentucky rivers have been published. In an attempt to more fully understand the distribution and ecological affinities of the Kentucky aquatic fauna and flora, we (1) developed, in conjunction with the Kentucky Department of Natural Resources and Environmental Protection, a computerized information/retrieval system for all the lotic organisms reported in the literature with indications of habitat, stream order, water chemistry, and other ecological notations, including river drainage, subdrainage, and physiographic region.

Although this system doubtless will require constant revision, purging of errors, and periodic updating as new information is published, this open-ended system is a very facile one that allows the retrieval of data in a variety of forms and correlations. The data presented here (correlations between fish species and stream magnitude in the Upper Cumberland and Upper Kentucky river basins) are but one example of the system's capability. Many others are possible, i.e., correlations between species and types of habitat, between species and water chemistry, between species and physiographic regions, and so forth.

Of the 5 major stream systems in east-

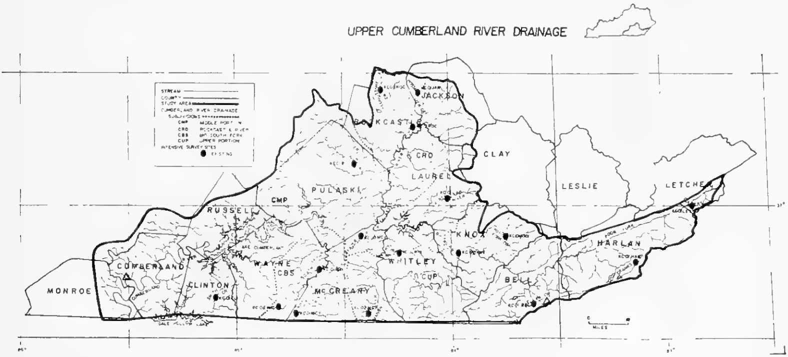

FIG. 1. From Harker et al. (3).

FIG. 2. From Harker et al. (3).

ern Kentucky, embracing approximately 53,600 km² in drainage, the Kentucky and Upper Cumberland drainages comprise approximately 68% of the total (2). The Upper Cumberland River arises in the highlands of SE Kentucky, draining an area of approximately 18,195 km² (Fig. 1). The main stream is formed at the junction of Poor Fork, Clover Fork, and Martin's Fork in Harlan County, flowing in a general westward course through a gap in Pine Mountain before reaching Cumberland Falls (3). Among its principal tributaries are the Big South Fork, the Laurel, and Rockcastle rivers in SE Kentucky.

The topography of the Upper Cumberland River basin is quite variable as the stream passes through several distinct physiographic regions. The easternmost portion of the watershed is mountainous with relief and elevation increasing toward the headwaters. Eastern portions of Laurel and Jackson counties, central Knox and Whitley counties and southcentral McCreary County lie in the Plateau Area which is the least rugged portion of the drainage. That portion of the drainage is characterized by undulating to rolling terrain. To the immediate west lies a narrow band known as the Escarpment Area that encompasses much of the Rockcastle and Big South Fork rivers and Cumberland Falls. The topography is rugged with steep-sided and clifty valleys and narrow ridges. The westernmost portion of the Upper Cumberland River drainage lies in the Mississippina Plateau, an area that is variable with some rolling and undulating terrain. In places it is hilly or karsted, and stream drainages may be rough and precipitous (3).

The Kentucky River basin arises in

TABLE 1.—DISTRIBUTION OF FISHES BY STREAM ORDER IN THE UPPER CUMBERLAND AND UPPER KENTUCKY RIVERS. K = KENTUCKY RIVER BASIN, C = CUMBERLAND RIVER BASIN, B = BOTH UPPER CUMBERLAND AND UPPER KENTUCKY RIVER BASINS

Species	Stream order						
	1	2	3	4	5	6	7
Acipenser fulvescens							C
Alosa chrysochloris				K		K	K
Ambloplites rupestris	K	B	B	B	B	B	B
Ammocrypta clara						C	
Ammocrypta pellucida			K	K	B	K	
Aplodinotus grunniens	C		C	K	B	B	B
Campostoma anomalum	K	B	B	B	B	B	B
Carassius auratus							K
Carpioides carpio				K		K	B
Carpioides cyprinus			K	K	K	K	K
Carpioides species							K
Carpioides velifer	K			K	K	B	K
Catostomus commersoni		B	B	B	B	B	B
Chaenobryttus gulosus		K	B	B	B	K	B
Chrosomus erythrogaster	K	B	B	B		C	C
Chrosomus cumberlandensis		C	C	C			
Cottus bairdi	C	K	K				
Cottus carolinae	B	B	B	B	B	C	C
Cyprinus carpio		C	K	B	K	K	B
Dorosoma cepedianum			K	K	B	B	B
Ericymba buccata		B	B	B	K	B	C
Erimyzon oblongus			C		K	C	
Esox americanus			K				
Esox masquinongy			K	K	B	K	
Etheostoma blennioides	K	B	B	B	B	B	B
Etheostoma caeruleum	B	B	B	B	B	B	B
Etheostoma camurum	K		C	B	C	C	
Etheostoma cinereum				C	C		
Etheostoma flabellare	K	B	B	B	B	B	B
Etheostoma kennicotti		C	C	C	C		
Etheostoma maculatum				B	B	C	
Etheostoma nigrum	K	K	B	B	B	B	C
Etheostoma obeyense		C	C	C	C	C	
Etheostoma rufilineatum	C	C	C	C	C	C	K
Etheostoma sagitta		B	B	B	B	C	C
Etheostoma simoterum		K	C	K	K	C	
Etheostoma spectabile	K	B	B	B	K		
Etheostoma species		B	B	B	B	B	
Etheostoma stigmaeum	C		C	C	C	C	C
Etheostoma tippecanoe					K	K	
Etheostoma variatum		K	K	K	K	K	K
Etheostoma virgatum		C	C	C	C	C	C
Etheostoma zonale	K	B	B	B	B	B	
Fundulus catenatus		K	C	C	C	C	
Fundulus notatus			K	B	K	K	C
Fundulus olivaceus			C				
Gambusia affinis			K	B	K	K	
Hiodon alosoides						K	K
Hiodon tergisus					K		K
Hybognathus nuchalis			C				
Hybopsis amblops		B	K	B	B	B	
Hybopsis dissimilis				B	B	K	
Hybopsis insignis					K		
Hybopsis species						K	
Hybopsis storeriana					K	K	K
Hypentelium nigricans	K	B	B	B	B	B	C
Ichthyomyzon bdellium	B			C			K

TABLE 1.—CONTINUED

Species	Stream order						
	1	2	3	4	5	6	7
Ichthyomyzon fossor				K			
Ichthyomyzon greeleyi		K		C	K		
Ichthyomyzon unicuspis					K		K
Ictalurus furcatus						K	K
Ictalurus melas		B	B	B	B	K	K
Ictalurus natalis	K		B	B	B		B
Ictalurus nebulosus		C	K	K	K	C	K
Ictalurus punctatus			K	B	B	B	B
Ictiobus bubalus						K	
Ictiobus cyprinellus			C			K	
Labidesthes sicculus			K	B	B	B	B
Lagochila lacera			C		C		
Lampetra aepyptera			C	K	K		
Lampetra lamottei	K			K	K		
Lampetra species				C			
Lepisosteus osseus			K	K	K	K	K
Lepomis cyanellus	B	B	B	B	B	B	B
Lepomis gibbosus					K		
Lepomis humilis			K		K		K
Lepomis macrochirus		B	B	B	B	B	B
Lepomis megalotis	K	B	B	B	B	B	B
Lepomis microlophus			B	K	K		K
Lota lota							K
Micropterus coosae		C	C	C			
Micropterus dolomieui	K	B	B	B	B	B	B
Micropterus punctulatus		B	B	B	B	B	B
Micropterus salmoides	K	K	B	B	B	B	K
Minytrema melanops			B	K	B	K	K
Morone chrysops				C	B	K	K
Moxostoma anisurum			K	K	B		K
Moxostoma carinatum				K	B	K	K
Moxostoma duquesnei		B	B	B	B	B	K
Moxostoma erythrurum	K	K	B	B	B	B	B
Moxostoma macrolepidotum		C	B	K	K	B	K
Nocomis biguttatus			K	K			
Nocomis effusus			C			C	
Nocomis micropogon	K	B	B	B	B	B	B
Notemigonus crysoleucas				K			
Notropis ardens	K	B	B	B	B	B	C
Notropis ariommus			B	B	B	C	
Notropis atherinoides		K	B	K	B	B	K
Notropis blennius				K	B		
Notropis boops	B	K	B	B	B		K
Notropis buchanani	K			K	K	K	K
Notropis chrysocephalus	K	B	B	B	B	B	B
Notropis fumeus					K		
Notropis galacturus	C	C	C	C	C	C	C
Notropis hudsonius			K	K			
Notropis leuciodus				C			
Notropis photogenis	B	K	K	B	B	C	
Notropis rubellus		K	B	B	B	C	
Notropis spilopterus		K	B	B	B	B	
Notropis stramineus		B	K	B	B	C	K
Notropis telescopus			C	C	C		
Notropis umbratilis		B	K	B	K	C	C
Notropis volucellus		B	B	B	B	C	
Notropis whipplei		B	B	B	B	B	
Noturus eleutherus				K	B	C	
Noturus exilis					K		

TABLE 1.—CONTINUED

Species	Stream order						
	1	2	3	4	5	6	7
Noturus flavus			B	B	B	B	K
Noturus furiosus				K	K		
Noturus gyrinus							K
Noturus insignis					K		
Noturus miurus	K		K	B	B	B	
Noturus nocturnus					K	K	
Noturus species				C		K	K
Noturus stigmosus					K		
Opsopoeodus emiliae				K			
Percina burtoni	C						
Percina caprodes	K	B	B	B	B	B	B
Percina copelandi				K	K	B	
Percina cymatotaenia			K	K	K		
Percina evides	K				K	K	
Percina macrocephala	K					B	
Percina maculata	C	B	B	B	B	B	B
Percina oxyrhyncha					K		
Percina phoxocephala			K	K	K	B	
Percina sciera	B		C	C	K		
Percina shumardi					K	K	
Percina squamata				C	C	K	
Phenacobius mirabilis				C	K		
Phenacobius uranops			C		C	C	
Pimephales notatus	K	B	B	B	B	B	B
Pimephales promelas		B	B	B	K	K	K
Pimephales vigilax				C	B		K
Polyodon spathula		C					K
Pomoxis annularis			B	K	B	K	B
Pomoxis nigromaculatus				K	K	K	B
Pylodictis olivaris		K	B	K	B	B	K
Rhinichthys atratulus	K	B	B	B			C
Salmo gairdneri			B	B	C	K	C
Salvelinus fontinalis	C			C			
Semotilus atromaculatus	B	B	B	B	B	B	C
Stizostedion canadense		C		K	C	B	K
Stizostedion vitreum					C	C	

rugged terrain of the Appalachian Plateau (Fig. 2), largely in Letcher, Leslie and Clay counties, and the stream follows a general NW course before flowing into the Ohio River at Carrollton. The principal tributaries are the North, Middle and South forks, the Red River, the Dix River, and Elkhorn and Eagle creeks. The basin comprises 17,975 km², much of it in relatively fertile limestone land (2). Portions of the headwaters are severely polluted by acid-mine drainage, coal-mine wastes, and by heavy siltation.

RESULTS

Utilizing information from the retrieval system developed by us, we obtained distributional data for 152 species of fishes reported from the Upper Cumberland and Upper Kentucky river basins, correlated by stream order and drainage basin. Of the total, 40 species occurred in the Upper Kentucky River exclusive of the Upper Cumberland, and 20 species occurred in the Upper Cumberland exclusive of the Kentucky River. The remaining 92 species were shared by the two drainages. The distributional data retrieved from the storage system are presented in Table 1.

This system allows investigators to easily discern various distributional patterns, such as stream-order restrictions, as exemplified by *Hiodon alosoides*, *H. ter-*

gisus and *Hybopsis insignis* (5th order or higher), rarity and/or disjunction, as in *Hybognathus nuchalis* and *Lepomis gibbosus*, and drainage restrictions, as in *Nocomis biguttatus*.

This article, of course, is merely an example of the system's capabilities. Many other combinations are possible. Interested investigators may contact Dean Donald L. Batch, Eastern Kentucky University, for additional information.

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Occurrence and Distribution of Rotifers in Barren River Reservoir, Kentucky

DAVID G. ABEL AND RUDOLPH PRINS

Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

ABSTRACT

A study of the spatial distribution and temporal occurrence and diversity of rotifers in relation to certain chemicophysical parameters was conducted in Barren River Reservoir, Kentucky, a monomictic flood control lake in southcentral Kentucky, from January, 1970, through January, 1971. Average rotifer densities, in the main pool and tailwater, ranged from 2 to 565/l. From July through September densities of rotifers at 6 m were significantly different from those at all other depths except 3 m (3 m was not significant from the remaining depths). A diel study in July revealed that this vertical pattern persisted over a 24-hour period. During other months (also shown in diel studies of April and January) rotifers were generally more uniformly distributed at all depths. Species diversity per sampling date was greatest from June through mid-October (12 species). This period was characterized by low reservoir discharge (50 cfs), decreased turbidity, increased Secchi disc transparencies (a mean of 3 m), and increased water temperatures and stratification. A total of 28 species referrable to 18 genera of rotifers was identified during the study. *Polyarthra* spp. (3), *Keratella* spp. (5), and *Conochilus unicornis* were the dominant rotifers; they comprised 75–85% of the population when present. *Keratella cochlearis*, *Polyarthra vulgaris*, and *Kellicottia bostoniensis* were most persistent and characteristic of the lake. *Keratella americana*, *Ploesoma* sp., *Hexarthra mira*, *Keratella crassa*, and *Brachionus angularis* were warm water forms. *Keratella quadrata*, *Kellicottia bostoniensis*, and *Polyarthra minor* were cold-water forms.

INTRODUCTION

This study was undertaken to determine the spatial and temporal distributions and diversity of rotifers in Barren River Reservoir in southcentral Kentucky and, where possible, to relate these findings to chemicophysical features characteristic of the reservoir. The study was conducted from January, 1970, through January, 1971, in the main pool area of the lake.

Description of Study Area

Barren River Reservoir (Table 1), a monomictic lake, is an integral unit of the comprehensive flood control plan for the Ohio and Mississippi Rivers enacted in 1938. Impounded in 1964, it is located in Allen, Barren, and Monroe counties, Kentucky; approximately 20 miles north of the Kentucky-Tennessee boundary.

Barren River Reservoir has a capacity for multilevel discharge with discharge ports at 161, 155, and 145 m mean sea level. During the study period, water was drawn from the various levels of the lake from January to April. From April through September, pool elevations of 171 m msl were maintained by the Corps of Engineers by regulating discharge which originated from the upper 3 m of the main pool. A conical extension with its aperature positioned upward was affixed to the tower around the port at 161 m msl to allow withdrawal at the 3 m level. This summer discharge regime was maintained as part of a more comprehensive program concerned with overall productivity of the reservoir (1). After 30 September, rapid drawdown was initiated to achieve a winter pool level of 161 m msl by December; the drawdown regime after 30 September was similar to that of January to April. Thus, the level of the main pool varied 25 m to 15 m annually due to the discharge regime employed, fluctuations in discharge sometimes reflecting the need to maintain a given pool level (Fig. 1).

MATERIALS AND METHODS

Plankton Samples

From 26 January, 1970, through 16 January, 1971, quantitative plankton sam-

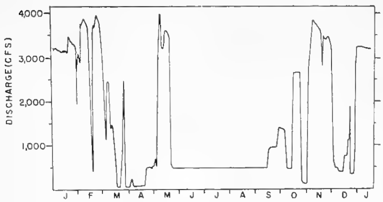

FIG. 1. Daily discharges, Barren River Reservoir, January, 1970—January, 1971.

TABLE 1.—HYDROGRAPHIC FEATURES OF BARREN RIVER RESERVOIR. SUMMER POOL ELEVATIONS WERE USED TO COMPUTE VOLUMES AND AREAS

Area	4,049 ha
Volume	316×10^6 m^3
Maximum depth	27 m
Mean depth	7.8 m
Drainage area	243.6 km^2
Length of dam	1,323 m
Main pool area	30–32 ha

ples were obtained biweekly approximately mid-morning to noon from the main pool and the tailwater of Barren River Reservoir using a Birge-Juday sampler equipped with a No. 20 net (68 meshes per cm). Paired, 10-liter samples were obtained at 3 m vertical intervals from the surface to 15 m in the main pool of the reservoir (maximum main pool depth was 25 m). Diel studies were conducted on 10–11 April, 1970, 18–19 July, 1970, and 29–30 January, 1971. Samples during these studies were taken at the

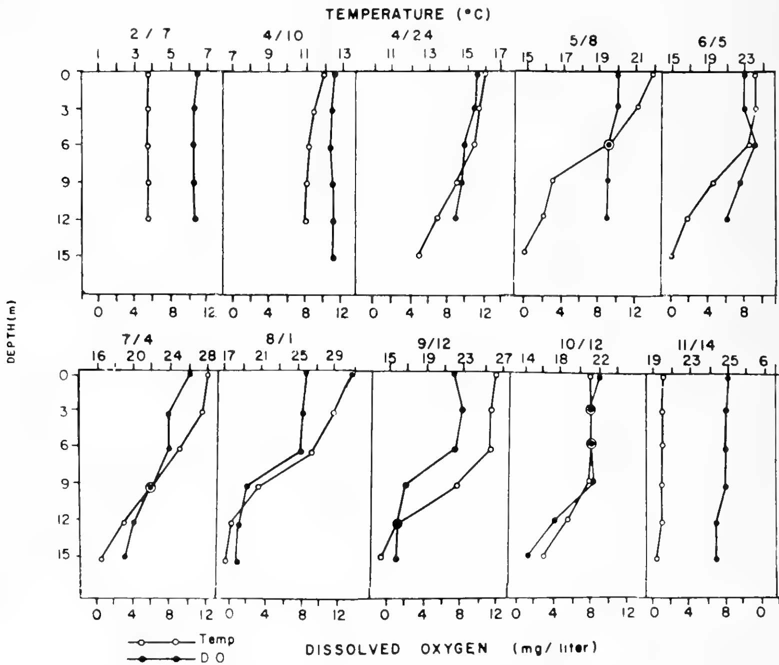

FIG. 2. Selected dissolved oxygen and temperature profiles for the main pool.

same depths as during routine sampling at 4-hour intervals over a 24-hour period. Tailwater samples were collected with the use of an automatic plankton sampler (2) located in the tailwater area. Samples of 114 liters were filtered through the net and bucket of the Birge-Juday sampler. All samples were preserved in 10% formalin. Enumeration was accomplished using a Sedgewick-Rafter counting cell.

Chemicophysical Measurements and Determinations

Dissolved oxygen, temperature, dissolved solids, and pH were determined from water samples collected with a 2-liter Kemmerer sampler. From 26 January through 10 April dissolved oxygen and temperature were measured with a Yellow Springs Instrument 51A oxygen meter and probe; thereafter, dissolved oxygen was measured with Hach Chemical Co. methods and reagents. Dissolved solids were measured with the Myron L DS meter. The pH was determined with a Sargent-Welch, Model PBL, pH meter within 10 hours after the water samples were returned to the laboratory. Secchi disc transparencies were determined in situ. Mean values were calculated from samples at depths. Daily discharge data were obtained from the Corps of Engineers, Louisville, Kentucky.

RESULTS

General Chemicophysical Features

The general temperature and dissolved oxygen distributions in the reservoir during the study period were typical of temperature zone lakes (Figs. 2, 3). Stratification began in late April, was completed by August, and fall circulation occurred in late October. The maximum temperature (30°C) at the surface was on 1 August, the lowest (3.1°C) was on 26 January; the metalimnion was 6–9 m from June to mid-October. There was a trace amount of oxygen in the hypolimnion throughout the summer and the average pH was consistently slightly alkaline.

The mean concentrations of dissolved solids (Fig. 4) ranged from a minimum of 110 mg/l on 27 February to a maximum of 193 mg/l on 29 December. Secchi disc transparencies were less than 2 m from 27 February through 8 May (Fig. 4) increasing to a maximum of 7.3 m on 5 June. Values of less than 1 m were found after fall turnover in late October. Except in early June, turbidity values generally mirrored Secchi Disc Transparencies (Fig. 4).

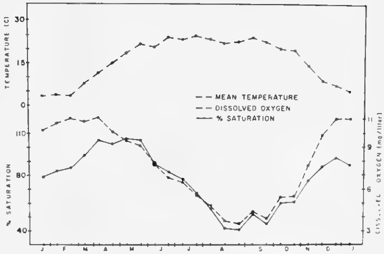

FIG. 3. Mean water temperatures, dissolved oxygen concentrations and the percent saturations in the main pool.

Rotifers

A total of 28 species referrable to 18 genera of rotifers was identified (Table 2). Densities of about 10/l occurred from January through March (Fig. 5) and vertical distribution patterns were irregular (Fig. 6). There was a mean of 54/l in the

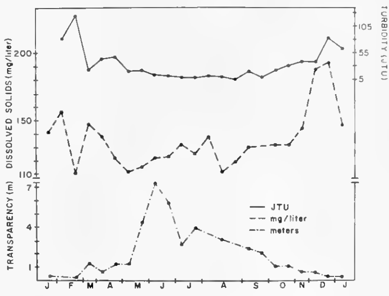

FIG. 4. Turbidity, dissolved solids, and Secchi disc transparencies in the main pool.

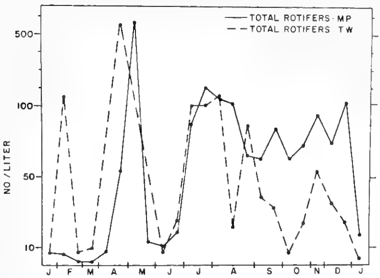

FIG. 5. Total rotifers (No./liter) in the main pool (MP) and tailwater (TW).

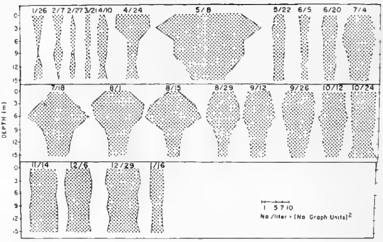

FIG. 6. Spatial distribution of rotifers (total No./liter), in the main pool. Figures are derived from the square root of the total No./liter at each depth.

main pool on 24 April, but on 8 May, a mean of 565/l was found. On this date as many as 1,326/l were found at 3 m and as few as 115/l were found at 15 m.

In subsequent months, rotifer densities fluctuated to a midsummer maximum mean of 154/l on 18 July on which date 483/l occurred at 6 m, just above the metalimnion (Fig. 6). From August until fall turnover in late October, this pattern of concentrating at 6 m persisted. A diel study conducted in July, 1970 revealed that this vertical distribution pattern per-

TABLE 2.—RELATIVE MONTHLY ABUNDANCE (NO./LITER) OF ROTIFERS IN THE MAIN POOL OF BARREN RIVER RESERVOIR, AS DENOTED BY: x ≤ 10; 10 < y ≤ 20; 20 < z ≤ 40; 40 < + ≤ 80; 80 < o ≤ 120; and 120 < *

	J	F	M	A	M	J	J	A	S	O	N	D
Keratella cochlearis Gosse	x		x	x	z	x	z	y	y	x	y	x
Keratella crassa Ahlstrom						x	+	z	y	x	x	x
Keratella earlinae Ahlstrom					x	x	x	x	x	x	x	x
Keratella americana Ahlstrom	x						x	x				
Keratella quadrata (Muller)												x
Polyarthra vulgaris Carlin	x	x	x	y	z	x	x	x	x	y	z	y
Polyarthra minor Voigt	x			x			x					y
Polyarthra euryptera Wierzejski						x	y		x	x	x	x
Synchaeta spp.	x			y	x		x	y	x	x		z
Brachionus angularis Gosse			x				x	x	x			x
Brachionus calyciflorus Pallas	x			x					x			y
Brachionus havanaensis Rousselet							x					
Ploesoma sp.							x	x	x	x		
Hexarthra mira (Hudson)							x	x	x		x	
Conochilus unicornis Rousselet				x	*		x	z	z			
Conochiloides sp.	x			x			x	x	x			
Filinia sp.	x	x				x		x		x		x
Kellicottia bostoniensis (Rousselet)	x		x		x	x	x	x	x	y	y	x
Asplanchna spp.			x	x			x	x	x	x	x	
Philodina (*Rotaria*?) sp.	x	x	x				x		x	x		
Cephalodella sp.	x	x		x		x						
Trichocerca spp.	x	x		x		x						
Collotheca mutabilis (Hudson)												x
Lecane curvicornis (Murray)	x											
Notholca sp.	x											
Platyias (=*Brachionus*) *patulus* (O. F. Muller)							x	x				
Platyias quadricornis (Ehrenberg)											x	

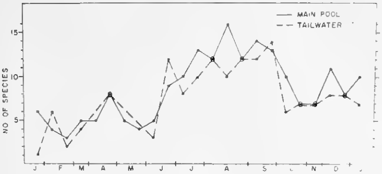

FIG. 7. Species diversity of rotifers in the main pool and tailwater.

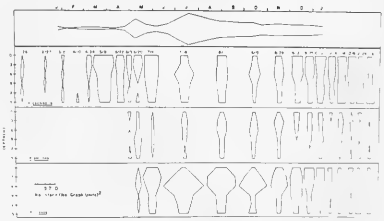

FIG. 8. Seasonal distribution of *Keratella* spp., and spatial distribution of *K. cochlearis*, *K. earlinae*, and *K. crassa* in the main pool.

sisted over a 24-hour period. Total depletion of rotifers never occurred at any depth.

Analyses of variance (3) were conducted on the vertical distributions for spring (March–June), summer (June–September), autumn (September–December), and winter (December–March). These analyses showed that the only significant difference between depths occurred during summer. With the use of Duncan's new multiple range test (3), it was found that total rotifers at 6 m and 3 m were not significantly different, but that densities at 6 m were significantly greater than those at all other depths.

Species richness was greatest during periods of maximum stability (mid-June through mid-October) (Fig. 7). An average of 12 species was found during these months (the maximum was 16 species on 15 August and the minimum was 9 species on 20 June), whereas, the average for all other months was six.

Rotifer densities in the main pool and those in the tailwater did not always correspond (Fig. 5). For example, on 24 April, (water was discharged from the upper 3 m beginning 1 April) 545/l were found in the tailwater, and only 54/l were found in the main pool. The average number of animals at the surface and 3 m was 134/l which was 83% of the total rotifers present in the water column. In the main pool on 18 July most rotifers were present at 6 m (483/l) an almost fourfold increase from 4 July at this depth; however, rotifer abundance within the tailwater showed little change—103/l on 4 July versus 102/l on 18 July. Throughout August, rotifer densities in the upper two depths (the surface and 3 m) of the main pool were high but diminishing; e.g., from combined mean values of 114/l on 15 August to 81/l on 29 August, to 78/l on 12 September. In the tailwater, densities fluctuated from 21/l to 80/l to 39/l on the same three dates, respectively. After 12 October, when drawoff was no longer restricted to the upper 3 m, the means of total rotifers in the main pool fluctuated in range of 60–85/l with a maximum of 118/l occurring on 29 December. In the tailwater, the densities fluctuated from 8–53/l. The increase that was observed in the main pool from 6 to 29 December was not reflected in the tailwater samples.

A dominant rotifer genus, *Keratella*, was represented by 5 species. The highest density of 127/l, all species combined, occurred on 18 July (Fig. 8). *Keratella cochlearis* was the only representative consistently found throughout the year. It was major component of the first rotifer pulse on 8 May with a mean of 47/l (Fig. 8), reaching a secondary maximum of 28/l on 4 July. After 18 July, *K. cochlearis* fluctuated irregularly, being represented by usually less than 14/l.

In the tailwater, *K. cochlearis* was erratic until 20 June, increasing sharply to a maximum of 43/l on 4 July, producing another slight pulse of 21/l on 29 August, continuing until 12 September. After this, it decreased sharply and fluctuated irregularly, never exceeding 6/l.

Keratella earlinae first appeared on 5

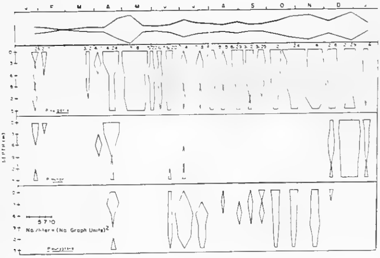

FIG. 9. Seasonal distribution of *Polyarthra* spp. and spatial distribution of *P. vulgaris, P. minor,* and *P. euryptera* in the main pool.

June (Fig. 8) and persisted for the rest of the year reaching maximum abundance of 8/l in August and diminishing after fall turnover. *Keratella crassa* was first observed in late May. It constituted about one-third of the rotifers on 4 July (28/l) and on 18 July it was the dominant member of the genus (97/l out of a total 127/l). The greatest density (344/l) was at 6 m with the lowest (2/l) at the surface (Fig. 8). Usually fewer than 5/l were found after turnover in October. Other species of *Keratella* that appeared sporadically in the tailwater and/or main pool areas and always in small numbers included *K. americana* and *K. quadrata*.

Three species of *Polyarthra* were found during the study. All species combined, they were most numerous in May and December (Fig. 9). *Polyarthra vulgaris*

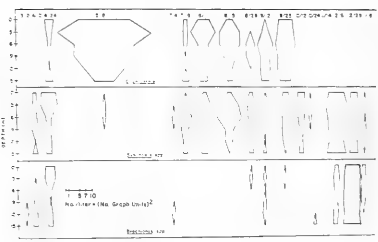

FIG. 10. Spatial distribution of *Conochilus unicornis, Synchaeta* spp., and *Brachionus* spp. in the main pool.

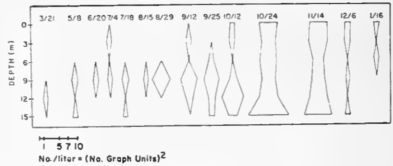

FIG. 11. Spatial distribution of *Kellicottia bostoniensis* in the main pool.

was the dominant species of this genus, occurring in the lake throughout the year (Fig. 9), but nearly disappearing in February. The maximum (65/l) was found on 8 May. *Polyarthra minor* was present sporadically (Fig. 9) appearing in relatively significant densities (10/l and 46/l on only 2 occasions, 24 April, 29 December, respectively). The only major increase of *P. euryptera* was on 4 July (16.1), (Fig. 9).

Although it occurred in the samples on only 2 occasions in late spring, *Conochilus unicornis* was the major component of the 8 May rotifer pulse with a mean of 452/l. The maximum was 1,159/l at 3 m and the minimum was 52/l at 15 m (Fig. 10). It did not reappear until 18 July, but then persisted through September.

Members of the genus *Synchaeta* were present primarily in April and after mid-July (Fig. 10). On 24 April, the largest number was 37/l at 3 m; 83% enumerated were from the surface and 3 m. These rotifers appeared in substantial densities on 1 August (13/l), on 15 August (24/l) and on 6 December (40/l).

Representatives of the genus *Brachionus* were observed in the spring, fall, and early winter (Fig. 10). *Brachionus calyciflorus* was the only species sampled from March through April. It was found again only in December and January with the largest number on 29 December (33/l). Even though *B. angularis* was the only species present consistently from July to August it was very rare (less than 1/l) as was *B. havanaensis* (4 July).

Kellicottia bostoniensis occurred irregularly and in low numbers until after the fall turnover was initiated around 12 October (Fig. 11). A maximum of 29/l was found on 24 October, with most occurring at 14 m. After 19/l were found on 14 November, there were usually fewer than 1/l during the remainder of the study.

Other rotifers that were few in number and/or occurred at irregular times were: *Asplanchna* sp., *Ploesoma* sp., *Hexarthra mira*, *Conochiloides* sp., *Filinia* sp., *Philodina* (*Rotaria*?) sp., *Cephalodella* sp., *Trichocerca* spp., and *Collotheca mutabilis*. In addition, rotifers found in supplemental samples not taken on routine sampling dates were: *Lecane cervicornis*, *Platyias* (=*Brachionus*) *patulus*, *P. quadricornis*, and *Notholca* spp.

DISCUSSION

Factors which may have influenced the vertical distribution of rotifers included the presence or absence of stratification particularly in reference to dissolved oxygen concentration and temperature. During the period of July through September the largest numbers of rotifers were found at 6 m. From Duncan's New Multiple Range Test (3) it was shown that the densities of rotifers at 6 m were significantly different from the densities at all other depths except 3 m (3 m did not differ significantly from the remaining depths). The diel study conducted on 18–19 July revealed that at least at that time the higher densities at 6 m persisted over a 24-hour period. However, diel studies in April and January indicated that rotifers were uniformly mixed in the water column. These latter two periods of nonstratification were characterized by high turbidity, low light, and circulation of the water by winds. The latter two factors have been suggested by Kikuchi (4) to be present during periods of very little vertical movements by rotifers. The circulation within the water column may have promoted a homogeneous vertical distribution.

Temperature distributions may have influenced the tendency for rotifers to aggregate at 6 m. The largest concentrations of rotifers in the metalimnion throughout the summer suggests a preference for this region. The laboratory studies of Harder (5), which showed an aggregation of zooplankton at temperature interfaces, might suggest a possible explanation for the consistently large numbers in the metalimnetic region, which is a temperature interface between the epilimnion and the hypolimnion.

In the 13-month study, species diversity of rotifers was greatest from June through mid-October. The period of greatest species diversity occurred when water temperatures reached their maxima. During this period, discharge volumes from the impoundment were low and restricted to the upper 3 m (Fig. 1). Such low discharges normally would have been accompanied by a slow flushing rate and, correspondingly, a higher rate of sedimentation in the upper reservoir similar to that reported in Lewis and Clark Lake (6). In the main pool area there was a decrease in turbidity, an increase in Secchi disc transparencies, and increases in temperatures accompanied by thermal stratification.

Ackefors (7) observed that maximum species diversity occurred from July through September in the northern Baltic. He suggested that it was closely associated with the short, warm water period. These data may be instructive, since Pennak (8) has reported that species diversity in lakes is very similar regardless of latitude or altitude. A greater variety of plankton was associated with warming of water by Robinson et al. (9) in their studies on the influence of artificial destratification on plankton populations in impoundments.

The following rotifers were most persistent and characteristic of Barren River Reservoir during the study: *K. cochlearis*, *P. vulgaris*, and *K. bostoniensis*. The following were typical summer forms, occurring from June through September: *K. americana*, *Ploesoma* sp., *H. mira*, *K. crassa*, and *B. angularis*. Some rotifers were characteristically epilimnetic in distribution: *C. unicornis*, *Synchaeta* spp., *Asplanchna* spp., and *K. crassa*. Cold-water forms included: *K. quadrata*, *K. bostoniensis*, and *P. minor*.

The surveillance of zooplankton activities within a reservoir by sampling from the tailwater is an important means of measuring annual loss in discharges (10). The comparability of numbers in the reservoir and tailwater would appear to be very important if such an estimate of discharge loss is to be measured. In Barren River Reservoir, the unique factor of discharge level may affect such an estimation of loss.

Since discharge from April through September was restricted to the upper 3 m, rotifer concentrations observed in this region of the main pool were compared with those in the tailwater. By means of Student's *t* test (3) it was determined that from June to mid-October numbers from the tailwaters and the mean numbers in the upper 3 m of the main pool were not significantly different. Furthermore, densities of rotifers found in the tailwater seemed to reflect those found in the surface samples more than those at 3 m. This might have been due to the orientation of the cone attached to the upper discharge port; i.e., with an upward facing opening at 3 m, water would have been drawn from the overlying surface layers, particularly during low discharges.

In a study conducted by the TVA Engineering Laboratory on Nolin Reservoir, Kentucky, an impoundment with a similar multilevel discharge capacity, discharges of 540 cfs from the upper 3 m were shown to have a velocity profile extending to 5 m within the reservoir (11). Hypolimnetic discharges of 50 cfs in Barren during the same study were too small to measure the influence of velocity. Since discharge rate in Barren River Reservoir remained at 50 cfs from late May to mid-September, the withdrawal was probably from the region much shallower than 5 m. Consequently loss of rotifers from the reservoir was probably minimal because the greatest densities tended to occur below this depth.

Qualitatively, plankters in the tailwater and in the main pool were very similar because rotifers did occur throughout the water column even though most concentrated at 4 m to 6 m. Consequently, a qualitative survey of the main pool from the tailwater during upper level discharges would be feasible. However, quantitative data probably would produce underestimates if the cone were in place due to the apparent exclusion of the bulk of rotifers from depths below the cone.

ACKNOWLEDGMENTS

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Trans. Ky. Acad. Sci., 44(3–4), 1983, 125–128

Distributional Records for Fourteen Fishes in Kentucky

STEPHEN P. RICE,[1] JOHN R. MACGREGOR,[2] WAYNE L. DAVIS[3]

ABSTRACT

Surveys of streams in Kentucky over a 7-year period resulted in new records and range extensions for 14 fish species, 10 of which are rare or poorly known. New records for *Lepisosteus oculatus, Esox niger, Notropis venustus, Ictalurus nebulosus, Fundulus notti, Lepomis marginatus,* and *Percina shumardi* are reported from the Jackson Purchase. A range extension within the Cumberland River drainage is noted for *Ichthyomyzon greeleyi. Hybopsis dissimilis* and *Notropis ariommus* are reported from the Salt River drainage for the first time since 1892. The ranges of *Notemigonus crysoleucas, Typhlichthys subterraneus,* and *Percopsis omiscomaycus* are extended, and a population of *Ammocrypta pellucida* in the Little Sandy River is discussed.

INTRODUCTION

Since 1975, members of the Kentucky Transportation Cabinet, Division of Environmental Analysis, have made collections of fishes from streams in Kentucky. Due to the continued threat of pollution to the streams of the Commonwealth from coal mining, petroleum exploration, stream dredging, land clearing, and other activities and the recent publication by the Kentucky Academy of Science of a list of fishes Endangered, Threatened, and Rare in Kentucky (1), we felt the following distributional records worthy of note.

ACCOUNTS OF SPECIES

This paper reports new drainage records, adds localities for several fishes of concern, and confirms the presence of 2 species not recorded from the Salt River drainage since Woolman's collections in 1890 and 1891 (2). Records are based on collections deposited in the Kentucky Transportation Cabinet, Division of Environmental Analysis Museum. Nomenclature follows Robins et al. (3).

Ichthyomyzon greeleyi Hubbs and Trautman. Mountain brook lamprey. This species was known from the Kentucky and Green river drainages and from the Little South Fork of the Cumberland River drainage (4, 5). On 9 May 1980, 4 adults of this lamprey were taken from the Rockcastle River about 4 km downstream from Billows. Specimens came from 2 shallow (30 cm) riffles where a large number of lampreys appeared to be constructing nests by moving small stones. The status of this species in Kentucky was listed as Undetermined by Branson et al. (1).

Lepisosteus oculatus (Winchell). Spotted gar. This gar, reported as rare in western Kentucky (5) and listed as Threatened by Branson et al. (1), has been recorded from Bayou du Chien (6), the lower Cumberland River drainage (7), the Tradewater River drainage, and the lower Green River drainage (8). Due to its presumed rarity, all of our collections are listed as follows: 1 from a tributary of Bayou du Chien, Fulton County, 1.2 km WNW from Halfmoon Pond, 14 June 1979; 1 from Dry Lake (Prehistoric Canal), Hickman County, at Whaynes Corner, 24 August 1978; 1 from Back Slough, Carlisle County, 1.8 km NE of Laketon, 13 June 1979; 1 from Three Ponds, Hickman County, 2.9 km NW of Whaynes Corner, 24 August 1978; 10 from an unnamed roadside slough, Fulton County, along KY 94, 1.4 km NE of the point where KY 94 crosses into Tennessee between Tyler and Miller, 12 June 1979; 11 from an unnamed roadside pool, Fulton County, 305 m E of Miller along the S side of KY 1282,

[1] Division of Environmental Analysis, Kentucky Transportation Cabinet, Frankfort, Kentucky 40622.

[2] Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky 40601.

[3] Kentucky Department of Fish and Wildlife Resources, Frankfort, Kentucky 40601.

21 August 1978; and 1 from Clarks River sloughs, Marshall County, adjacent to US 641 at Benton, 10 March 1980. The largest numbers were taken within the Reelfoot National Wildlife Refuge from 2 small seasonal pools, abundant with submersed and emergent aquatic vegetation, which are inundated by flood water from Reelfoot Lake.

Esox niger Lesueur. Chain pickerel. The chain pickerel was known from 4 localities in Kentucky: Middle Fork of Clarks River (9) and 3 oxbow lakes in McCracken, Ballard, and Carlisle counties (10). We took 2 specimens from an unnamed tributary of Bayou du Chien, Fulton County, 1.2 km WNW of Halfmoon Pond, 14 June 1979; 8 were captured with 2 *Esox americanus* Lesueur from Whaynes Branch, Hickman County, 610 m E of Whaynes Corner, 15 June 1979; and 1 was taken from Three Ponds, Hickman County, 24 August 1978. Whaynes Branch was a sluggish stream with banks heavily overgrown with bald cypress and a substrate of silt and organic debris. In contrast, the unnamed tributary of Bayou du Chien had a substrate of very deep silt with little organic debris and little shade-providing vegetation. Branson et al. (1) considered this peripheral species to be Threatened.

Hybopsis dissimilis (Kirtland). Streamline chub. The only record of this fish from the Salt River drainage was that of Woolman (2) who reported it as very rare in Rolling Fork. On 22 April 1980, we took an individual from a swift, rubble-bottomed riffle in Rolling Fork just downstream from the KY 412 bridge, Marion County, and M. L. Warren, Jr. and R. R. Cicerello captured 10 approximately 1.7 stream km upstream from the KY 55/US 68 bridge, Marion County, 21 September 1982 (pers. comm.).

Notemigonus crysoleucas (Mitchill). Golden shiner. According to Burr (5), there were no records of this species in Kentucky east of the Kentucky River drainage. We captured 7 individuals in an unnamed slough near the US 23 crossing of Grays Branch in Greenup County on 7 September 1978. It was abundant and was the only species observed. Though possibly introduced at this location, it likely is native since Trautman (11) stated that this shiner was present in the Ohio counties bordering the Ohio River before 1900.

Notropis ariommus (Cope). Popeye shiner. This fish has been collected from the Salt River drainage only by Woolman (2) who took it from Rolling Fork. We collected 1 specimen from Cloyds Creek at the KY 412 bridge in Marion County, 22 April 1980. It was seined from shallow water over a substrate of gravel and small rubble. Cloyds Creek is a small tributary of Rolling Fork. The status of the popeye shiner is listed as Undetermined (1).

Notropis venustus (Girard). Blacktail shiner. According to Burr (5), this fish was known from Bayou du Chien, the Mississippi River, and the lower Ohio River. On 19 March 1981, we seined the lower section of Sugar Creek, Mayfield Creek, and what was apparently the remains of the old, unchannelized Mayfield Creek; all near the US 62 bridge over Mayfield Creek about 1.6 km S of Lovelaceville, Ballard County. The shiners (*Notropis*) collected were 2 *N. stramineus* (Cope), 3 *N. whipplei* (Girard), and 1 *N. venustus*. Branson et al. (1) listed the blacktail shiner as a peripheral species of Special Concern.

Ictalurus nebulosus (Lesueur). Brown bullhead. Burr (5) reported this catfish as sporadic from the lower Cumberland River to the Licking River. He did not include the records from the Jackson Purchase, i.e., those of Woolman (2) from Bayou du Chien and Mayfield Creek, because no specimens are extant (B. M. Burr, pers. comm.). On 12 June 1979, we collected 17 brown bullheads from an unnamed roadside slough in the Reelfoot Lake drainage about 1.4 km NE of where KY 94 crosses into Tennessee between Tyler and Miller, Fulton County. The slough had an abundance of aquatic vegetation, a mud bottom, and clear water. Brown bullheads were the only ictalurids captured.

Typhlichthys subterraneus (Girard). Southern cavefish. Known in Kentucky from caves in Barren, Edmonson, Hart, Warren (Upper Green River drainage), and Pulaski (Upper Cumberland River drainage) counties (5), Cooper (12) included localities for it in the Lower Cumberland and Lower Tennessee river drainages in Tennessee. On 1 May 1981, we collected 1 specimen from Big Sulphur Cave in Trigg County about 2.44 km W of Peedee on the North side of a bend of the Little River. The subterranean stream is part of the Lower Cumberland River drainage. According to David L. Swofford (pers. comm.), he and Gregory A. Sievert collected 4 specimens from the cave in the summer of 1979 (specimens not extant). This species was considered Threatened by Branson et al. (1).

Percopsis omiscomaycus (Walbaum). Trout perch. The trout perch was known from the Green, Salt, Ohio, Licking, and Little Sandy river drainages and from the Big Sandy River drainage only as far upstream as Little Blaine Creek (5, 13). In May of 1978, Ron Cicerello, Lewis Kornman, and the authors captured 7 specimens from Right Fork of Beaver Creek 762 m E of Eastern in Floyd County, extending the range approximately 110 km upstream into the Levisa Fork Big Sandy River drainage. The fish were seined from pools over substrates of sand and fine gravel. It was listed as a peripheral species of Special Concern by Branson et al. (1).

Fundulus notti (Agassiz). Starhead topminnow. Branson (14) reported this fish from Murphey's Pond (Obion Creek drainage) in Hickman County and Sisk (15) reported it from Open Pond (Reelfoot Lake drainage) in Fulton County. In June of 1979, we collected it from 2 additional localities in the Reelfoot Lake drainage: 3 from an unnamed roadside slough about 1.4 km NE of the point where KY 94 crosses into Tennessee in Fulton County; and 1 from a small stream that drains Blue Pond into Running Slough near the KY 311 bridge 670 m S of the intersection of KY 311 and KY 1282, Fulton County. R. R. Cicerello and M. L. Warren, Jr. reported taking 5 individuals from Running Slough, Fulton County, at Ledford, 24 June 1982 (pers. comm.). This topminnow was considered a species of Special Concern by Branson et al. (1).

Lepomis marginatus (Holbrook). Dollar sunfish. This fish of swamps and sluggish streams (16) was known in Kentucky only from Murphey's Pond (10) and Terrapin Creek (5). On 15 July 1982 we preserved 7 of 15 specimens seined from a spring-fed, perennial pool in Graves County 1.9 km NE of Kaler. The pool was within a lowland swamp, composed predominantly of saturated ground with emergent hydrophytes and some wetland shrubs and trees, that is inundated seasonally by flood waters from the West Fork of Clarks River. The 65 m long, 9 m wide pool had a substrate heavily dominated by firm clay with minor amounts of silt and silt mixed with gravel. The water was clear and lacked any aquatic vegetation although sweet flag, *Acorus calamus* L., tearthumb, *Polygonum sagittatum* L., and rice cutgrass, *Leersia orizoides* (L.) grew on the banks to the water's edge.

Two months previous to our collections (May 4), R. R. Cicerello and M. L. Warren, Jr. seined 1 specimen from an unnamed wetland approximately 7.3 km S of our site (pers. comm.). This wetland was being drained and was located adjacent to West Fork of Clarks River 0.9 km ENE of Clear Springs, Graves County.

These are the first records of the species from the Tennessee River drainage in Kentucky although Bauer (16) reported it from that drainage in Tennessee. Branson et al. (1) listed it as Threatened in Kentucky.

Ammocrypta pellucida (Putnam). Eastern sand darter. This darter is known in Kentucky from the Ohio, Big Sandy, Rolling Fork, Kentucky, Licking, Green, Cumberland, and Little Sandy river drainages (17). As reported in Branson et al. (18), we took this fish from the Little Sandy River between Grayson and Argillite. Four sites yielded 9 specimens from clean sand in gentle to moderate current. Additionally, M. L. Warren and R. R. Cicerello took 3 adults near Pactolus on 14 September 1982 (pers. comm.). According to Burr (5), the eastern sand darter is rapidly declining in numbers in the state. However, in the Little Sandy River downstream of Grayson Lake, a relatively intact population of this species appears to exist. The species was listed as Threatened by Branson et al. (1).

Percina shumardi (Girard). River darter. Within the Jackson purchase, this species was known previously from only Obion Creek (2). On 15 June 1979 we collected 4 immature specimens from a backwater slough of Bayou du Chien, about 3 km NW of Fulton County High School, Fulton County.

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Regression Analysis Techniques Applied to Petrographic Studies

Alan D. Smith, Gary L. Kuhnhenn, and John H. Traub

Department of Geology, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

The Strodes Creek Member of the Lexington Limestone is a body of irregulary bedded limestone and shale exposed in several outcrops in north-central Kentucky. Field observations, along with study of 98 polished slabs and 113 thin sections were used in order to study the depositional environment of the Strodes Creek Member and its relationship to the enclosing Millersburg and Tanglewood Limestone members. The Strodes Creek Member consists of 8 microfacies: an algal boundstone, a claystone, a dolomitic ostracode packstone, a dolomitic packstone, a dolomitic wackestone, a dolomitic carbonate mudstone, a *Tetradium* packstone, and a skeletal grainstone which represent various subenvironments within a shallow water, slightly restricted and sheltered depositional framework. Regression-analysis techniques and a detailed description of the steps involved, including hypothesis testing and stepwise regression, were used to statistically verify the microfacies classification.

Introduction

Petrographic analysis and its related procedures are commonly used to provide the basic information in formulating environments of deposition. Oriented thin sections and slabs derived from outcrop and core samples represent the major source of petrographic information. In addition to various classification schemes, point counts are usually performed on thin sections to obtain data for statistical analysis. Various statistical methods are commonly used. However, the use of multiple linear regression techniques can provide a wealth of information that is not easily obtainable by other techniques. Multiple linear regression can be used to establish relationships among point-count data parameters and categorical or continuous variables. Regardless of the nature of the variable, however, any hypothesis can be tested by the regression approach so long as the least-square approach with a single criterion is used.

Petrographic Applications

The Upper Ordovician Strodes Creek Member of the Lexington Limestone is a sequence of mud-dominated limestone and shale which is exposed at several localities in north-central Kentucky. As with most units that have complex facies relations and have been under study for many years, the nomenclature has undergone many changes. Figure 1 presents the general stratigraphy of the Blue Grass region. The western edge of the Strodes Creek trends north-northwest between Winchester and Cynthiana, Kentucky (Fig. 2). The Strodes Creek appears to be a lens within the Millersburg Member of the Lexington Limestone throughout most of its occurrence. Relatively little work has been done on the petrology of the Strodes Creek Member.

Methods

The study area encompasses those parts of north-central Kentucky where the Strodes Creek Member of the Lexington Limestone is exposed (Fig. 3). A total of 11 outcrops was described and measured for this study, and are located in five 7.5 minute geologic quadrangles. Each outcrop was sampled from the bottom to the top. A sample of each limestone in the Strodes Creek Member was collected from every outcrop, along with several samples of the interbedded shales. Where the member is well exposed at two locations, samples were collected from both ends of the outcrop to better determine lateral variations. Where possible, samples were also collected from the enclos-

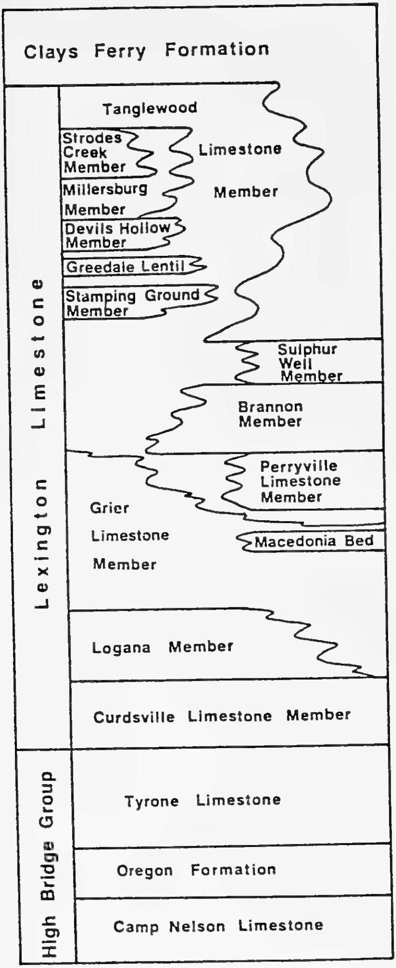

FIG. 1. General stratigraphic nomenclature in Blue Grass region (modified from Cressman and Karlins (1)).

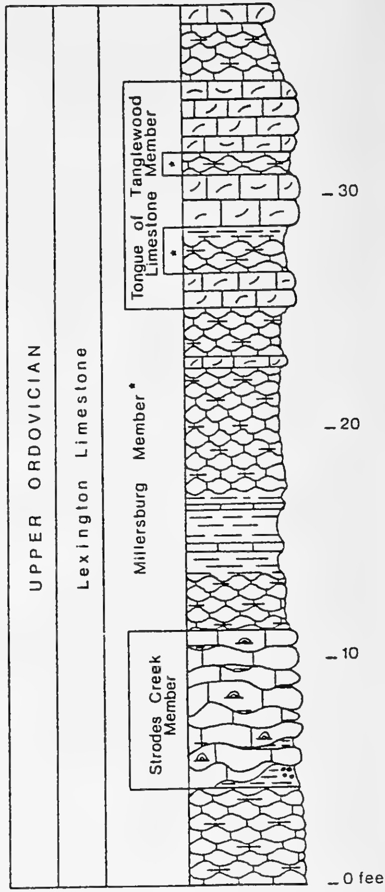

FIG. 2. Stratigraphic section of Winchester outcrop (modified from Black and Cupples (2)).

ing strata. A total of 125 samples were collected from the Strodes Creek Member and enclosing strata, of which 113 were limestone and 12 were shale.

A thin section was prepared from each collected limestone sample. The thin sections were ground to slightly greater than standard thickness (0.003 mm) and stained with a combined solution of alizarin red S and potassium ferricyanide (1, 2). When possible, a polished slab was prepared from each limestone sample and studied with a binocular reflecting light microscope.

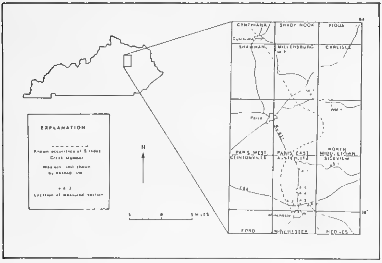

FIG. 3. Location of measured sections and western limit of Strodes Creek Member (modified from Black and Cupples (2)).

Insoluble residues were prepared from each shale sample and several limestone samples. A 2-gram sample was dissolved in 20% hydrocloric acid in order to obtain the insoluble portion. The shale samples were subjected to X-ray analysis by allowing a powdered sample to differentially settle in a water-filled cylinder, and then withdrawing the clay fraction with a pipet. This portion was then transferred to 3 slides and allowed to dry. In order to identify the clay minerals, 1 slide was left untreated, 1 was glycolated, and 1 was heat treated.

Point-count data obtained through petrographic study were statistically analyzed by application of regression analysis to perform hypothesis testing and stepwise regression to determine the validity and significant characteristics of the microfacies.

TABLE 1.—VARIABLE DESCRIPTIONS

Variable	Variable description
MICRO 1	microfacies descriptions; 1 if algal boundstone, 0 if other
MICRO 3	microfacies description; 1 if ostracode packstone, 0 if other
MICRO 4	microfacies description; 1 if skeletal packstone, 0 if other
MICRO 5	microfacies description; 1 if skeletal wackestone, 0 if other
MICRO 6	microfacies description; 1 if carbonate mudstone, 0 if other
MICRO 7	microfacies description; 1 if *Tetradium* ackstone, 0 if other
MICRO 8	microfacies description; 1 if skeletal grainstone, 0 if other
OSTRA	ostracodes
BRACH	brachiopods
BRYOZ	bryozoans
ENBRY	encrusting bryozoans
GASTR	gastropods
PELEC	pelecypods
TRILO	trilobites
STROM	stromatoporoids
TETRA	*Tetradium*
GIRVA	*Girvanella*
SOLEN	*Solenopora*
CODIA	Codiaceans
DASYC	Dasycladaceans
DOLOM	dolomite
MICRI	micrite
SPARR	sparry calcite
QUART	quartz
PYRIT	pyrite
VOIDS	voids
UNKNO	unknown bioclasts
PELMA	pelmatozoans
PHOSP	phosphate
BROWN	brown organics

STATISTICAL ANALYSIS

Multiple linear and stepwise regression, as well as discriminative-analysis techniques, were used to determine if the microfacies, derived by petrographic observation, were statistically valid; and if they were valid, what were the discriminating variables characterizing each microfacies? Table 1 illustrates the descriptions of the variable labels used in the analysis.

RESULTS

Discriminant analysis allows the investigator to statistically distinguish between 2 or more groups of cases. In this study, discriminant analysis techniques with a dichotomous criterion variable were used to determine which allochemical and orthochemical parameters would statistically distinguish each of the microfacies. The results of discriminant analysis were corrected for multiple comparison using the method of Newman and Fry (3) for a two-tailed nondirectional test with an alpha level of 0.05. The discrim-

TABLE 2.—CHARACTERISTIC VARIABLES AND BEST PREDICTOR VARIABLES FOR ALL MICROFACIES

Microfacies	Characteristic variable	Rank of best predictor variable
MICRO 1	SOLEN	SOLEN
MICRO 3	OSTRA	OSTRA
MICRO 4	UNKNO PYRIT	UNKNO PELEC
MICRO 5	DOLOM PYRIT MICRI	DOLOM PYRIT MICRI
MICRO 6	UNKNO DOLOM MILRI PYRIT VOIDS	UNKNO DOLOM
MICRO 7	TETRA BROWN	TETRA BROWN
MICRO 8	SPARR PELMA GASTR TRILO GIRVA DOLOM MICRI	SPARR PELMA

inant or characteristic variables for each microfacies are listed in Table 2.

Stepwise regression allows the investigator to determine which variables are the best predictors for each of the microfacies. Forward stepwise regression was used to determine which allochemical and orthochemical variables would be the best predictors for each of the microfacies. The foward regression enters the independent variables (allochems and orthochems) only if they meet certain statistical criteria (alpha level set to 0.05). The order of inclusion is determined by the respective contribution of each variable to explained variance. By using this method, the maximum number of best predictor variables chosen was 3. The best predictor variables for each microfacies are listed in Table 2. The predictors for each microfacies and the R^2, multiple R, degrees of freedom, F-ratio, and probability for each are listed in Table 3.

A power analysis of the research hypotheses using Cohen's (4) tables was included. A power test, using a medium effect size (0.15), was performed for the best predictor variables and discriminating

TABLE 3.—STEPWISE REGRESSION ANALYSIS OF MICROFACIES CLASSIFICATION ACCORDING TO VARIOUS ALLOCHEMICAL AND ORTHOCHEMICAL PARAMETERS

Criterion	Pred.	R^2	Mult. R	df	F	Prob.
MICRO 1	SOLEN	0.9908	0.9954	[a]1/85	9,166.8619	0.0000
MICRO 3	OSTRA	0.5086	0.7131	[a]1/85	87.9637	0.0000
MICRO 4	UNKNO	0.2124	0.4608	[a]1/85	22.9180	0.0000
	PELEC	0.2705	0.5201	[b]2/84	15.5770	0.0000
MICRO 5	DOLOM	0.1094	0.3308	[a]1/85	10.4460	0.0017
	PYRIT	0.1812	0.4257	[b]2/84	9.2972	0.0002
	MICRI	0.2295	9.4791	[c]3/83	8.2434	0.0001
MICRO 6	UNKNO	0.2614	0.5113	[a]1/85	30.0875	0.0000
	DOLOM	0.3728	0.6106	[b]2/84	24.9663	0.0000
MICRO 7	TETRA	0.6179	0.7861	[a]1/85	137.4401	0.0000
	SPARR	0.6433	0.8021	[b]2/84	75.7444	0.0000
	BROWN	0.6619	0.8136	[c]3/83	54.1583	0.0000
MICRO 8	SPARR	0.6158	0.7847	[a]1/85	136.2420	0.0000
	PELMA	0.6799	0.8246	[b]2/84	89.2159	0.0000

[a] The power for the hypothesis using a medium effect size is .95
[b] The power for the hypothesis using a medium effect size is .91
[c] The power for the hypothesis using a medium effect size is .84

Table 4.—Summary of F-Ratios, probability levels, R^2 for both the full and restricted models, degrees of freedom-numerator, degrees of freedom-denominator, and significance for each research hypothesis testing predictive relationships among MICRO 8 and various allochemical and orthochemical parameters

Variable[a]	R^2 full	R^2 restr.	df	F	Probability	Sign.
OST	0.0020	0.0	1/85	0.1706	0.6806	NS
BRACH	0.0593	0.0	1/85	5.3639	0.0230	NS
BRY	0.0937	0.0	1/85	8.7919	0.0039	NS
ENBRY	0.0017	0.0	1/85	0.1439	0.7053	NS
GAS	0.1150	0.0	1/85	11.0498	0.0013	S
PELEC	0.0006	0.0	1/85	0.0501	0.8234	NS
TRIL	0.1258	0.0	1/85	12.2273	0.0008	S
STROM	0.0002	0.0	1/85	0.0171	0.8962	NS
TET	0.0070	0.0	1/85	0.6019	0.4400	NS
GIR	0.1142	0.0	1/85	10.9526	0.0014	S
SOL	0.0002	0.0	1/85	0.0202	0.8874	NS
COD	0.0125	0.0	1/85	1.0769	0.3023	NS
DASY	0.0374	0.0	1/85	3.2990	0.0728	NS
DOL	0.2253	0.0	1/85	24.7229	0.0000	S
MIC	0.2342	0.0	1/85	25.9892	0.0000	S
SPAR	0.6158	0.0	1/85	136.2419	0.0000	S
QTZ	0.0625	0.0	1/85	5.6652	0.0195	NS
PYR	0.0000	0.0	1/85	0.0006	0.9807	NS
VDS	0.0001	0.0	1/85	0.0098	0.9214	NS
UNK	0.0497	0.0	1/85	4.4470	0.0379	NS
PELMAT	0.1103	0.0	1/85	10.5359	0.0017	S
PHOS	0.0329	0.0	1/85	2.8966	0.0924	NS
BO	0.0062	0.0	1/85	0.5275	0.4697	NS

Note. An F-test was utilized to test for significant relationships between MICRO 8 and various allochemical and orthochemical parameters. The assigned alpha level of 0.05 for a two-tailed nondirectional test was considered statistically significant. However, the employment of a correction for multiple comparisons was necessary, using the Newman and Fry (2) method. The corrected alpha level of 0.002 was used before the research hypothesis was considered significant.

[a] The power for the hypothesis using a medium effect size is 0.95.

variables of each microfacies. The power for each predictor variable is listed in Table 3. The microfacies determined by petrographic observation were found to be statistically valid in all but one case (microfacies 6), and this may be due to the presence of stromatoporoid, which resulted in unusually high counts of this allochem and resulted in lower counts of the matrix. Table 4 is example of the results of the hypothesis testing and model comparisons for microfacies 8 for illustrative purposes.

A Pearson correlation was performed on the allochemical and orthochemical variables in each of the microfacies, and then related variables chosen by this function were compared to the predictor variables to check for multicollinearity. The predictor variables were not found to be highly interrelated (Table 5), thus multicollinearity and the limitations associated with it were not seen as a problem in the study.

Conclusions

Multiple regression is a powerful and flexible technique for handling data analysis. With researchers involved with many choices for statistical techniques, they should be able to justify the statistical procedure they select. This paper presents multiple linear regression, which is unfamiliar or frequently misunderstood by many, as a basic research tool and clarifies selected steps in the hypothesis- and model-comparisons process. An example was made with a recent petrographic analysis of the Strodes Creek Member (Upper Ordovician) of the Lexington Limestone in north-central Kentucky to illustrate how these statistical techniques

TABLE 5.—PEARSON CORRELATION OF MICROFACIES

Microfacies	Significant variables[a]	Significantly correlated with[b]
MICRO 1		
MICRO 3	OSTRA	BRYOZ, GASTR, MICRI, QUART, VOIDS, PHOSP
MICRO 4	UNKNOW	BRACH, STROM, DASYC, MICRI
	PELEC	BRACH, ENBRY, TRILO, GIRVA, DASYC
	PYRIT	ENBRY, PHOSP, BROWN
MICRO 5	DOLOM	STROM, QUART
	PYRIT	OSTRA, DASYC
	MICRI	SPARR, QUART
MICRO 6	UNKNO	
	DOLOM	STROM, SPARR
	MICRI	STROM, SPARR, QUART, PHOSP
	PYRIT	MICRI, SPARR, VOIDS, PHOSP
	VOIDS	
MICRO 7	TETRA	SOLEN, CODIA
	SPARR	GASTR, PELEC
	BROWN	BRYOZ, PELEC, TRILO
MICRO 8	SPARR	QUART, DOLOM, PELMA
	PELMA	BRYOZ, SPARR
	GASTR	MICRI
	TRILO	QUART, PYRIT
	GIRVA	TRILO
	DOLOM	BRACH, BRYOZ, PELEC, TETRA, SPARR, VOIDS, PHOSP
	MICRI	OSTRA, BRYOZ, GASTR, QUART, PYRIT

[a] Significant at 0.05 level, once corrected for multiple comparisons.
[b] Significant at 0.05 level, for a nondirectional test.

can be applied. The regression analysis techniques were used to statistically verify the microfacies selected and serves as an aid to the petrographer in classifying the complex relationships among point-count data. Of course, the statistical techniques are no substitute for sound geological judgement but may be treated as any other tool that the petrographer uses.

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Predicting Runoff from Small Appalachian Watersheds

Ian D. Moore, George B. Coltharp, and Patrick G. Sloan

Departments of Agricultural Engineering and Forestry, University of Kentucky, Lexington, Kentucky 40546-0075

Abstract

A simple conceptual rainfall-runoff model was developed for predicting runoff from small, steep-sloped, forested Appalachian watersheds. The model requires only daily precipitation and an estimate of daily potential evapotranspiration, such as pan evaporation, as basic hydrological and meteorological inputs. The model was tested with 6½ years of observed discharge and meteorological records from the 81.7 ha undisturbed Little Millseat watershed in the Eastern Mountain and Coalfield region of Kentucky. Three and a half years of records were used for calibrating the model and 3 years were used for validation. There was good agreement between the observed and predicted daily discharges, and the results demonstrate the ability of the model to simulate the "flashy" hydrologic response of this type of watershed.

Introduction

Within Kentucky, 116 daily read stream-gauging stations, 123 crest stage, and 102 low-flow partial-record stations are maintained by the U.S. Geological Survey and other Federal and State agencies (1). In addition, a limited number of gauging stations are maintained for special purposes; for example, by the University of Kentucky for research. These gauging stations serve to monitor the flow of more than 16,000 km of flowing streams in Kentucky and are confined chiefly to larger streams and tributaries of the major river basins. It is economically impractical to gauge every stream, especially first, second, and third order streams.

Knowledge of the hydrologic behavior of ungauged streams and watersheds is very important to all persons carrying out, or potentially affected by, activities that disturb and modify the hydrologic balance, whether it is for surface mining for coal, timber harvesting, road construction, agriculture, or other forms of development. Federal and state regulation of these types of activities often mandate that baseline water quantity and quality characteristics be known and evaluated. To make such evaluations is an extremely difficult task, particularly on the ungauged watersheds that comprise the majority of the potentially affected watersheds in eastern Kentucky. Studies by Springer and Coltharp (2) and others of the hydrology of small watersheds in eastern Kentucky have shown the "flashy" behavior of streams in this region, with quick-flow accounting for almost half the total runoff volume. Flooding is a common problem in many of the eastern Kentucky watersheds.

One cost-effective method of determining the hydrological character of a watershed is via the use of simulation models. These models predict watershed discharge (and quality) as either deterministic or stochastic functions of precipitation and other variables that are more readily and cost-effectively measured than discharge. The application and/or evaluation of a number of deterministic rainfall-runoff models on watersheds in Kentucky has been reported, including Haan's Water Yield Model (3), the TVA Daily Streamflow Simulation Model (4), and the Stanford Watershed Model (5). The complexity of these rainfall-runoff models and their input data requirements vary, the internal time step in the model being an important factor. Generally, the smaller the time step, the greater the complexity of the model and the greater the input data requirements. Haan's model predicts monthly watershed yield and is the simplest of the three models. The TVA model predicts daily streamflow, while the Stanford model predicts hourly

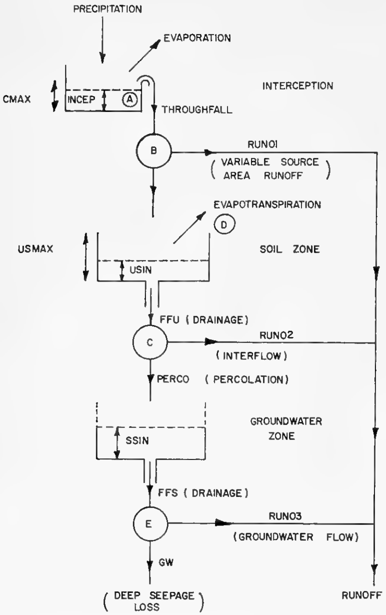


FIG. 1. Schematic flow diagram of the model.

streamflow. In tests of rainfall-runoff models of varying complexity, Haef (6) showed that simple models can give satisfactory results. He could not prove that complex models give better results than simpler ones. However, he did demonstrate that neither the simple nor the complex models were free from failure in certain cases.

In Kentucky, and many other parts of the United States, the majority of rainfall and runoff records are held as daily values. Many of the questions concerning the baseline hydrological behavior of watersheds can be answered using these daily data, or simple models that can predict daily streamflow. Nuckols and Haan (4) reported poor results with the TVA Daily Streamflow Simulation Model (7) in Kentucky. The study reported herein is aimed at developing and validating a simple rainfall-runoff model, requiring a minimum of input data, that is suitable for predicting baseline streamflow from small steep-sloped forested Appalachian watersheds on a daily basis. The model was validated on the Little Millseat watershed.

DESCRIPTION OF THE MODEL

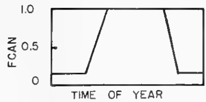
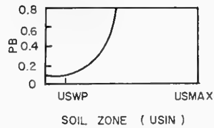
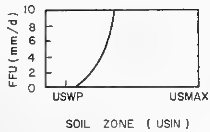
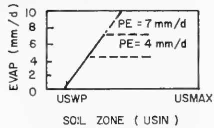
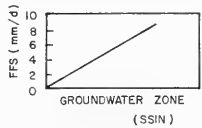
The model, schematically illustrated in Figure 1 and mathematically formulated in Table 1, is a conceptual lumped-parameter representation of the rainfall-runoff process. In this model, a watershed is idealized as consisting of a series of interconnected water storages with the in- and outflow representing actual physical processes. These processes are described using both physically and empirically based equations (Table 1). The concepts used in the model are common to many daily rainfall-runoff models including those of BROOK (8, 9), BOUGHTON (10, 11), and MONASH (12, 13). These 3 models are the basis of the watershed model described herein.

The model consists of 3 conceptual water stores or zones—the Interception Zone; the Soil Zone; and the Groundwater Zone—and has 13 parameters and 1 function (FCAN) that characterize the watershed. Definitions of these parameters are given in Table 2.

Since snow is an insignificant form of precipitation in eastern Kentucky (2), the model does not account for snowfall or snowmelt runoff. However, the model could be modified easily to include a degree-day approach for representing this process.

Precipitation is added to the interception store and any excess (throughfall) becomes available for infiltration or runoff from the saturated source areas. The capacity of the interception store is a function of the maximum interception storage capacity (CEPMAX) and the degree of canopy development (FCAN). CEPMAX is dependent on the type of vegetation and the maximum leaf-area and stem-area indices, and FCAN reflects the annual canopy growth characteristics and stem-area index. Evaporation from the inter-

TABLE 1.—MODEL FUNCTION DESCRIPTIONS

FUNCTION	EQUATION	FUNCTION SCHEMATIC	PROCESS
A	$CMAX = CEPMAX * FCAN$		INTERCEPTION
B	$RUNO1 = PB * PRECIP$ $INFIL = (1 - PB) * PRECIP$ $PB = FSTR + PC e^{PAC * (USIN / USMAX)}$		VARIABLE SOURCE AREA RUNOFF
C	$RUNO2 = K1 * FFU$ $PERCO = (1 - K1) * FFU$ $FFU = FU * \left(\frac{USIN}{USMAX}\right)^{KU}$		SOIL ZONE: DRAINAGE & INTERFLOW
D	$AEVAP = EVAP \; (EVAP < PE)$ $= PE \; (EVAP > PE)$ $EVAP = \frac{(USIN - USWP)}{ERATE}$		SOIL ZONE: EVAPOTRANSPIRATION
E	$RUNO3 = K2 * FFS$ $GW = (1 - K2) * FFS$ $FFS = FS * (SSIN)^{KS}$		GROUNDWATER ZONE: SEEPAGE & GROUNDWATER FLOW

ception store is assumed to occur at the potential rate.

The size of the saturated source area increases exponentially as the Soil Zone wet ups (i.e., as USIN increases). This source area consists of the stream area (FSTR) and the near-stream saturated zones that expand and contract in response to precipitation. This process is represented by the empirical equation proposed by Federer and Lash (8) and is represented by Function B (variable source area process) in Table 1. Overland flow from the saturated source area is subtracted from the precipitation excess, and the remainder represents the infiltration into the Soil Zone. Infiltration rates in steep-sloped forested watersheds of the Appalachian region are very high and traditional Hortonian (14) infiltration rarely occurs. The infiltration rates were therefore assumed to be infinite.

Drainage from the Soil Zone is dependent on the water content or water volume of the soil zone (USIN) and increases exponentially as the water content increases. Campbell (15) proposed a simple method of determining the hydraulic

TABLE 2.—MODEL PARAMETER DESCRIPTIONS AND VALUES

Process/zone	Parameter	Definition	Parameter value (Little Millseat Watershed)
INPUT VARIABLES			
Interception	CEPMAX	Maximum interception capacity (mm)	2.02
	FCAN	Canopy development function: modifies CEPMAX for time of year (i.e. canopy development)	See Table 1
Variable source area runoff	FSTR	Fraction of watershed always contributing to direct runoff (i.e. area of stream)	0.05 (0.05)†
	PAC	Source area exponent	39.295 (40)**
	PC	Source area coefficient	4.11×10^{-6} (4.1×10^{-6})**
Soil zone	USMAX	Soil zone thickness (mm)	1,087 (1,070)
	KU	Soil water conductivity exponent (KU = 2b + 3, where −b is the slope of a log-log plot of the soil water retention curve)	11.810 (11.467)
	FU	Soil water conductivity coefficient	1.49×10^7
	K1	Fraction of Soil Zone drainage becoming interflow	1.0 (1.0)
Evapotranspiration	USWP	Wilting point water volume (input as % by volume, used as mm of water in program)	124 (130)
	ERATE	Evapotranspiration rate coefficient	11.44% (12.14%)
Groundwater zone	FS	Groundwater exponent (1 for linear groundwater recession)	—*
	KS	Groundwater recession constant	—*
	K2	Fraction of groundwater drainage becoming baseflow	—*
OTHER VARIABLES			
	CMAX	Actual interception capacity (mm)	
	USIN	Actual soil water volume (mm)	
	SSIN	Actual groundwater volume (mm)	
	PB	Fraction of water contributing to direct runoff	

* Groundwater Zone does not exist in the Little Millseat watershed.
† Values in parentheses are the initial parameter estimates prior to optimization.
** Values used in BROOK model (Federer and Lash, 1978) for Hubbard Brook Watershed.

conductivity as a function of water content from the soil water retention curve. The method assumes that, and is only valid if, the soil water retention function can be described by the relationship: $h = a\theta^{-b}$, where h is the pressure head, θ is the volumetric water content (USIN/USMAX), and a and b are constants. This form of the equation was proposed by Gardner et al. (16). This relationship is only valid if the water retention function plots as a straight line on a log-log scale. If the first equation is a valid representation of the water retention curve then Campbell's equation can be used to estimate the hydraulic conductivity. Campbell's equation is: $FFU = FU\theta^{2b+3}$, where FFU is the hydraulic conductivity (Soil Zone drainage rate), FU is a coefficient, and the other variables are as previously defined. The function is the same as that describing Function C in Table 1. The water draining from the Soil Zone is divided between interflow and percolation to the Groundwater Zone. This division is assumed to be a fixed fraction, K1, of the total drainage, FFU.

Evapotranspiration from the Soil Zone

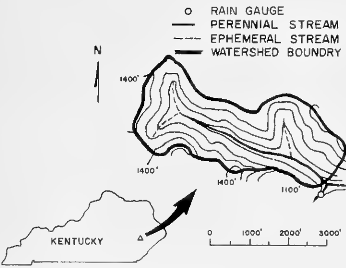


FIG. 2. Little Millseat Watershed.

is limited by either the atmospheric demand (potential evapotranspiration) or by the plant available water (USIN-USWP, where USWP is the wilting point water content). The evapotranspiration is equal to the lesser of either the available water divided by a rate constant (ERATE) or the potential evapotranspiration (Function D, Table 1). In the model, potential evapotranspiration is estimated from the input daily pan evaporation. Many techniques for estimating potential evapotranspiration have been proposed (17, 18, 19) and could be used if the required input data were available. The model is not sensitive to the natural daily variation of potential evapotranspiration, but it is sensitive to the long term average evapotranspiration rates over periods of months and years.

Groundwater movement is modeled by a groundwater store with no fixed capacity (SSIN). Groundwater recharge occurs by percolation from the Soil Zone to the Groundwater Zone. Water is subsequently lost from the store as baseflow to the stream (groundwater flow) or deep seepage. Deep seepage models the loss of water to underlying aquifers and the ungauged water flowing beneath the river bed. The normal groundwater storage-discharge relationship used in this type of rainfall-runoff model is linear, but Porter and McMahon (12) argue that within many watersheds more than one groundwater source or storage exists, leading to nonlinear behavior of the groundwater flow component. A nonlinear discharge function is therefore used in the model (Function E, in Table 1). The groundwater drainage is linearly divided (K2) between baseflow and deep seepage.

DESCRIPTION OF THE LITTLE MILLSEAT WATERSHED

The Little Millseat watershed, located in the University of Kentucky's Robinson Forest in the Eastern Mountain and Coalfield region of Kentucky (Fig. 2), is 81.7 ha in area and is characterized by steep slopes, narrow valleys, and a southeast aspect (20). The hill-slopes average about 42% and the channel slope is about 6% (21).

The soils of the watershed are similar to those of the adjacent Field Branch watershed (40.5 ha) which are comprised mainly of the Shelocta, Gilpin, DeKalb, Sequoia, and Cutshin soil types (22). All these soils have moderately rapid to rapid permeabilities (23). The Shelocta-Cutshin series, a cove association, varies in depth from about 1.22 m to 1.83 m, the Shelocta-Gilpin association averages 1.40 m deep, and the DeKalb-Sequoia series, a ridge top association, is the shallowest at about 1.00 m (22). Smith (22) found the average weighted soil depth in Field Branch watershed to be about 1.07 m, with the wilting point and field capacity water contents averaging about 12% and 30% by volume, respectively. The average total porosity is about 46% by volume. The deepest soils occur along the upslope sides of benches and in cove sites, while rock outcrops are common along slopes and outslope edges of benches (2). The bedrock is comprised of alternating layers of sandstones, siltstones, shales, and coal of the Pennsylvania Age (24).

Vegetation in the watershed is dominated by the White Oak–Red Hickory type. Cove sites consist of the Yellow Poplar type and ridge-tops and upper southwest exposures are classified as Shortleaf Pine–Oak type (25). A complete list of tree species found in Robinson Forest has been compiled by Carpenter and Rumsey (26).

TABLE 3.—ANNUAL OBSERVED AND PREDICTED FLOW SUMMARY

Year		Mean daily flow (cms × 10^{-3})	Standard deviation (cmsd × 10^{-3})		Coefficient of determination	
			Monthly	Daily	Monthly	Daily
Optimization Period						
1971**	1*	8.67	160.3	19.27	0.619	0.637
	2	11.88	138.9	11.77		
1972	1	26.81	907.3	61.55	0.920	0.719
	2	24.84	781.7	40.39		
1973	1	13.43	353.6	33.38	0.891	0.812
	2	17.32	386.5	28.08		
1974	1	27.55	745.0	64.44	0.956	0.846
	2	25.97	677.7	53.34		
Test Period						
1975	1	24.00	812.1	52.30	0.962	0.848
	2	24.42	693.6	39.65		
1976	1	17.26	432.0	34.73	0.933	0.724
	2	17.28	412.9	34.78		
1977	1	18.22	378.5	40.35	0.857	0.854
	2	15.43	264.5	21.76		

* 1 observed; 2 predicted.
** Partial year only (August–December).

RESULTS AND DISCUSSION

The hydrologic and meteorological data used by the model and used to validate the model included daily precipitation, daily pan evaporation and mean daily streamflow. Precipitation was measured with a weighing-bucket type gauge located in a clearing near the confluence of the Little Millseat and Field Branch watersheds (Fig. 2). Continuous streamflow was measured with a permanent 3:1 sideslope, broad-crested V-notch weir, equipped with a FW-1 water level recorder. The weir has a rated head of 0.9 m, which corresponds to a flow capacity of 4.83 m^3/s. Daily evaporation measurements, in the form of pan evaporation data, were obtained from Buckhorn Reservoir in Perry County, Kentucky, about 30 km southwest of the Little Millseat Watershed.

A split-record technique was used to evaluate the rainfall-runoff model. One section of the 6½ years of available record was used to calibrate the model (Aug. 1971 to Dec. 1974), while the remainder was used to independently evaluate model performance (Jan. 1975 to Dec. 1977).

The input parameters of the model were first estimated from the physical characteristics of the watershed described ear-

TABLE 4.—STATISTICAL COMPARISON OF MODEL PERFORMANCE

Statistic		Optimization Period Monthly	Optimization Period Daily	Test Period Monthly	Test Period Daily
Mean*	Observed ($\bar{\theta}$)	636.4	20.89	603.5	19.82
	Predicted ($\bar{P}$)	647.9	21.26	579.8	19.04
Standard Deviation*	Observed (σ_o)	686.2	52.40	565.1	43.15
	Predicted (σ_p)	600.6	39.73	490.9	29.20
Coefficient of Variation	Observed (C_{v_o})	1.078	2.508	0.936	2.177
	Predicted (C_{v_p})	0.927	1.868	0.847	1.533
Standard Error of Estimates*	(SE)	169.4	18.4	132.2	12.92
Coefficient of Determination	(r^2)	0.920	0.785	0.927	0.805
Coefficient of Efficiency	(E)	0.913	0.769	0.917	0.755
Residual Mass Curve Coefficient	R	0.782	0.794	0.868	0.859
Coefficient of Variation of Residuals	(C_o)	0.314	1.206	0.266	1.076
Ratio of Relative Error to the Mean	(R_m)	0.018	0.018	-0.039	-0.039
Maximum Error of Model	(K)	0.260	0.734	0.228	0.700
Sign Test	(Z)	–	3.518		2.183

* All flow values are in cmsd x 10^{-3}

$$\bar{\theta} = \frac{\Sigma \theta}{n}$$

$$\sigma_o = \left[\frac{\Sigma(\theta_i - \bar{\theta})^2}{n-1}\right]^{1/2}$$

$$C_v = \sigma_o / \bar{\theta}$$

$$SE = \sigma_o (1 - r^2)^{1/2}$$

$$r^2 = \frac{[\Sigma(\theta_i - \bar{\theta})(P_i - \bar{P})]^2}{\Sigma(\theta_i - \bar{\theta})^2 \, \Sigma(P_i - \bar{P})^2}$$

$$E = \frac{\Sigma(\theta_i - \bar{\theta})^2 - \Sigma(\theta_i - P_i)^2}{\Sigma(\theta_i - \bar{\theta})^2}$$

$$R = \frac{\Sigma(D_o - \bar{D}_o)^2 - \Sigma(D_o - D_p)^2}{\Sigma(D_o - \bar{D}_o)^2}$$

$$C_o = \left[\frac{\Sigma(P_i - \theta_i)^2}{n}\right]^{1/2} / \bar{\theta}$$

$$R_m = \frac{\Sigma(P_i - \theta_i)}{n\bar{\theta}}$$

$$K = C_v \left[\left(\frac{n-1}{n}\right) C_o^2 + 1\right]^{\frac{1}{2}}$$

θ_i = Observed flow

P_i = Predicted flow

D_o = Departure from mean for observed residual mass curve

D_p = Departure from mean for predicted residual mass curve

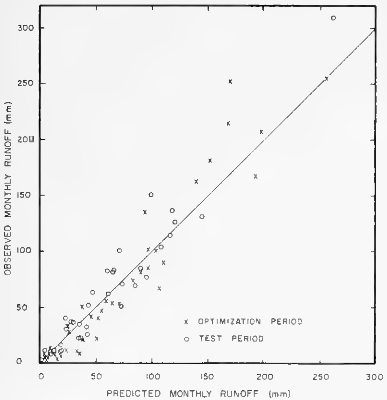


FIG. 3. Observed and predicted monthly runoff for the optimization and test periods.

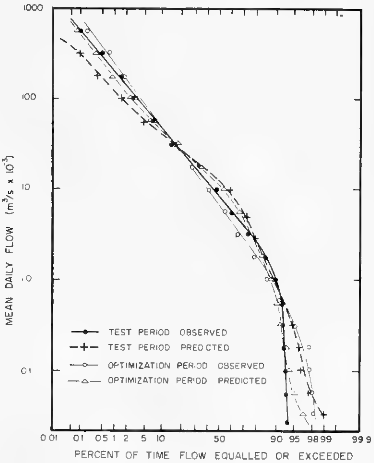


FIG. 4. Observed and predicted 1-day flow duration curves for the optimization and test periods.

lier. These initial estimates are shown in parentheses in Table 2. Individual parameters and groups of parameters were then adjusted so that the predicted and observed hydrographs showed good agreement. It was found that a visual comparison of the observed and predicted hydrographs, although subjective in nature, was the most effective means of optimizing the model's parameters. Finally, the steepest ascent method of automatic optimization (11) was used to refine the parameter set. The sum of squares of the errors in the daily flows was the objective function for this optimization. The final parameter set is presented in Table 2. From this table it can be seen that the limited optimization produced very little change in the parameter set. The main effect of the optimization was to modify the peak flows, and determine the appropriate values of CEPMAX and FU, for which little information was initially available.

Evaluation of the standard of simulation achieved by a watershed rainfall-runoff model is difficult because streamflow provides a large amount of data of a range of types (27), and no one test will satisfactorily evaluate all types (e.g., peak flow, low flow, mean flow, etc). Therefore, a variety of statistical and graphical tests is presented so that the reader may evaluate the model's performance. Many of these statistical and graphical tests are described by Aitken (28), WMO (29), Moore and Mein (30), and Weeks and Hebbert (27), and the reader is referred to these citations for more complete details of the methods.

Tables 3 and 4 present the annual summary and the optimization/test period summaries, respectively, on a monthly and daily flow basis. Graphical comparisons of the observed and predicted monthly runoff, the daily flow duration curves, and the residual mass curves for the optimization and test periods are presented in Figures 3, 4, and 5, respectively. Figure 6 presents the annual hydrograph of the observed and predicted daily flows for 1976. This example represents the worst simulation for the test period in terms of the coefficient of determination of the daily flows ($r^2 = 0.724$), and the predicted peak flows. The results show that there is no significant difference in the standard of simulation in the

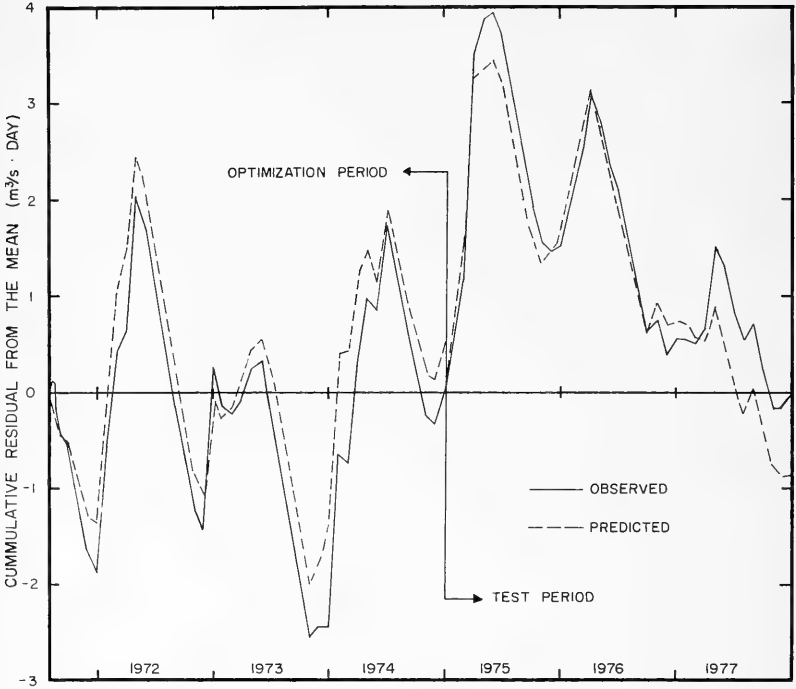


FIG. 5. Observed and predicted residual mass curves for the optimization and test periods.

optimization and test periods of the record.

The mean flow and the standard deviations of the observed and predicted monthly flows are in good agreement on an annual basis (Table 3) and during the optimization and test periods (Table 4). However, the standard deviations of the daily flows predicted by the model are significantly lower than the observed (Tables 3 and 4). For example, the coefficient of variation (standard deviation/mean) of the observed flows are 2.508 and 2.177 for the optimization and test periods, respectively, whereas those for the predicted flows are 1.868 and 1.533, respectively. Hence, the observed flows exhibit greater variability than the predicted flows.

The coefficients of determination (r^2) of the monthly and daily flows are uniformly high, averaging about 0.92 and 0.80, respectively. However, neither the mean, standard deviation, or coefficient of determination can indicate if there is bias, or systematic errors, in the predicted flows. Aitken (28) indicated that the coefficient of efficiency (E) could be used to detect bias. If the coefficient of efficiency is less than the coefficient of determination then bias is indicated. Table 4 shows that in all cases the coefficient of efficiency is slightly less than the coefficient of determination, indicating a small bias in

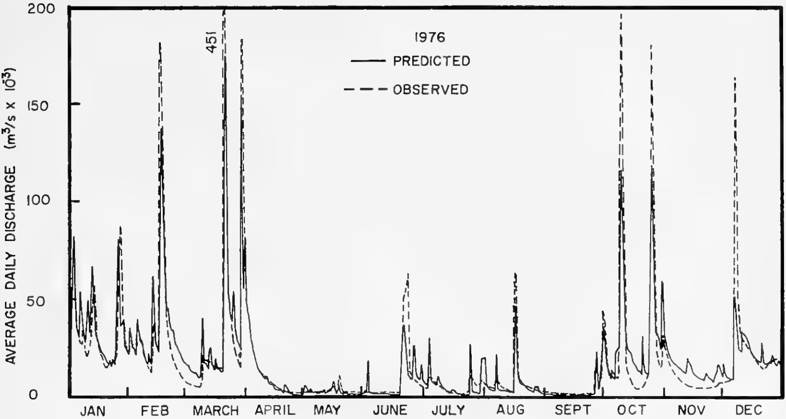


FIG. 6. Annual hydrographs of the observed and predicted daily flows for 1976.

the model. The sign test (27, 28) can also be used to detect systematic errors. The technique is based on the number of runs of residuals of the same sign which the data set exhibits. The expected number of runs is normally distributed, and a Chi-square test indicates systematic errors. If the magnitude of the normalized variate (Z in Table 4) is greater than 1.96, then the number of runs is significantly different from that expected for random errors at the 0.05 level of statistical significance. Table 4 shows that $|Z| > 1.96$ for the daily flows during both the optimization and test periods, thus indicating a small amount of bias in the model. This finding is consistent with the comparison of the coefficients of determination and efficiency.

Weeks and Hebbert (27) described the maximum error of the model statistic (K in Table 4) and showed that it can be interpreted as being equivalent to a constant error in the results. Table 4 shows that the maximum error of the model ranges from 23 to 26% for the monthly flows and 70 to 73% for the daily flows. As expected, the daily flows exhibit a relatively high error.

The monthly predicted and observed runoff (Fig. 3), the daily flow duration curves (Fig. 4), and the residual mass curve (Fig. 5) all show very good agreement between the predicted and observed flows. The residual mass curve coefficient (R) measures the relationship between the sequence of flows and not simply the relationship between individual flow events (28). The residual mass curve coefficients are reasonably high, averaging about 0.79 and 0.86 for the optimization and test periods, respectively.

During the period of record, 1971 to 1977, the maximum observed peak daily flow was 0.837 m^3/s, and the corresponding peak predicted flow was 0.834 m^3/s. Generally, however, the extreme peaks were underestimated by the model, as is evident from an examination of the flow duration curves for probabilities of occurrence of less than about 1%. Figure 6 shows that the hydrograph recessions and the timing of the peak flows are modeled very well. These results, plus the steepness of the flow duration curves, indicate that the model represents the "flashy" behavior of the watershed very well. This "flashy" behavior is characteristic of the streams in Robinson Forest (2), and the Appalachian region in general.

SUMMARY

A daily rainfall-runoff model was developed for predicting runoff from steep-sloped forested Appalachian watersheds. The model was validated on the Little Millseat watershed located in Eastern Kentucky, using a split-record technique. The initial estimates of the model parameters, determined from the physical characteristics of the watershed, were very close to the optimized values, indicating the physical significance of their values.

The results show very good agreement between the predicted and observed flows, and demonstrate the ability of the model to predict the "flashy" response of the watershed. The statistical and graphical comparison of the observed and predicted flows indicated a slight bias, or systematic error, in the predicted flows.

ACKNOWLEDGMENTS

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The Effect of Temperature on the Rate of Development of *Aphidius matricariae* Haliday (Hymenoptera: Aphidiidae)[1]

M. K. GIRI, B. C. PASS, AND K. V. YEARGAN[2]
Department of Entomology, University of Kentucky, Lexington, Kentucky 40546-0091

ABSTRACT

The developmental rates of *Aphidius matricariae* Haliday at 9 constant temperatures, 10, 12.8, 15.6, 18.3, 21, 24, 26.7, 29.5, and 32 C, are reported. The developmental rates were fitted with a logistic curve ($100/Y = (k/1 + e^{a-bx})$). The shortest time for development was 11.5 days at 26.7 C and the longest time was 41 days at 10 C. The duration of development decreased as temperature increased up to 26.7 C. At 29.5 C, developmental times slightly increased, and at 32 C, the parasite did not survive to the adult stage. Males developed significantly faster ($P < 0.05$) than females except at 26.7 and 29.5 C.

INTRODUCTION

Aphidius matricariae Haliday, an endoparasite of the green peach aphid, *Myzus persicae* (Sulzer), has been utilized to control this pest in greenhouses (1, 2 and 3). The parasite has been reported to parasitize 40 different species of aphids from 21 genera (4), and it has been reported from 19 countries in Asia, Europe and North and South America. *Aphidius matricariae* has been reported from hot deserts in Israel and Iran (4) and from cool plains in England (5) and Canada (1), yet the effects of temperature on its development are not adequately reported. Rabasse and Shalaby (6) reported that the development of *A. matricariae* was slower in younger hosts (*Myzus persicae*) than in older hosts at 10 and 15 C, but the development was slower in older hosts at 20 C. Giri et al. (7) reported this parasite's mating behavior and production of progeny under different temperature regimes. The present study was performed to determine optimal temperature regimes

[1] This paper is published with the approval of the Director of the Kentucky Agricultural Experiment Station as Journal article no. 82-7-302. To simplify information in this publication, trade names of some products are used. No endorsement by the Kentucky Agricultural Experiment Station is intended, nor is criticism implied of similar products not named.

[2] Graduate student, Professor, and Associate Professor, respectively.

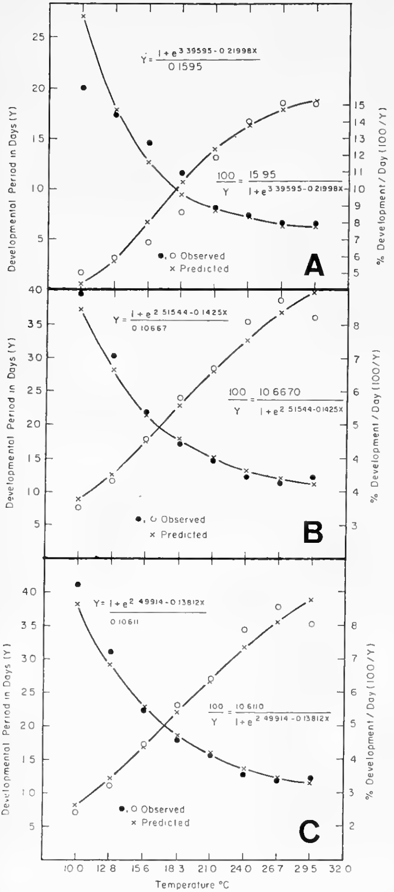

FIG. 1. Relationship between temperature and development for (A) mummy stage, (B) adult male and (C) adult female *Aphidius matricariae* Haliday. (●) Temperature-time and (○) Temperature-developmental-velocity curves.

which could improve mass rearing techniques for this parasite.

MATERIALS AND METHODS

The parasite was colonized on radishes, *Raphanus sativus* Linnaeus, in the greenhouse. Mummified aphids were picked and placed in gelatin capsules (no. 00, Eli Lilly and Co.) individually so that emerging parasites could be sexed and mated. Ten mated female parasites, which had emerged within the past 24 h, were individually introduced into small cages containing 50 aphids/cage.

Paper cartons (0.5 l) were used as parasitizing cages. The root of a 2-leaf stage radish plant with 50 aphids was inserted into and sealed inside a 7.4 cc glass vial. The neck of the vial was then fitted into a hole cut in the paper container 3 cm below the upper rim. A similar hole was cut 2 cm above the lower rim and closed with a cork stopper. Filter paper was fitted tightly in the bottom of the cage. The top of the cage was covered with transparent plastic wrap which was punctured with insect pins to permit ventilation.

The total duration of development was defined as the time required from the day of parasitism to the day of adult parasite emergence; this was determined at 10, 12.8, 15.6, 18.3, 21, 24, 26.7, 29.5, and 32 C. The time required to develop from the day of parasitism to aphid mummy formation was also recorded. This was done by checking daily for the formation of mummies. The duration of development at different constant temperatures was converted to rate of development per day to fit a temperature-developmental

TABLE 1.—DEVELOPMENT PERIODS OF *Aphidius matricariae* HALIDAY FROM OVIPOSITION TO THE MUMMY STAGE, ADULT MALE AND FEMALE AT 9 DIFFERENT CONSTANT TEMPERATURES. OBSERVED NUMBERS ARE WITHIN PARENTHESES

Temp (C)	Development periods (in days)		
	Mummy stage	Male*	Female*
10.0	20.0 (208)	39.6 (167)	41.0 (383)
12.8	17.0 (331)	30.3 (211)	31.0 (504)
15.6	14.6 (205)	21.8 (270)	22.4 (161)
18.3	11.6 (310)	17.2 (280)	17.9 (360)
21.0	8.4 (155)	14.9 (173)	15.6 (377)
24.0	7.1 (165)	12.3 (67)	12.7 (138)
26.7	6.7 (50)	11.4 (45)	11.7 (66)
29.5	6.6 (9)	12.2 (2)	12.4 (1)
32.0	—	—	—

* There was significant difference ($P < 0.05$) between male and female emergence in temperature regimes from 10.0 to 24.0 C. (Student's *t*-test).

velocity curve. The temperature-time and temperature-developmental velocity curves were fitted using Davidson's (8) equations $Y = (1 + e^{a-bx})/k$ and $100/Y = k/(1 + e^{a-bx})$, respectively, where Y = developmental time, x = temperature, and a, b and k are constants.

RESULTS AND DISCUSSION

The rate of development of *A. matricariae* increased with higher temperature from 10 to 26.7 C, and then decreased at 29.5 C; at 32 C the parasite did not survive to the adult stage (Table 1). When the duration of development from oviposition to mummy stage (Y) was plotted against temperature (x), the line represented the course of the temperature-time curve. When the reciprocals for developmental time (100/Y), representing the average percentage development/day, were fitted with Davidson's (8) logistic curve, the upper inflection appeared near 29 C (Fig. 1A). Similar logistic equations were used separately to fit data on developmental rates from time of parasitism to adult male and female emergence (Fig. 1B & C) because there were significant differences in developmental time of males and females at temperatures from 10 to 24 C (Table 1). Wiacknowski (9) described similar differences in developmental time for male and female *Aphidius smithi* Sharma and Subba Rao.

The threshold temperature was calculated to be approximately 5 C by extrapolation of a straight line from the most linear portion of the temperature-developmental-velocity curve. The point at which this line intercepted the temperature axis was assumed to be the threshold temperature. Based on this threshold temperature, degree-days were calculated for mummy stage (from parasitism to mummy formation), and male and female adults (from parasitism to male or female emergence) as 142.4, 235.8 and 243.3, respectively.

Results presented here and by Giri (10) indicate that *A. matricariae* can develop from 10 C to 29.5 C. At higher temperatures, development was terminated by the death of the host. The optimal temperature in terms of the shortest developmental period or the maximal rate of development was 26.7 C. However, considering the number of progeny produced and survival (7) as well as the rate of development, 21 C is the optimal temperature for greenhouse rearing of the parasite.

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Distribution of Riverine Yeasts in the Barren River, Warren County Kentucky

RICHARD A. VANENK

Department of Microbiology, University of Kansas Medical Center, Kansas City, Kansas 66103

AND

DR. LARRY P. ELLIOTT

Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101

ABSTRACT

Yeasts were isolated and identified the 12-month period March 1978 through February 1979 from 5 sampling sites in the Barren River, Warren County Kentucky. Sporadic yeast counts were obtained that averaged 40 CFU/ml for the effluent, while the river averaged 15 CFU/ml. No seasonal variation in yeast counts was noted. A total of 318 yeast cultures were isolated and identified, including 16 different genera with *Cryptococcus* being the most common genus observed. The Barren River contained a characteristic yeast population which varied with several environmental factors at a statistically significant level, and the effluent released several pathogenic yeast species which were not indigenous riverine yeasts.

INTRODUCTION

The yeasts, or unicellular fungi, make up a substantial portion of the microbiological flora of soil and water. Several studies reported yeasts from rivers, but the data are contradictory with respect to the relationship between sewage pollution and yeast numbers. Simard and Blackwood (1, 2) concluded that yeast counts in the St. Lawrence River varied over a 5-month sampling period but no consistent relationship was seen between yeast counts and indices of pollution such as coliforms, total bacteria, dissolved oxygen (DO), and biological oxygen demand (BOD).

Spencer et al. (3) sampled the South Saskatchewan River and concluded that several yeast species, including some possible pathogens, had originated from urban sewage. They suggested that the differences in yeast numbers and species between sites upstream and downstream of a city could be used to indicate the degree of biological pollution of the river contributed by the municipal sewage effluent.

Cooke et al. (4) surveyed the yeast flora of several sewage treatment plants and reported the presence of many yeast species that are considered opportunistic human pathogens. All these studies suggest that microbiological examination of rivers for water quality should not be limited to the coliform test. The examination of yeast floras may also give valuable information about river pollution.

The purposes of this study were to examine the Barren River for the presence of yeasts; to determine whether the Bowling Green sewage treatment plant in southwestern Kentucky was contributing high numbers or unique species to the natural river yeast flora; and to attempt to correate selected physical-chemical and biological features with river yeast counts.

MATERIALS AND METHODS

Description of Sample Area

The Barren River drains 5,853.4 square km of primarily agricultural land in Southwestern Kentucky. It flows at an average rate of 91,918 l per second through Bowling Green, Kentucky before joining the Green River, a tributary of the Ohio River. The water level of the Barren River is controlled by an Army Corps of Engineers dam located 66.1 km upstream from Bowling Green.

The Bowling Green municipal sewage treatment plant discharges 21×10^6 l of water per day into the water. All effluent receives primary and secondary treatment via an activated biological filter system, and automatic chlorination.

Water samples were taken from 5 study sites established in the Barren River (5).

Enumeration and Characterization

Samples were taken from midstream in sterile bottles using the grab-sample technique. They were placed on ice and transported immediately to the Western Kentucky University Microbiology Laboratory for analysis. Yeast counts were determined by the spread-plate technique by plating in triplicate 0.1 ml of each sample on petri plates containing Plate Count Agar (Difco, Detroit, Mi.) supplemented with 100 mg each of Chloramphenicol and Chlortetracycline (Sigma, St. Louis, Mo.) to inhibit bacterial growth (6). After incubation at 25 C for five days, all yeasts were counted and streaked for purification on Sabouraud Dextrose Agar (Difco). All specimens were identified using standard techniques (7, 8). The tests used for identification of the yeast isolates consisted mainly of the fermentation and assimilation of a battery of 12 carbohydrates. In addition, Barnett's and Pankhurst's (9) keys for the identification of yeasts were used.

Physical-Chemical Characteristics of Water Samples

Several environmental parameters were measured at each site. River height and velocity data were obtained from the Army Corps of Engineers, monitored daily in Bowling Green. Dissolved oxygen was determined by the iodometric test, azide modification (10). Iron, nitrate, ortho-phosphate, and turbidity were determined using a Hach Direct Reading Engineer's Laboratory Kit (Hach Chemical Company, Ames, Ia.). Water temperature and pH were determined for each sample, and effluent chlorine content data were kindly supplied by treatment plant personnel. Total viable aerobic bacteria counts were done on each sample using the spread-plate technique on Plate Count Agar (Difco).

TABLE 1.—COMPARISON OF YEAST COUNTS FROM FIVE SAMPLE SITES IN THE BARREN RIVER

Site	Mean	Standard error	Range
Upstream	12	12.1	0–40
Effluent	40	73.5	0–300
Downstream #1	18	40.3	0–193
Downstream #2	13	21.9	0–103
Downstream #3	15	25.1	0–116

Statistical Analysis

The data were analyzed as previously described (5) by computer which performed means, standard deviations, ranges, analysis of variance, correlation analysis, and regression analysis.

RESULTS AND DISCUSSION

The most notable fact to emerge from the yeast-count data was the large amount of variability in the river bi-weekly viable yeast counts. These viable counts ranged from 0 to 300 colony forming units per ml (CFU/ml) with the effluent averaging 40 CFU/ml and the river sites averaging 15 CFU/ml. The upstream site yielded the lowest average counts and showed the least variability (Table 1). The sewage effluent exhibited both the highest yeast count average and the greatest variability over the sampling period. The effluent counts seemed to have no relationship to the river counts, suggesting that different factors may be controlling yeast numbers in the two sources.

No seasonal trends were noted in total yeast counts. The St. Lawrence River also yielded approximately equal yeast numbers throughout a 5-month study period (1, 2). In that study, however, certain yeast species, notably *Rhodotorula* spp., seemed to increase at some sites in late summer. In the Barren River, all yeast

TABLE 2.—COMPARISON OF PHYSICAL-CHEMICAL PARAMETERS AT FIVE SAMPLING SITES

Parameter	Unit	Sampling sites UPS	EFF	DS #1	DS #2	DS #3
DO	mg/l	10.7* (7.8–15.4)	10.7 (7.7–15.9)	10.7 (7.6–15.0)	10.6 (7.2–15.0)	10.6 (7.8–15.0)
pH		6.59 (5.8–7.2)	6.65 (6.1–7.2)	6.77 (6.1–7.3)	6.77 (6.2–7.4)	6.80 (6.2–7.4)
Turbidity	J.T.U.	26.6 (9–70)	27.6 (7–90)	37.6 (0–310)	25.1 (6–7.9)	26.7 (0–110)
Nitrate	mg/l	3.17 (0–11.0)	8.87 (0–37.0)	3.37 (0–7.0)	3.04 (0–8.3)	3.12 (0–6.6)
Phosphate	mg/l	0.45 (.075–2.2)	1.13 (0.2–2.0)	0.44 (0.18–1.0)	0.42 (.05–1.3)	0.45 (.03–1.6)
Iron	mg/l	0.106 (0–.90)	0.103 (0–.35)	0.056 (0–.15)	0.078 (0–.29)	0.091 (0–.38)
Water temperature	°C	16.4 (3–27)	17.3 (3–27)	16.7 (6–27)	16.5 (3–27)	16.5 (3–27)
Total aerobic	CFU/ml	6,500 **(2–950)	48,000 (1–3,000)	10,000 (3–1,300)	9,700 (3–1,650)	3,500 (3–300)

* Given as mean of all samplings, with range in parentheses below.
** Range value times 10^2.

species appeared in approximately the same proportions throughout the year. This apparent lack of seasonal dependence indicated that factors other than temperature were the major determinants of yeast growth during the study. Rheinheimer (11) discovered a higher winter than summer count in the Elbe River of Germany, and suggested that competition for certain nutrients was more important than temperature in controlling yeast reproduction. He also postulated that concentration of these nutrients was largely dependent on fast-growing algae, which are less populous in winter.

Mean iron levels, DO, pH, and turbidity values were not statistically different from station to station (Table 2). No correlation was found between the iron, DO, and pH values and the yeast counts (Table 3); however, turbidity affected the yeast population. A maximum level of 0.3 mg/l iron in freshwater used for drinking purposes has been set (12). The mean iron levels did not exceed this limit. None of the DO values were lower than the minimum allowable level of 5.0 mg/l that has been established for freshwater streams. All the pH values were within the limits set for freshwater streams of 6.0–9.0 (13). No standards were set for turbidity in streams.

The mean nitrogen-nitrate level for the EFF was significantly higher ($F = 8.818$) than the means of the other 4 stations. This situation was also noted by Cherry et al. (14) who found high nitrate levels associated with effluent from sewage treatment plants. A limit of 45 mg/l nitrogen-nitrate has been established for drinking water while averages must be below 10 mg/l to control eutrophication (12). A statistical correlation was found between the nitrate levels and the yeast counts.

The mean phosphate level for the EFF was significantly higher than the other station means ($F = 14.76$). The recommended limit for phosphates in freshwater streams is no more than 0.015 ml/l (10). The mean levels for phosphate exceeded the set limit at all stations. A statistical correlation was demonstrated between the phosphate levels and the yeast counts.

The mean of the EFF counts of total aerobic chemoorganotrophic bacteria isolated on Plate Count agar with the spread-plate technique was significantly higher than the means of the other 4 stations (F = 3.48) (Table 2). The second highest mean was that of DS #1 which may have reflected input of organisms from Jennings Creek or cells washed downstream from the EFF. Water from the Lost River Cave complex resurges near Dishman Mill on Jennings Creek. Elliott (15) found these waters to have an average total coliform count of over 5,000/100 ml, the maximum allowed by the Kentucky Water Commission for public water supplies. All fecal coliform densities were greater than the recommended maximum of 200/100 ml for contact recreation in Kentucky. Lovan et al. (16) found the mean total coliform count of Jennings Creek to be 641,950/100 ml and the fecal coliform count to be 17,375/100 ml.

The mean chlorine level was 0.60 ppm. Since chlorine was measured only at EFF, no statistical analysis between chlorine levels and yeast counts at the other stations was done. A negative correlation was found between chlorine levels and yeast counts. This is not surprising, since Jones and Schmitt (17) demonstrated that 100% of 10^5 *Candida albicans* cells per ml were killed when exposed to 4 ppm of chlorine for 30 minutes.

The average flow rate over the year-long sampling period was 91,918 l/sec. It was assumed that the river flow registered at the monitoring station corresponded to the flow rate at the sampling sites. A statistical correlation between flow rate and yeast counts was significant (0.05 level).

Of all the parameters tested, regression analysis revealed that only turbidity, nitrate, and chlorine gave significant F-values. These 3 variables seemed to have the most influence on yeast content, suggesting that several factors influence the rate of yeast growth in water and sewage. Nutrient concentration, reflected by nitrate and turbidity, and levels of toxic chemicals, such as chlorine, appeared to be the most important. Since these factors varied more in the sewage effluent than in the river, they likely made a large contribution to the increased variability in yeast counts seen in the effluent.

TABLE 3.—CORRELATION COEFFICIENTS OF MEASURED PARAMETERS VERSUS YEAST COUNTS

Parameter	Correlation coefficient
Chlorine[1] (−)[2]	−.569**
Turbidity	.501**
Total aerobic bacteria	.379**
Phosphate	.370**
Nitrate	.225*
Flow Rate	.202*
pH	.192
Iron	.182
Water temperature (−)	−.181
DO	.098

* Significance at the .05 level.
** Significance at the .01 level.
[1] Chlorine was tested in the effluent only.
[2] Negative correlation.

The river was shown to contain a natural flora of yeasts with respect to the yeast isolated from the effluent, and the total number of yeasts was not significantly altered by release of treated sewage effluent into the river. In this respect, the Barren River was similar to the St. Lawrence River, but differed from the South Saskatchewan River.

A total of 318 yeasts among 16 genera were isolated and identified during the course of the study (Table 4). The genus *Cryptococcus* was the most frequently isolated genus (30%). The species *Cryptococcus laurentii* was the most common species. Other major genera represented were *Candida* (22%), *Trichosporon* (13%), *Rhodotorula* (9%), and *Torulopsis* (7%). These figures are unique in some respects, but quite similar to those obtained from other rivers. Lazarus and Koburger (6) found the Suwanee River in Florida to contain *Candida* (28%), *Rhodotorula* (24%), *Cryptococcus* (16%) *Torulopsis* (12%), and *Trichosporon* (3%). Simard and Blackwood (1, 2) found *Rhodotorula* (57%), *Candida* (24%), and *Cryptococcus* (8%) in the St. Lawrence River. The South Saskatchewan River (3) contained *Candida* (25%), *Rhodotorula* (23%), *Trichosporon* (13%), *Cryptococcus* (7%), and *Torulopsis* (5%).

The yeast flora contained in the Bowling Green sewage effluent was slightly

TABLE 4.—YEAST SPECIES ISOLATED, WITH SITE AND FREQUENCY OF ISOLATION

Species	Site					
	UPS	EFF	DS1	DS2	DS3	Total
Cryptococcus:						
laurentii						
var. *flavescens*	12	10	18	5	11	56
var. *laurentii*	3	1	2	2	0	8
var. *magnus*	1	1	1	0	0	3
albidus	1	1	2	2	0	6
hungaricus	3	2	1	1	2	9
luteolus	4	0	0	1	0	5
terreus	0	2	1	0	0	3
uniguttulatus	0	0	0	0	2	2
gastricus	1	0	0	0	0	1
flavus	0	0	0	1	0	1
Total	25	17	25	12	15	94
Candida:						
guilliermondii	7	4	1	3	1	16
parapsilosis	3	7	0	2	2	14
sake	1	6	1	2	0	10
valida	1	3	0	1	0	5
ingens	1	3	1	0	0	5
intermedia	0	2	0	2	0	4
aquatica	0	0	2	0	0	2
lambica	0	1	1	0	0	2
cifferrii	0	1	1	0	0	2
javanica	1	1	0	0	0	2
diddensii	0	0	0	0	1	1
rugosa	0	0	0	0	1	1
valdiviana	0	0	0	1	0	1
curvata	0	1	0	0	0	1
marina	1	0	0	0	0	1
melinii	1	0	0	0	0	1
shehatae	1	0	0	0	0	1
zeylanoides	0	1	0	0	0	1
Total	17	30	7	11	5	70
Trichosporon:						
cutaneum	5	11	1	2	3	22
capitatum	0	8	0	0	1	9
penicillatum	0	4	0	1	0	5
fennicum	1	0	0	1	0	2
brassicae	1	0	0	0	0	1
melibiosaceum	0	0	0	0	1	1
Total	7	23	1	4	5	40
Rhodotorula:						
glutinis	2	4	1	1	2	10
graminis	0	3	0	1	0	4
rubra	0	1	2	0	1	4
marina	1	0	2	0	0	3
minuta	0	1	1	0	0	2
pallida	0	0	0	2	0	2
lactosa	0	0	1	0	0	1
aurantiaca	0	0	0	1	0	1
Total	3	9	7	5	3	27
Torulopsis:						
candida	0	2	0	0	3	5
xestobii	1	2	1	0	1	5
fujisanensis	0	3	0	0	0	3
versatilis	0	0	0	1	1	2

TABLE 4.—CONTINUED

Species	Site					
	UPS	EFF	DS1	DS2	DS3	Total
torresii	0	0	0	0	1	1
haemulonii	0	0	0	0	1	1
wickerhamii	0	0	0	1	0	1
glabrata	0	0	0	1	0	1
anatomiae	0	1	0	0	0	1
ingeniosa	1	0	0	0	0	1
insectalens	0	1	0	0	0	1
Total	2	9	1	3	7	22
Brettanomyces:						
naardenensis	3	6	3	2	4	18
custersianus	0	2	0	0	0	2
Total	3	8	3	2	4	20
Leucosporidium:						
capsuligenum	0	7	0	1	0	8
Pichia:						
chambardii	0	0	0	0	1	1
trehalophila	0	0	1	0	0	1
etchellsii	0	1	0	0	0	1
castilae	0	1	0	0	0	1
pijperi	0	1	0	0	0	1
Total	0	3	1	0	1	5
Sporobolomyces:						
salmonicolor	0	1	0	1	3	5
gracilis	0	0	1	0	0	1
Total	0	1	1	1	3	6
Sterygmatomyces:						
halophilus	0	4	0	0	0	4
Kluyveromyces:						
phaseolosporus	0	0	0	0	2	2
Endomycopsis:						
ovetensis	0	2	0	0	0	2
Oosporidium:						
margaritiferum	1	0	0	0	0	1
Rhodosporidium:						
sphaerocarpum	0	0	0	1	0	1
Saccharomycoides:						
ludwigii	0	0	1	0	0	1
"Black Yeasts"	0	10	1	1	3	15
Total	58	123	48	40	48	318

different from the river flora. The most frequently found effluent yeast genera were *Candida*, *Trichosporon*, *Cryptococcus*, and *Rhodotorula*, in decreasing order of frequency. The survey by Cooke et al. (4), found the order of occurrence in their effluent samples to be *Candida*, *Rhodotorula*, and *Trichosporon*.

The results of this study also indicate that municipal sewage effluent may be a source of medically important yeasts. If one uses the API (API 20C, Analytab Products, Inc., Plainview, N.Y.) listing of 25–30 yeast species as being clinical isolates and potential pathogens in humans whose health is compromised, then the river contained 15 of such human-associated yeasts. Finding these yeasts in a river is significant both as an indicator of possible human pollution of the river and as a potential source of yeast infections for humans in contact with the river water. From this group of 15 species, 7 consisted of *Cryptococcus terreus, Candida zeylanoides, Trichosporon capitatum, Trichosporon penicillatum, Candida parapsilosis, Trichosporon cutaneum, Rhodotorula glutinis,* the first 4 species being limited to the effluent only. Fifty six isolates of these medically important yeasts were also identified using a commercial yeast identification system (API 20C) in a comparison study with conventional methodology (18). The API 20C system, with computer assistance, identified 100% of the isolates for which it was designed. Although the above species are considered potential pathogens, their virulence is quite low, and they pose minimal health hazards. The opportunistic yeast pathogen, *C. albicans,* was not isolated from any Barren River station. No other river studies reported its isolation except for the Long Island Sound estuary study where Buck et al. (19) reported its presence inside shellfish in polluted water.

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The Sine-Gordon Equation in an Anisotropic Cosmological Background

B. W. STEWART

Department of Physics, Thomas More College, Ft. Mitchell, Kentucky 41017

ABSTRACT

The sine-Gordon equation was examined in a Kasner cosmological background. A one soliton solution is given. A procedure to obtain additional solutions is suggested.

INTRODUCTION

There has been much interest in the sine-Gordon (SGE) equation (1) over the last decade, partly due to the numerous and diverse applications (1) of the equation. One area in which the SGE has been applied is the theory of elementary particles. In this paper I examine the SGE in a cosmological background metric. The problem is not purely mathematical in nature because the effect of an expanding universe upon solitons propagating therein is of physical interest as well. Since we are solving the SGE in a given background metric, we are assuming the contribution to the background due to the energy-momentum tensor of the soliton field is negligible.

METHODS

We begin by examining the Einstein field equations for a source consisting of the self-interacting sine-Gordon field:

$$R\mu\nu - \tfrac{1}{2}g\mu\nu R = K\, T\mu\nu \qquad (1)$$

with

$$T\mu\nu = -\phi,\mu\phi,\nu + \tfrac{1}{2}g\mu\nu\cdot (\phi_{,\alpha}\phi_{,}{}^{\alpha} - 2M^2\sin^2\phi). \qquad (2)$$

The sine-Gordon field itself satisfies the equation

$$[\sqrt{-g}\,\phi_{,}{}^{\mu}]_{,\mu} + \sqrt{-g}\,M^2\sin\phi = 0 \qquad (3)$$

$$g \equiv \det g\mu\nu. \qquad (4)$$

Unfortunately, the system of equations (1), (2), and (3) is a highly non-linear set of partial differential equations the solution of which is generally very difficult. However, if we assume that ϕ is small in amplitude, we can effectively decouple the equations. In this case we first solve equation (1) for a vacuum metric ($T\mu\nu = 0$) then solve the sine-Gordon equation (3) on this background metric. We are essentially assuming that the right hand side of (1) is essentially zero; that is, the influence of ϕ upon the metric is a negligible perturbation, but ϕ is not so small that we must linearize the sinϕ term in (3). In this case we can see non-linear effects in the propagation of ϕ without having to account for the gravitational field generated by ϕ. This is true, as an example, for water waves at the surface of the Earth. Here non-linear propagation does not mean that we must consider the gravitational field of the wave.

Consider the special case of the vacuum Kasner (2) line-element

$$ds^2 = dt^2 - t^{2p_1}dx^2 - t^{2p_2}dy^2 - t^{2p_3}dz^2 \qquad (5)$$

where

$$p_1 + p_2 + p_3 = p_1{}^2 + p_2{}^2 + p_3{}^2 = 1$$

In this case

$$\sqrt{-g} = t. \qquad (6)$$

For simplicity, we will assume that $\phi = \phi(t,z)$ only. In this case equation (3) becomes

$$\phi_{,tt} + t^{-1}\phi_{,t} - t^{-2p_3}\phi_{,zz} + M^2\sin\phi = 0. \qquad (7)$$

A futher simplification occurs if we choose $p_3 = 0$. This particular background metric has been the object of study concerning the propagation of electromagnetic waves (3). Equation (7) becomes in this case

$$\phi_{,tt} + t^{-1}\phi_{,t} - \phi_{,zz} + M^2\sin\phi = 0. \quad (8)$$

RESULTS

Before giving the solution to (8), we examine the small amplitude case, $\phi \ll 1$. In this limit

$$\sin\phi \approx \phi$$

and equation (8) becomes

$$\phi_{,tt} + t^{-1}\phi_{,t} - \phi_{,zz} + M^2\phi = 0, \quad (9)$$

which is readily solved by standard techniques. The solution is

$$\phi = AJ_0(Kt)\exp[\pm i\sqrt{K^2 - M^2}\,Z] \quad (10)$$

where A and K are constants. In the asymptotic time limit, $t \rightarrow \infty$, the solution represents a plane wave propagating along the z-axis, as long as $K^2 > M^2$.

Returning to the exact equation (8), if we perform the complex coordinate transformation

$$\begin{aligned} z &\rightarrow i\tau \\ t &\rightarrow i\rho, \end{aligned} \quad (11)$$

equation (8) becomes

$$\phi_{,\tau\tau} - \phi_{,\rho\rho} - \rho^{-1}\phi_{,\rho} + M^2\sin\phi = 0. \quad (12)$$

This is just the (2 + 1) dimensional SGE where τ is the time-like coordinate and ρ is the space-like co-ordinate. The solution is (4)

$$\phi = \pm 2\cos^{-1}\mathrm{sn}\left[\frac{\alpha}{K}(\rho - \beta\tau), K\right] \quad (13)$$

where α and β are constants related to the Lorentz factor, γ, and the wave speed, v, respectively, and sn is a Jacobian elliptic function sine amplitude of modulus K.

Transforming to the original co-ordinates we obtain

$$\phi = \pm 2\cos^{-1}\mathrm{sn}\left[\frac{i\alpha\beta}{K}\left(z - \frac{t}{\beta}\right), K\right].$$

One can use similar complex co-ordinate substitutions in order to utilize a procedure suggested by Liebbrandt (5) in order to obtain addition solutions to the SGE in this background. Leibbrandt has determined a method to obtain multi-soliton solutions to the (2 + 1) dimensional SGE (12). In order to apply his technique one needs only to follow Leibbrandt to obtain the multi-soliton solution to equation (12) and then apply the inverse transformation to obtain a multi-soliton solution to equation (8).

DISCUSSION AND SUMMARY

In this note we have briefly examined the solution to the SGE in a cosmological background metric. The SGE in a special case of the Kasner anisotropically expanding background is related to the (2 + 1) dimensional SGE of flat space via a complex co-ordinate transformation. This relationship can be exploited in order to adapt a known solution of the (2 + 1) dimensional SGE to the present case. A procedure recently proposed by Leibbrandt (5) can also be adapted in order to obtain multi-soliton solutions to the particular SGE investigated here.

The solution given here also has an application in a recent theory of gravity given by Rosenbaum et al. (6). The sine-Gordon field ϕ given here is related to the scalar field under consideration by Rosenbaum and co-workers (6) by

$$i\,\phi = \theta; \qquad \pm i \equiv \sqrt{-1}.$$

The solution(s) given here can, then, be applied to the investigation of that theory of gravity as well.

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A New Variant of *Plethodon wehrlei* in Kentucky and West Virginia[1]

Paul V. Cupp, Jr. and Donald T. Towles

Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

Abstract

A new variant of *Plethodon wehrlei* was discovered in Letcher County, Kentucky and Summers County, West Virginia. The specimens from Kentucky represent a new state record for this species, and extend the known geographic range of the species by 85 km. This variant differs from other *P. wehrlei* in its possession of large, yellow spots on the dorsum.

Introduction

A new variant of Wehrlei's salamander, *Plethodon wehrlei*, was found in SE Kentucky by D. T. Towles and in SW West Virginia by R. Highton. Highton (pers. comm.) collected a juvenile of this morph 4 km N of Hinton, Summers County, West Virginia on 8 May 1981. Subsequent visits to this site disclosed no additional specimens. Towles collected an adult and a juvenile on 13 June 1981 from a shale-rock cliff on a hillside above Line Fork Creek in Lilley Cornett Woods, Letcher County, Kentucky. Subsequent visits disclosed only 6 additional specimens, 1 adult and 5 juveniles. The animals from Kentucky were found primarily at night on wet areas of the cliff face during and following periods of rainfall.

The specimens had a brownish ground color with relatively large (1–2 mm), irregularly-shaped, yellow spots scattered over the dorsum and extending on to the upper portion of the tail (Fig. 1). In adults and juveniles, the yellow spots are usually present at irregular intervals in 2 rows over the dorsum. Also, juveniles from the 2 separate localities in Kentucky and West Virginia are very similar in color pattern. There are many small, light spots on the lateral surfaces of the body, the sides of the head and under the neck, extending down to the chest. The venter and underside of the tail are light gray. All specimens have 17 costal grooves and distinctly webbed toes as is characteristic of *P. wehrlei* (1).

Both adults were 52 mm in snout–vent length and 6.5 mm in head width. The juveniles averaged 31 mm in snout–vent length and 4.3 mm in head with (n = 6).

Specimens from other populations of *P. wehrlei* are not known to have large, yellow spots. Small, red spots are present on the dorsum of juveniles in some localities (1, 2, 3). Red dorsal spots are present in adult *P. wehrlei* in the southern part of their geographic range (1, 3, 4). Newman (4) described a red-spotted population from Montgomery County, Virginia as a distinct species, *P. jacksoni*, later synonymized with *P. wehrlei* (1). There is considerable variation of pigmentation in

Fig. 1. Yellow-spotted variant of *Plethodon wehrlei* from Kentucky. Scale = 10 mm.

[1] Publication no. 8 from Lilley Cornett Woods Appalachian Ecological Research Station, Eastern Kentucky University.

P. wehrlei from various localities (1, Thomas Pauley pers. comm.). In the morph described here, the red is apparently replaced by a yellow pigment.

The reported geographic range of *P. wehrlei* extends from SW New York through Western Pennsylvania, West Virginia and Virginia into North Carolina (1, 5). The occurrence of *P. wehrlei* in Letcher County, Kentucky extends the geographic range of this species NW by 85 km from the nearest reported locality at White Top Mountain, Virginia; this is the first report of this species from the state. Because the shale-rock habitat extends over much of eastern Kentucky it is likely that other populations will be located.

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NOTES

A Report on the Occurrence of *Chrysamoeba radians* Klebs (Chrysophyceae) in Kentucky—In April 1980, a water sample was collected from a small marsh alongside Jenny Ridge Road in the northern portion of Land-Between-the-Lakes (LBL), Trigg Co., Kentucky. Dense growths of *Spirogyra* and *Mougeotia* were present in the marsh and the water temperature and pH were 14 C and 6.3, respectively. Microscopic examination of the sample revealed the presence of an infrequently encountered chrysophycean alga, *Chrysamoeba radians* Klebs. This alga has been described from various localities in the United States (Prescott, Algae of the Western Great Lakes Area, Wm. C. Brown Co., Dubuque, Ia., 1962; Smith, Bull. Wis. Nat. Hist. Surv. 57:1–243, 1920; Smith, The Fresh-Water Algae of the United States, McGraw-Hill Co., N.Y., 1950; Tiffany, Contr. Franz Theodore Stone Lab, 6:1–112, 1934; Whitford and Schumacher, A Manual of Fresh-Water Algae, Sparks Press, Raleigh, N.C., 1973), but has not been reported from Kentucky (Dillard, An Annotated Catalog of Kentucky Algae, Ogden College, Western Kentucky Univ., Bowling Green, Ky., 1974; Dillard and Crider, Trans. Ky. Acad. Sci. 31: 66–72, 1970; Dillard, Moore, and Garrett, Trans. Ky. Acad. Sci. 37:20–25, 1976). The living LBL specimen was studied for several weeks and a number of photographs and drawings were made.

The genus *Chrysamoeba* (Klebs, Z. Wiss. Zool. 55:353–445, 1893) includes those non-loricate rhizopodial chrysophycean algae with a temporary flagellate stage in their life cycle, the cells of which do not remain attached by their rhizopodia after division. Several investigators (Doflein, Arch. Protistenk. 44:149–213, 1922; Hibberd, Br. Phycol. J. 6: 207–223, 1971; Mack, Ost. Bot. Z. 98:249–279, 1951; Penard, Proc. Acad. Nat. Sci. Philad. 73:105–168) have provided detailed descriptions of the type species, *C. radians*. Eight additional species, *C. planktonica* (Pascher, Ber. Dt. Bot. Ges. 29:523–532, 1911), *C. nana*, (Scagel and Stein, Can. J. Bot. 39: 1205–1213, 1961), *C. pyrenoidifera* (Korshikov, Arch. Protistenk 95:22–44, 1941), *C. tenera* (Matvienko, Notul. Syst. Inst. Cryptog. Horti. Bot. Petropol, 7: 10–18, 1951), *C. microkonta* (Skuja, Nova Acta R. Soc. Scient. Upsal., Ser. IV, 16:1–404, 1956), *C. helvetica* (Reverdin, Arch. Sci. Phys. Nat., 1:302–345, 1919), *C. extensa* (Korshikov, 1941) and *C. gelatinosa* (Bourrelly, Revue Algol., Mem. Hors. Ser., 1:1–412, 1957), have been described. The last 5 species have been placed in synonymy of *C. radians* (Hibberd, 1971). Distinguishing characteristics of the freshwater species of *Chrysamoeba* are presented in Table 1.

Chrysamoeba radians is distinguished from *C. pyrenoidifera* by its lack of a noticeable pyrenoid. Hibberd (1971) reported pyrenoids in the organism he identified as *C. radians*, but they were observable only with the electron microscope. In contrast, the pyrenoids of *C. pyrenoidifear* can be seen with the light microscope. *C. planktonica* is readily distinguishable from *C. radians* by its smaller size and from *C. pyrenoidifera* by its smaller size and absence of a distinct pyrenoid. Hibberd (1971) considers Klebs' (1893) diagnosis of *C. radians* (Table 1) to be somewhat in error since the drawing accompanying his description depicts one (not two) chloroplast per cell. This error has been perpetuated by Smith (1950), Prescott (1962), and Whitford and Schumacher (1973).

The characteristics of the *Chrysamoeba* collected from LBL corresponded to those presented for *C. radians* by Hibberd (1971). The naked cells were ovoid (5.0 to 6.6 × 6.0 to 8.2 μm) with several long, thin acicular pseudopodia (Fig. 1). Each cell had a single curved plate-like chloroplast, 2 contractile vacuoles, and a single nucleus. A pyrenoid or stigma was not observed. The delicate bifurcate pseudopodia arose laterally and several had small granules which were observed moving along them. Asexual reproduction was by cell division with the daughter cells remaining attached for a short time by their pseudopodia (Fig. 2). Although a free swimming flagellate stage was not observed, close microscopic inspection revealed the presence of a short flagellum on the amoeboid stage. Hibberd (1971) observed a second much reduced flagellum in electron microscopic investigations of the alga he identified as *C. radians*. This vestigial flagellum was not observed with the light microscope.

Pascher (Die Susswasser-Flora Deutschlands, Österreichs und der Schweiz, 2, Flagellatae II, 7–

TABLE 1.—DISTINGUISHING CHARACTERISTICS OF THE FRESHWATER SPECIES OF *Chrysamoeba* KLEBS

Species	Cell size (μm)	Number of chloroplasts	Pyrenoid*	Number of contractile vacuoles	Reference
C. radians	12–15	2	—	2–3	Klebs (1893)
C. radians	4.5–8.5 × 5–12	1	—	2	Lund (1937)
C. radians	15–18	1	—	1	Penard (1921)
C. radians	6–10	1	—	2	Hibberd (1971)
C. planktonica	2–4	1	—	1	Pascher (1911)
C. pyrenoidifera	16	1	+	1	Korschikov (1941)

* — indicates absence upon observation of cells with light microscope.

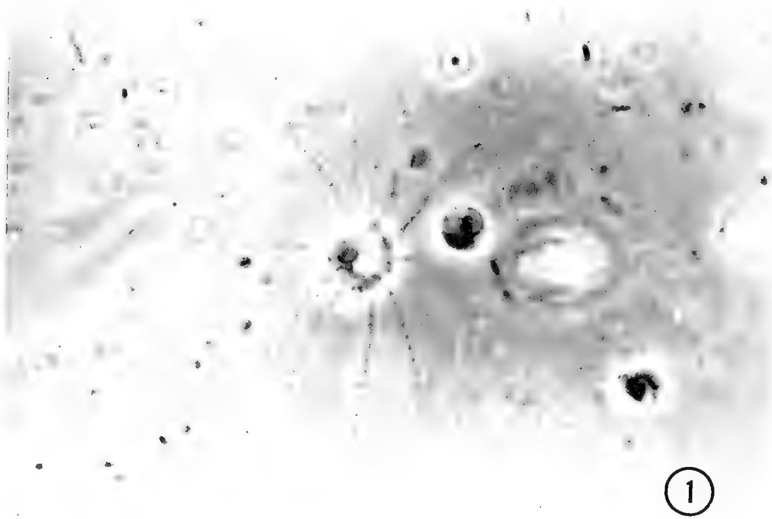

FIG. 1. Vegetative cell of *Chrysamoeba radians* showing pseudopodia, contractile vacuole, and plastid.

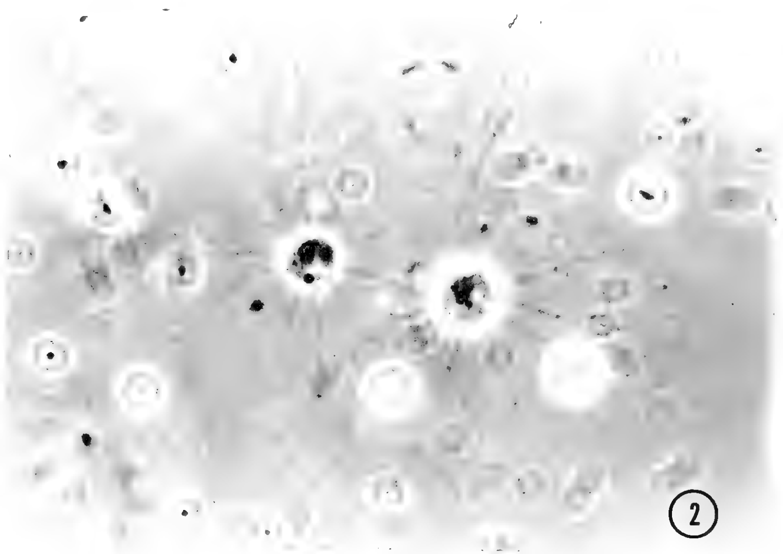

FIG. 2. Two vegetative cells attached by a pseudopodium.

95, 1913) considered the presence of a flagellate stage as requisite for inclusion of rhizopodial forms in *Chrysamoeba*. He thus erected the genus *Rhizochrysis* for amoeboid forms morphologically similar to *Chrysamoeba* but for which a flagellate stage was not observed. He included 3 species in this genus. Two, *R. planktonic* Pascher (Pascher) and *R. scherffelii* Pascher, had been described previously as *C. planktonic* (Pascher 1911) and *C. radians* (Scherffel, Bot. Ztg. 59:143–158, 1901), respectively. The third, *R. crassipes*, was described by Pascher as a new species. Smith (1920) included a fourth organism, *R. limnetica*, in this genus. However, Matvienko (Handbook of Freshwater Algae of the U.S.S.R., 3, Chrysophyta, Moscow, 1954) disagreed with Pascher's emphasis on the use of flagellar characters in separating *Rhizochrysis* and *Chrysamoeba* and combined these genera. Hibberd (1971) noted the difficulty in observing flagella on the amoeboid cells and that these structures are ephemeral in some species. He concluded that presence or absence of flagella should not be used as a sole characteristic for separating these genera.

Some taxonomic treatises (Smith 1920, Prescott 1962, Whitford and Schumacher 1973) depict *Chrysamoeba* with shorter and stouter pseudopodia than *Rhizochrysis*. However, the observations of *C. radians* by the author and Hibberd (1971) indicate that the flagellate amoeboid cells have several long, delicate pseudopodia which may be granulate in appearance. The presence of granules was not reported in the above mentioned treatises. It therefore seems that the use of pseudopodial characters in separating these genera is questionable. On the basis of this information, I suggest that there is little, if any, justification in assigning organisms to *Rhizochrysis*.

Our knowledge of the distribution and life histories of chrysophycean algae is limited. Factors which control their occurrence are poorly understood and their collection is essentially a matter of chance. Our inability to establish laboratory cultures of chrysophycean algae has denied us opportunities to experimentally assess their growth requirements and morphological development. Several investigators (Dillard, J. Elisha Mitchell Sci. Soc. 86:128–130, 1970; Hibberd 1971; Nicholls, Phycol. 20:131–137, 1981; Whitford, Phycol. 8:199–200, 1969) have been frustrated in their attempts at collection and cultivation of these organisms. Similar problems were encountered in the present study of *Chrysamoeba radians*. Repeated trips to the LBL marsh failed to yield additional specimens and attempts at establishing laboratory cultures of this alga were unsuccessful. Such problems are undoubtedly a major cause of the taxonomic confusion that shrouds chrysophycean algae.

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Some delphacid planthoppers of Kentucky (Homoptera).[1]—The delphacid fauna of Kentucky is poorly known. Among the few published records are *Stobaera tricarinata* Say (Slosson, Ent. News 7:262–265, 1896), *Liburniella ornata* Stal (Forbes and Hart, Bull. Il. Agric. Exp. Sta. 60:397–532, 1900) and *Delphacodes puella* Van Duzee (Osborn, Ann. Rept. Ohio St. Acad. Sci. 8:65, 1900 according to Metcalf, General Catalogue of Hemiptera, Ed China, 1943). We verified and failed to find any mention of Kentucky in the reports of Forbes and Hart and Osborn. Sperka and Freytag (Trans. Ky. Acad. Sci. 36(3/4):57–62, 1975) reported collecting *Delphacodes* spp. including *Delphacodes lutulenta* (Van Duzee), in connection with the parasitism by mermithid nematodes.

Delphacids were collected using D-Vac sampler and an insect net in pastures of Fayette and other counties of Kentucky from May to October of 1980 and 1981. The collected specimens were killed and preserved in 75% ethyl alcohol until sorted and identified. Confirmation of many identified specimens was made by J. P. Kramer, U.S. National Museum, Washington, D.C.

Adult delphacids were found in pastures from the early part of May to the end of October. By early May, the delphacids began reproduction as evidenced by the presence of nymphs by early June. *Delphacodes lutulenta* was the most abundant delphacid in this area (unpublished data). During the 2 collecting seasons, a total of 6 genera and 14 species were collected, including 8 *Delphacodes*, 1 *Liburniella*, 1 *Sogatella*, 1 *Euides*, 2 *Pissonotus* and nymphs that looked like *Stenocranus*. Among these, *Delphacodes campestris, D. lateralis, D. mcateei, D. andromeda, D. uhleri, D. montezumae, Sogatella kolophon, Euides weedi, Pissonotus flabellatus* and *P. marginatus* are new records for the state. The counties where *D. lutulenta* and *D. campestris* were collected are shown in Fig. 1. Other species were collected in Fayette County. *Stobaera tricarinata* was collected from Bullitt County.

[1] This paper is published with the approval of the Director of the Kentucky Agricultural Experiment Station as Journal Article No. 82-7-207.

FIG. 1. Map of Kentucky showing counties where *Delphacodes lutulenta* (●) and *Delphacodes campestris* (*) were collected.

TABLE 1.—LIST OF KENTUCKY DELPHACIDS WITH ADDITIONAL DATA

Taxa	Collection dates	Sex collected	Wing forms*		Identification confirmed by:
			B	M	
Delphacodes lutulenta Van Duzee	May 1–Oct 30	Both	X	X	Freytag & Giri
D. campestris (Van Duzee)	May–Oct	Both	X	X	Kramer
D. puella (Van Duzee)	July–Oct	Both	X	X	Kramer
D. lateralis (Van Duzee)	Sept 25	♂	X	X	Kramer
D. andromeda (Van Duzee)	Aug 14–21	♂	X	X	Kramer
D. mcateei Muir & Giffard	Aug 14–Sept 18	♂	X	X	Kramer
D. uhleri Muir & Giffard	Aug 21–Sept 25	♂	X		Kramer
D. montezumae Muir & Giffard	June 3	♂		X	Freytag & Giri
Liburniella ornata (Stal)	May–Nov	Both	X	X	Kramer
Liburniella sp.	Aug 28	♀		X	?
Sogatella kolophon (Kirkaldy)	Sept 18–Oct 23	Both		X	Kramer
Euides weedi (Van Duzee)	July 24–Oct 23	Both	X	X	Kramer
Pissonotus flabellatus (Ball)	Aug 7–Oct 10	Both	X	X	Kramer
P. marginatus Van Duzee	Sept 4	♂	X		Kramer
Stenocranus sp. ?	June 17–Aug 21	Nymphs			Kramer
Stobaera tricarinata (Say)[1]	?	?			Metcalf (1943)

* B = Brachypterous, M = Macropterous.
[1] Slosson 1896.

Some of the planthoppers showed wing dimorphism of short wing (Brachypterous) and long wing (Macropterous) the time of occurrence, sexes, wing-forms and the persons who confirmed the identification are summarized in the Table 1. Most species were collected from pastures dominated by tall fescue (*Festuca arundinacea* Schreb.), orchardgrass (*Dactylis glomerata* L.) and Kentucky bluegrass (*Poa pratensis* L.), with green foxtail (*Setaria faberi* Herrm.), Nimblewill (*Muhlenbergia schreberi* Gmel.), hairy crabgrass (*Digitaria sanguinalis* L.) appearing in the later part of the summer or fall, either in pure stand or mixed with broadleaf weeds.

We attempted to colonize the species of planthoppers in which both males and females were collected. *Delphacodes lutulenta* and *D. campestris* were colonized on the following plants: *F. arundinacea*, *D. glomerata*, *P. pratensis*, *S. halepense*, *D. sanguinalis*, *Triticum aestivum* L. Var. Abe (wheat) and *Avena sativa* L. (oats). *Delphacodes puella* colonized on *D. sanguinalis* while *L. ornata*, *S. kolophon* colonized on *T. aestivum* and *A. sativa*.

TABLE 2.—SPECIES OF DELPHACIDS TESTED FOR COLONIZATION ON GRASSES

Species of Delphacids	Plants tested	Colonized on grasses indicated[1]
Delphacodes lutulenta	1. *F. arundinacea*, 2. *D. glomerata*, 3. *P. pratensis*, 4. *D. sanguinais*, 5. *S. halepense*, 6. *T. aestivum*, 7. *A. sativa*	1, 5, 6, & 7
D. campestris	1. *F. arundinacea*, 2. *D. glomerata*, 3. *P. pratensis*, 4. *D. sanguinais*, 5. *S. halepense*, 6. *T. aestivum*, 7. *A. sativa*	1, 5, 6, & 7
D. puella	4. *D. sanguinalis*, 6. *T. aestivum*, 7. *A. sativa*	4
Liburniella ornata	1. *F. arundinacea*, 6. *T. aestivum*, 7. *A. sativa*	6 & 7
Sogatella kolophon	6. *T. aestivum*, 7. *A. sativa*	6 & 7
Pissonotus flabellatus	1. *F. arundinacea*, 6. *T. aestivum*, 7. *A. sativa*	—
P. marginatus	1. *F. arundinacea*, 6. *T. aestivum*, 7. *A. sativa*	—

[1] The numbers correspond to the numbers on the column of plants tested.

Methods of colonization are discussed by Giri (dissertation, Univ. Kentucky, 1982). Colonization was considered successful if oviposition and development of immatures to adults took place. All species tested except the 2 *Pissonotus* spp. colonized on one or more of the tested plants (Table 2).—M. K. Giri and P. H. Freytag,[2] Dept. of Entomology, Univ. Kentucky, Lexington, Kentucky 40546, USA.

[2] Graduate Student and Professor.

Tuomeya and *Sirodotia,* Freshwater Red Algae New to Kentucky.—The taxonomy, distribution, and ecology of the freshwater red algae of Kentucky are poorly known, as exemplified by the recent addition of 3 red algal genera to Kentucky's flora (Camburn, Trans. Ky. Acad. Sci. 43:74–79, 1982). The present investigation adds *Tuomeya americana* (Kutzing) Papenfuss and *Sirodotia suecica* Kylin sensu Flint to the known flora. Historically, *T. americana* has been referred to as *T. fluviatilis* Harvey, and all literature citations herein have used this latter name.

Both *T. americana* and *S. suecica* are widely distributed in the eastern United States (Flint, Freshwater Red Algae of North America, Vantage Press, New York, 1970). Few authors, however, have specifically addressed the habitat requirements of these algae. In streams of southern Ontario (Sheath and Hymes, Can. J. Bot. 58:1295–1318, 1980), *S. suecica* was a minor component of the epilithic flora in riffles, while *T. americana* commonly occurred in riffles as well as areas of slower flow. *Tuomeya americana* was likewise reported to grow in great abundance on rocks in a swiftly flowing stream in Pennsylvania (Webster, Butler Univ. Bot. Stud. 13: 141–159, 1958).

Tuomeya americana and *S. suecica* were collected from the lower reaches of Kinniconick Creek in northeastern Lewis County, Kentucky, on 15–16 September 1982. This high-quality stream is characterized by frequent, shallow riffles which have slow to moderate current. Extending upstream from the mouth, 13 aquatic survey stations were established along a 60 km segment of the stream. *Tuomeya americana* and *S. suecica* occurred at 6 and 1 stations, respectively. *Tuomeya americana* grew attached to cobbles, boulders, and bedrock in shallow riffle areas of slow to moderate current. At some stations, this alga formed profuse growths composed of large, dark, linear masses (up to 5.3 cm in length) which covered most of the rock surfaces in large areas of the stream. Growth of *S. suecica* was restricted to a single boulder in an area of moderate current.

With these additions, the freshwater red algal genera known from Kentucky are *Batrachospermum, Chroodactylon* (as *Asterocystis*), *Lemanea, Rhodochorton* (as *Audouinella*) (Dillard, An Annotated Catalog of Kentucky Algae, W. Ky. Univ., Bowling Green, Ky., 1974), *Boldia, Compsopogon, Thorea* (Camburn 1982), *Sirodotia,* and *Tuomeya.* The strickly terrestrial red alga *Porphyridium* was reported from the phytoplankton of Kentucky Reservoir (Prather, Kinman, Sisk, Dobroth, and Gordon, Trans. Ky. Acad. Sci. 43:27–42, 1982); however, this habitat suggests a probable misidentification.

The apparent rarity of *T. americana* in Kentucky is probably due in part to its resemblance to aquatic bryophytes, while *S. suecica* is easily confused with the commonly occurring genus *Batrachospermum.* Consequently, their rarity may be a function of misidentification as well as a lack of comprehensive collecting in many regions of the state.

I wish to thank Dr. Franklyn D. Ott, Memphis State University, for verifying these specimens and Mr. Melvin L. Warren, Jr. of the Kentucky Nature Preserves Commission for editorial comments.—Keith E. Camburn, Kentucky Nature Preserves Commission, 407 Broadway, Frankfort, Kentucky 40601.

Three-Dimensional Modeling of Residual Surfaces.—Higher-order polynomial regression equations, in trend-surface analysis, may reflect the variation in particular values with geographic or spatial distributions with more accuracy than lower-order surfaces, but the low-order surfaces may be more useful in isolating important local or regional trends that may exist over larger areas. Thus, surface analyses can be considered a process of filtering input signals (measured values or Z-values), where the surface represents the resultant signal after filtering. The order of the surface determines the upper limit of variability or frequency of the input data that will pass through the gate or filter. Localized or site-specific variation will be blocked by the filter when lower orders are used, and it will be increasingly transmitted as the order of the surface increases. This filtering process is in contrast to standard linear interpolation used in contouring, where all the input data are taken in equal importance (Harbough and Merriam, Computer applications in

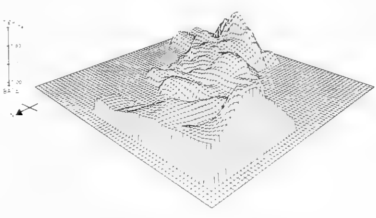

FIG. 1. First order residual surface for Bouguer gravity, as viewed from the northwest direction. (Positive residual values are in milligals.)

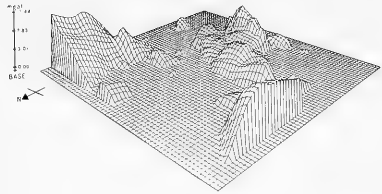

FIG. 2. Second order residual surface for Bouguer gravity, as viewed from the northwest direction. (Positive residual values are in milligals.)

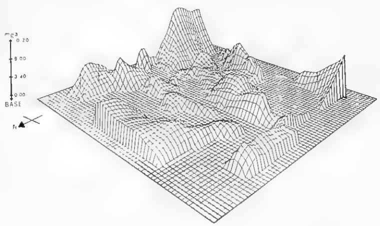

FIG. 3. Third order residual surface for Bouguer gravity, as viewed from the northwest direction. (Positive residual values are in milligals.)

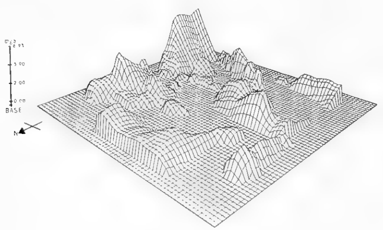

FIG. 4. Fourth order residual surface for Bouguer gravity, as viewed from the northwest direction. (Positive residual values are in milligals.)

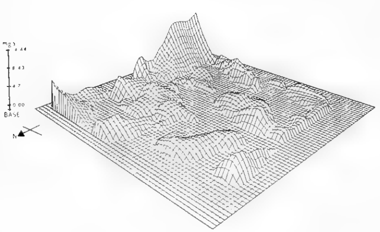

FIG. 5. Fifth order residual surface for Bouguer gravity, as viewed from the northwest direction. (Positive residual values are in milligals.)

stratigraphic analysis, John Wiley, NY, 1967; Dougenik and Sheehan, SYMAP user's reference manual, Harvard U., Cambridge, MA, 1979). However, a visual check on the accuracy of the filtering mechanism of trend-surface analysis would be very helpful in localing sources of noise or localized variation. In addition, visual inspection would be of great value in determining the effectiveness of increasing the order of the regression equations to account for additional variation of the spatially oriented data.

A recent study by Henning and Smith (Trans. Ky. Acad. Sci. (abs.) 43 (1–2):92, 1982) dealing with a gravity survey of Early and Middle Precambrian rock units in southwestern Marathon County, central Wisconsin, utilized trend-surface analyses. Bouguer and free-air gravity values collected from 208 stations were analyzed to determine regional trends and sequentially compared with hand-specimen petrology on representative samples of 738 samples collected at approximately 100 sites to determine if an interpretative relationship existed between the gravity anomalies and major lithographic units in the area. However, in determining the effects of increasing the order of the regression equation on local variation and where residuals were occurring, the authors created three-dimensional plots at The University of Akron's computer center, via an incremental drum plotter reading a data matrix from tape. The data matrix was created by using SYMAP and creating a tape file for each residual surface, first through sixth order, for Bouguer and free-air gravity values. The original gravity stations were evenly distributed over the entire study area.

Figures 1 through 5 are representative three-dimensional plots of positive residual surfaces of Bouguer and free-air gravity values, measured in milligals. All figures are viewed from the NW, 30° from the datum plane. Figures 1 through 5 are the first complete to the fifth-order residual surfaces for Bouguer gravity, respectively.

From a brief visual inspection of the various models of the positive residual surfaces (Fig. 1) a definite NW–SE trend of residual values or localized noise, not explained by the first degree surface, is illustrated. As one inspects the second residual surface (Fig. 2), the NW–SE trend is still visable, as well as a large residual anomaly in the NE corner of the study area. Figures 3, 4, and 5 illustrate the greater spatial diversity or spread of the noise in the gravity values, as the order of the surface increases.—A. D. Smith and R. J. Henning, Dept. of Geol., East. Ky. Univ., Richmond, Kentucky 40475.

First Records of *Ligumia subrostrata, Toxolasma texasensis*, and *Uniomerus tetralasmus* for Kentucky.—The mussel fauna of Kentucky is relatively well-known; however, the lowland areas of the western one-third of the state have only recently been examined for unionid species. Aquatic biota surveys in Ohio River tributaries and the lower Green, Tradewater, and Clarks rivers resulted in the addition of three pelecypod species to the fauna of Kentucky: *Ligumia subrostrata, Toxolasma*

(=*Carunculina*) *texasensis*, and *Uniomerus tetralasmus*.

Price (Nautilus 14:75–79, 1900) mentioned *L. subrostrata* from Kentucky although no locality or drainage was given, and based on Price's report, Ortmann (Ann. Carnegie Mus. 17:167–189, 1926) speculated that the species may be present in the lower Green River. Ortmann's speculation was recently confirmed upon examination of specimens from a Pond River oxbow in Hopkins Co. (G. J. Fallo, pers. comm.). Our specimens were collected in Weirs Creek Swamp (Tradewater River drainage), 13 August 1980, 3.4 km SE of the junction of KY 814 and U.S. 41A and 6.4 km WSW of Nebo, Hopkins Co. and West Fork Clarks River (Tennessee River drainage), 4 May 1982, at the Ky 131 crossing, Graves Co. Although these are the first substantiated records of the species from Kentucky, its occurrence is not unexpected since the species is known throughout the Mississippi River drainage north to Wisconsin and South Dakota (Parmalee, Ill. State Mus. Pop. Sci. Ser. 8:1–108, 1967).

The record reported herein for *T. texasensis* represents the first published locality for Kentucky. Although some authors regard *T. texasensis* as a synonym (Johnson, Bull. Mus. Comp. Zool. Harvard Univ. 149:77–189, 1980) or possible form (Parmalee 1967) of *T. parva*, we follow Stansbery (Ohio State Mus. Zool. Rept. No. 4:1, 1982) in assigning the specific epithet. The species was discovered in Smith Ditch (Tradewater River drainage) on 9 December 1981 at the U.S. 60 crossing in Union Co. Parmalee (1967) characterized the distribution as the southern Mississippi River drainage with the northernmost populations occurring in southern Illinois.

Although Bickel (Sterkiana 28:7–20, 1967) included *U. tetralasmus* in a list of Kentucky species based on Simpson (A Descriptive Catalogue of the Naiades, or Pearly Freshwater Mussels: Parts I and II, Bryant Walker, Detroit, Mich., 1900), no published drainage or locality records are available for the state. The species was collected from the following Kentucky localities: Craborchard Creek (Tradewater River drainage), 9 December 1981, at the KY 1340 crossing, Webster Co.; Donaldson Creek (Tradewater River drainage), 10 December 1981, at the KY 293 crossing, Caldwell Co.; Smith Ditch (Tradewater River drainage), 9 December 1981, U.S. 60 crossing, Union Co.; Crane Pond Slough (Green River drainage), 23 July 1980, 3.4 km NE Pleasant Ridge, Daviess Co.; Capertown Swamp (Ohio River drainage), 12 May 1981, 6.3 km SW town of Harrods Creek, Jefferson Co.; Canoe Creek (Ohio River drainage), 10 September 1908, at U.S. 41A crossing, Henderson Co. The records cited herein indicate that *U. tetralasmus* is widespread in western Kentucky and apparently common in the Tradewater River. The species is widely distributed in the Mississippi River drainage (Parmalee 1967).

The 3 species noted herein for the first time in Kentucky are all inhabitants of ponds, sloughs, backwaters, and other soft-bottomed lentic environments (Parmalee 1967). Additionally, as noted, they are all widespread in the Mississippi River drainage and have been reported in several surrounding states. Based on the available evidence, the lack of substantiated records for these species is not due to their rarity or limiited distribution but is a result of the neglect of collecting in their preferred habitats. Most pelecypod surveys have focused on the upland portions of Kentucky's rivers, and little effort has been directed toward lowland habitats. We feel that these species are more widely distributed and common than our records indicate, and the Kentucky range will undoubtedly be expanded as survey efforts focus on the lowland habitats of western Kentucky. Nevertheless, documentation of *L. subrostrata*, *T. texasensis*, and *U. tetralasmus* in Kentucky further expands our knowledge of the speciose Kentucky fauna and emphasizes the need for additional collecting in poorly known regions of the state.

We wish to thank Dr. David H. Stansbery, Ohio State Museum of Zoology, for identifying various specimens and Mr. Keith E. Camburn of the Kentucky Nature Preserves Commission for editorial comments.—Melvin L. Warren, Jr., Kentucky Nature Preserves Commission, 407 Broadway, and Samuel M. Call, Division of Environmental Services, 18 Reilly Road, Frankfort, Kentucky 40601.

Comparison of Serum Proteins and Esterases in Three Subspecies of the Bobwhite Quail (*Colinus virginianus*).—This study was conducted to determine if differences in biochemical characters exist between 3 subspecies of the bobwhite quail: *Colinus virginianus virginianus*, *Colinus virginianus*, and *Colinus virginianus texanus*. The presence of significant dissimilarities could possibly support the credibility of the subspecies of this species. A number of avian systematists believe the category of subspecies to be pointless (Dorst, The Life of Birds. Columbia Univ. Press, Vol. 1; 1974) because the subspecies may be synonymous with local populations (Farner and King, *Avian Biology*. Academic Press, New York, Vol. 1; 1971).

Montag and Dahlgren (The Auk 90:318–323, 1973) found esterases, transferrins, and pre-albumins the most likely serum components to show intraspecific variation. This study was, therefore, based upon a qualitative and quantitative comparison of serum proteins (including transferrins and pre-albumins) and serum esterase isozymes.

Sibley and Johnsgard (Condor 61:85–95, 1959) established that individual avian species can be identified by electrophoretic analysis of their sera. Sibley (Condor 102:215–284, 1960) obtained valuable taxonomic information at the species level by studying avian egg-white proteins using paper electrophoresis.

Transferrins are known to show genetic variation in a wide range of species. Mueller et al. (Genetics 47:1285–1392, 1962) were able to distinguish *Columba livia* and *C. guinea* by means of transferrin phenotypes. Baker and Hanson (Comp. Biochem. Physiol. 17:997–1007, 1966) found 3 *Branta canadensis* subspecies to have different transferrin phenotypes than those observed in 4 other subspecies.

Quinteros et al. (Genetics 50:579–582, 1964) found

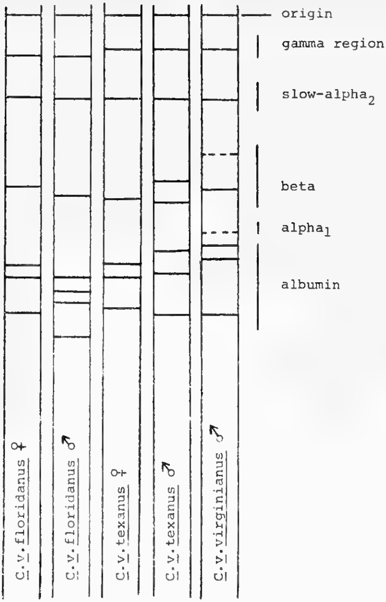

FIG. 1. Esterase pattern of three subspecies of the bobwhite quail. Dashed lines indicate esterase isozymes occasionally present.

TABLE 1.—MEANS OF SERUM PROTEIN FRACTIONS OF THREE SUBSPECIES OF THE BOBWHITE QUAIL

	C. v. floridanus n = 6	*c. v. virginianus* n = 39	*C. v. texanus* n = 13
pre-albumin	1.78	2.12	2.09
albumin	34.28	29.40	31.81
$alpha_1$	4.38	4.27	4.74
beta	19.58	20.71	19.19
$slow\text{-}alpha_2$	13.64	16.92	16.92
gamma	6.78 -------	10.40 -------	6.05

---- indicates significant difference at the $P < 0.05$ level.

3 albumin phenotypes, possibly controlled by a pair of codominant alleles, in the hybrid descendants of 2 species of turkey, *Meleagris gallopavo* and *M. ocellata*. Baker and Hanson (loc. cit.) found the serum albumins of all *Branta* and *Anser* geese to be identical in borate gels except for 1 individual. Although Baker et al. (Comp. Biochem. Physiol. 17: 467–499, 1965) were able to distinguish *Phasianus colchicus* from *P. versicolor* on the basis of serum albumin mobility, they could not differentiate *P. colchicus* subspecies on the basis of any serum protein.

Kristjansson (Genetics 48:1059–1063, 1963) observed 2 electrophoretically different pre-albumins in swine. Three pre-albumin phenotypes have been detected in some inbred strains of mice using starch-gel electrophoresis (Shreffler, Genetics 49:629–634, 1964). Baker and Hanson (loc. cit.) found considerable individual variation in the pre-albumins of geese. They observed up to 6 pre-albumin bands, but no more than 4 bands occurred in any one individual.

Serum esterases show considerable variation in the species that have been studied. Glick (Comp. Biochem. Physiol. 45:109–111, 1973) identified 6 areas of esterase activity on acrylamide gel from the sera of New Hampshire chickens. Baker and Hanson (1966) found quantitative and qualitative variation in esterase isozymes of geese (*Branta* and *Anser*), but were unable to show any pattern as being species specific. Baker et al. (loc. cit.) also found considerable quantitative and qualitative variation in serum esterases of the ring-necked pheasant, *Phasianus colchicus*. Serum samples from *P. versicolor* and subspecies of *P. colchicus* showed a similar range of esterase variation (9 main regions of activity). Kaminski (Nature 209:723–725, 1966), found 6 active esterase components in the *Coturnix* quail.

The bobwhite subspecies used in this study were obtained from Kentucky and Illinois (*C. v. virginianus*), Florida (*C. v. floridanus*), and Texas (*C. v. texanus*). Thirty one-day-old Kentucky bobwhites were obtained from the Game Farm in Frankfort, Kentucky, and were kept in captivity for 1 year. Fifty 8-week old Illinois birds were obtained from a game farm at Mt. Vernon, Illinois and were kept in captivity for 11 months. Six adult Florida and 13 adult Texas bobwhites were trapped in their respective states and kept in captivity for 6 months. The birds were kept in an isolated room in wire-floored cages, either individually or in groups, at ambient temperature and under natural lighting. The birds were given Purina game bird feed and water *ad libidum*. Approximately 1 ml of blood was obtained from the brachial vein of each bird. The blood was placed in 10 × 75 mm test tubes and allowed to coagulate. Samples were then centrifuged at 2,000 rpm for 10 minutes after which the serum was removed and stored at −20° C.

Twenty microliter aliquots for total protein and esterase runs were diluted 1:1 with 0.25 M sucrose and refrigerated until electrophoresis. The remaining serum was incubated at room temperature for 30 minutes with ferrous ammonium sulfate (0.1 g/ml) for the tranferrin sample, centrifuged, and 20 μl of the supernatant serum were removed and diluted 1:1 with 0.25 M sucrose.

Ten % cyanogum 41 polyacrylamide discs were used for total protein and transferrin separations and 6% discs were used for esterases. Gels were made up with and run in a Tris Borate buffer, pH 8.2. The discs were prerun at 36 mA and 200 volts for 30 minutes before the samples were added.

Twenty microliter aliquots were applied to each disc. Total protein separations were run at 36 mA (3mA per disc) and 200 volts for 4 hours and esterases were run at 36 mA and 200 volts for 2 hours.

After separation the gel discs were stained for either total proteins, transferrins, or esterase isozymes. Total protein gels were stored at 4°C and were kept moist until being scanned by a densitometer.

The protein pattern generally observed was composed of 6 regions: pre-albumin, albumin, $alpha_1$, beta, slow-$alpha_2$, and gamma globulins. Pre-albumin was the most anodal in migration followed by the other fractions in the above order. The pre-albumin portion consisted of the pre-albumin I, migrating just in front of the albumin fraction, and a pre-albumin II, migrating faster than pre-albumin I and sometimes separating into 2 bands. The albumin component separated into 2 fractions with slight differences in migration occurring. The $alpha_1$ fraction consisted of 2 or 3 faint bands. Beta, the next fraction, separated into 2 to 5 bands. Occasionally, the resolution of these beta bands was difficult due to the high concentration of the beta fraction. Following the beta fraction was the slow-$alpha_2$ component which separated into 1 large or 2 smaller bands. No tests were performed to validify the alpha fractions; they were named on the basis of protein fractions generally observed in polyacrylamide gels (Peacock et al., Science 147:1451–1453, 1965). The gamma fraction was an arbitrary name given to any protein fraction migrating slower than the slow-$alpha_2$ band.

Each protein fraction was recorded by a densitometer as per cent of the total scan. A Student's *t*-test was performed on each protein fraction between the 3 subspecies studied. Table 1 gives the means for each protein fraction and indicates which comparisons showed a significant difference. No significant difference was found between any of the protein fractions of *C. v. floridanus* and *C. v. texanus*. A significant difference was found between the gamma fractions of *C. v. virginianus* and *C. v. floridanus* and between the gamma fractions of *C. v. virginianus* and *C. v. texanus*. A single classification analysis of variance with unequal sample sizes (Sokal and Rohlf, Biometry, W. H. Freeman and Company, San Francisco, 1969) was performed to determine if the difference in gamma fractions was due to variation among the subspecies or variation within the subspecies. A significant added variance component was found among the subspecies at $P = 0.01$. To interpret this added variance, an estimation of variance components in a single classification anova with unequal sample sizes was performed. This test showed that 39.17% of the variation occurred among the 3 subspecies and 60.84% within the subspecies.

Six main regions of esterase activity were found in the sera of most of the bobwhites studies. Three bands migrated in the albumin region. The other bands migrated in the beta, slow-$alpha_2$, and gamma regions (Fig. 1). Forty six percent of *C. v. virginianus* had a faint $alpha_1$ region esterase. This band was not found in the other 2 subspecies. The beta region band was found in members of each subspecies studied, but all birds did not have it. A few members of each subspecies showed a fast beta region esterase. Thirty-six % of *C. v. virginianus* did not show the slow-$alpha_2$ but all birds of the 3 subspecies studied had the gamma band.

Johnsgard (Grouse and Quails of North America, Univ. Nebraska Press, Lincoln, 1973) suggested southern Mexico as a possible region of origin for the genus *Colinus*. The early pre-*virginianus* stock probably moved northward along the Gulf Coast, ultimately reaching the eastern United States where its expansion was limited on the north by cold winters and on the west by arid climates and sparse woody vegetation.

Although observed electrophoretic patterns showed some variation, no pattern was limited to any 1 subspecies. Different phenotypic patterns were observed in the $alpha_1$ and beta regions but it was not within the scope of this study to postulate any specific genetic control. The major esterase phenotypic variation occurred in the albumin region. Baker et al. (loc. cit.) found much of the individual esterase variability in the albumin region of ring necked pheasants. No esterase pattern could be correlated with sex, laying status, or subspecies. The results of this study support the belief of many avian taxonomists that the subspecies category for bobwhite quail is pointless. No significant variation in total protein or esterase electrophoretic patterns was found among the 3 bobwhite subspecies compared in this study.—D. R. Varney and Rebecca N. Tabatabai, Dept. Biol. Sci., Eastern Kentucky University, Richmond, Kentucky 40475.

Trans. Ky. Acad. Sci., 44(3–4), 1983, 168–170

NEWS AND COMMENT

Science Education Committee The following persons have been asked to serve on the Science Education Committee during 1983. President Rodriguez takes this opportunity to thank Ms. Neal for her continuing efforts on behalf of the Academy of Science.

Anna S. Neal (1984) (Chairperson)
Fayette County Public Schools
701 East Main Street
Lexington, Kentucky 40502

J. Truman Stevens (1984)
Department of Curriculum and Instruction
University of Kentucky
Lexington, Kentucky 40506

Sue K. Ballard (1985)
Department of Chemistry
Elizabethtown Community College
Elizabeth, Kentucky 42701

Foster Levy (1985)
Department of Biology
Pikeville College
Pikeville, Kentucky 41501

Joe Winstead (KAS Vice-President)
Department of Biology
Western Kentucky University
Bowling Green, Kentucky 42101.

* * * * *

Botany Foundation Fund President Rodriguez appreciates the willingness of the following individuals to serve on the Botany Foundation Committee.

Joe Winstead (1983) (Chairperson)
Department of Biology
Western Kentucky University
Bowling Green, Kentucky 42101

William S. Bryant (1983)
Thomas More College
Box 85
Ft. Mitchell, Kentucky 41017

Larry Geismann (1984)
Department of Biology
Northern Kentucky University
Highland Heights, Kentucky 41076.

* * * * *

Floristic Grant Fund Committee The following persons have been asked to serve on the Floristic Grant Fund Committee. President Rodriguez extends his thanks for their acceptance of this important responsibility.

John Thieret (1983) (Chairperson)
Department of Biological Sciences
Northern Kentucky University
Highland Heights, Kentucky 41076

Ralph Thompson (1984)
Department of Biology
Berea College
Berea, Kentucky 40403

Willem Meijer (1985)
Department of Biological Sciences
University of Kentucky
Lexington, Kentucky 40506.

* * * * *

Committee to Study Legislatively Mandated Education Programs (ad hoc) The following persons have been asked to serve on this important committee. President Rodriguez takes this opportunity to express his thanks to Dr. Dixon for his diligence as chairperson of the committee for the last two years.

Wallace Dixon (Chairperson)
College of Natural and Mathematical Sciences
Eastern Kentucky University
Richmond, Kentucky 40475

William H. Dennen
Department of Geology
University of Kentucky
Lexington, Kentucky 40506

Anna S. Neal
Fayette County Public Schools
701 East Main Street
Lexington, Kentucky 40502

William F. Wagner
Department of Chemistry
University of Kentucky
Lexington, Kentucky 40506.

* * * * *

Junior Academy of Science Governing Board The Academy of Science is greatly indebted to Herb Leopold for his long dedication and labors in directing the affairs of the Junior Academy of Science. For these services, President Rodriguez expresses his appreciation.

Herbert Leopold (Chairperson)
Department of Health and Safety
Western Kentucky University
Bowling Green, Kentucky 42101

Arvin Crafton (1984)
College of Human Development and Learning
Room 311, Mason Hall
Murray State University
Murray, Kentucky 42071

J. Truman Stevens (1984) (Editor, KJAS Bulletin)
College of Education
Department of Curriculum and Instruction
210 Taylor Education Building
University of Kentucky
Lexington, Kentucky 40506

Stephen A. Henderson (1984) (Treasurer)
Model Laboratory School
Eastern Kentucky University
Richmond, Kentucky 40475.

* * * * *

Committee on Rare and Endangered Species (ad hoc) The Committee on Endangered Species is reappointed. President Rodriguez thanks the committee members for their continued service to the Academy.

Branley A. Branson (Chairman)
Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky 40475

Jerry Baskin
Department of Biological Sciences
University of Kentucky
Lexington, Kentucky 40506

Donald L. Batch
Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky 40475

Wayne Davis
Department of Biological Sciences
University of Kentucky
Lexington, Kentucky 40506.

* * * * *

Committee on Location and Time of Meeting President Rodriguez thanks Dr. Philley for assuming the duties of this committee.

John C. Philley
Department of Physical Sciences
Morehead State University
Morehead, Kentucky 40351.

* * * * *

New Page Charges for *Transactions* As of 1 January 1984, by mandate of the Board of Directors, the mandatory author page charges for publication in the *Transactions of the Kentucky Academy of Science* are raised to $30.00 per published page. All authors must be members in good standing of the Kentucky Academy of Science.

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69th Meeting of the Kentucky Academy of Science The 69th annual meeting of the Kentucky Academy of

Science will be held at the University of Louisville, Belknap Campus, on 11–12 November 1983.

* * * * *

A Drive for Membership There is an urgent need for all active members to thoroughly solicit new members and to urge old members to rejoin our ranks. Please contact all members of your department or organization and urge them to pay their dues or become new members of this fine society.

* * * * *

Important Publications on Kentucky Two important publications of interest and importance to Kentucky scientists have recently appeared in print. *Bird Species on Mined Lands*, by Pierre N. Allaire, released by the Institute for Mining and Minerals Research, Lexington, Kentucky, not only includes photocopies of several original watercolors by Alan Barron, but it also includes sections on mining methodology, habitats and census methods, habitat preferences, and a discussion of the bird species that frequent mined lands and their management. ($10).

The second publication, prepared by the Kentucky Nature Preserves Commission for the Division of Water, Kentucky Natural Resources and Environmental Protection Cabinet, is authored by R. R. Hannan, 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.* The 459-page report provides a comprehensive inventory of Kentucky's most outstanding aquatic resources, provides water-quality standards designed for the protection of the resources, and discusses the Rare, Endangered or Threatened species associated with each of the areas considered.

INDEX TO VOLUME 44

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.

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Gene Frequencies in Domestic Cat Populations of South-Central Kentucky

DANIEL J. TWEDT[1]

Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101.

ABSTRACT

Gene frequencies were estimated from independent surveys of 223 cats in Warren County and 114 cats in Logan County, Kentucky. Estimated gene frequencies in the combined south-central Kentucky cat population. Based on coefficients of genetic identity, the cats of south-central Kentucky are genetically more similar to populations of southwestern North America than to northeast populations. An hypothesis for this similarity, based on Mississippi River trade routes, is proposed.

INTRODUCTION

Gene frequencies for color, pattern, and length of coat have been reported in world-wide domestic cat populations. Although data have been presented for several North American cat populations, information from much of the south-eastern United States is lacking. To fill this void, surveys were conducted from September 1980 through December 1981 to ascertain the gene frequencies in domestic cat populations of Warren and Logan Counties in south-central Kentucky.

METHODS

Phenotypes of cats from Warren and Logan Counties were recorded for free-ranging cats observed by the author. Both phenotype and location were recorded to minimize the likelihood of duplicate recordings. Mutant alleles considered in these surveys included: sex-linked non-orange vs orange (0^+,0); and autosomal agouti vs non-agouti (a^+,a); striped vs blotched tabby (t^+,t^b); intense vs dilute pigmentation (d^+,d); white spotting vs non-spotted (S,S^+); dominant white vs. pigmented (W,W^+); Siamese dilution vs non-Siamese (c^s,c^+); and short vs long hair (L^+L). Nomenclature follows that of the Committee on Standardized Genetic Nomenclature for Cats (3). Robinson (9, 10) detailed the modes of inheritance and interaction of these alleles.

Recessive allelic frequencies (q) were calculated as the square root of the observed phenotype frequencies. Dominant allelic frequencies (P) were calculated as 1-q. Standard errors were obtained as $1-q^2/4N$ and $(2-P)P/4N$ for recessive and dominant alleles, respectively. Sex ratios were determined by maximum likelihood estimates (11). Conformity to the Hardy-Weinberg Equilibrium was determined by chi-square comparison of observed and expected phenotypes of sex-linked orange. Gene frequencies between the Warren and Logan County cat populations of other North American cities was determined by calculating coefficients of genetic identity (8), based on 5 loci (0, a, t^b, d, and W) as employed by Anderson and Jenkins (1).

[1]Present address: U.S. Fish and Wildlife Service, Kentucky Research Station, 334 15th Street, Bowling Green, Kentucky 42101

RESULTS AND DISCUSSION

The Warren County sample consisted of 223 cats; 114 cats were sampled in Logan County. Analyses of the observed and expected distribution of sex-linked orange (Table 1) indicate only the Logan County population appears to conform the Hardy-Weinberg equilibrium (X^2=1.99; P=0.37), thus warranting the assumption of panmixia. The sex ratio deviates significantly from 1:1 with a greater proportion of males in both Logan County (X^2=30.9; P<0.01) and in Warren County (X^2=40.48; P<0.01).

TABLE 1. Number of observed and expected ( ) genotypes and estimated gene frequencies (±- standard error) of the sex-linked non-orange (0+), orange (0) allele in two south-central Kentucky cat populations.

Phenotype (genotype)	Warren County	Logan County	Combined
Orange (0/-)	26 (32.5)	22 (25.1)	48 (57.0)
Orange (0/0)	7 (3.1)	4 (2.3)	11 (5.4)
Tortoiseshell (0+/0)	19 (20.3)	10 (10.3)	29 (31.0)
Black (0+/0+)	31 (33 6)	10 (11.4)	41 (44.6)
Black (0+/-)	114 (107.5)	59 (55.9)	173 (164.0)
X^2	6.88	1.99	8.15
$P_{(df=2)}$	P=0.03	P=0.37	P=0.02
q0	0.232±-0.035	0.310±-0.046	0.258±-0 028

TABLE 2. Number of observed mutant phenotypes, "wild" phenotypes, and estimated gene frequencies (± standard error) in two south-central Kentucky cat populations.

Phenotype (allele)	Warren County mutant (wild)	Logan County mutant (wild)	Combined
Non-agouti (a)	117 (47) .845±-.021	42 (32) .753±-.038	.817±-.019
Blotched tabby (t^b)	4 (71) .231±-.056	3 (54) .229±-.064	.230±-.042
Dilute (d)	17 (179) .294±-.034	9 (96) .293±-.047	.294±-.028
White spotting (S)	100 (97) .298±-.025	46 (59) .250±-.032	.281±-.020
Long hair (l)	17 (196) .282±-.031	23 (89) .453±-.042	.351±-.026
Dominant White (W)	16 (197) .038±-.009	7 (105) .023±-.012	.036±.007
Siamese (c^s)*	10 (213) 4.48%	2 (112) 1.75%	3.56%

* Incidence of Siamese cats

Estimated gene frequencies for autosomal alleles were calculated for both samples by a maximum likelihood method (Table 2). Siamese phenotypes have been excluded from gene frequency calculations as suggested by Todd and Todd (13), but the incidence of Siamese cats is included in Table 2. Estimated gene frequencies differed significantly between the Logan and Warren County cat populations only for non-agouti (X^2=4.89; P=0.03) and long hair (X^2=10.72; P 0.01).

Data from both counties were combined to obtain the estimated gene frequencies in the cat population of south-central Kentucky (Tables 1 and 2). Estimated gene frequencies in other North American cat popu-

FIG. 1 Coefficients of genetic identity between south-central Kentucky and other North American cat populations. (A coefficient of 1.00 indicates genetically identical populations.)

lations have been summarized by Gerdes (6), Fagen (5), Morrill and Todd (7), and Anderson and Jenkins (1). Coefficients of genetic identity between the cat population of south-central Kentucky and the cat populations of other North American cities (Fig. 1), indicate the south-central Kentucky cat population appears to be shifted from the 'Anglo' cat population of eastern North America and has a greater genetic similarity to the 'Spanish/Mexican' cat population of western North America as identified by Todd et al. (12). Possible explanations for the deviation of the Phoenix and Vera Cruz cat populations from other 'Spanish/Mexican' populations are offered by Todd et al. (12).

The high degree of similarity between this Kentucky cat population and the 'Spanish/-Mexican' cat populations of Texas and other western cities is unexpected based on Kentucky immigration patterns. Several south-central Kentucky communities were first established around 1780 with increased European immigration beginning shortly thereafter (4). By 1800 the human population of the two counties had grown to over 10,000 (2). The population more than doubled during the next 10 years and by 1810 was over 24,000 (14). (Political boundaries have not remained consistent since original counties were established.) The majority of these immigrants, originating in the former British colonies of Virginia, Maryland, and the Carolinas, entered Kentucky via the Cumberland Pass with additional immigrants moving down the Ohio River from Pennsylvania.

Between 1785 and 1795 Mississippi River trade between Kentucky and the territories of New Spain was at its zenith. Additionally, the colonization schemes of Spain in the central Mississippi River Valley culminated during these years (4). These activities, coinciding with the initial pre-1800 settlement of south-central Kentucky, may have provided 'Spanish/Mexican' cats, which in turn produced sufficient offspring to resist the influence of 'Anglo' cats arriving with the later post-1800 influx of 'Anglo' immigrants. These hypothetical cats of 'Spanish/Mexican' lineage could account for the high degree of genetic identity between the cat population of south-central Kentucky and the cat populations of Texas and other western cities. Estimated gene frequencies in cat populations of Tennessee, Arkansas, Mississippi, and Louisana are needed to further elucidate this hypothesis.

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Influence of Support Systems on the Occurence and Distribution of Roof Falls in Selected Coal Mines of Eastern Kentucky

ALAN D. SMITH

Coal Mining Administration, College of Business
Eastern Kentucky University, Richmond, Kentucky 40475

RICHARD T. WILSON

Department of Geology, Eastern Kentucky University

ABSTRACT

Mine roof support and resupport systems in coal mines are the leading element of expense in ground control. Selected parameters associated with support systems were collected in 5 coal mines, located in Pike, Martin, and Floyd Counties, eastern Kentucky, to aid in determining the degree of relationship among support and resupport systems on the occurence and distribution of mine roof falls. A total of 250 falls were measured that involved 4 coal seams: Peach Orchard, Brods, Pond Creek, and Fire Clay.

Results illustrate the vast majority of falls occured either in the entry or intersection, had spans of approximately 20 feet, portrayed some presence of water before the actual fall, occured in less than 30 weeks after initial coal extraction, usually were located more than 100 feet from the nearest coal face, gave evidence of cracks in mine roof before occurrence of the fall, generally presented a stable roof profile before the fall, showed presence of sloughing of coal ribs, and exhibited little or no evidence of floor heave. Most roofs were either originally supported by mechanical anchor bolts (57.2%) or resin bolts (38.8%); very rarely did the roof fail if supported by posts or cribs. The results of 7 research hypotheses testing the relationship of the type of initial mine roof support system and selected physical parameters illustrated that only 2 hypotheses were statistically significant. In general, the shorter the time between coal excavation and the mine roof fall, the greater the frequency of full column or resin roof bolts were in use. Also, sloughing of the coal ribs were associated with a greater occurence of resin roof bolts.

INTRODUCTION

Roof fall occurrence is a common ground control problem. In fact, roof falls are so common many mining operatings consider them a part of the regularly computed downtime (1, 2). In some instances, it may cost as much to clean up a fall as it does to mine actual coal. The loss of revenues associated with downtime is not the only tragedy involved; there is sometimes a loss of life. Roof falls are the major cause of death in underground coal mines in the United States, accounting for over 50 percent of all fatalities (2). Nearly all roof failures can be traced to 2 major causes: 1 the interaction of stresses in the roof, pillars and floor exceeded the rupture point of the roof rock strata; and 2 geological disturbances in the immediate roof, such as slickslides, channel sands, transition zones, rider coal seams, kettlebottoms, cracks and joints, and the presence of water, are often associated with roof falls (3,4,5,6).

As coal is excavated, stresses are set up in the mine roof because the equilibrium of the in-situ stress state is upset, resulting in pressures that cause fractures and slight movements that are frequently difficult to detect. Unless the immediate roof in the excavated area is given support by artificial means, an increasing probability of a roof fall or a succession of falls, highly variable in size, exists. The two broad types of roof support systems involve the artificial support of the immediate roof above the coal and the main roof. In general, artificial support for mining purposes is only concerned with the immediate roof, since large blocks of solid coal or pillars will support the main roof.

SUPPORT SYSTEMS

If the immediate roof is made of interbedded material, laterally continuous and void of irregularities, it can be supported (3). The most widely used method of supporting underground entries is the roof bolt (1,7). Roof bolts have been found to have some advantages over other types of roof supports, such as timbers, posts, or cribs. Production has increased and fatalities have decreased since the introduction of roof bolts in the 1950's (7). Most estimates place the current roof bolt consumption at slightly over 100 million per year. At an in-place cost of approximately $10 per bolt; this represents an annual effort of over $1 billion. Of all the roof bolts installed, mechanically anchored bolts account for about three-quarters of all the bolts. However, in spite of such extensive use of rock bolts, the mechanism by which bolts provide support is not completely understood. Each year a large number of injuries are caused by bolt failures at the rib and roof areas. Maintaining adequate tension in the bolts adds substantially to the competence of the roof strata by the mechanisms of suspension, friction, and keying (8,9).

Peng (1) documents the existence of a high correlation between roof fall fatalities and questionable roof support practices. In addition, roof-bolt length often determines the height of the fall by holding more roof strata together and causing it to fall as a single unit (5). Peng (1) suggested that roof bolts do not adequately perform under the following conditions: 1 the bolts are too short to anchor in a suitable horizon and thus permit excessive bleedoff of bolt tension; 2 the bolts do not adequately torque during installation; 3 the bolts are not routinely checked for bleedoff; 4 the roof falls at or above the anchorage horizon.

The blasting of coal or rock places high stresses on the roof strata and can adversely affect roof bolts in the strata (10). Blasting has been linked to the loss of bolt tension, the breaking and bending of bolts, and cracks in the roof causing the roof rock to lose its ability to support a load, thus initiating roof falls.

Vibrations caused by machinery associated with mining may also lead to roof bolt failures. These vibrations are transmitted into the bolt anchorages by the operation of transportation systems in the immediate area of the roof bolts.

RESUPPORT SYSTEMS

Most roof falls are not cleaned up and resupported because resupporting these roof falls often exposes men and equipment to dangerous unsupported roofs. Inspection of roof fall statistics by Sterns, et al. (11) indicate that 5 per cent of all roof fall fatalities occurred during resupport operations. The process is also very expensive and unless it is a vital entry, such as a beltway, haulage, or aircourse, it is abandoned (11,12). Supports made of cribbing or beams in some cases are not effective protection due to the shrinkage of timbers, thus losing contact with the rock.

Conventional methods of rehabilitating mine roofs include: 1 drive a bypass around the fall (this has a low initial cost but can lower production by reducing haulage speeds and causing the rerouting of tracks and belts); 2 cribbing of the fall by the use of posts, cribbs, steel beams or headers. Resupport by this method reduces production by narrowing passages and therefore slowing haulage speeds (12). An alternative to standard roof resupport is the steel arch canopy. This method has been proven effective in minimizing exposure of miners to dangerous roof resupport work. However, canopies are often prohibitively expensive.

METHODS

Cooperation by 4 mining companies, located in Pike, Martin, and Floyd Counties, allowed the investigation and data collection of mine roof falls in 5 different coal mines (Fig. 1) to aid in the determination of the influence of support/resupport systems on the occurrence and distribution of roof falls in eastern Kentucky. A total of 250 falls were measured and involved 4 coal seams: Peach Orchard, Broas, Pond Creek, and Fire Clay. Multiple linear regression analysis techniques (13) were performed, via SPSS (Statistical Package for the Social Sciences) and DPLINEAR (Double Precision Linear Regression), to test hypotheses relating type of support before the fall (coded either resin or nonresin for discriminative analysis purposes) with selected physical parameters. In

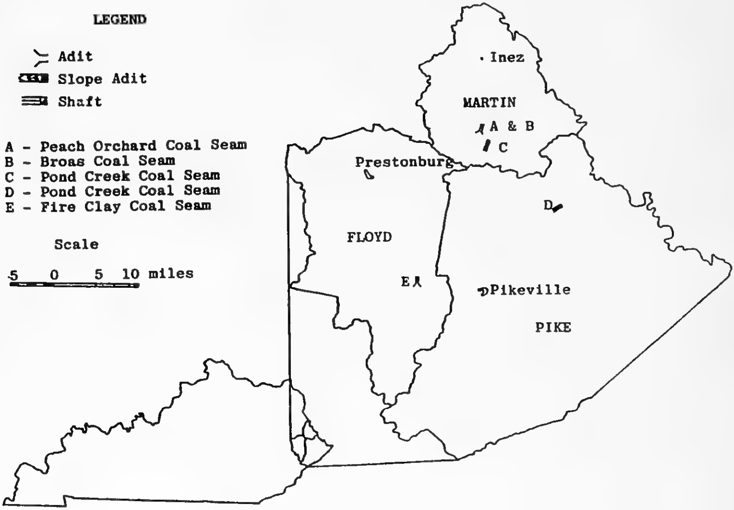

FIGURE 1 Location of entrances to the coal seams for the mines studied.

addition, a combination of the computer softward packages of SPSS and PLOTALL, a computer-graphics software to generate frequencies and visual profiles of the distribution of selected parameters, were completed. Specifically, the variables collected and analyzed concerning type of support before and after the fall, length of bolts before and after the fall, and descriptions of the original support and resupport systems. Associated parameters that are related to support systems and their design that were also studied included: location of the fall, mine roof span, presence of water before the fall, time of roof fall after coal excavation, distance to the nearest coal face, presence of cracks before the fall, assumed condition of the roof before the fall, sloughing of coal ribs before the fall, and presence of floor heave condition before the fall.

RESULTS AND DISCUSSION

Table 1 illustrates the summary of frequency counts, relative frequencies, and cumulative frequencies for support and associated physical parameters for the mine roof falls studied. Table 2 represents a sum mary of the F-ratios, probability levels, R^2 for both the full and restricted models, degrees of freedom, and significance for each research hypothesis testing discriminative relationships among the type of support system (resin or nonresin) before the occurrence of the mine roof fall and selected physical parameters. Figs. 2 through 6 graphically display the distribution of the type of support and resupport system (Fig. 2 and 3, respectively), location of the fall (Fig. 4), span of the roof or entries (Fig. 5), and assumed condition of the roof before the occurence of the fall (Fig. 6).

TABLE 1.—SUMMARY OF FREQUENCY COUNTS, RELATIVE FREQUENCIES, AND CUMULATIVE FREQUENCIES FOR SUPPORT SYSTEMS AND ASSOCIATED PHYSICAL PARAMETERS.

Parameter	Value Label	Absolute Frequency	Relative Frequency (%)	Adjusted Cumulative Frequency(%)
Location of Fall	ENTRY	101	40.4	40.4
	CROSSCUT	35	14.0	54.5
	INTERSECTION	86	34.4	88.8
	HAULAGE ROAD	20	8.0	96.8
	BELTWAY	4	1.6	98.4
	AIRWAY	4	1.6	100.0
	TOTAL	250	100.0	
Mine Roof Span (ft.)	16.0	1	0.4	0.4
	17.0	2	0.8	1.2
	18.0	17	6.8	8.0
	19.0	27	10.8	18.8
	20.0	203	81.2	100.0
	TOTAL	250	100.0	
Presence of Water Before the Fall	YES	195	78.0	78.0
	NO	55	22.0	100.0
	TOTAL	250	100.0	
Time of Roof Fall After Coal Excavation (weeks)	0.00-0.99	23	9.2	10.0
	1.00-1.99	23	9.2	20.0
	2.00-2.99	16	6.4	27.0
	3.00-3.99	9	3.6	30.9
	4.00-4.99	25	10.0	41.7
	5.00-9.99	19	7.6	50.0
	10.00-19.99	22	8.8	59.1
	20.00-29.99	28	11.2	71.3
	30.00-39.99	10	4.0	75.7
	40.00-49.99	7	2.8	78.7
	50.00-99.99	23	9.2	88.7
	100.00-199.99	16	6.4	95.7
	200.00-599.99	10	4.0	100.0
	MISSING	20	8.0	100.0
	TOTAL	250	100.0	
Distance to the Nearest Face (ft.)	0.0-9.9	16	6.4	7.0
	10.0-24.9	4	1.6	8.7
	25.0-49.9	3	1.2	10.0
	50.0-74.9	14	5.6	16.6
	75.0-100.0	15	6.0	23.1
	101-	176	70.4	100.0
	MISSING	21	8.4	100.0
	TOTAL	250	100.0	

Cracks in Roof Before Fall	YES	188	75.2	85.1
	NO	33	13.2	100.0
	MISSING	29	11.6	100.0
	TOTAL	250	100.0	
Assumed Condition of the Roof Before the Fall	EXCELLENT	1	0.4	0.4
	VERY GOOD	6	2.4	2.8
	GOOD	152	60.8	63.6
	POOR	79	31.6	95.2
	VERY POOR	12	4.8	100.0
	TOTAL	250	100.0	
Sloughing of Coal Ribs Before the Fall	YES	108	43.2	47.0
	NO	122	48.8	100.0
	MISSING	20	8.0	100.0
	TOTAL	250	100.0	
Presence of Floor Heave Before the Fall	YES	7	2.8	3.1
	NO	220	88.0	100.0
	MISSING	23	9.2	100.0
	TOTAL	250	100.0	
Type of Support Before the Fall	RESIN BOLTS	97	38.8	38.8
	ANCHOR BOLTS	143	57.2	96.0
	POST	1	0.4	96.4
	CRIBBS	3	1.2	97.6
	NOT SUPPORTED	6	2.4	100.0
	TOTAL	250	100.0	
Spacing of Roof Bolts Before the Fall (ft.)	2	1	0.4	0.4
	4	239	95.6	100.0
	MISSING	10	4.0	100.0
	TOTAL	250	100.0	
Type of Support After the Fall	RESIN BOLTS	16	6.4	6.4
	ANCHOR BOLTS	63	25.2	31.6
	POST	6	2.4	34.0
	BARS	1	0.4	34.4
	CRIBBS	91	36.4	70.8
	CRIBBED OFF	21	8.4	79.2
	NOT SUPPORTED	51	20.4	99.6
	CANOPY	1	0.4	100.0
	TOTAL	250	100.0	
Spacing of Roof Bolts After the Fall (ft.)	2	6	2.4	7.6
	4	73	29.4	100.0
	MISSING	171	68.4	100.0
	TOTAL	250	100.0	

Length of Roof Bolts Before the Fall (in.)	30	2	0.8	0.8
	42	18	7.2	8.3
	48	90	36.0	45.8
	54	1	0.4	46.2
	60	111	44.4	92.5
	72	7	2.8	95.4
	84	1	0.4	95.8
	96	10	4.0	100.0
	MISSING	10	4.0	100.0
	TOTAL	250	100.0	
Length of Roof Bolts After the Fall	30	1	0.4	1.3
	42	3	1.2	5.1
	48	8	3.2	15.2
	60	23	9.2	44.3
	72	6	2.4	51.9
	78	1	0.4	53.2
	84	10	4.0	65.8
	96	27	10.8	100.0
	MISSING	171	68.4	100.0
	TOTAL	250	100.0	

[a]Adjusted cumulative frequency for the exclusion of missing cases or data values.

TABLE 2.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM, AND SIGNIFICANCE FOR EACH RESEARCH HYPOTHESIS TESTING DISCRIMINATIVE RELATIONSHIPS AMONG SUPPORT BEFORE THE FALL AND SELECTED PHYSICAL PARAMETERS.

Variables: Dependent	Variables: Independent	R^2_f	R^2_r	df	F-Ratio	Prob. Sign
Time of Roof Fall After Coal Excavation	Support Before the Fall	0.05372	0.0	1/193	10.95715	0.0011 S
Cracks in Roof Before Fall	Support Before the Fall	0.00680	0.0	1/193	1.32139	0.2518 NS
Distance to the Nearest Face	Support Before the Fall	0.00579	0.0	1/193	1.12388	0.2904 NS
Presence of Water Before Roof Fall	Support Before the Fall	0.01502	0.0	1/193	2.94264	0.0879 NS*
Assumed Condition of the Roof Before the Fall	Support Before the Fall	0.01938	0.0	1/193	3.81489	0.0522 NS*
Sloughing of Coal Ribs Before the Fall	Support Before the Fall	0.24169	0.0	1/193	61.51320	0.0000 S
Presence of Floor Heave Before the Fall	Support Before the Fall	0.00977	0.0	1/193	1.90335	0.1693 NS

Note. An F-test was utilized to test for significant relationships among types of support before the fall and seleced physical parameters. The assigned alpha level of 0.05 for two tailed, nondirectional test was considered statistically significant. However, the employment of a correction for multiple comparisons was necessary, using the Newman and Fry (14) method. The corrected alpha level of 0.007 was used before any specific research hypothesis was considered significant

*approaching significance at the 0.05 level

The power for each specific research hypothesis, using a medium effect size is 0.995

As evident from an inspection of Table 1, the vast majority of falls occurred either in the entry (40.4%) or intersection (34.4%), had spans of approximately 20 feet (81.2%), portrayed some presence of water before the actual fall (78.0%), occurred in less than 30 weeks after initial coal excavation (71.3%), were located usually greater than 100 feet from the nearest coal face (70.4%), gave evidence of cracks in mine roof before occurrence of fall (75.2%), generally portrayed a good roof condition before the fall (60.8%), showed presence of sloughing of coal ribs (48.8%), and no occurrence of floor heave (88.0% no heaving) before occurrence of fall. In terms of the characteristics of the original support by mechanical-anchor bolts (57.2%) or resin or full-column bolts (38.8%); very rarely did the roof fail if supported by posts (0.4%) or cribs (1.2%). The roof-bolt spacing is usually associated with 4-foot centers in the vast majority of the cases studied, both before and after the fall, which is standard engineering practice in eastern Kentucky coal mines. The length of roof bolts do appear to be longer in resupported roof systems than used in the initial roof support system (92.5% of initial support systems used 60 inch bolts or less as compared to 44.3% of the resupported mine roofs).

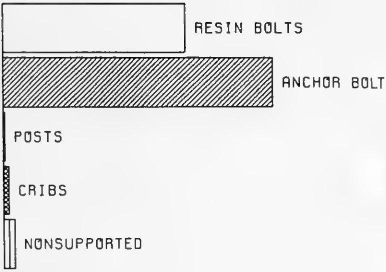

FIG. 2. Distribution of type of initial mine roof support systems (resin bolts, mechanical-anchor bolts).

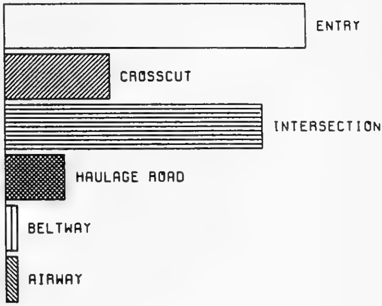

FIG. 4. Location of the occurrence of mine roof falls (entry, crosscut, intersection, haulage road, beltway, airway).

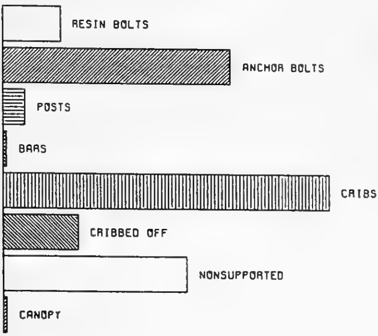

FIG. 3. Distribution of type of resupport mine roof systems (resin bolts, anchor bolts, posts, bars, cribs, cribbed off, nonsupported, canopy).

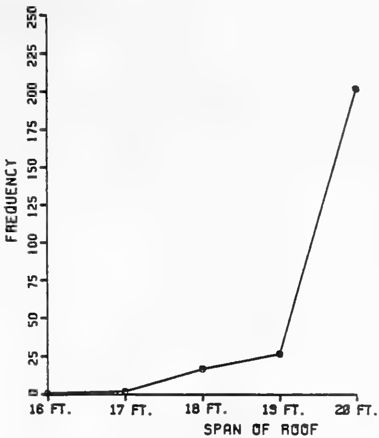

FIG 5 Frequency of span of mine roof in feet.

The results of 7 research hypotheses testing the relationship of the type of initial mine roof support system (resin or nonresin for discriminative analysis purposes) and selected physical parameters illustrated that only 2 hypotheses were found to be statistically significant at the 0.05 alpha level for a nondirectional test, once corrected for multiple comparison using the Newman and Fry (14) method of adjusting the decision criterion. The parameters of times of roof fall after initial coal excavation and presence of sloughing of the coal ribs or sides before the occurrence of the actual fall were found to be significantly related to the initial support system. In general, the shorter the time between coal excavation and roof fall, the greater the frequency of full column or resin roof bolts were in use. Since resin bolts are generally used in roof rock that is in poor condition or a suitable anchor horizon is not available, the presence of the bolts appear to shorten the length of time between coal excavation and the roof fall occurrence. Possibly, the individual roof layers in the immediate roof are already weakened and near failure, hence failure occurs relatively quickly after coal excavation, which provided the initial support. In addition, sloughing of the coal ribs were associated with a greater occurrence of resin roof bolts. This may indicate that the resin support systems hold the immediate roof bed as a thicker or more rigid unit, thus allowing for greater stress concentrations to occur along the coal ribs. If the stress concentrations exceed the allowable rupture strength of the coal, then failure and eventual sloughing of the ribs will develop.

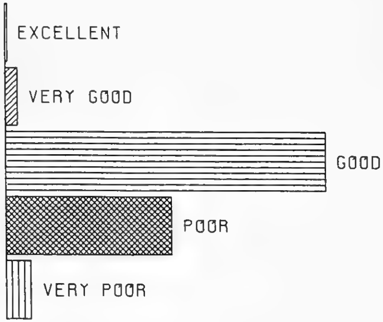

FIG. 6 Distribution of assumed condition of mine roof before occurrence of the actual roof fall (excellent, very good, good, poor, very poor).

The parameters of cracks in roof before the fall, distance to the nearest face, presence of water before the fall, assumed condition of the mine roof before the fall, and presence of floor heaves before the fall were not found to be statistically related to the type of original mine support systems. Hence, these factors are not directly influenced by or on the initial support system.

CONCLUSIONS

The last decade has shown considerable advancement in the knowledge of improved roof control systems and the prediction of potential problem areas. Advances in satellite imagery analysis of linears and their correlation with "bad top" or mine roof-fall areas, improved pillar design, barrier blocks, and mine projections, utilization of differential movement station via extensonmeters to monitor separations in roof layers, and utilizations of the bore scope and T.V. camera to monitor the mine roof as the mining aproaches suspected problem areas are all techniques that are important and should be standard mining practice in ground control. However, as illustrated in this study, a detailed analysis of selected factors associated with mine roof support and resupport systems, based on historical record of falls, can give important correlations that may be useful in forecasting potential problem areas that are under the immediate control of the ground control supervisor, engineer, or shift foreman.

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Additions to the Crayfish Fauna of Kentucky, with New Locality Records for *Cambarellus shufeldtii*

BROOKS M. BURR AND HORTON H. HOBBS, JR.

Department of Zoology, Southern Illinois University at Carbondale, Illinois 62901,

and Department of Invertebrate Zoology, Smithsonian Institution, Washington, D. C. 20560

ABSTRACT

Recent collections in western Kentucky have added 5 crayfishes, *Cambarellus puer, Fallicambarus fodiens, Orconectes lancifer, O. palmeri,* and *Procambarus viaeviridis,* to the faunal list of the state, and several new localities are reported for *Cambarellus shufeldtii.* Five of the 6 species (*F. fodiens* being the exception) are limited in geographic occurrence to the Jackson Purchase region; all are in need of conservation status evaluations by the Endangered Species Committee of the Kentucky Academy of Science.

INTRODUCTION

Nearly 40 years ago, Rhoades (1) presented the first comprehensive report on the crayfishes of Kentucky. He visited each of the 120 counties in the state and reported the presence therein of 27 species and subspecies. Since that time, several of Rhoades' subspecies have been elevated to specific rank (2), new species have been described or reported from Kentucky (3, 4, 5), and the presence of 1 species in the western part of the state has been discovered as a result of additional collecting (6). Recently, extensive field work, particularly in western Kentucky waters, has revealed the presence of 5 previously unreported species of crayfishes. Several new distributional records for *Cambarellus shufeldtii* (Faxon 1884), a species previously known from only one locality in Kentucky (6), were also discovered. It is the purpose of this paper to report records of 6 crayfishes, all of which have limited ranges in Kentucky, so that knowledgeable evaluations of their conservation status may be made by the Endangered Species Committee of the Kentucky Academy of Science.

ACCOUNT OF SPECIES

Distributional records are based mostly on recent collections made in western Kentucky and on those deposited in the Illinois Natural History Survey (INHS), the U.S. National Museum of Natural History (NMNH), and Southern Illinois University at Carbondale (SIUC).

Species accounts include the locality, major drainage, county, date of collection, and (in parentheses) the museum in which specimens are deposited, their sex, and reproductive condition. The abbreviation "I" designates form I or first form males; "II" form II or second form males; "j", juveniles; and "ovig.", ovigerous females. Genera and species are treated alphabetically. For synonymy and statements concerning the ranges of each, see Hobbs (2).

Cambarellus puer Hobbs 1945 — New Kentucky locality: (1) unnamed cypress swamp (Mayfield Cr. dr.) 4.0 km. E Melber at Hwy. 1241 crossing, Graves-McCracken Co. line, 29 September 1979 (NMNH 6♂ II, 8♀, 1j♂, 1j♀); 17 November 1979 (NMNH 2♂I, 1♀); 22 December 1979 (NMNH 2♂I, 1♂II, 1♀); 15 January 1980 (NMNH 1♂II, 2♀); 22 February 1980 (NMNH 1♂I, 4♂II, 6♀).

REMARKS—This crayfish ranges from Brazos and Brasorio counties, Texas to the Mississippi River basin in which it occurs from the lower delta to Johnson County, Illinois. Despite considerable collecting efforts in presumably suitable habitats throughout much of western Kentucky, *Cambarellus puer* has been found in only 1 locality. Most of the localities sampled, all of which appeared to provide suitable ecological conditions, yielded *C. shufeldtii,* a species considered by Penn and Fitzpatrick (7) to be dominant to *C. puer.* The 2 species rarely coexist, at least for long periods of time, and *C. shufeldtii* was reported (7) to have supplanted *C. puer* in several localities farther south. Crayfishes associated with *C. puer* at the swamp adjacent to Mayfield Creek were *Cambarus diogenes* subsp. and *Procambarus acutus acutus* (Girard 1852).

Page and Burr (6) reported the occurrence of *Cambarellus puer* in southern Illinois and southeastern Missouri. The locality cited here is the first for Kentucky and helps to fill the distributional gap between southern Illinois and western Tennessee. Because of its limited occurrence in Kentucky, we recommend that *C. puer* be considered by the Endangered Species Committee for Special Concern or Threatened status.

Cambarellus shufeldtii (Faxon 1884)—New Kentucky localities: (1) Fish Lake (Ohio R. dr.), 4.8 km. W Barlow at Hwy. 118 crossing, Ballard Co., 21 July 1978 (INHS 1 j♂, 1j♀). (2) Fish Lake (Mississippi R. dr.), 2.4 km. W Burkley, Carlisle Co., 19 July 1978 (NMNH 1♂II, 1♀). (3) Back Slough (Mayfield Cr. dr.), 2.4 km. N Laketon, Carlisle Co., 19 July 1978 (NMNH 1♂I, 2♂II, 5♀). (4) Lake No. 9 (Reelfoot Lake dr.), 4.0 km. W Tyler, Fulton Co., 20 July 1978 (NMNH 3♂II, 2♀). (5) Murphy Pond (Obion Cr. dr.), 3.2 km. SE Beulah, 19 July 1978 (NMNH 4♂I, 2♂II, 1 ovig. ♀); 29 September 1979 (NMNH 3♂I, 3♂II, 6♀). (6) Open Pond (Reelfoot Lake dr.), 1.6 km. WSW Sassafras Ridge, Fulton Co., 20 March 1980 (NMNH 1♀). (7) Bayou du Chien (Mississippi R. dr.) at Hickman; county road 3.4 river km. from River, Fulton Co., 15 June 1973 (NMNH, 4♂II, 3♀).

Remarks—Page and Burr (6) reported the only previous record of *Cambarellus shufeldtii* from Kentucky (Mitchell Lake, 1 km. W Oscar, Ballard County), and predicted that this species would be found in other oxbow lakes. It has been found only in lowland sloughs, lakes, and oxbows, usually around bald cypress knees in association with submergent vegetation and organic debris. Crayfishes associated with *C. shufeldtii* were *Cambarus diogenes* subsp., *Orconectes lancifer* (Hagen 1870), *Procambarus acutus acutus*, and *P. clarkii* (Girard 1852).

The status of the species was listed as undetermined by Branson et al. (8) because insufficient information was available to permit an assessment of its occurrence within the state. Although its range is limited to the extreme western counties, it is more widespread in Kentucky than previously thought. In veiw of the new records reported here, we recommend that *Cambarellus shufeldtii* be reassigned to the status of Special Concern.

Fallicambarus fodiens (Cottle 1863)—New Kentucky localities: (1) W. Fk. Clarks R. (Tennessee R. dr.), 3.2 km. NW Brewers at Hwy. 80 crossing, Marshall Co., 26 April 1975 (INHS 1j♂, 1j♀). (2) Cr. (Clarks R. dr.), 4.4 km. W Brewers on Hwy. 80, Marshall Co., 14 April 1969 (NMNH 1♂I, 1♀, 1j♂, 1j♀). (3) Lee Cr. (Tennessee R. dr.), 3.2 km. N Altona, Livingston Co., 14 June 1979 (NMNH 2j♀). (4) trib., Fish Lake (Mississippi R. dr.), 1.6 km. W Burkley, 19 April 1980 (NMNH 1♀). (5) Little Cr. (Obion Cr. dr.), 4.0 km. SE Milburn at Hwy. 307 crossing, Carlisle Co., 22 February 1980 (NMNH 1♂II). (6) trib., Green R. (Ohio R. dr.), at Reed, Henderson Co., 5 June 1979 (NMNH 2j♂, 2j♀). (7) Sulphur Run (Green R. dr.), at Sulphur Springs at Hwy. 69 crossing, Ohio Co., 11 March 1979 (NMNH 4j♀). (8) Obion Cr. (Mississippi R. dr.), at Hwy. 51 crossing, Hickman Co., 10 May 1973 (NMNH 1j♂, 2j♀). (9) Cr. (Bayou du Chien dr.), 10.2 km. SW Wingo on Hwy. 45, Graves Co., 15 April 1969 (NMNH 5♂II). (10) roadside ditch (Clarks R. dr.), 15 km. W Aurora on Hwy. 80, Marshall Co., 14 April 1969 (NMNH 1j♀). (11) Cr. (Mississippi R. dr.), 3 km. WNW Hwy. 802 on Hwy. 121, Ballard Co., 12 June 1982 (NMNH 1j♂).

REMARKS—The relationships between *Fallicambarus fodiens* and *F. hedgpethi* (Hobbs 1948) are not understood. In view of their apparent overlapping ranges in the Mississippi Basin and the doubt surrounding the assignment of populations, including some of those occurring in Kentucky, to one or the other of the two, perhaps *F. hedgpethi* should be relegated to the synonymy of *F. fodiens*. Until a thorough study has been made of populations throughout their combined ranges, which extend from Ontario southward to Texas and Georgia, we are tentatively assigning all of the members of *Fallicambarus* that we have examined from the state to *F. fodiens*. One of the reasons why such a study has not already been undertaken is the paucity of first form males in collections; for example, only one such specimen has been obtained from the 11 localities reported here. As pointed out by Crocker and Barr (9), *F. fodiens* is primarily a burrowing species, and the sporadic occurrence of adults in open water probably accounts for the lack of adequate samples of the adult population in available collections. The same may be said of *F. hedgpethi*.

Crayfishes associated with *F. fodiens* in Kentucky were *Cambarus diogenes* subsp., *Orconectes rusticus* (Girard 1852), *O. immunis* (Hagen 1870), *Procambarus a. acutus, P. clarkii,* and *P. viaeviridis* (Faxon 1914). The conservation status of this species has not been established, but because of the extent of its known range in the state and of its habits, there is no reason to suspect that its presence in Kentucky is in any way endangered.

Orconectes lancifer (Hagen 1870)—New Kentucky localities: (1) Fish Lake (Ohio R. dr.), 4.8 km. W Barlow at Hwy. 118 crossing, Ballard Co., 21 July 1978 (INHS 1j♀). (2) Metropolis Lake (Ohio R. dr.), 4.8 km. N Grahamville, near end of Hwy. 305, McCracken Co., 26 April 1975 (INHS 1j♀). (3) Mississippi R. backwater at Hickman, Fulton Co., 6 August 1982 (SIUC 1♂II). (4) Back Slough (Mayfield Cr. dr.), 2.4 km. N Laketon, Carlisle Co., 19 July 1978 (NMNH 4♂II, 4♀). (5) Fish Lake (Mississippi R. dr.), 2.4 km. W Burkley, Carlisle Co., 19 July 1978 (1j♂, 1j♀).

REMARKS—*Orconectes lancifer* has not been previously reported from Kentucky, but is known from southern Illinois (6) and western Tennessee (2). In Kentucky, this crayfish has been collected only from sloughs, bottomland lakes, and backwaters of the Mississippi River. It was found near shore among vegetation, sticks, and other organic debris, usually in association with bald cypress. As pointed out by Black (10) it seldom occurs in large numbers and rarely in a sexually mature condition. Crayfishes associated with *O. lancifer* in the localities cited here were *Cambarellus shufeldtii* and *Cambarus diogenes* subsp.

Although not formally reported from Kentucky, the Endangered Species Committee (8), on a recommendation from Burr (in lit.), assigned *O. lancifer* to a status of Special Concern, primarily because of its limited geographic occurrence in the state. Such a status is consistent with evaluations made for other species having a similar distribution.

Orconectes palmeri palmeri (Faxon 1884)—New Kentucky locality: Obion Cr. (Mississippi R. dr.), 2.4 km. NW Oakton at Hwy. 123 crossing, Hickman Co., 22 July 1980 (NMNH 3♀, 7j♂, 7j♀); 7 November 1981 (NMNH 1♂I).

REMARKS—Previously known from adjacent western Tennessee and farther south in the lower Mississippi valley (11), *Orconectes p. palmeri* has not been reported from Kentucky. This crayfish has been taken twice from Obion Creek in swift, debris-ridden riffles over a mixed sand, mud, and gravel bottom. *Cambarus diogenes* subsp. was the only crayfish collected with *O. p. palmeri* in Obion Creek. Although the latter was described from nearby Reelfoot Lake in Obion County, Tennessee, because of its limited geographic occurrence in Kentucky, this crayfish should be considered for state Endangered/Threatened status.

Procambarus viaeviridis (Faxon 1914)—New Kentucky localities: (1) E. Fk. Clarks R. (Tennessee R. dr.), 1.6 km. ENE Hardin at Hwy. 80 crossing, Marshall Co., 25 April 1980 (NMNH 2j♀). (2) Bayou du Chien (Mississippi R. dr.) at Hickman; county road 3.4 river km from River, Fulton Co., 15 June 1973 (specimens not extant; examined by HHH, 1♂I, 1♀). (3) Cr. (Mississippi R. dr.), 3 km WNW Hwy. 802 on Hwy. 121, Ballard Co., 12 June 1982 (NMNH 1j♂, 1j♀).

REMARKS—*Procambarus viaeviridis* was known to occur in northeastern Arkansas, western Tennessee (12), and southern Illinois (6), but has not been previously reported from Kentucky. It was collected from debris-ridden pools of 3 lowland streams; crayfishes associated with it were *Cambarellus shufeldtii, Cambarus diogenes* subsp., *Fallicambarus fodiens, Orconectes rusticus* (or a closely related, undescribed species), *Procambarus a. acutus,* and *P. clarkii*.

This species is still so poorly known in Kentucky that it should probably be placed in the category of Special Concern. Additional collecting in suitable habitats, particularly during fall and spring months, will undoubtedly reveal other localities for the species.

DISCUSSION

The list of Kentucky crayfishes has expanded considerably since Rhoades (1) presented the first comprehensive account of the crayfishes of the state. This has been due to the discovery of new species, the resurrection of one from synonymy, the elevation of subspecies to specific rank, and intensive collecting in poorly worked areas. Hobbs (2, 12) presented a list of 33 species that were believed to occur in Kentucky, but 2 of them were found to have been included in error: *Cambarus dubius* Faxon (1884) had been misidentified as *Cambarus carolinus* (Erichson 1846), and *Orconectes juvenilis* (Hagen 1870) was shown to be a synonym of *O. rusticus* (Girard 1852) by Bouchard (13). Subsequent to the appearance of Hobbs' list, Page and Burr (6) cited the first localities for *Cambarellus shufeldtii;* Hobbs and Bouchard (14) described *Cambarus cumberlandensis* and recorded specimens from Kentucky; Bouchard (3) described *Cambarus buntingi* from Tennessee and Kentucky; Hobbs (2) reported the presence of *Cambarus dubius;* Schuster (5) described *Cambarus batchi* from eastern Kentucky; and Bouchard (15) resurrected *Cambarus graysoni* Faxon (1914) from synonymy with *Cambarus striatus* Hay (1902). With the addition of 5 species reported here, not counting undescribed ones, the total number of Kentucky crayfishes is 42.

Of these 42 species, 15 are already represented on the state Endangered/Threatened list (8). Three more species are here recommended for inclusion; if approved, this will bring the total number of Endangered/Threatened crayfishes in Kentucky to 18 (or 43% of the fauna).

Warren and Cicerello (16, 17) have observed a number of man-caused disturbances that are actively reducing the lowland habitat in western Kentucky that is now available to crayfishes. In view of these modifications of the environment, we hope that future recommendations for management of Kentucky waterways will include provisions for preserving some of the state's lowland swamps, sloughs, and oxbow lakes where members of rare Kentucky fishes also occur.

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A Geotechnical Application of Computer-Generated Statistical Models of Contour, Trend, and Residuals Surfaces

ALAN D. SMITH

Coal Mining Administration, Department of Business Administration
Eastern Kentucky University, Richmond, KY 40475

DAVID H. TIMMERMAN

Department of Civil Engineering, The University of Akron
Akron, OH 44325

GAYLE A. SEYMOUR

Computer Center, The University of Akron
Akron, OH 44325

ABSTRACT

Computer generated three dimensional models of contour, first through sixth order trend surfaces, and their residuals of the geotechnical parameter depth to bedrock were completed by the use of several standard software packages. In addition, statistical models were generated to test the addition to explained variance by the employment of sequentially higher degree polynomial trend surfaces. The visual inspection of the computer graphics illustrated that the second and third order distributions had lower values than the other residual or error surfaces. However, the sixth order trend surface was found to the best statistical fit, using the full and restricted model principle, but contained the largest magnitudes of residuals, especially along the periphery of the study area. The combined use of visual inspection of the computer generated models and common sense aid the investigators in selecting the second or third degree polynomials as the best fit.

INTRODUCTION

The expanding uses of computer graphics and its application to engineering and geologic problems and data gathering are rapidly becoming an essential tool by investigators from a variety of disciplines. However, the usefulness of data collected and analyzed should also be based on its ability to communicate the results. The primary purpose of this paper is to present the use of selected computer graphical techniques in the trend surface analysis process, using the geotechnical parameter, depth to bedrock surface, as an example for illustrative purposes.

Higher order regression equations, in trend surface analysis, may reflect the variation in particular values with a geographic or spatial distribution with more accuracy than lower order surfaces, but the low order surfaces may be more useful in isolating important local or regional trends that may exist over a larger area. Thus, surface analyses can be considered a process of filtering an input signal (measured values or Z-values), where the surface represents the resultant signal after filtering. In this process, the order of the surface determines the upper limit of variability or frequency of the input data which will pass through the gate or filter. Localized or site-specific variation will be blocked by the filter when lower orders are used, and it will be increasingly transmitted as the order of the surface increases. This filtering process is in contrast to standard linear interpolation used in contouring, in which all the input data are taken in equal importance. However, a visual check on the accuracy of the filtering mechanism of trend surface analysis would be very helpful in locating sources of noise or localized variation. In addition, visual inspection would be of great value in determining the effectiveness of increasing the order of the regression equations to account for additional variation of the spatially oriented data.

METHODS

Incremental Drum Plotter

The incremental drum plotter, which was the major device used to create the computer graphics in this study, refers to a type of plotter on which the paper is held by two rolls—a supply roll and a take-up roll—separated by a drum. The drum itself facilitates movement of the paper from the supply roll to take-up roll and provides a surface suitable for a pen. A pen holder is mounted on a bar above, parallel to the length of the drum. The pen is free to move along the length of the bar or, in other words, across the width of the paper. Also, the pens can be raised or lowered in the holder to either make contact with the paper or not be in contact with the paper. Hence, a combination of paper and pen movements can produce lines in practically any direction resulting in a finished graph. The movement of the pen from point to point in a series of steps or increments can be as small as 0.0025 inch. The computer graphics produced in the present study used the incremental drum plotter for the final output. However, the data base that was used as initial input into the plotting routines was the software package SYMAP.

SYMAP

SYMAP is a computer package designed for the purpose of producing line-printer maps to depict spatial distributed data. It is suited to a broad range of applications and has numerous options to fit a variety of needs. The SYMAP program is written in FORTRAN IV language and the source deck for the package is at The University of Akron, the University of Kentucky, and many other installations. Overall design and concept for the SYMAP program were developed by Northwestern Technological Institute. However, recent developments in the SYMAP program were completed by the Laboratory for Computer Graphics at Harvard University. The 3 types of 2-dimensional, line printer maps produced by SYMAP are contour maps or isoline maps, conformant, and proximal maps.

The contour map consists of closed curves or contour lines that connect points having the same numeric value. Contour lines emerge from the datum plane in a series of levels which are determined from the scale of the map and the data range. The use of this type of mapping procedure should be restricted to the representation of continuous information such as the structural contours and geophysical data.

The conformant map hold data values within specific appointed areas. In other words, each data zone is enclosed by a boundary determined by a predefined spatial unit. The entire spatial unit is given the same value and symbolism is assigned according to its numeric class.

The proximal map is a hybrid of both the contour and conformant mapping procedures. It has the approach of the contour map, but functions as a conformant map. Spatial units are defined from point information. Each character location of the line printer map is assigned the value of the data point nearest to it. Boundaries are assumed along the line where the values change and the conformant mapping procedure is then applied (1).

The investigators used the contour SYMAP procedure to display the sample distribution of depth to bedrock from surface of 138 borehole sites from the various construction projects involved on The University of Akron's campus. The result was a line printer map with contours. Several electives available to the potential user of the program were then used to create a data matrix of 89 columns and rows on disk file to be used in the production of 3-dimensional plots (2,3).

Three Dimensional Plotting Software

The 3-dimensional plotting programs can be used via the incremental drum plotter to produce statistical surfaces of geographic units with assigned values of continuous data such as population density. There are a variety of options available to the user and these programs also produce their own diagnostic messages for common errors that the user may encounter. There are basically 4 programs under the 3-dimensional plotting programs, each 1 designed to give either a completely different type of plot or flexibility in the presentation of its final form; these options are known as QUSMO, QUSMO2, QUCRS, and OUTAB.

Quick Smooth (QUSMO) produces a smoothed surface over an input data matrix and places the surface on a base or plane. This This program performs a 9-point quadratic interpolation between the input data points to give the plot a smooth appearance. QUSMO², however, combines the features of QUSMO but allows for control over the size output, vertical scale, and read the data matrix from tape storage. QUSMO2, similar in function to the commercially available SURFACE II software (4), was used to produce the 3-dimensional plot found in this study.

Quick Crosscut (QUCRS) also produces a smoothed surface over the input data as does QUSMO and QUSMO2. However, it does not put interpolated surface on a plane. A base is drawn for the surface so that it can be visualized as if it was isolated in space.

Quick Tabular (QUTAB) produces a plot similar to a 3-dimensional histogram. Each data point of the data matrix is assumed to be the center of a plotted cell and thus appears as many small squares at various levels. Since there is no interpolation between the input data points, the program produces a step-like surface. In addition, all 4 plotting routines have the option to view the surface from 8 directions (north, south, east, west, northwest, northeast, southeast, southwest).

Trend Surface Analysis

Another technique used in the course of the study was model comparisons to test for significant relationships among the trends produced in predicting depth to bedrock, as derived from borehole logging. A trend is a statistical surface to explain variations in a given set of values, known as Z-values, that have a given geographic position, either regularly or irregularly distributed in the X-Y plane. The surface is the representation of an equation using the least-squares criterion. This means that the generated surface will be fitted to the input data in such a way that the sum of the squared deviations will be minimized. The F-test for significance of a fit tests the null hypothesis that the partial regression coefficients are equal to zero and, hence, there is no regression. If the computed F-value exceeds the F-value having a probability of a set alpha level, commonly 0.01 to 0.05, then the null hypothesis is rejected and an alternative hypothesis is accepted. According to Davis (5), in polynomial trend-surface analysis, it is customary for investigators to fit a series of successively higher degrees to the data without statistically testing the higher order's contribution to explained variance. Davis (5) and Smith (7) further suggested that an analysis of variance table be expanded to analyze the contribution of the additional partial regression coefficients to give a measure of the appropriateness of increasing the order of the equations, that is, model comparisons of trends (6, 7, 8).

Study Area

The study area was the 114-acre urban campus of The University of Akron, Ohio. This campus is centrally located in an industrial urban area of approximately 1.5 million persons. Since, at the time of the study, new construction was underway and being planned, bore-hole data from previous building sites within the campus were gathered in an attempted to extrapolate geotechnical information into these new areas, based on their relationships and derived degree of reliability. The data collected, for illustrative purposes for the whole campus were: elevation and depth, in feet, of the bedrock surface.

RESULTS

The graphic displays of the 3-dimensional plots for depth of bedrock can be found in Figs. 1 through 13. The viewing direction was from the northeast, 30° from the data plane. Figure 1 presents the contour surface; Figs. 2 through 7 show the first, second, third, fourth, fifth, and sixth orders of trend surfaces, respectively; Figs. 8 through 13 graphically display the positive residuals, both magnitude and location, for each degree of trend surface generated. The inspection of the computer-generated graphical presentations of the increasing order trend-surface equations show the complexity and variance in magnitude of prediction. The maximum depth, as illustrated in Fig. 1, was 23.5 feet. The maximum depth as modeled by first-order trend (Fig. 2) was 13.12 feet; 86.73 feet for the second-degree trend (Fig. 3); 138.62 feet for the third-order trend (Fig. 4); 128.19 feet for the fourth-degree trend (Fig. 5); 4640.69 feet for the fifth order trend (Fig. 6); and 5271.19 feet for the highest-degree trend studied (Fig. 7). Obviously, along the periphery, equations are quite distorted, due to lack of control points outside or adjacent to the study area.

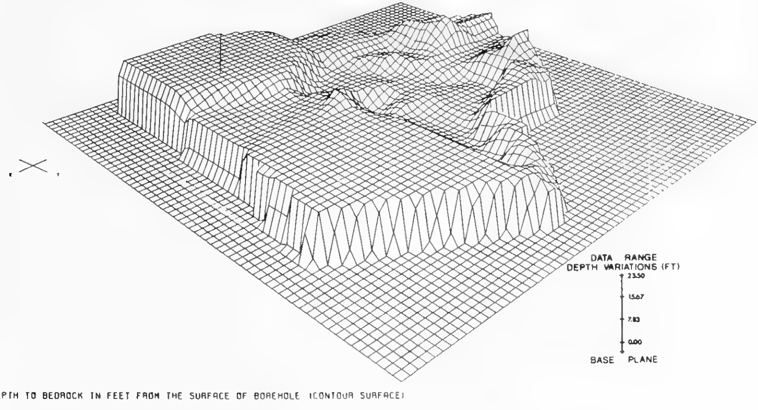

FIG. 1.—Structure contour surface of depth to bedrock from surface of borehole.

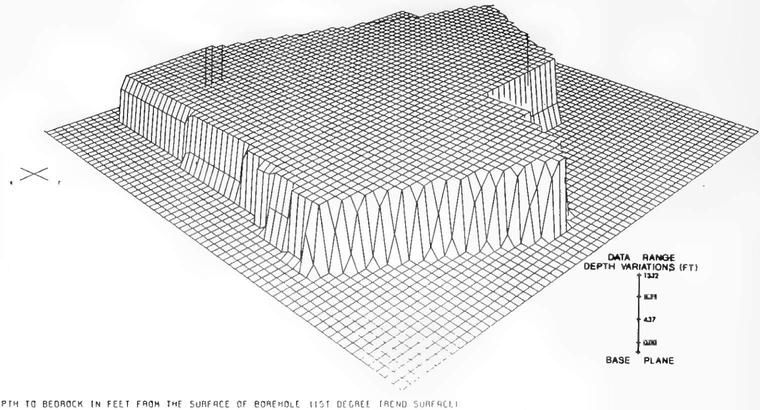

Fig. 2.—First degree polynomial trend surface of depth to bedrock from surface of borehole.

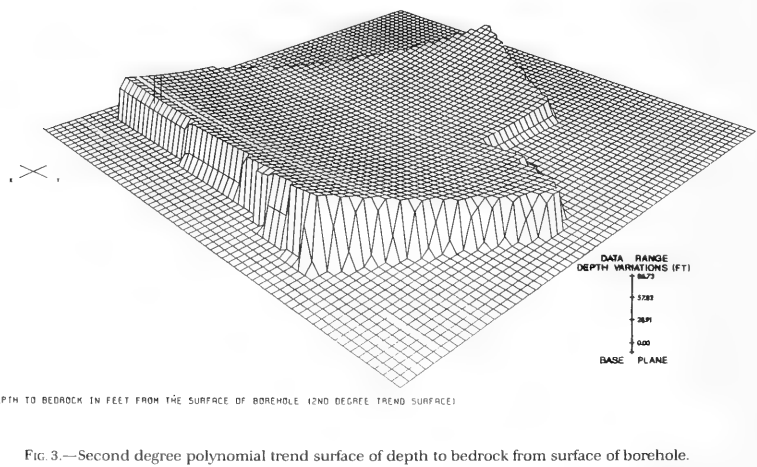

FIG. 3.—Second degree polynomial trend surface of depth to bedrock from surface of borehole.

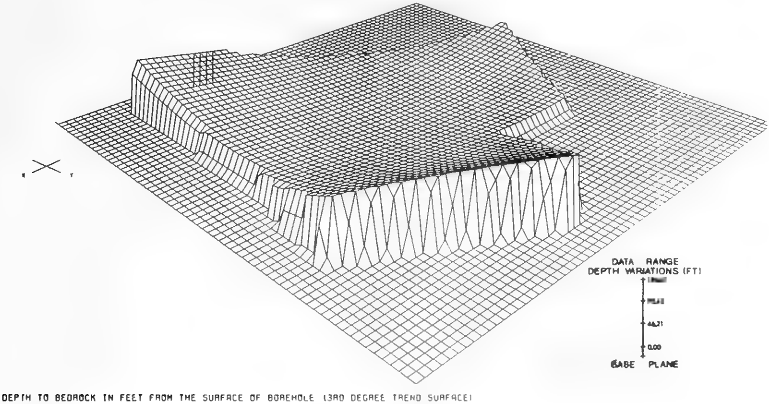

FIG. 4.—Third degree polynomial trend surface of depth to bedrock from surface of borehole.

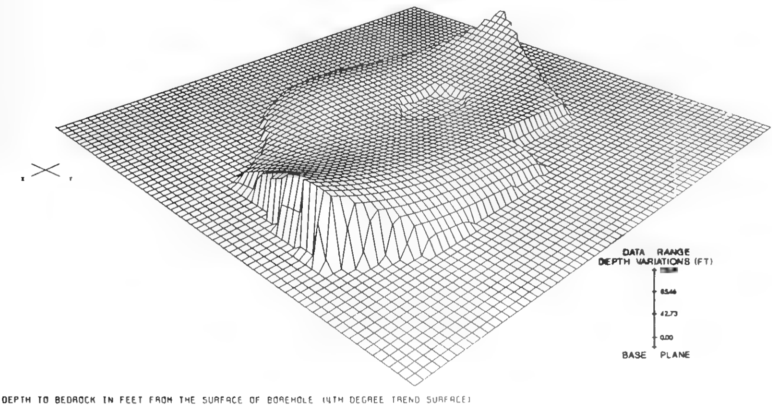

FIG. 5.—Fourth degree polynomial trend surface of depth to bedrock from surface of borehole.

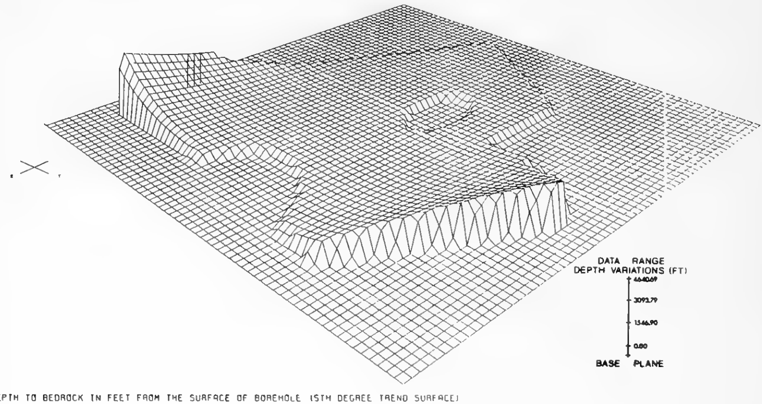

FIG. 6.—Fifth degree polynomial trend surface of depth to bedrock from surface of borehole.

The residual diagrams are displayed in Fig. 8 through 13. Only the positive residuals were plotted, due to the limitations of the software used. As shown in Fig. 8, the first-order residual surface is quite similar in appearance to the contour surface (Fig. 1), since it represents the deviations from a plane surface cutting through the observed data points by the least sum of squares criterion. The maximum positive deviation or residual was 11.47 feet. The maximum positive residuals for the second-order residual surface (Fig. 9) was 10.54 feet, while for the third-degree residual surface (Fig. 10), the maximum was 8.43 feet. Evidently, a second or third degree polynomial surface was a better fit than the first. However, as suggested by Davis (4), hypothesis testing and model comparisons are needed to determine if the contribution to be explained variance by increasing the order of the regression equations is statistically significant. Figure 11 illustrates the residual model or surface for depth of bedrock for the fourth degree trend, the maximum residual was 629.36 feet. The maximum residual value for the fifth (Fig. 12) and sixth (Fig. 13) degree polynomial degree trends are 136.79 and 12576.95 feet, respectively. It appears that the residuals were minimized more dramatically with the fifth order surface than either the fourth or sixth degree trends.

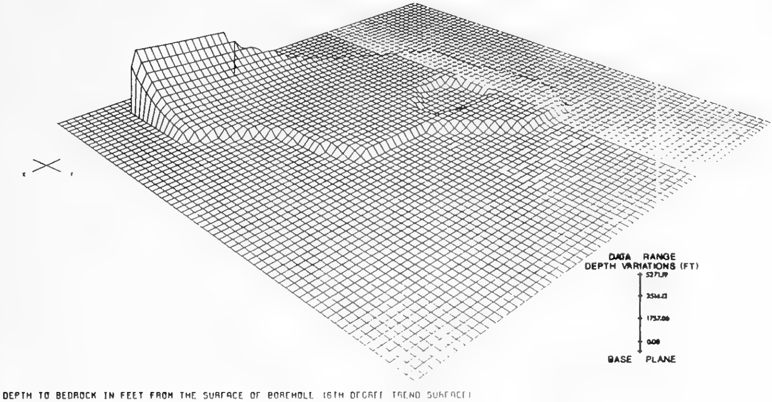

FIG. 7.—Sixth degree polynomial trend surface of depth to bedrock from surface of borehole.

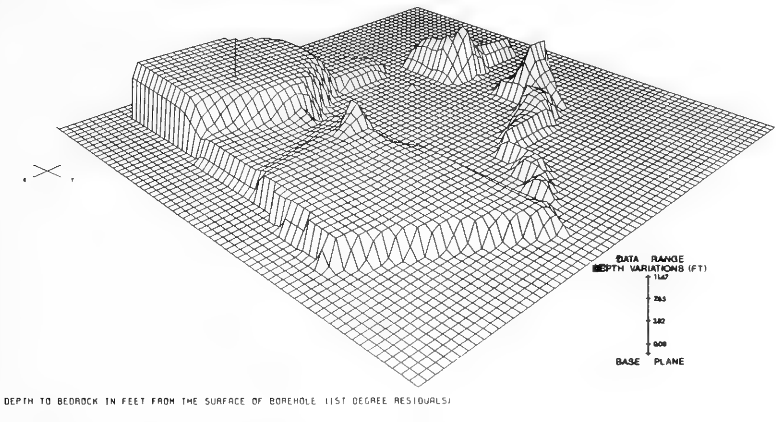

FIG 8.—Residual surface of first degree polynomial trend of depth to bedrock from surface of borehole.

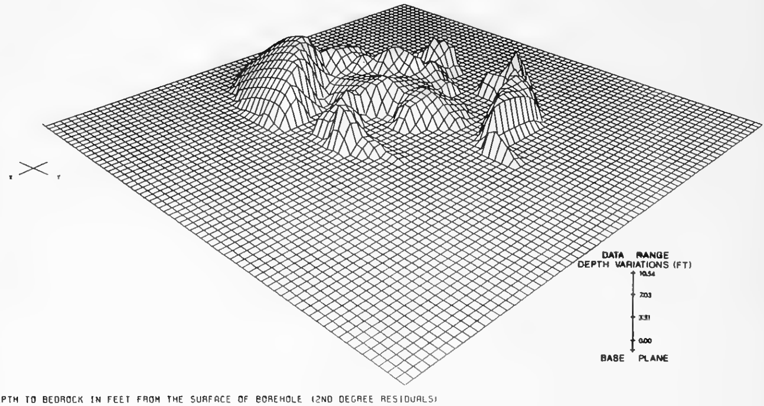

FIG 9. -Residual surface of second degree polynomial trend of depth to bedrock from surface of borehole.

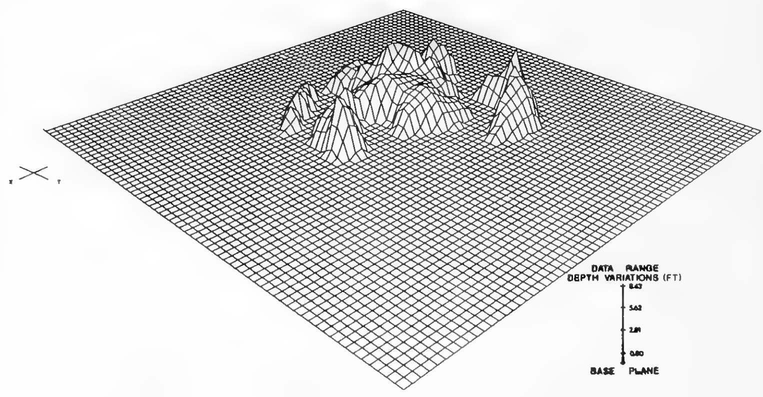

FIG 10.—Residual surface of third degree polynomial trend of depth to bedrock from surface of borehole.

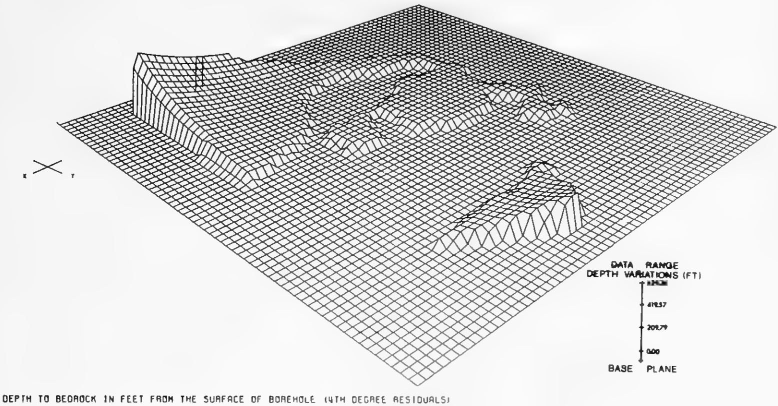

FIG. 11.—Residual surface of fourth degree polynomial trend of depth to bedrock from surface borehole.

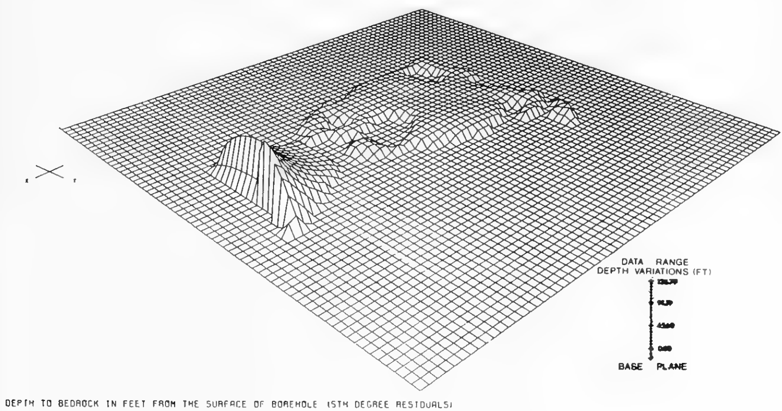

FIG. 12.—Residual surface of fifth degree polynomial trend of depth to bedrock from surface of borehole.

Table 1 is a summary of F-ratios, probability levels, R^2 for both the full and restricted models, degrees of freedom-numerator, degrees of freedom-denominator, and statistical significance for the hypothesis testing and model comparisons among trend surfaces for bedrock depth. The R^2 term is an indication of the amount of variance explained or accounted for by the regression equation describing the actual depth to bedrock distribution. Thus, for the first degree surface, only 2.02 percent of the variance in the geographically distributed bedrock depth was accounted for by the surface. When this R^2 was tested over random variation, which has an R^2 equal 0.0, this was not found to be significant. The 1 vs. 2 term in the table makes use of the full versus restricted model concept. For example if the first model, $Z = \beta_0 + \beta_1 X_i + \beta_2 Y_i + \xi_i$, where β_0 is equal to the constant term, β_1 and β_2 are the regression coefficients, and X and Y are the geographic coordinates of each of the 138 borehole locations in the study area, ξ is the error or residual vector, and Z is depth to bedrock at each location, is termed the full model, then the restricted model is the full model with the null hypothesis being true. The null hypothesis in the case testing the first degree trend over random variation, β_1 and β_2 would be equal to zero, hence there would be no first order regression. In model comparisons, the restricted model would contain only the regression weights of the next lower degree surface, since the null hypothesis would assign a value of zero to the higher order regression coefficients. As illustrated in the table, assuming a 2-tailed, nondirectional test with an alpha level set at 0.05, the second through the sixth order trend surfaces were found to be statistically significant in predicting depth to bedrock over random variations. In the model comparisons process, the second order surface accounted for more explained variance than the first. Since as shown in Fig. 9 and 10, the positive residual values and their locations were similar, they were not found to be statistically significant. Following the model comparison process, the sixth order surface was found to be statistically better fit than the fifth. However, as shown in Fig. 13, the magnitude of the residuals are located accurately, larger errors will be made in predicting depth to bedrock for this high order polynomial surface.

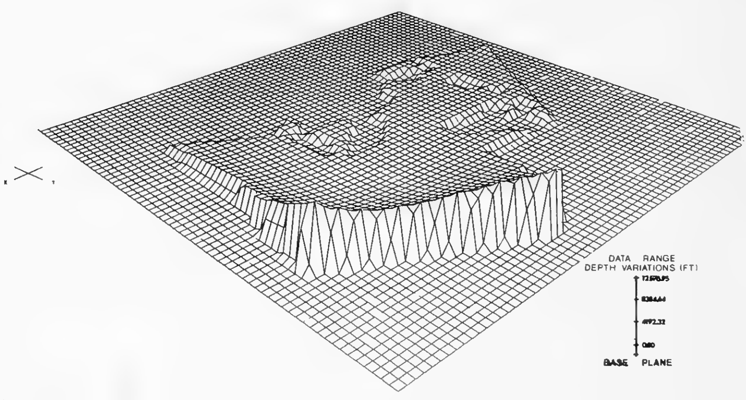

FIG. 13.—Residual surface of sixth degree polynomial trend of depth to bedrock from surface of borehole.

TABLE 1.—SUMMARY OF F-RATIOS, PROBABILITY LEVELS, R^2 FOR BOTH THE FULL AND RESTRICTED MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, AND SIGNIFICANCE FOR EACH TREND SURFACE FOR THE GEOTECHNICAL VARIABLE BEDROCK DEPTH FROM SURFACE OF BOREHOLE.[1]

Order of Trend Surface	R^2f	R^2r	df	F	Probability	Sign.
1	0.0202	0.0	2/135	1.3931	0.2518	NS
2	0.4766	0.0	5/132	24.0416	0.0000	S
3	0.4947	0.0	9/128	13.9259	0.0000	S
4	0.6026	0.0	14/123	13.3231	0.0000	S
5	0.7146	0.0	20/117	14.6456	0.0000	S
6	0.7807	0.0	27/110	14.5010	0.0000	S
1 vs 2	0.4766	0.0202	3/132	38.3693	0.0000	S
2 vs 3	0.4947	0.4766	4/128	1.1472	0.3374	NS
3 vs 4	0.6026	0.4947	5/123	6.6782	0.0000	S
4 vs 5	0.7146	0.6026	6/117	7/6488	0.0000	S
5 vs 6	0.7807	0.7146	7/110	4.7356	0.0001	S

(N = 138)

[1]An alpha level of 0.05 was employed before each hypothesis was considered statistically valid.

SUMMARY

The computer mapping of the contour, polynomial trends, and residuals can be a valuable aid in using trend surface analysis as a potential tool for predictive analysis. As illustrated in this paper, a visual inspection of the trends, residuals and their magnitudes seem to indicate the second or third order surfaces as being the best fitted polynomial surface. However, by using a F-test and the full and restricted model concept, the sixth order surface was found to be statistically the best fit. The R^2s values are inflated because of degrees of freedom in the numerator due to added terms in the full model, which might explain why the sixth order polynomial trend was found to be significant. The use of plotting the surfaces can give the investigator a chance to actually visualize what the trend surface looks like and locate the residuals and their magnitudes. This process can bring in the investigators' "common sense" and geological judgement into play to determine the best fit. With the increasing use and availability of appropriate software and hardware, computer modeling should be used in conjunction with statistical models in estimating the usefulness and limitations of trend surface analysis for predictive purposes.

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The Fishes of Jessamine Creek, Jessamine County, Kentucky

MICHAEL BARTON

Division of Science and Mathematics, Centre College, Danville, KY 40422

ABSTRACT

During the summer of 1983, a survey was made of the fishes of Jessamine Creek. This represents a contribution towards the completion of a floral and faunal inventory of the Jessamine Creek Gorge, a natural area that has recently come under the management of the Kentucky Nature Conservancy. A total of 1,555 individuals, representing 26 species, were collected. Although the creek has a history of pollution, this study indicates that no substantial alteration of the fish fauna has occurred.

INTRODUCTION

In 1982, the Kentucky chapter of the Nature Conservancy entered into agreements with landowners in the Jessamine Creek Gorge area to protect and preserve what is considered one of the most ecologically significant natural areas in the state. A stewardship committee was formed to develop an inventory of the flora and fauna of the gorge area. Because of the relative inaccessability of the gorge, the terrestrial flora and fauna are considered to be minimally impacted. There has been much concern, however, that pollution, in the form of effluents from sewage treatment plants serving the towns of Wilmore and Nicholasville as well as from other sources, may have altered the community composition of the stream ichthyofauna eliminating many sensitive species. This report presents the results of a survey of fish populations in Jessamine Creek and its major tributary, Town Fork.

STUDY AREA

Jessamine Creek and Town Fork originate from springs in north-central Jessamine County and course through a deep and largely inaccessible valley in southwest Jessamine County to empty into the palisades section of the Kentucky River. The stream bed is fairly typical of central Kentucky streams with a substrate of bedrock, limestone slab, and coarse rubble. The upper reaches of the stream are characterized by riffle and shallow pool areas flowing through croplands and pasture. Near the town of Wilmore, the creek descends into a steep gorge that is part of the palisades. Here, short stretches of riffles separate pools that may be hundreds of meters long and several meters deep. Most of the gorge is densely canopied by a riparian forest. The Nicholasville sewage treatment plant is located on Town Fork which empties into Jessamine Creek above the gorge while the Wilmore sewage treatment plant is located on a small tributary that empties into Jessamine Creek at the head of the gorge.

MATERIALS AND METHODS

Sampling was conducted at several sites from June, 1983 to August, 1983:

1. Jessamine Creek at KSR 29 overpass, 2.6 km from Nicholasville.
2. Jessamine Creek at Glass Mill Road overpass, 3.3 km West of Wilmore (sampled twice)
3. Jessamine Creek crossing at Campground Lane, 3.3 km West of Wilmore.
4. Town Fork at Shun Pike bridge, 6 km West of Wilmore
5. Jessamine Creek Gorge, 0.5 km stretch of stream approximately 2.5 km downstream from Site 5.

Fish were collected using standard electroshocking and seining techniques. At roadway overpass sites, the length of stream sampled was approximately 150 m. Over one km of stream within the gorge was sampled (sites 5, 6, 7). Fish were identified to species, counted, maximum and minimum sizes recorded, and returned to the stream. Those species that were unidentifiable in the field were preserved in 10% buffered formalin and saved.

RESULTS AND DISCUSSION

A total of 1,555 individuals, comprising 26 species, were collected during the course of this study (Table 1). Among the most abundant species were the minnows *Campostoma anomalum, Pimephales notatus,* and *Semotilus atromaculatus* (30.5%, 14.8%, and 4.1%, respectively). The blacknose dace, *Rhinichthys atratulus,* was the most abundant species at the Town Fork site (8.2%). The large numbers of smallmouth bass *(Micropterus dolomieui)* recorded were mostly juveniles in the 25 to 45 mm size range. The most abundant darter was the rainbow darter *(Etheostoma caeruleum),* which was recorded at all sampling stations, while the closely related orangethroat darter *(E. spectabile)* was restricted to headwater sites. According to Clay (1), *E. spectabile* generally occurs in smaller streams than *E. caeruleum* and two species rarely overlap in distribution.

TABLE 1.—NUMBER OF FISH SPECIES COLLECTED AT 7 SAMPLING SITES ON JESSAMINE CREEK, KENTUCKY. NUMBER IN PARENTHESES REPRESENT SIZE RANGE IN MM FOR EACH SPECIES.

Species	Sample Site							Total No.	% Total
	1	2	3	4	5	6	7		
Campostoma anomalum	1 (66)	103 (41-94)	100 (40-148)	34 (38-80)	88 (40-115)	85 (36-120)	65 (40-126)	476	30.5
Notropis ardens		4 (46-47)				1 (57)		5	.3
N. atherinoides			6 (18-20)		4 (70-74)		1 (69)	11	.7
N. chrysocephalus					35 (54-127)	16 (55-80)	8 (55-72)	59	3.8
Pimephales notatus	29 (34-49)	153 (43-76)	10 (35-50)	22 (21-52)	4 (40-44)	7 (31-41)	6 (40-50)	231	14.8
P. promelas		1 (66)		13 (24-30)				14	.9
Rhinichthys atratulus		4 (33-69)		123 (23-80)				127	8.2
Semotilus atromaculatus	2 (46-66)	19 (50-120)	3 (45-128)	31 (45-128)	1 (133)	7 (60-82)	1 (45)	64	4.1
Catostomus commersoni	4 (28-39)		16 (178-190)	4 (65-67)				24	1.5
Hypentelium nigricans			10 (92-138)		12 (39-236)	10 (66-21)	5 (29-160)	37	2.4
Ictalurus melas				1 (35)		1 (225)		2	.1
I. natalis		4 (26-105)	1 (175)		1 (148)			6	.3
Noturus flavus					1 (38)	2 (30-62)	3 (21-110)	6	.3
Gambusia affinis		10 (19-28)						10	.6
Micropterus dolomieui		9 (25-80)	25 (23-190)		4 (41-106)	18 (32-170)	16 (21-174)	72	4.6
M. salmoides					1 (155)			1	.1
Lepomis cyanellus	6 (38-95)	13 (61-100)	5 (40-82)	5 (21-114)	4 (25-96)		1 (102)	34	2.2
L. macrochirus	8 (67-104)		4 (76-90)	1 (100)		9 (82-110)	2 (40-122)	24	.15
L. megalotis						1 (83)	7 (81-117)	8	.5
Ambloplites rupestris					1 (118)	3 (45-97)	5 (110-132)	9	.6
Etheostoma blennioides	2 (33-34)	1 (50)	3 (52-71)		7 (40-80)	1 (82)	2 (68-68)	16	1.0
E. caeruleum	5 (26-44)	14 (33-52)	23 (30-50)	1 (34)	18 (35-53)	64 (29-55)	42 (36-50)	167	10.7
E. flabellare	11 (30-42)	5 (30-35)	1 (52)	11 (36-40)	4 (38-40)	5 (36-44)	4 (19-44)	41	2.6
E. spectabile	58 (24-38)			27 (28-36)				85	5.5
Percina caprodes							2 (86-108)	2	.1
Cottus carolinae	3 (30-38)	3 (28-40)	1 (33)	17 (40-59)				24	1.5
								1555	
Total no. species	11	14	14	13	15	15	16		

In the late 1960's and early 1970's, the late Dr. Henry Howell of Asbury College collected fishes from Jessamine Creek in conjunction with student field projects. The species list compiled was similar to that reported here although no relative abundance data were available (2). Additional species recorded by Howell as occuring in Jessamine Creek include the carp *(Cyprinus carpio),* the golden redhorse *(Moxostoma erythrurum),* and the warmouth *(Lepomis gulosus).* These may have been obtained in large, deep pools which were not sampled in this study. Some of the 27 species recorded by Howell (2), including the bullhead minnow *(Pimephales vigilax)* and the brown bullhead *(Ictalurus nebulosus),* may have been misidentified by students since they would not be expected to be present in streams of the Kentucky drainage (1, 3, 4). Five species recorded in this study, the fathead minnow *(Pimephales promelas)*, the black bullhead *(Ictalurus melas)*, the yellow bullhead *(I. natalis)*, the mosquitofish *(Gambusia affinis)*, and the orangethroat darter *(Etheostoma spectabile)* were not reported by Howell (2). When the results of this study are compared with other studies on central Kentucky stream fishes (4, 5), Jessamine Creek appears to be fairly typical of a small to medium sized stream of moderate gradient with respect to the diversity of the fish population. Although no sampling was attempted near the mouth of the creek, additional species characteristic of larger rivers probably are present there. None of the endangered, threatened or rare species reported by Branson et al. (6) were recorded. Comparison of the total number of species recovered in this study with the species diversity reported for a polluted creek in central Kentucky (7) suggests that the pollution that affects Jessamine Creek is not sufficient to have caused a substantial change in the fish population. More detailed analysis of the age structure of these populations is needed before this can be verified.

In summary, comparison of the species list compiled in this study with that compiled by Howell (2) and his students suggests that no major changes have occurred in the fish populations in the last 15 years. The area of Jessamine Creek Gorge to be managed by the Nature Conservancy supports a relatively diverse and seemingly healthy fish population that has not been severly impacted by pollution in the watershed.

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Development of the Potato Leafhopper On Selected Legumes

A. M. SIMMONS, K. V. YEARGAN AND B. C. PASS

Department of Entomology, University of Kentucky
Lexington, Kentucky 40546-0091.

ABSTRACT

Developmental rates for the potato leafhopper [*Empoasca fabae* (Harris)] were determined at 2 constant temperatures, 24°C and 27°C. Seven kinds of leguminous host plants were used: 'Apollo', 'Buffalo', and 'Riley' alfalfa; 'Major' broad bean; 'Kenstar' and 'Kuhn' red clover; and 'Williams' soybean. Development of the leafhopper varied among hosts. The least time was required to develop from egg to adult emergence on broad bean; the leafhoppers developed at the rates of 5.08% and 6.0% per day at 24°C and 27°C, respectively. A relatively slow rate of development was attained by potato leafhoppers on soybean (4.44% and 5.39% per day at 24°C and 27°C, respectively). Males developed faster than females in most cases.

INTRODUCTION

The potato leafhopper, *Empoasca fabae* (Harris), is a polyphagous insect which is commonly found on alfalfa, clover, soybean, and many other cultivated and wild plants in Kentucky. Broad bean (*Vicia faba* L.) is a plant on which the potato leafhopper is easily reared. Consequently, much information on the potato leafhopper has been compiled using broad bean as the host. However, broad bean is not commonly grown in the areas where this insect is a pest. Simonet and Pienkowski (1) (using broad bean as the host) and Kouskolekas and Decker (2) (using 'Buffalo' alfalfa as the host) reported different threshold temperatures for nymphal development of the potato leafhopper. Saxena et al. (3), working with other species of leafhoppers, reported that host plants can influence the developmental rate of leafhoppers.

It is imperative that the biology of the potato leafhopper be understood in order to devise sound management strategies for this pest. The study reported herein tested for influence of host plant on the development of the potato leafhopper.

MATERIALS AND METHODS

Seven kinds of greenhouse-grown, leguminous host plants were used for developmental studies: 'Apollo', 'Buffalo' and 'Riley' alfalfa; 'Major' broad bean; 'Kenstar' and 'Kuhn' red clover (the former a pubescent variety and the latter a variety with a few closely-appressed hairs); and 'Williams' soybean. Alfalfa and red clover plants were cut and allowed to regrow 1.5 to 2 weeks (to a height of 10 to 15 cm) prior to being used in this study. Broad bean plants ca. 15 cm tall and soybean plants at growth stages V2 through V3 (4) were selected to start the experiment. Two environmental chambers were maintained at a 15:9 L:D photoperiod and at 24 ± 2°C and 27 ± 2°C, mean temperatures which the potato leafhopper frequently encounters in its natural environment. Illumination was by high output, cool white, 40 watt fluorescent lamps.

The host plants were caged with 61 cm x 15.2 cm diameter plexiglas tubing, the detailed design of which was described by Simmons (5), and placed in the environmental chambers in a randomized block design, 2 blocks/chamber. There were 5 such replicates at each temperature. Relative humidity varied from 60% to 99%, depending on the temperature and when the plants were watered. Plants were watered from the bottom as needed.

Insects were collected from an alafalfa field in Fayette Co., KY, with a sweep net. The contents were emptied into a 30 x 30 x 40 cm plexiglas cage, which had a sleeve opening (covered with stockinnette) which permitted hand entry. The leafhopppers could easily be sexed without magnification as they rested on the sides of the transparent cage. Adult female potato leafhoppers were aspirated from the cage into a 65 ml cup, the lid of which had a 2 cm diameter opening; an alfalfa stem was placed in each cup and a piece of cotton was inserted into the opening after aspirating the leafhoppers. Ten females were collected per cup, one cup being used for each host plant. During hot weather the cups of leafhoppers were placed in an ice chest until they were transported to the laboratory.

Female potato leafhoppers were allowed to oviposit over a 12 hour period of continuous light. The amount of time required by the potato leafhopper to develop from egg to adult emergence at 24°C and 27°C on each host plant was recorded. The first day was counted as 12 hours after the oviposition period ended. Adults which emerged on each day were removed from the cage, sexed, and the number of each gender recorded for each host plant.

Duncan's Multiple Range Test was used to separate the mean developmental rates of the leafhoppers among host plants. Treatment (host plant) means were compared within temperatures (24°C and 27°C) for the sexes combined, as well as for males and females separately.

RESULTS AND DISCUSSION

The number of days required for the potato leafhopper to develop from egg to the adult stage on 7 leguminous hosts at 24°C and at 27°C is presented in Table 1. The number of days required for the potato leafhopper to develop at 24°C ranged, among the plants tested, from 19.8 days (19.4 for males and 20.1 for females) on broad bean to 22.7 days (22.4 for males and 22.9 for females) on soybean. A similar duration (ca. 19.0 days) for newly oviposited eggs to reach the adult stage on broad bean at 24°C can be calculated from a study by Simonet and Pienkowski (1). At 27°C the duration in days for development ranged from 16.7 days (16.5 for males and 17.4 for females) on broad bean to 18.7 (18.1 for males and 19.2 for females) on soybean.

Developmental rates for the potato leafhopper on the 7 host plants at 24°C and 27°C are presented in Tables 2 and 3. Significant differences ($P<0.05$) were found among developmental rates of leafhoppers on different host plants. The fastest development was on the broad bean at 27°C; one of the 2 fastest rates at 24°C also occurred on the broad bean. The mean per cent development per day on broad bean was 5.08 (5.17 for males and 5.0 for females) at 24°C; at 27°C the rate was 6.0%/day (6.07%/day for males and 5.85%/day for females). In the order of decreasing rate of development on the other host plants, the trend was as follows: alfalfa, red clover, and soybean. Among the 3 alfalfa varieties, the potato leafhopper developed at the fastest rate on 'Buffalo' at 24°C, but there were no differences among alfalfa varieties at 27°C. Between the 2 red clover varieties, the fastest rate was on Kuhn at 24°C, but no significant difference in developmental rates was observed between red clover varieties at 27°C. Development of the potato leafhopper on soybean was the slowest of all plants tested at 24°C and one of the 2 slowest at 27°C. At 24°C on soybean, the developmental rate was 4.44%/day (4.5%/day for males and 4.38%/day for females), and at 27°C the developmental rate was 5.39%/day (5.54%/day for males and 5.24% day for females).

Male potato leafhoppers developed faster than females (Tables 2 and 3). This was true for development at both temperature regimes and on all plants tested, with 2

TABLE 1. DURATION IN DAYS FOR DEVELOPMENT OF THE POTATO LEAFHOPPER FROM EGG TO THE ADULT STAGE ON DIFFERENT LEGUMINOUS HOSTS AT 24°C AND 27°C.

Host plants	Male	Female	Both sexes
	24°C		
Broad Bean	19.4	20.1	19.8
Buffalo (alfalfa)	19.5	20.5	20.0
Kuhn (red clover)	20.3	21.0	20.7
Apollo (alfalfa)	20.2	21.5	20.9
Riley (alfalfa)	20.5	21.9	21.2
Kenstar (red clover)	21.5	22.2	21.8
Soybean	22.4	22.9	22.7
	27°C		
Broad Bean	16.5	17.4	16.7
Buffalo (alfalfa)	16.7	17.8	17.2
Riley (alfalfa)	16.4	17.9	17.5
Apollo (alfalfa)	17.2	18.0	17.6
Kuhn (red clover)	17.5	18.3	17.9
Kenstar (red clover)	18.0	18.8	18.5
Soybean	18.1	19.2	18.7

TABLE 2. MEAN PER CENT DEVELOPMENT PER DAY (EGG TO ADULT) OF MALE AND FEMALE POTATO LEAFHOPPERS ON LEGUMINOUS PLANTS AT 24 ±2°C.

	Male		Female		Both sexes
Host plants	N	Mean	N	Mean	Mean
Broad Bean	30	5.17a*,**	29	5.0a	5.08a
Buffalo (alfalfa)	56	5.15a	50	4.90ab	5.03a
Kuhn (red clover)	60	4.95b	66	4.79bc	4.86b
Apollo (alfalfa)	49	4.97b	55	4.67cd	4.81bc
Riley (alfalfa)	73	4.90b	73	4.60de	4.75c
Kenstar (red clover)	36	4.68c	31	4.50ef	4.60d
Soybean	26	4.50c	33	4.38f	4.44e

* Means within a column and followed by the same letter are not significantly different (P>0.05).

** On each host plant males developed significantly (P<0.05) faster than females, except for soybean on which there was no difference between developmental rates of the sexes.

TABLE 3. MEAN PER CENT DEVELOPMENT PER DAY (EGG TO ADULT) OF MALE AND FEMALE POTATO LEAFHOPPERS ON LEGUMINOUS PLANTS AT 27 ±2°C.

	Male		Female		Both sexes
Host plants	N	Mean	N	Mean	Mean
Broad Bean	50	6.07a*,**	20	5.85a	6.0a
Buffalo (alfalfa)	36	6.05ab	31	5.68ab	5.87b
Riley (alfalfa)	43	5.93b	55	5.54bc	5.78b
Apollo (alfalfa)	36	5.86b	34	5.67ab	5.72bc
Kuhn (red clover)	35	5.70cd	35	5.46cd	5.60cd
Kenstar (red clover)	7	5.58cd	10	5.29de	5.54de
Soybean	15	5.54d	16	5.24e	5.39e

* Means within a column and followed by the same letter are not significantly different (P>0.05).

** On each host plant males developed significantly (P<0.05) faster than females, except for 'Kenstar' red clover on which there was no difference between developmental rates of the sexes

exceptions: no significant differences were observed between sexes on soybean at 24°C or on 'Kenstar' red clover at 27°C. Newton and Barnes (6) also noted that female potato leafhoppers required longer than males to develop.

The sex ratio of all adults which emerged was 51:49, male to female (49:51 at 24°C and 52:48 at 27°C).

The results reported herein indicate that host plants can influence the developmental rate of the potato leafhopper. This suggests that some of the earlier data obtained on the biology of the potato leafhopper using broad bean as a host plant may not be directly applicable to other host-plant systems. For example, if one utilized developmental data obtained from potato leafhoppers reared on the broad bean to predict phenological events occurring on soybeans, those events would occur later than predicted. On the other hand, those same data should provide accurate predictions of development on 'Buffalo' alfalfa, a variety commonly grown in Kentucky.

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Discriminative Analysis of Selected Rock Strengths and Geological Parameters Associated with Basic Lithologies Derived From the Eastern Kentucky Coal Field

ALAN D. SMITH

Coal Mining Administration, College of Business, Eastern Kentucky University, Richmond, KY 40475

JAMES C. COBB

Kentucky Geological Survey, University of Kentucky, Lexington, KY 40506

KOT F. UNRUG

Department of Mining Engineering, University of Kentucky, Lexington, KY 40506

ABSTRACT

A computer-based information system for engineering and geological data pertaining to surface mining was developed under the Title III Program by the Kentucky Geological Survey and the University of Kentucky Mining Engineering Department. Approximately 1,000 tests were performed on cores derived from the Eastern Kentucky Coal Field using slake durability, direct shear, Brazilian tensile, punch shear, and ultimate and compressive strength testing. Statistical analyses were performed on the data generated by this project. Multiple linear regression, hypothesis testing, power analysis, stepwise regression, and model building were the statistical methods applied to the Title III data base. The analyses provided estimates of relationships between the sets of engineering test results and the geological criteria in the overburden rocks. Statistically significant relationships were found among the parameters: slake durability, direct shear-test mean and standard deviation, punch shear-stress mean and deviation, Brazilian tensile-test mean and standard deviation, and the criterion gross-overburden lithology. No predictive relationships with the various engineering and geological tests were found associated with depth of core sampling.

INTRODUCTION

There are at least 36 types of rocks in the coal-bearing strata of Kentucky that can be differentiated by geologic characteristics. All these rocks occur in the highwalls and spoils of surface mines. Each rock type was deposited as sediment under different conditions and responds differently to weathering and compaction, particularly after disturbances such as mining. As a result, each rock will weather at a different rate, produce water with different pH, and remain stable after backfilling at varying slope angles. There is, unfortunately, no source of information which contains data on the weatherability and strength of these rocks from which mining and reclamation planning can be based.

However, with the introduction of state and federal legislation governing reclamation procedures for surface-mined lands, immediate needs were checked for defining geological characteristics and engineering behavior of overburden rocks. Data of this type are usually incomplete and scattered throughout various agencies, reports, and private sources. The acquisition of these data for use by all public and private parties will lend support in particular to Sec. 515 (3) of Public Law 95-87:

> To restore to approximate original contour, the operator, at a minimum shall backfill, grade, and compact (where advisable) using all available overburden and other spoil and waste materials to attain the lowest practicable grade but not more than the angle of repose.

Provided adequate data are available for geological and engineering classification of the overburden, groupings of rocks could be introduced which would serve as an aid to more effective and efficient backfilling of the overburden. Additionally, the technical feasibility of mining coal at a particular location and the durability and safety of a proposed excavation, whether in a strip underground mine, cannot be assessed adequately without comprehensive data on the engineering characteristics of the rock units which confine and support the coal strata to be removed. The design of the slopes and other reclamation procedures, applications of excavating equipment, blasting patterns, and haul roads in a surface mine or the size openings and selection of mining methods in an underground mine are governed by the types of rock encountered. Only by obtaining comprehensive information on the properties of the rocks, both geological and engineering, can the most effective and economical design be attained.

The principal goal of this project was to develop a computer-based information system for geotechnical data related to surface mining and reclamation. Other objectives were: (1) to generate data on the geological and engineering properties of overburden rocks, (2) to create computer programs to access and analyze this data, (3) to perform statistical analyses on the data generated, (4) to direct theses projects in diverse aspects of geology and engineering related to overburden rocks, and (5) to develop a user's manual for the computer information system. The thrust of this paper is to report the results of statistical analysis on the data initially generated from this project.

METHODS

Location of Cores Used for Testing

In order to make the study of overburden characteristics relevant to Kentucky's coal-producing areas, drill cores were sought from many sources. Government agencies and private companies were contacted for drill cores or coal-bearing sequences in which typical overburden rocks were encountered. These cores were geologically described, sampled, and prepared for physical testing. The geological description was done using the 3-digit code system of Ferm and Weisenfluh (1). This system was selected for use because it is the method recommended by the Kentucky Bureau of Surface-Mining Reclamation and Enforcement and it facilitates computer storage of geologic data. In addition, the names applied to the rock types are a combination of driller and geologists' terms. As noted by Farm and Weisenfluh (op. cit.), the cores logged by their methods should alert engineers to rock types which can produce problems in slope and shaft construction, and general planning for underground and surface mines. The classification employes a three-digit system instead of the traditional descriptive classification. The first digit, ranging from one to nine, describes the rock type by grain size. The second digit may describe either the sand components, color, or fossil content. The third place digit describes any sedimentary features present. Other descriptive symbols, such as the term "flat" (FLT) or "rippled" (RIP) may follow the description if shale or sandstone streaks are present. If the streaks are horizontal and parallel, the term "flat" is used; and if the streaks are wavy, the term "rippled" is used. Table 1 is a summary of the three-digit rock classification, and accompanying geological description of the overburden rock types found in the cores studied. Table 2 shows the core locations, recorded by computer identification number, Carter coordinates, geological quadrangle, county, surface elevation, and cored interval of the cores used in the present study.

TABLE 1.—THREE-DIGIT CLASSIFICATION CODES AND THE ASSOCIATED GEOLOGICAL DESCRIPTION

Code	Geological Description
013	Slumped shale
014	Slumped sandy shale
017	Shale mud flow
018	Sandy shale mud flow
020	Coal
113	Black shale with coal streaks
114	Black shale
123	Dark gray shale with coal streaks
124	Dark gray shale
127	Dark gray fire clay
313	Black shale with sandstone streaks
322 FLT	Dark gray shale and interbedded sandstone, flat
322 RIP	Dark gray shale and interbedded sandstone, rippled
323	Dark gray shale with sandstone streaks
324	Dark gray massive sandy shale
325	Dark gray massive churned sandy shale
326	Dark gray churned sandy shale
327	Dark gray sandy fire clay
328	Dark gray burrowed sandy shale
332	Light gray-green shale and interbedded sandstone
541	Gray crossbedded sandstone
542	Gray sandstone, layered
543	Gray sandstone with shale streaks
543 FLT	Gray sandstone with shale streaks, flat
543 RIP	Gray sandstone with shale streaks, rippled

TABLE 2—LOCATION OF CORES USED IN THE PRESENT STUDY

Computer ID	Carter Coord.	Geologic Quadrangle	County	Elevation	Cored Interval
C338	12-T-78	Bruin	Elliott	1080	10-646
C400	1-F-69	Fount	Knox	1570	14-525
C307	19-C-70	Middlesboro N.	Bell	1311	10-306
C253	9-J-73	Buckhorn	Perry	920	3-115
C385	17-M-77	Guage	Breathitt	1542	15-974
C382	5-0-80	Ivyton	Johnson	1007	25-707
BECC	18-I-81	Mayking	Letcher	1800	15-510
MECC	8-L-86	Lick Creek	Pike	1296	12-205
LECO	14-H-74	Cutshin	Leslie	1560	0-505
CE01	14-H-79	Blackey	Letcher	1009	15-57
CE02	14-H-79	Blackey	Letcher	1059	11-187
CE03	14-H-79	Blackey	Letcher	1182	0-68
CE04	16-L-71	Booneville	Owsley	1054	216-307
CE05	14-H-79	Blackey	Letcher	1008.0	21-67
CE06	16-L-71	Booneville	Owsley	840	7-191
CE07	16-L-71	Booneville	Owsley	820	7-167
CE08	16-L-71	Booneville	Owsley	820	5-160

ENGINEERING ROCK-TESTING

Procedures

The following list contains brief descriptions of the various tests performed on selected rock cores.

BRAZILIAN TENSILE TEST: 1. Objective: This test is used for the determination of the tensile strength of rocks. 2. Procedure: The Brazilian Test is an indirect method of determining the tensile strength of rocks. This test involves a solid circular disc with a length to diameter ratio of 1:1. The disc is loaded diametrically (line or strip load) until failure. This test is only valid when primary fracture initiates from the center of the disc spreading along the loading diameter. 3. Application: The data from Brazilian test along with the data from the Uniaxial Compression test will give the limits of minimum and maximum strength of the rock. This information can be used for the mechanical winning of minerals in rock, drilling and blasting of rock, and failure predictions of roofs and floors in underground mines.

PUNCH SHEAR AND DIRECT SHEAR: 1. Objective: These tests are used to determine the shear strength of rocks parallel and perpendicular to bedding planes. 2. Procedure: The punch-shear test involves a flat disc of rock cut parallel to bedding. The thickness of the disc may range from 0.25 to 0.50 inches. The shearing effect is achieved by loading a cylindrical plunger perpendicular to bedding until the plunger punches through the disc (i.e., failure occurs). The direct-shear test uses a shear box that has two movable parts. The specimen is placed in the shear box and is set in hydrostone to prevent movement. The lower half of the shear box remains stationary while the upper half is loaded until sliding movement initiates across the lower half. Thus, failure is achieved when the sample breaks parallel to bedding. 3. Application: The application of the direct shear and punch shear data is used for the calculations of sliding and failure of a high wall in strip mining. Since the data is determined parallel and perpendicular to bedding, a limit of shear strength of the high wall can be determined for highwall stability.

UNIAXIAL AND ULTIMATE COMPRESSIVE STRENGTH, POISSON'S RATIO, AND YOUNG'S MODULUS: 1. Objective: The objective of this test is to determine the Compressive Strength, Poisson's ratio, and Young's Modulus of a rock sample. 2. Procedure: A cylindrical, right-angled specimen of rock with a length-to-diameter ratio of 2:1 is uniaxially loaded between the platens of a testing machine. The displacement of the original dimensions caused by uniaxial loading is measured by linear variable differential transducers (LVDI). This displacement of dimensions is used in the calculation of a stress-strain curve of the sample. From this curve the Poisson's strength of the sample is found at the failure point of the curve for the sample. 3. Application: The data obtained from the test is used for the basic calculations of elastic theory and can be related to the angle of internal friction. This in turn can be used for the design of high walls and foundation work in strip mining and refill work, respectively.

SLAKE DURABILITY: 1. Objective: This test is used for the determination of weather durability of rock. 2. Procedure: The Slake Durability test uses 10 pieces of a sample weighing 40 to 60 grams each. These samples are placed in a wire-mesh basket which is immersed in water. The basket is rotated at 60 rpm for 30 minutes. Later, the basket is oven dried for 24 hours to remove all excess water and weighed. The Slake Durability

Index is calculated as a percentage of final weight to initial weight of the sample. The Slake-Durability Index ranged from 0 to 100%. The 0% represents total disintegration of the sample. 3. Application: The Slake Durability Index gives the weathering durability of the rock sample. It also gives the percentage of matrix material produced during the handling of the spoil material and can be related to fill calculations.

RESEARCH QUESTIONS

The major research questions asked in the present study are: 1. Are there predictive relationships among the various engineering tests and basic lithologies? 2. Can each specific rock type according to the system of Ferm and Weisenfluh (1) be descriminated from the remaining rock types based on the results of the engineering-rock testing?

STATISTICAL TECHNIQUES

MULTIPLE LINEAR REGRESSION AND HYPOTHESIS TESTING—Multiple linear regression is an extremely flexible technique that makes available much statistical information once certain mechanical topics are mastered. Newman (2) and Fraas and Newman (3), in a discussion of the advantages of regression hypotheses testing procedures, compiled several reasons why multiple linear regression is an appropriate and, in many cases, preferable procedure. A few advantages are: 1. Multiple linear regression is the general case of the least sum of squares solution. Chi square, t- and F-tests are special cases of the least squares solution. Therefore, anytime anyone could use any of the special cases of the least squares solution, the more general case would be appropriate, 2. With the regression procedure one states the hypothesis and then writes the regression model to test the hypothesis. So every test of significance is a test of a specific hypothesis, 3. Regression is more flexible in being able to write the models that specifically reflect the research hypotheses, 4. Since regression can deal with categorical and continuous variables, it is more flexible in its ability to reflect real world problems, 5. All analyses of covariance procedures are really regression procedures because the covariables are always held constant by regressing it on the criterion.

MODEL BUILDING—Applied researchers who use multiple regression frequently are interested in: 1. Estimating the relationship between a set of predictive variables to a criterion in a sample for the purpose of generalizing to the population; 2. Estimating the magnitude of relationships from sample to sample and then to the population. Generally, in any regression model, a R^2 needs to be large enough to be practically as well as statistically significant. This means that the regression model or equation should actually be able to predict significantly better than by chance alone as well as visual inspection, especially in the case of rock mechanics studies. If the model does not predict significantly better, then the model is not practically useful and one must reconsider the variables that went into the model. The following are some reasons that may be considered in explaining why the model may not be predicting well: 1. The variables used in the model should be considered as interactions. However, there could be first, second, third, and higher orders of interactions, which increases the number of variables examined in the model. As more interactions are added, the number of variables decreases, thus causing a greater instability in the regression equation's ability to accurately predict, 2. There may be second or higher degree curvilinear relationships between the criterion and predictor variables that are not reflected in the model. Therefore, in multiple linear regression, if curvilinear relationship exists, the linear predictor is not a good predictor since the model does not reflect the curvilinear aspect. One can examine by plotting the error vector or residuals to see if a regular second or higher order pattern exists, hence reflecting a possible curvilinear relationship. Unfortunately, everytime a higher order term is added to the model the number of variables increase, thus reducing the data collected to variable ratio, 3. Other important considerations include the reliability and validity estimates of the variables. Even though a particular variable has been demonstrated in the literature as an important factor, the current estimates, limited by present data collection and instrumentation techniques, of the variable may be poor and better estimates should be sought before it is included in the model. Obviously, the model will only be as good as the degree of relevancy of the variables entered into the model.

Once the variables in the model are determined to be a good predictor and have practical significance, usually determined by hypothesis testing and model comparisons, interpretation of the regression weights and associated values for the variables are another major concern. Each variable in the model has a partial regression weight by which it is multiplied. These weights are calculated by the least sum of squares method via a commercial computer program like SPSS or SAS, and are intended to maximize the prediction. Generally, the larger the R^2 term the more accurate the prediction. However, a common problem with this procedure is that researchers and readers of research tend to interpret the partial regression weights and the standardized regression weights by attaching greater importance to those variables with higher weights. This is only legitimate if the variables are not significantly correlated, or there is no multicolinearity. The more the correlation between the predictor variables, and hence multicolinearity, the less appropriate it is to interpret these weights.

RESULTS

Overburden Rock Testing

Almost 1,000 individual tests were performed on cores, using slake durability, direct shear, punch shear, Brazilian tensile, compressive, and ultimate compressive strength. Whenever possible, 3 samples were used in the testing process, with a recorded mean and standard deviation for the strength test. A total of 262 different rock samples with partially paired data were recorded and used in the statistical analysis of the results to answer the major research questions generated in this study. Table 3 presents a summary of the coded label and description of the geological and engineering parameters used in the study.

TABLE 3—DESCRIPTIVES OF THE GEOLOGICAL AND ENGINEERING PARAMETERS STUDIED.

Parameter Label	Parameter Description
FERM	Ferm and Weisenfluh's (1981) Rock Classification Number.
BRAZM	Brazilian Tensile Test Mean Performed on Three Rock Samples of Same Rock Classification Number. (Units in kg/cm^2)
BRAZDEV	Brazilian Tensile Test Standard Deviation Performed on Three Rock Samples of Same Rock Classification Number.
SLAKE	Slake Durability Test. (Units in percentage)
DSHEAR	Direct Shear Test Mean Performed on Three Rock Samples of Some Rock Classification. (Units in kg/cm^2)
DSDEV	Direct Shear Test Standard Deviation Performed on Three Rock Samples of Same Rock Classification.
PUNCHSR	Punch Shear Test Mean Performed on Three Rock Samples of Same Rock Classification. (Units in kg/cm^2)
PUNCHDV	Punch Shear Test Standard Deviation Performed on Three Rock Samples of Same Rock Classification.
STRESSM	Compressive Uniaxial Strength Test Mean Performed on Three Rock Samples of Same Rock Classification. (Units in kg/cm^2)
ETAN	Young's Modulus of Elasticity
DEPTH	Depth from Ground Surface to Core Sample (Units in feet)
ELEVATION	Elevation of the Top of the Core Sample. (Units in feet)
VY	Poisson's Ratio. (Vertical Direction)
VX	Poisson's Ratio. (Horizontal Direction)
VAVER	Poisson's Ratio. (Averaged) (VY + VX)/2
POSS	Transformed Poisson's Ratio. (VY -VX)
MOMENT	Bending Moment. (Units in kg/cm^2)
SOIL	Soil Type. (Intervals in feet)
CO	Ultimate Compressive Strength (Rupture). (Units in psi)

HYPOTHESIS TESTING AND MODEL COMPARISONS

The first general research question was attempted by using multiple linear regression analysis techniques, as discussed in the previous section. To accomplish this task, the Ferm's and Weisenfluh's number was grouped into 4 gross categories; where 000 to 039 equal to 1, 090 to 299 equal to 2, 300 to 499 equal to 3, and 500 to 900 equal to 4. The rationale for this manipulation is to place the overburden rocks derived from the cores into one of the following major

TABLE 4—SUMMARY OF MODELS TESTED, BOTH FULL AND RESTRICTED MODELS, R^2 FOR BOTH MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, F-RATIO, PROBABILITY LEVELS, AND STATISTICAL SIGNIFICANCE FOR EACH RESEARCH HYPOTHESIS THAT TESTED FOR DISCRIMINATIVE RELATIONSHIPS AMONG THE ENGINEERING AND GEOLOGICAL PARAMETERS AND THE CRITERION VARIABLE FERM CLASSIFICATION AND GROSS LITHOLOGY

Engineering or Geological Parameter(s)	R^2_{full}	$R^2_{restr.}$	df	F-Ratio	Prob.	Significance
BRAZM, BRAZDEV	0.22778	0.0	2/47	6.93169	0.0023	S
BRAZM[a]	0.06050	0.0	1/48	3.09089	0.0851	NS
BRAZDEV[a]	0.11511	0.0	1/48	6.24386	0.0159	S
VX, VY, VAVER, POSS, CO	0.02798	0.0	4/48	0.34548	0.8459	NS
VX[b]	0.01304	0.0	1/51	0.67402	0.4155	NS
CO[b]	0.01440	0.0	1/51	0.74488	0.3921	NS
VY[b]	0.00982	0.0	1/51	0.50559	0.4803	NS
VAVER[b]	0.01325	0.0	1/51	0.68497	0.4117	NS
POSS[b]	0.00088	0.0	1/51	0.04511	0.8327	NS
SLAKE	0.12219	0.0	1/55	7.65626	0.0077	S
DSHEAR, DSDEV	0.40786	0.0	2/16	5.51030	0.0151	S
DSHEAR[a]	0.39528	0.0	1/17	11.11237	0.0039	S
DSDEV[a]	0.40786	0.0	2/16	5.51030	0.0151	S
PUNCHSR, PUNCHDV	0.25882	0.0	2/53	9.25366	0.0004	S
PUNCHSR[a]	0.24759	0.0	1/54	17.76929	0.0001	S
PUNCHDV[a]	0.01225	0.0	1/54	0.66975	0.4167	NS
MOMENT, STRESSM	0.02676	0.0	2/79	1.08616	0.3425	NS
MOMENT[a]	0.02429	0.0	1/80	1.99132	0.1621	NS
STRESSM[a]	0.02673	0.0	1/80	2.19675	0.1422	NS
VY, VX, CO, ETAN	0.06158	0.0	4/48	0.78744	0.5390	NS
DEPTH	0.00322	0.0	1/115	0.37180	0.5432	NS
ETAN	0.01853	0.0	1/51	0.96293	0.3311	NS

NOTE. An F-test was utilized to test for statistically significant relationships among the various engineering and geological parameters studied with the lithology reclassified from the Ferm's rock designation code. The assigned alpha level of 0.05 for a two-tailed, nondirectional test was used because each specific research hypothesis was considered statistically significant. However, a correction for multiple comparisons was deemed necessary in a number of cases in the hypothesis-testing process. The alpha level was corrected using the Newman and Fry (4) method. The corrected alpha level was used before each specific hypothesis was considered statistically significant. Listed below are the corrected alpha levels for the affected hypotheses. The symbols S denotes statistical significance, while NS denotes nonsignificance at the stated alpha level

[a]corrected alpha level is equal to 0.025

[b]corrected alpha level is equal to 0.010.

rock groups: sandstones (pebbly and sandstones and conglomerates), sandy shales and fireclays, shales and fireclays, ironstone, limestones, and flint clays. Hence, the coding of 500 to 900 represents relatively coarse-grained rocks of sandstones, pebbly sandstones, and conglomerates. The coding of 090 to 299 illustrates the basic lithology of shales and fireclays coupled with ironstone, limestone, and flint clay; while the coding of 000 to 039 represents coal and bone. As illustrated in the coding scheme, increasing significance is granted to coarser-grained rock and the reverse is true for finer-grained rock. By this grouping, all the rock samples (N=262) can be entered into the regression equations for predictive purposes and allow for sufficient power of the test for internal validity purposes. Table 4 is a summary of the models tested, both full and restricted models, R^2 for both models, degrees of freedom-numerator, degrees of freedom-denominator, F-ratio, probability levels, and statistical significance for each research hypothesis that tested for discriminative relationships among the engineering and geological parameters and the criterion variable, gross lithology.

The second general research question was approached by coding all the other classification numbers as a 2, and the actual classification number as a 1. This allowed for the formulation of a dichotomized criterion variable to be used for discriminative analysis purposes. The dependent and engineering and geological parameters were entered into multiple linear regression equations. The results of this testing, for illustrative purposes, are summarized in Tables 5 through 7. However, due to the general lack of success of this procedure, not all possible combinations of classification numbers were delineated in this manner. Table 8 is a summary table illustrating the results of the hypotheses testing and model comparisons using depth to the top of the sample core as the criterion.

TABLE 5—SUMMARY OF MODELS TESTED, BOTH FULL AND RESTRICTED MODELS, R^2 FOR BOTH MODELS, DEGREES OF NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, F-RATIO, PROBABILITY LEVELS, AND STATISTICAL SIGNIFICANCE FOR EACH RESEARCH HYPOTHESIS THAT TESTED FOR DISCRIMINATIVE RELATIONSHIPS AMONG THE ENGINEERING AND GEOLOGICAL PARAMETERS AND THE CRITERION VARIABLE FERM CLASSIFICATION 138 (LIGHT GRAY FIRECLAY)

Engineering or Geological Parameter(s)	R^2_{full}	$R^2_{restr.}$	df	F-Ratio	Prob.	Significance
BRAZM, BRAZDEV		0.0		NOT TESTABLE[c]		
BRAZM[a]		0.0		NOT TESTABLE[c]		
BRAZDEV[a]		0.00		NOT TESTABLE[c]		
VX, VY, VAVER, POSS, CO	0.37798	0.0	4/48	7.29200	0.0001	S
VX[b]	0.00399	0.0	1/51	0.20421	0.6533	NS
CO[b]	0.35951	0.0	1/51	28.62660	0.0000	S
VY[b]	0.01800	0.0	1/51	0.93468	0.3382	NS
VAVER[b]	0.01101	0.0	1/51	0.56796	0.4545	NS
POSS[b]	0.00005	0.0	1/51	0.00232	0.9618	NS
SLAKE	0.00022	0.0	1/51	0.01209	0.9128	NS
DSHEAR, DSDEV		0.00		NOT TESTABLE[c]		
DSHEAR[a]		0.0		NOT TESTABLE[c]		
DSDEV[a]		0.0		NOT TESTABLE[c]		
PUNCHSR, PUNCHDV		0.0		NOT TESTABLE[c]		
PUNCHSR[a]		0.0		NOT TESTABLE[c]		
PUNCHDV[a]		0.0		NOT TESTABLE[c]		
MOMENT, STRESSM		0.0		NOT TESTABLE[c]		
MOMENT[a]		0.0		NOT TESTABLE[c]		
STRESSM[a]		0.0		NOT TESTABLE[c]		
VY, VX, CO, ETAN	0.43801	0.0	4/48	9.35266	0.0000	S
DEPTH	0.00008	0.0	1/115	0.00912	0.9241	NS

TABLE 5—CONTINUED

NOTE. An F-test was utilized to test for statistically significant relationships among the various engineering and geological parameters studied with the lithology reclassified from the Ferm's rock designation code. The assigned alpha level of 0.05 for a two-tailed, nondirectional test was used before each specific research hypothesis was considered statistically significant. However, a correction for multiple comparisons was deemed necessary in a number of cases in the hypothesis-testing process. The alpha level was corrected using the Newman and Fry (4) method. The corrected alpha level was used before each specific hypothesis was considered statistically significant. Listed below are the corrected alpha levels for the affected hypotheses. The symbol S denotes statistical significance, while NS denotes nonsignificance at the stated alpha level.

[a]corrected alpha level is equal to 0.025.

[b]corrected alpha level is equal to 0.010.

[c]variables in the equation are constant or have missing correlations and cannot be processed.

TABLE 6—SUMMARY OF MODELS TESTED, BOTH FULL AND RESTRICTED MODELS, R^2 FOR BOTH MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, F-RATIO, PROBABILITY LEVELS, AND STATISTICAL SIGNIFICANCE FOR EACH RESEARCH HYPOTHESIS THAT TESTED FOR DISCRIMINATIVE RELATIONSHIPS AMONG THE ENGINEERING AND GEOLOGICAL PARAMETERS AND THE CRITERION VARIABLE FERM CLASSIFICATION 127 (DARK GRAY FIRE-CLAY)

Engineering or Geological Parameter(s)	R^2_{full}	$R^2_{restr.}$	df	F-Ratio	Prob.	Significance
BRAZM, BRAZDEV	0.19453	0.0	2/47	5.67553	0.0062	S
BRAZM[a]	0.05974	0.0	1/48	3.04975	0.0871	NS
BRAZDEV[a]	0.17182	0.0	1/48	9.95807	0.0028	S
VX, VY, VAVER, POSS, CO	0.04956	0.0	4/48	0.62571	0.6464	NS
VX[b]	0.00138	0.0	1/51	0.07058	0.7916	NS
CO[b]	0.04345	0.0	1/51	2.31663	0.1342	NS
VY[b]	0.00136	0.0	1/51	0.06942	0.7932	NS
VAVER[b]	0.00159	0.0	1/51	0.08122	0.7768	NS
POSS[b]	0.00056	0.0	1/51	0.02875	0.8660	NS
SLAKE	0.02916	0.0	1/55	1.65214	0.2041	NS
DSHEAR, DSDEV	0.12258	0.0	2/16	1.11760	0.3513	NS
DSHEAR[a]	0.07646	0.0	1/17	1.40734	0.2518	NS
DSDEV[a]	0.08043	0.0	1/17	1.48699	0.2393	NS
PUNCHSR, PUNCHDV	0.16943	0.0	2/53	5.40564	0.0073	S
PUNCHSR[a]	0.03461	0.0	1/54	1.93574	0.1698	NS
PUNCHDV[a]	0.13351	0.0	1/54	8.32061	0.0056	S
MOMENT, STRESSM		0.0		NOT TESTABLE[c]		
MOMENT[a]		0.0		NOT TESTABLE[c]		
STRESSM[a]		0.0		NOT TESTABLE[c]		
VY, VX, CO, ETAN	0.06830	0.0	4/48	0.87975	0.4831	NS
DEPTH	0.00195	0.0	1/115	0.22468	0.6364	NS

NOTE. An F-test was utilized to test for statistically significant relationships among the various engineering and geological parameters studied with the lithology reclassified from the Ferm's rock designation code. The assigned alpha level of 0.05 for a two-tailed, nondirectional test was used because each specific research hypothesis was considered statistically significant. However, a correction for multiple comparisons was deemed necessary in a number of cases in the hypothesis-testing process. The alpha level was corrected using the Newman and Fry (4) method. The corrected alpha level was used before each specific hypothesis was considered statistically significant. Listed below are the corrected alpha levels for the affected hypotheses. The symbols S denotes statistical significance, while NS denotes nonsignificance at the stated alpha level.

[a]corrected alpha level is equal to 0.025

[b]corrected alpha level is equal to 0.010.

[c]variables in the equation are constant or have missing correlations and cannot be processed.

TABLE 7—SUMMARY OF MODELS TESTED, BOTH FULL AND RESTRICTED MODELS, R^2 FOR BOTH MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, F-RATIO, PROBABILITY LEVELS, AND STATISTICAL SIGNIFICANCE FOR EACH RESEARCH HYPOTHESIS THAT TESTED FOR DISCRIMINATIVE RELATIONSHIPS AMONG THE ENGINEERING AND GEOLOGICAL PARAMETERS AND THE CRITERION VARIABLE FERM CLASSIFICATION 136 (LIGHT GRAY SHALE)

Engineering or Geological Parameter(s)	R^2_{full}	$R^2_{restr.}$	df	F-Ratio	Prob.	Significance
BRAZM, BRAZDEV	0.02968	0.0	2/47	0.71874	0.4926	NS
BRAZM[a]	0.01681	0.0	1/48	0.82050	0.3696	NS
BRAZDEV[a]	0.01985	0.0	1/48	0.97190	0.3291	NS
VX, VY, VAVER, POSS, CO	0.02547	0.0	4/48	0.31365	0.8675	NS
VX[b]	0.00445	0.0	1/51	0.22811	0.6350	NS
CO[b]	0.00915	0.0	1/51	0.47120	0.4955	NS
VY[b]	0.01346	0.0	1/51	0.69571	0.4081	NS
VAVER[b]	0.00951	0.0	1/51	0.48945	0.4874	NS
POSS[b]	0.00265	0.0	1/51	0.13540	0.7144	NS
SLAKE	0.11663	0.0	1/55	7.26125	0.0093	S
DSHEAR, DSDEV		0.0		NOT TESTABLE[c]		
DSHEAR[a]		0.0		NOT TESTABLE[c]		
DSDEV[a]		0.0		NOT TESTABLE[c]		
PUNCHSR, PUNCHDV	0.01613	0.0	2/53	0.43452	0.6499	NS
PUNCHSR[a]	0.00002	0.0	1/54	0.00124	0.9721	NS
PUNCHDV[a]	0.01610	0.0	1/54	0.88343	0.3514	NS
MOMENT, STRESSM		0.0		NOT TESTABLE[c]		
MOMENT[a]		0.0		NOT TESTABLE[c]		
STRESSM[a]		0.0		NOT TESTABLE[c]		
VY, VX, CO, ETAN	0.09734	0.0	4/48	1.29398	0.2857	NS
DEPTH	0.00455	0.0	1/115	0.52511	0.4701	NS

NOTE. An F-test was utilized to test for statistically significant relationships among the various engineering and geological parameters studied with the lithology reclassified from the Ferm's rock designation code. The assigned alpha level of 0.05 for a two-tailed, nondirectional test was used because each specific research hypothesis was considered statistically signicant. However, a correction for multiple comparisons was deemed necessary in a number of cases in the hypothesis-testing process. The alpha level was corrected using the Newman and Fry (4) method. The corrected alpha level was used before each specific hypothesis was considered statistically significant. Listed below are the corrected alpha levels for the affected hypotheses. The symbols S denotes statistical significance, while NS denotes nonsignificance at the stated alpha level.

[a]corrected alpha level is equal to 0.025.

[b]corrected alpha level is equal to 0.010.

[c]variables in equation are constant or have missing correlations and cannot be processed.

TABLE 8—SUMMARY OF MODELS TESTED, BOTH FULL AND RESTRICTED MODELS, R^2 FOR BOTH MODELS, DEGREES OF FREEDOM-NUMERATOR, DEGREES OF FREEDOM-DENOMINATOR, F-RATIO, PROBABILITY LEVELS, AND STATISTICAL SIGNIFICANCE FOR EACH RESEARCH HYPOTHESIS THAT TESTED FOR DISCRIMINATIVE RELATIONSHIPS AMONG THE ENGINEERING AND GEOLOGICAL PARAMETERS AND THE CRITERION VARIABLE DEPTH TO SAMPLE CORE

Engineering or Geological Parameter(s)	R^2_{full}	R^2_{restr}	df	F-Ratio	Prob.	Significance
BRAZM, BRAZDEV	0 007251	0 0	2/47	1 83730	0 1705	NS
BRAZM[a]	0 04916	0 0	1 48	2 48185	0 1217	NS
BRAZDEV[a]	0.00923	0 0	1/48	0 44715	0.5069	NS
VX, VY, VAVER, POSS, CO		0 0		NOT TESTABLE[c]		
VX[b]		0 0		NOT TESTABLE[c]		
CO[b]		0 0		NOT TESTABLE[c]		
VY[b]		0 0		NOT TESTABLE[c]		
VAVER[b]		0 0		NOT TESTABLE[c]		
POSS[b]		0 0		NOT TESTABLE[c]		
SLAKE	0 06430	0 0	1 47	3.22990	0 0787	NS
DSHEAR, DSDEV	0 04217	0 0	2 16	0 35222	0 7084	NS
DSHEAR[a]	0 00316	0 0	1 17	0 05394	0 8191	NS
DSDEV[a]	0 03022	0 0	1 17	0 52980	0 4766	NS
PUNCHSR, PUNCHDV	0 04859	0 0	2 53	1.35329	0 2672	NS
PUNCHSR[a]	0 02381	0.0	1, 54	1 31727	0 2561	NS
PUNCHDV[a]	0 02523	0 0	1 54	1 39794	0 2422	NS
MOMENT, STRESSM		0.0		NOT TESTABLE[c]		
MOMENT[a]		0 0		NOT TESTABLE[c]		
STRESSM[a]		0 0		NOT TESTABLE[c]		
VY, VX, CO, ETAN		0 0		NOT TESTABLE[c]		

NOTE. An F-test was utilized to test for statistically significant relationships among the various engineering and geological parameters studied with the lithology reclassified from the Ferm's rock designation code. The assigned alpha level of 0.05 for a two-tailed, nondirectional test was used because each specific research hypothesis was considered statistically significant. However, a correction for multiple comparisons was deemed necessary in a number of cases in the hypothesis-testing process. The alpha level was corrected using the Newman and Fry (4) method. The corrected alpha level was used before each specific hypothesis was considered statistically ha level is equal to 0.025

[b]corrected alpha level is equal to 0.010

[c]variables in the equation are constant or have missing correlations and cannot be processed

FREQUENCY DISTRIBUTIONS AND DESCRIPTIVE STATISTICS

The frequencies of the various engineering and geological parameters are displayed in Table 9 and selected parameters visually displayed in computer-generated graphics in Figures 1 through 13. Descriptive statistics are performed on selected continuous variables and summarized in Table 10.

Parameter	Absolute Frequency	Relative Frequency (%)	Adjusted[a] Cumulative Frequency (%)
Slake Durability (%) (N=57)			
0.0 - 10.0	3	1.1	5.3
10.0 - 20.0	0	0.0	5.3
20.0 - 30.0	1	0.4	7.0
30.0 - 40.0	0	0.0	7.0
40.0 - 50.0	0	0.0	7.0

TABLE 9—CONTINUED

Parameter	Absolute Frequency	Relative Frequency (%)	Adjusted[a] Cumulative Frequency (%)
50.0 - 60.0	0	0.0	7.0
60.0 - 70.0	4	1.5	14.0
70.0 - 80.0	9	3.4	29.8
80.0 - 90.0	18	6.9	61.4
90.0 - 100.0	22	8.4	100.0
MISSING CASES	205	78.2	100.0
	262	100.0	
Direct Shear Stress (Kg/cm²) (N=30)			
0.0 - 10.000	3	1.1	10.0
10.000 - 20.000	7	2.7	33.3
20.000 - 30.000	4	1.5	46.7
30.000 - 40.000	4	1.5	60.0
40.000 - 50.000	4	1.5	73.3
50.000 - 60.000	3	1.1	83.3
60.000 - 70.000	2	0.8	90.0
70.000 - 80.000	3	1.1	100.0
MISSING CASES	232	92.7	100.0
	262	100 0	
Shear Standard Deviation (N=19)			
0.0 - 0.10000	3	1.1	10.3
0.100 - 0.2000	6	2.3	41.9
0.2000 - 0.3000	0	0.0	41.9
0.3000 - 0.4000	0	0 0	41.9
0.4000 - 0.5000	3	1.1	57.7
0.5000 - 0.6000	2	0.8	68.2
0.6000 - 0.7000	3	1.1	84.0
0.7000 - 0.8000	2	0 8	100.0
MISSING CASES	243	92.7	100.0
	262	100.0	
Brazilian Tensile Test Mean (Kg/cm²) (N=58)			
0.0 - 10.000	1	0.4	1.7
10.000 - 20.000	0	0.0	1.7
20.000 - 30.000	1	0.4	3.4
30.000 - 40.000	0	0.0	3.4
40.000 - 50.000	8	3.1	17.2
50.000 - 60.000	11	4.2	36.2
60.000 - 70.000	13	5.0	58.6
70.000 - 80.000	17	6.5	87.9
80.000 - 90.000	4	1.5	94.8
90.000 - 100.000	1	0.4	96.5
100.000 - 110 000	1	0.4	98.3
110.000 - 120.000	1	0.4	100.0
MISSING CASES	204	77.9	
	262	100.0	

TABLE 9—CONTINUED

Parameter	Absolute Frequency	Relative Frequency (%)	Adjusted[a] Cumulative Frequency (%)
Punch Shear Stress Mean (Kg/cm²) (N=57)			
50.0 - 100.00	18	6.9	31.6
100.00 - 150.00	12	4.6	52.6
150.00 - 200.00	11	4.2	71.9
200.00 - 250.00	6	2.3	82.5
250.00 - 300.00	4	1.5	89.5
300.00 - 350.00	4	1.5	96.5
350.00 - 400.00	1	0.4	98.2
400.00 - 450.00	1	0.4	100.0
MISSING CASES	205	78.2	100.00
	262	100.0	
Punch Shear Stress Standard Deviation (N=56)			
0.0 - 0.100	7	2.7	12.5
0.100 - 0.200	12	4.6	33.9
0.200 - 0.300	12	4.6	55.4
0.300 - 0.400	11	4.2	75.0
0.400 - 0.500	8	3.1	89.3
0.500 - 0.600	4	1.5	96.4
0.600 - 0.700	2	0.8	100.0
MISSING CASES	206	78.6	100.0
	262	100.0	
Elevation to Top of Core (feet) (N=125)			
1007.0	20	7.6	16.0
1080.0	18	6.9	30.4
1830.0	87	33.2	100.0
MISSING CASES	137	52.3	100.0
	262	100.0	
Depth to Core Sample (feet) (N=117)			
0.0 - 100.0	27	10.3	23.1
100.0 - 200.0	25	9.5	44.4
200.0 - 300.0	17	6.5	60.0
300.0 - 400.0	23	8.8	78.6
400.0 - 500.0	16	6.1	92.3
500.0 - 600.0	7	2.7	98.3
600.0 - 700.0	1	0.4	99.1
700.0 - 800.0	0	0.0	99.1
800.0 - 900.0	0	0.0	99.1
900.0 - 1000.0	1	0.4	100.0
MISSING CASES	145	55.3	100.0
	262	100.0	

Parameter	Absolute Frequency	Relative Frequency (%)	Adjusted[a] Cumulative Frequency (%)
Fern Classification Groupings (N=262)			
000 - 039	10	3.8	3.8
090 - 299	35	13.4	17.2
300 - 499	101	38.5	55.7
500 - 810	116	44.3	100.0
MISSING CASES	0	0.0	100.0
	262	100.0	
Uniaxial Compressive Strength (Kg/cm²) (N=82)			
0.000 - 10.000	27	10.3	32.9
10.000 - 20.000	19	7.3	56.1
20.000 - 30.000	16	6.1	75.6
30.000 - 40.000	10	3.8	87.8
40.000 - 50.000	6	2.3	95.1
50.000 - 60.000	3	1.1	98.8
60.000 - 70.000	0	0.0	98.8
70.000 - 80.000	1	0.4	100.0
MISSING CASES	180	68.7	100.0
	262	100.0	
Young's Modulus of Elasticity (N=55) (X10⁶ lbs/in²)			
0.000 - 0.500	0	0.0	0.0
0.500 - 1.000	2	0.8	3.6
1.000 - 1.500	3	1.1	9.1
1.500 - 2.000	10	3.8	27.3
2.000 - 2.500	15	5.7	54.5
2.500 - 3.000	10	3.8	72.7
3.000 - 3.500	12	4.6	94.5
3.500 - 4.000	3	1.1	100.0
MISSING CASES	207	79.0	100.0
	262	100.0	
Poisson's Ratio (Average) (N=55)			
0.000 - 0.050	0	0.0	0.0
0.050 - 0.100	2	0.8	3.6
0.100 - 0.150	4	1.5	10.9
0.150 - 0.200	5	1.9	20.0
0.200 - 0.250	9	3.4	36.3
0.250 - 0.300	5	1.9	45.5
0.300 - 0.350	15	5.7	72.7
0.350 - 0.400	7	2.7	85.5
0.400 - 0.450	8	3.1	100.0
MISSING CASES	207	79.0	100.0
	262	100.0	

TABLE 9—CONTINUED.

Parameter	Absolute Frequency	Relative Frequency (%)	Adjusted[a] Cumulative Frequency (%)
Ultimate Compressive Strength (lbs/in²) (N=53)			
5,000.0 - 10000.0	7	2.7	13.2
10000.0 - 11000.0	6	2.3	24.5
11000.0 - 12000.0	10	3.8	43.4
12000.0 - 13000.0	6	2.3	54.7
13000.0 - 14000.0	4	1.5	62.3
14000.0 - 15000.0	2	0.8	66.0
15000.0 - 16000.0	13	5.0	90.6
16000.0 - 17000.0	1	0.4	92.5
17000.0 - 18000.0	0	0.0	92.5
18000.0 - 19000.0	0	0.0	92.5
19000.0 - 30000.0	4	1.5	100.0
MISSING CASES	209	79.8	100.0
	262	100.0	

[a]Adjusted cumulative frequency for the exclusion of missing cases or data values.

TABLE 10—DESCRIPTIVE STATISTICS ON SELECTED CONTINUOUS GEOLOGIC AND ENGINEERING PARAMETERS

Parameter	Mean	Range	Variance	Standard Deviation	Kurtosis	Skewness
SLAKE (N=57)	80.719	91.300	444.735	88.724	21.147	2.643
DIRECT SHEAR STRESS (N=30)	35.620	78.969	500.923	22.381	-0.913	0.296
DIRECT SHEAR DEVIATION (N=19)	0.375	0.695	0.064	0.252	-1.707	0.146
BRAZILIAN TENSICE (N=58)	65.638	106.822	303.457	17.420	1.674	-0.255
BRAZILIAN DEVIATION (N=50)	0.201	0.464	0.013	0.113	-0.605	0.416
PUNCH SHEAR STRESS (N=57)	163.343	352.770	7536.871	86.815	0.215	0.948
PUNCH SHEAR DEVIATION (N=56)	0.281	0.594	0.026	0.162	-0.806	0.378
ELEVATION TO TOP OF CORE (N=125)	1590.32	823.00	132990.06	364.678	-1.244	-0.873
DEPTH OF CORE SAMPLE (N=117)	258.106	896.200	29606.475	172.065	0.465	0.705
COMPRESSIVE STRESS (N=82)	20.029	72.389	260.668	16.145	0.253	0.835

TABLE 10—CONTINUED.

Parameter	Mean	Range	Variance	Standard Deviation	Kurtosis	Skewness
YOUNG'S MODULES OF ELASTICITY (N=55)	2.465	3.050	0.478	0.691	-0.320	-0.201
POISSON'S RATIO (HORIZONTAL) (N=55)	0.289	0.437	0.012	0.109	-0.289	-0.364
POISSON'S RATIO (VERTICAL) (N=55)	0.282	0.450	0.010	0.102	-0.310	-0.463
POISSON'S RATIO (AVERAGE) (N=55)	0.285	0.355	0.010	0.098	-0.728	-0.468

NOTE. The symbol 'N' represents the total number of valid data points or cases analyzed for each parameter.

DISCUSSION

Predictive Relationships Among the Geological and Engineering Parameters with Gross Lithology of Overburden

Eight specific research hypotheses (Table 3) were found to be statistically significant at the 0.05 alpha level, once corrected for multiple comparisons, in discriminating among the basic lithologies based upon information derived from the geologic and engineering parameters studied. Testing results derived from the Brazilian Tensile Test, Slake Durability Test, Direct Shear-Stress Test, and the Punch Shear Stress Test significantly differentiated among the gross lithologies.

In general, both the Brazilian Tensile Test and the standard deviation determined from the 3 tests run on each rock sample significantly predicted or discriminated between the various gross lithologies. The variables accounted for 22.78% of the common or explained variance in predicting the variance in lithology (P=0.0023). However, when tested separately, only the standard deviation associated with the Brazilian Tensile Test mean accounted for enough variance in predicting the variance associated with the varying lithologies. The standard deviation of the test, which is a measure of the variability of the results of the Brazilian Tensile strengths of the rock tested accounted for 11.51% of the common variance in lithology (P=0.0159). It appears as the variability, as measured by the standard deviation of the test results, decrease, an increased in grain size (greater occurrence of sandstones) resulted. Hence, less variability of the test results were statistically associated with coarser-grained rocks.

Slake Durability Test results (Table 4) illustrated a significant relationship in differentiating basic rock types. The common or technique variance associated with slake durability accounted for 12.22% of the variance in lithology (p=0.0077). A direct relationship between lithology and slake durability was found. Hence, as slake durability increased, a predictive increase in grain-size or coarsening in lithology was found.

Both Direct Shear-Stress mean and standard deviation were found to statistically discriminate among the gross lithologies tested (Table 4). The 2 strength parameters accounted for 40.79% of the common variance in predicting the variance among lithologies. However, this figure is inflated, as mentioned in the methodology section, due to a relative low number of samples. However, the standard deviation associated with the direct shear stress testing did not account for a significant amount of variance in isolating the variance in gross lithology of the rocks tested. The results from the direct shear stress testing accounted for a significant amount of variance (39.53%) of the variance in discriminating lithologies (P=0.0039). However, as previously discussed, inflation of the R^2 is a problem in the interpretation of this result. In general, as direct shear stress or strength increased, a predictive increase in coarsening of grain-size into sandstones was evident.

Both Punch Shear Stress mean and standard deviation accounted for a statistically significant among the variance in predicting the variance associated with lithologies, when the results were considered collectively. Approximately 25.88% of common variance was accounted for in predicting the variance among lithologies by both parameters (p=0.0004). However, when tested individually, only the punch shear test mean accounted for enough explained variance in discriminating lithology (25.76% of common variable and probability due to change alone, alpha equal to 0.0001). In general, increase in punch shear strength was associated with increasing grain-size.

PREDICTIVE RELATIONSHIPS AMONG THE GEOLOGICAL AND ENGINEERING PARAMETERS WITH EACH SPECIFIC ROCK CLASSIFICATION

The multiple linear regression analysis, using the concepts of discriminative analysis techniques as discussed in the methodology section, tested for differential relationships among the engineering and geological parameters and each rock classification, are summarized in Tables 5 through 7. Table 8 is a summary of the hypothesis testing and model comparisons with depths to top of core as the dependent or criterion variable. However, the success in isolating discriminative complex relationships among the engineering and geological parameters was extremely limited and eventually discontinued. Hence, not all rock classification codes were inspected and the authors greatly suggest that if this methodology is to be followed in future studies, a much greater data base needs to be established first. A total of 8 hypotheses were found to be statistically significant in discriminating among the rock classification schemes investigated. However, due to the insufficient power and lack of control of the distributions of the individual parameters, a detailed discussion of the significant results is not warranted.

In terms of depth, as illustrated in Table 8, no statistically significant relationships among the various engineering tests and geological parameters were found. Hence, based on the sampling and testing completed in the process of the present study, no predictive relationships with depth to the top of the core sample were found.

CONCLUSIONS

The ability to predict the ultimate behavior of rocks in highwalls and spoil banks after surface-mining disturbances from their geologic attributes alone would greatly aid in mine and reclamation planning. This ability would reduce the need for expensive and time consuming rock tests. The present investigation is only the most preliminary study of the physical properties of a wide variety of rocks routinely encountered in surface mining. Much more work is needed before the behavior of rocks in mine spoil can be generalized.

Lastly, some discussion is needed on the limitations of the study. To begin with, the type of regression and correlation analysis completed is ex post facto, hence no cause and effect statements can be made. This, however, is true of most geological studies, since geologists have little or no control in the formation of the earth materials. In addition, the time between the drilling and preparation of the core and strength testing was not recorded or controlled. Therefore, desiccation and contamination of the core samples is a real problem. In addition, secondary bedding features, recrystallization, and a variety of other equally important geological features were not inspected. The relationship among these parameters and the results of rock strength testing are important but not parameterized in the present study, and hence, unknown.

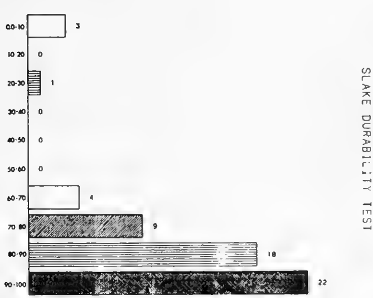

FIG. 1. Graphical Presentation of Slake Durability Test Results (%).

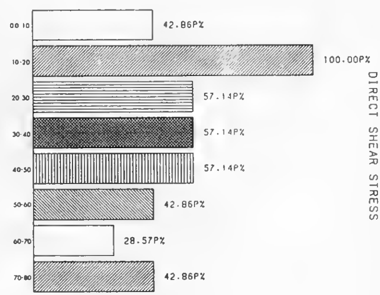

FIG. 2. Graphical Presentation of Direct Shear Stress Test Mean Results (Kg/cm²) as a Percent of the Greatest Value Interval.

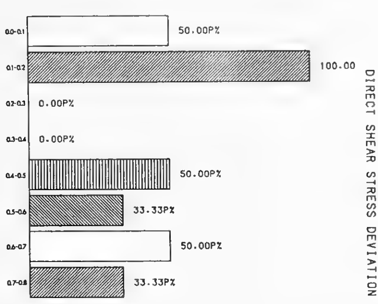

FIG. 3. Graphical Presentation of Direct Shear Stress Standard Deviation Results as a Percent of the Greatest Value Interval.

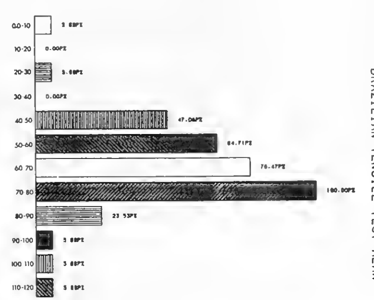

FIG. 4. Graphical Presentation of Brazilian Tensile Test Mean Results (Kg/cm²) as a Percent of the Greatest Value Interval.

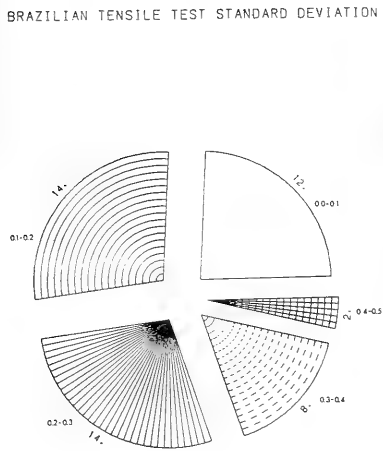

FIG. 5. Graphical Presentation of Brazilian Tensile Test Standard Deviation Results as a Part of the Total Sample.

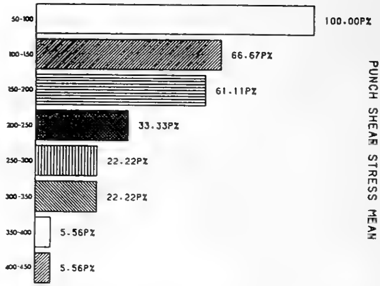

FIG. 6. Graphical Presentation of Punch Shear Stress Test Mean Results (Kg/cm²) as a Percent of the Greatest Value Interval.

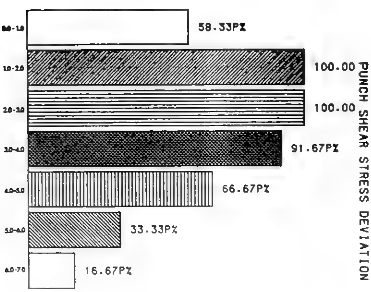

FIG. 7. Graphical Presentation of Punch Shear Stress Test Standard Deviation as a Percent of the Greatest Value Interval.

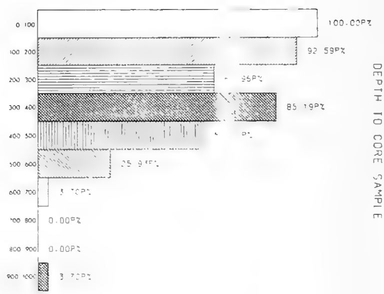

FIG. 8. Graphical Presentation of Depth to Core Sample (ft) as a Percent of the Greatest Value Interval.

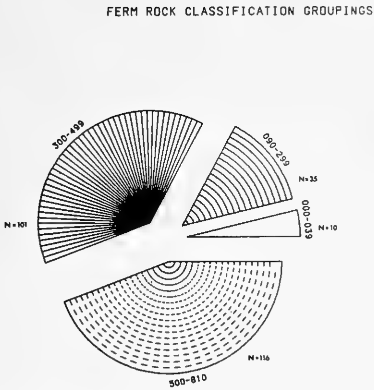

Fig. 9. Graphical Presentation of Ferm and Weisenfluh's Classification Groupings as a Part of the Total Sample.

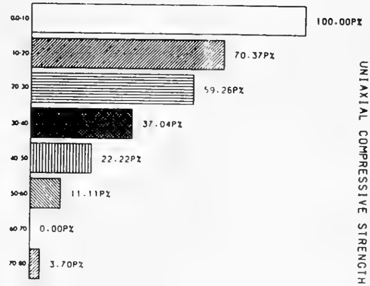

Fig. 10. Graphical Presentation of Uniaxial Compressive Strength Test Results (Kg/cm^2) as a Percent of the Greatest Value Interval.

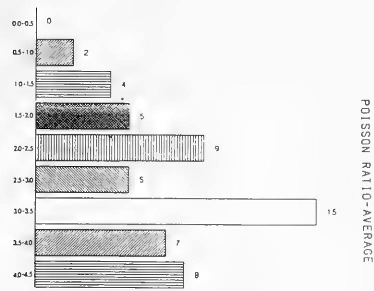

Fig. 12. Graphical Presentation of Poisson's Ratio (Average) as a Part of the Total Sample.

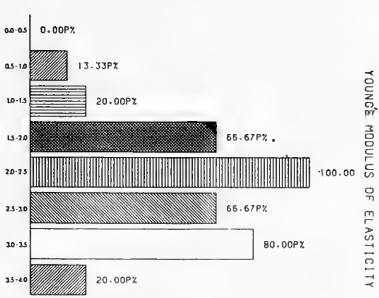

Fig 11. Graphical Presentation of Young's Modulus of Elasticity as a Percent of the Greatest Value Interval.

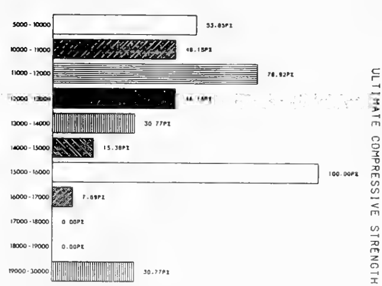

Fig 13. Graphical Presentation of Ultimate Compressive Strength Test Results as a Percent of the Greatest Value Interval.

ACKNOWLEDGEMENTS

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Age at First Pregnancy Among Females at the Indian Knoll OH 2 Site

ELIZABETH FINKENSTAEDT

Department of Art, University of Kentucky, Lexington, Kentucky 40456

ABSTRACT

Four archaeologically demonstrable cases of maternal death were used as an index to age at first pregnancy among women 15-30 years of age at the archaic site of Indian Knoll. Two primaparous individuals were found to be age 18 ±, while two multiparas were 23+. An additional 38 females were examined according to established skeletal criteria for age and maternal status. Among the total number, 17 women between the ages of 15-20 were classified as nulliparous/primaparous, two multiparous and one questionable. In the age group 21 and over, 8 were nulliparous/primaparous, 9 multiparous, and one questionable. Based on the lowest possible skeletal age, the mean age at first pregnancy was found to be 16.6 years. Based on the highest possible skeletal age, the mean figure was 19.7 years.

INTRODUCTION

Investigation of the maternal status of females in the age range 15-30 by means of established skeletal criteria strongly suggests that age at first pregnancy at the Indian Knoll site was between 16 and 19 years. The shell midden site was occupied for more than a millennium, between 3352 ± 300 to 2013 ± 350 according to C^{14} readings taken from antler points, but these figures are based on Libby's (1) unrefined half-life for C^{14} and are certainly inaccurate. More recent adjustments in the half-life of the trace element as well as in dating methods have been put forward by Derricourt (2) with respect to Egyptian material.

While population density at any given time must have been very limited at Indian Knoll, Snow's (3) estimate of twenty-five concurrent inhabitants undoubtedly is too low. He based his calculations on two erroneous hypotheses, that the site was continuously occupied throughout the year and that the principal staple foodstuff was mussels, a marginal nutritional source which would not have supported a large population (3). The general health status of the Indian Knoll people as attested by skeletal remains suggests that a more varied and healthier diet was available.

METHODS

Four cases of archaeologically attested pregnancy or childbirth related deaths are used here as an index to maternal status of an additional 38 females in the age ranger 15-30 years to determine the earliest probable age at first pregnancy. More than 4 deaths from obstetric causes must have occurred, but only those which are clearly defined archaeologically are taken into account here. Among males at Indian Knoll, slightly more than 50% died between the ages of 15-30 as opposed to slightly more than 60% of females. Differences in life expectancy, however, cannot be attributed wholly to birth trauma (4). All statistics are based on 836 individuals currently housed at the Museum of Anthropology, University of Kentucky.

The individuals in the comparative group were selected on the basis of skeletal age and good condition of the remains. No individual with skeletal pathologies owing to systemic disease was included. Criteria for maternal status for all 43 females are summarized in Table 1. Skeletal age is based on standard criteria: 1. condition of the public symphysis; 2. epiphyseal union and ossification; 3. suture closure ectocranially and where possible, endocranially; 4. absence/-presence of third molars. Maternal status is based on the following criteria: 1. condition of the pubic symphysis; 2. ventral lipping of the *os pubis*. 3. dorsal pitting of the *os pubis;* 4. absence/presence of tubercles; 5. absence/presence of auricular grooves.

None of these criteria is wholly reliable. Auricular grooves, for example, may occur in females presenting no other skeletal signs of childbirth or even in males (5). The condi-

Burial	Age	Auricular Groove	Pubic Symphysis	Ventral Lipping	Dorsal Pitting	Tubercle	Status	Totals	
9	24-25	r: slight, l:deep	r: very worn	-	-	-	M	N/P 20 yrs. and under:	17
10	20-22	-	no damage	-	-	-	N/P	M 20 yrs. and under:	2
13	30+	deep	missing	yes	yes	-	M	M 20 yrs. and under:	1?
17	25-30	-	damage	pit	-	-	M		
39	18-29	-	no damage	-	-	-	N/P		
52	23-25	deep	worn	yes	yes	yes	M		
68	20-22	slight	no damage	-	-	-	NP	N/P 21 and over:	8
75	18-20	none	wear: dorsal margin	-	-	-	N/P	M 21 and over:	9
81	25-30	slight	no damage	-	-	-	N/P	M 21 and over:	1?
107	25-28	slight	no wear	-	-	-	N/P		
								18	
109	25-30	slight	worn	-	1 pit	-	M	Grand Total	38
121	18-19	INS	no wear	-	-	-	N/P		
140	25-28	yes	worn	yes	-	yes	M		
146	23+	slight	INS	yes	yes	-	M?		
153	15	none	no wear	-	-	-	N/P		
184	19-20	slight	no wear	-	-	-	N/P		
170	15	slight	no wear	-	-	-	N/P		
183	25-27	rectangular	slight wear	yes	yes	-	M		
191	19-20	l: deep, r: slight	worn	-	-	-	M		
205	25-28	r: deep	no wear	-	-	-	N/P		
215	17-18	INS	wear	yes	yes	-	M		
269	27	slight	pm damage	severe	slight	-	M		
302	16-17	-	no wear	-	-	-	N/P		
314	23-24	slight	worn	-	-	-	M		
338	28-35	deep	worn	severe	deep	-	M		
381	17-19	deep	pm damage	-	yes	-	M?		
398	22-23	slight	no wear	-	-	-	N/P		
417	19-20	slight	no wear	-	-	-	N/P		
440	22-25	slight	no wear	-	-	-	N/P		
483	14	slight	no wear	-	-	-	N/P		
501	16-19	slight	no wear	-	-	-	N/P	Legend:	
522	22-23	-	slight wear	-	-	-	N/P		
545	20	-	no wear	-	-	-	N/P	N/P nullipara/primapara	
563	16	-	no wear	-	-	-	N/P	M multipara	
576	19	deep	no wear	-	-	-	N/P	INS insufficient	
588	19-20	deep	pm damage	-	-	-	N/P	r, l right, left	
751	16-17	-	no wear	-	-	-	N/P	- absent	
761	20-21	slight	no wear	groove	-	-	N/P		
Childbirth Cases									
146	23+	slight	worn	yes	deep left	-	M		
240	18-20	deep	no wear	yes	yes	-	P		
242	23-24	deep	severe wear	yes	yes	yes	M		
340	17-18	yes	no wear	-	mild	-	P		

TABLE 1.—Summary of Pelvic Features

tion of the pubic symphysis is given the greatest weight in evaluation of both age and maternal status. Multiparous status is considered to have existed only in the presence of definitive scarring of the pubic symphysis and at least one other criterion or, in some instances, in the presence of 3 of the criteria if symphyseal wear cannot be thoroughly assessed.

Case 1

Burial #340 represents one of the two teenage females. Epiphyseal union had occurred in all long bones, but the epiphyseal scars are strongly marked. The iliac crests are not fused. Both maxillary and mandibular molars were in the process of erupting at the time of death. An approximate age a few months either side of 18 is reasonable.

The pubic symphysis, the most important skeletal evidence in this case, is immature and completely undamaged. Slight dorsal pitting of the *os pubis* as well as slight bilateral auricular grooves of Houghton's (5) GL type are present. Houghton (5) does not regard either as indicative of mechanical stress.

The young woman was buried in a flexed position on the abdomen while remains of the fetus buried with her are described in the burial records as being beneath her pelvic cavity. Fetal remains are fragmentary. Only one measurement is possible, that of both tibiae which measure identically 5.8 cm. The proximal tibial epiphyses cannot be identified in the incomplete remains. These would not be present, however, if fetal age were less than nine intra-uterine months (6). An approximate calculation of fetal length is 44.25 cm based on Smith's reduction table cited by Krogman (6). These figures indicate that the fetus was not simply buried with the adult but in fact was unborn. One can conclude only that the individual died in consequence of her first pregnancy. No significant pathologies can be identified in the skeletal remains to account for this event.

Case 2

According to analysis of fetal remains, a second individual, burial #240, apparently died as a result of premature childbirth. Burial was in a shallow pit without grave goods. The adult was placed in a tightly flexed position on the abdomen. The remains of a fetus in middle to late intrauterine life were found beneath the left foot of the mother in a context which apparently had been disturbed in antiquity. The fetal femur measures 5.4 cm and the tibia 4.9 cm; thus the fetus was roughly 36-37 cm in length.

The young woman was 18 or 19 at the time of death. The distal humeri show traces of epiphyseal fusion while the distal fibula is fused but the epiphyseal line is visible on the posterior aspect. Neither the iliac crests nor the ischial rami are fused.

The billowing, completely undamaged symphyseal surfaces of the *os pubis* indicate that the individual was experiencing her first pregnancy. Slight dorsal pitting is present but would not necessarily suggest a previous birth episode (7). Very slightly ventral lipping on the *os pubis* is present, and a deep auricular groove on the right innominate contrasts with a much smaller groove on the left. Non-symmetrical or even unilateral appearance of auricular grooves is not uncommon in this population. The presence of these 3 traits would indicate a multipara were it not for the totally undamaged pubic symphysis.

Case 3

An interesting anomaly is offered by #146, the burial of a woman who died in childbirth as the direct result of the malpresentation of a full-term infant. The infant had become inextricably wedged in the birth canal. The excavation photographs are unclear on this point, but according to the archaeologist's notes, both arms and one leg had been born and were to have been followed by a cervical certebra. This extraordinary complication must indicate a fatal anencephaly in the infant. The right femur of the infant measures 7.5 cm. and the tibiae 6.4 cm. for an over-all length of about 47-50 cm., not too small for full term in this gracile population. The age of the mother must have been 22-23. All cranial sutures are two-thirds closed ectocranially. The third molars are present and slightly worn. All epiphyses are fused except for the medial ends of the clavicles. The left pubic symphysis was retrieved, and the ventral demi-face is worn while the dorsal half retains some billowing of the surface. Ventral lipping and dorsal pitting are present, but the minimal auricular grooves are Houghton's GL, a type mentioned above as characteristic of nulliparas and males in whom auricular grooves occur. The question arises whether one can determine that symphyseal wear is the result of repeated childbirth or simply of chronological age. While it is not unlikely that the individual had experienced a previous birth episode, there is little difference between the condition of her pubic symphysis and those of males in the same age group. Thus one may speculate that the number of pregnancies in this case was small.

Case 4

Burial #242 is that of a woman about 25 years of age whose death is attributable to childbirth as a primary cause. The burial records attest that fetal bones were found in the pelvis. The fetal remains cannot be located now, and the fetal age is unknown. The woman was buried in a pit barely large enough to contain the body, and, and at that, the limbs must have been bound in tight flexion.

Age may be estimated from a number of skeletal criteria. The basilar suture is closed, as are the iliac crests, the ischial rami, and the epiphyses of all long bones. All third molars had erupted with the exception of 1 M3. The pubic symphyses show a strong ventral rampart and considerable resorption and granulation of both demi-faces. The ventral margins are very worn and flattened, features which may be ascribed to repeated birth episodes. Marked dorsal pitting is present. A deep auricular groove occurs on the right innominate with a lesser groove on the left. The individual may be regarded as multiparous.

DISCUSSION

Among these 4 individuals, the earliest age at pregnancy was about 18, while the 2 multiparas were over 20. Thirty-eight additional females, selected as stated above, also were examined. None attests skeletal evidence for childbirth before about age 17 at the earliest. It is entirely possible that early death among females at Indian Knoll is attributable to birth trauma associated with first pregnancy. Therefore, the nulliparous/primaparous group must be treated as a single unit since in either case skeletal evidence of birth trauma would not necessarily be present.

Among the N-P group of 27 females, the mean age at pregnancy was 19.7 years based on the latest age derived from skeletal criteria. The earliest possible mean age was 16.6. Both are included here to allow for inevitable variations in reading the same data, since no criterion for aging prehistoric remains is entirely reliable. That skeletal evidence does not attest signs of a birth episode in any individual before age 17 but does suggest nulliparous or primaparous status in individuals in their twenties indicates that age at first pregnancy was relatively late at the Indian Knoll site. Moreover, the very limited index offered by the known maternal deaths is seen to represent an accurate view of maternal status at this site.

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Small-Stream Recovery Following Surface Mining in East-Central Kentucky

Branley A. Branson, Donald L. Batch and Willie R. Curtis[1]

Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky 40475
and
Northeastern Forest Experiment Station
U. S. Forest Service, Berea, Kentucky 40403

Abstract

Analyses of physio-chemical, piscine and macrobenthological data secured from two small-stream drainages affected by surface mining in eastern Kentucky are presented. Adverse pH values were not encountered during the study. Stream magnesium, calcium, manganese and sulfate concentrations increased rapidly during the onset of mining and continued to increase until 1982. The bottom sediments in both streams have remained very heavy throughout the study.

The creek chub, *Semotilus atromaculatus*, has greatly increased its populations in the headwaters while populations of other piscine species have remained virtually unchanged. Although active mining has ceased in the Leatherwood Creek drainage, fish population recovery has been minimal. A few species have been successful in re-establishing small populations, but many species are still absent. A second impulse of mining started in 1979 in Bear Branch probably resulted in a setback of recovery in that stream.

None of the macrobenthological data have been published previously. Analysis of these data demonstrated a decrease in the total taxa and mean diversity of Leatherwood Creek and Bear Branch from June 1968 to October 1970 followed by a modest increase in these 2 features from October 1970 to July 1982. The population level in most taxa remains low and mollusca have been extirpated in both streams. Mean diversity indices may be misleading, principally because of habitat changes that allow groups of organisms like the Heteroptera to replace other groups.

Introduction

To evaluate the impact of surface mining on the fish faunas of first and second order streams in east-central Kentucky, Branson and Batch (1) conducted a 17-month study from 1967 through 1969. The study area is located in Breathitt County, Kentucky and includes Leatherwood Creek and Bear Branch. Six stations were established on each stream (Fig. 1). The principal aim of the study was to document the effects of surface mining activities on benthos and fish fauna. Another objective was to trace changes in stream chemistry. Settleable solids were considered to be one of the most important features relating to changes in fish and benthos.

Results of the aforementioned study (1) indicated that fishes were progressively eliminated from headwaters downstream and that the benthic food organisms were reduced in number and kind, often by as much as 90%. Reproduction in darters and most minnows was curtailed.

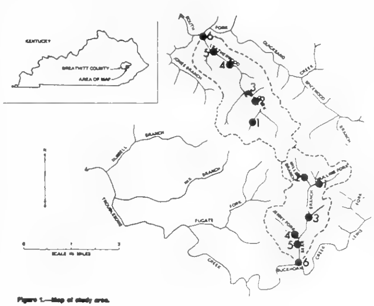

Fig. 1. Proximity map of the study area, Breathitt County, Kentucky.

Semotilus atromaculatus seemed to be resistant to silt and turbidity, principally because of its ability to feed off the water surface. Although considerable data on the benthos were collected and analyzed they have not been previously published. These data, and new information gleaned during

[1]*Hydrologist, U. S. Forest Service, Berea, Kentucky 40403.*

the present study, are presented here.

A follow-up study, conducted during 1972, indicated no tendency toward recovery by the fish fauna (2). In fact, further degradation and elimination of species had occurred. With many of the competing species gone, the creek chub population expanded, a phenomenon observed also in Tennessee (3).

The mining history of this area and streams, including normal and mining-induced chemical and physical features, were discussed and analyzed by Bryan and Hewlett (4), Curtis (5, 6, 7), and Dyer and Curtis (8).

In the interim, several other studies with direct bearing on the problem of coal mining and the environment have appeared, particularly with reference to benthic organisms. Because of their limited mobility, benthic organisms may be better indicators of mine pollution than fishes (9). Increased sedimentation not only degrades habitat for fishes, particularly during increased water temperatures (10), but it also often severely alters or eliminates benthic organisms dependent upon a clean-gravel habitat. Sediments often fill the interstices of gravel to depths of one meter or more, replacing a cobble-gravel habitat with a silty sand one (11). In the case of the streams we studied, the silt load during active mining was observed to reach 46,400 ppm (5). Highest yields of sediment from surface mining normally comes during the first 6 months after mining (7).

Sedimentation poses direct problems for benthic organisms (12). It has been known that insect drift downstream is the major means of recolonization of both natural and altered streams (13); upstream migration of insects being only 5-30% as important in repopulating a decimated area (14). Changing the bottom from a cobble-gravel habitat to a sandy one, however, may preclude active recolonization by upstream migration in larval insects such as stoneflies like *Pteronarcys* and *Acroneuria* because of the unstable sand. By contrast, caddisflies with heavy cases *(Dicosmoecus)* are more successful in moving upstream on sand (15). Such phenomena can produce unbalanced benthic faunas by allowing resistant forms to control a given habitat.

The objectives of this study were to collect data on fish populations and benthos invertebrates to compare with data collected in the original studies made in 1967-1969, and to trace changes in water chemistry following surface mining and reclamation activities.

MATERIALS AND METHODS

As in the previous studies, the fish populations at each station were sampled by 30 minutes of intensive seining. During all sampling visitation, invertebrates were hand-collected from representative, random sections at each sampling site, care being exercised to include all habitat conditions.

Mean diversity "d" indices were calculated using the machine formula method of Lloyd, Zar and Karr (16) see also, Weber (17), an index that is compared with a hypothetical maximum "d" based upon arbitrarily selected distributions (18) related to MacArthur's (19) broken-stick model. This model results in a distribution frequently encountered in nature (17), i.e., a few abundant species and a progressively large number of species that are less abundant. Since in nature the members of a given local community are highly unlikely to be equally abundant, Lloyd and Ghelardi (20) proposed the concept of "equitability" "e" and presented a table for its determination (17) using a number of species in a sample "s" with the number of species expected "s′" from a community that conforms to MacArthur's (19) model: $e = \frac{s'}{s}$. Our calculations of "e" follow these authors' recommendations.

The physio-chemical measurements were made by standard methods in the laboratories of the Northeastern Forest Experiment Station, USDA, Forest Service, Berea, Kentucky. Samples were collected at monthly intervals.

RESULTS

Water Quality

Determinations of water quality have been made since late 1967 in Leatherwood Creek and since the spring of 1968 in Bear Branch (5). Although many individual substances and elements were monitored by the Northeastern Forest Experiment Station at Berea, Kentucky, we are reporting the results only for the substances that readily indicate the influence of surface mining on water quality or substances that may be implicated as partially responsible for the perturbation of biotic communities.

Low pH is often a serious problem in waters affected by surface mining, primarily due to the formation of hydrosulfuric acid following the oxidation of various pyritic materials (21). However, adverse pH was never encountered at any of our study stations (Figs. 2-5).

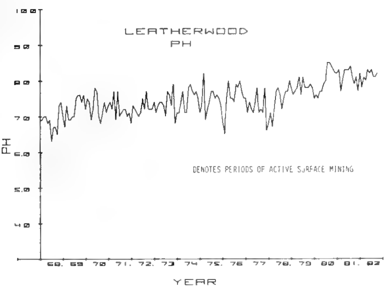

FIG. 2. pH in Leatherwood Creek.

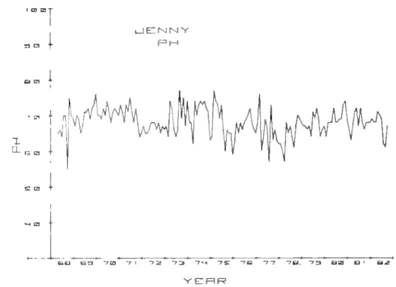

FIG. 3. pH in Jenny Fork of Bear Branch.

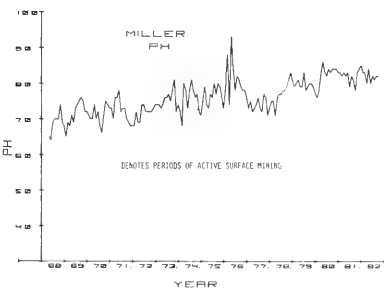

FIG. 4. pH in Miller Branch of Bear Branch.

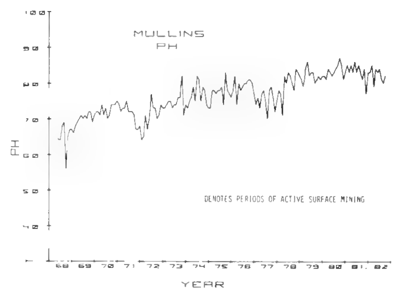

FIG. 5. pH in Mullins Fork of Bear Branch.

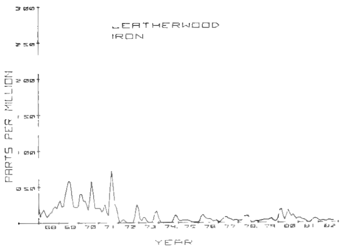

FIG. 6. Iron concentration in Leatherwood Creek.

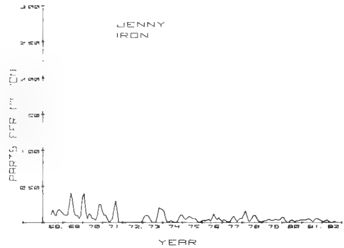

FIG. 7. Iron concentration in Jenny Fork.

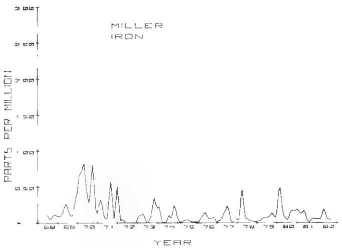

FIG. 8. Iron concentration in Miller Branch.

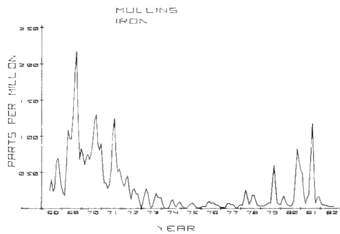

FIG 9. Iron concentration in Mullins Fork.

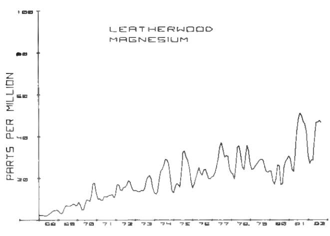

FIG 10. Magnesium concentration in Leatherwood Creek.

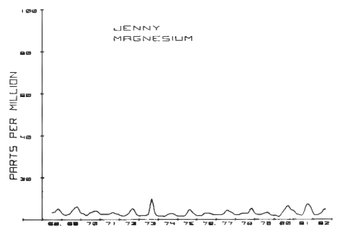

FIG. 11. Magnesium concentration in Jenny Fork.

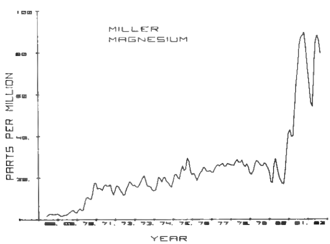

FIG. 12. Magnesium concentration in Miller Branch.

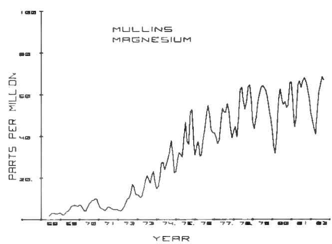

FIG. 13. Magnesium concentration in Mullins Fork.

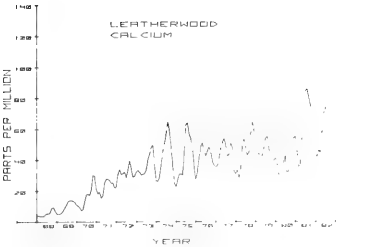

FIG. 14. Calcium concentration in Leatherwood Creek.

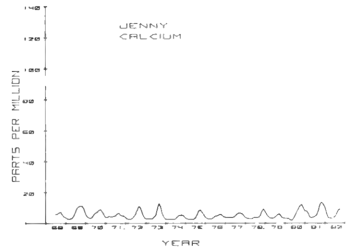

FIG. 15. Calcium concentration in Jenny Fork.

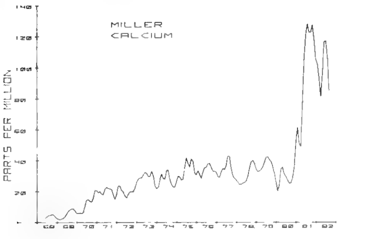

FIG 16. Calcium concentration in Miller Branch.

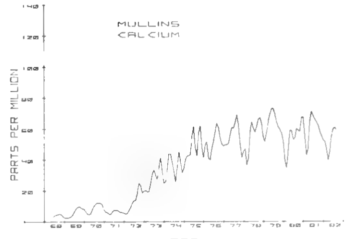

FIG. 17. Calcium concentration in Mullins Fork.

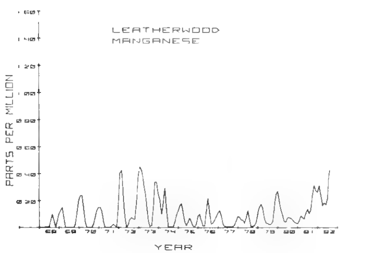

FIG. 18. Manganese concentration in Leatherwood Creek.

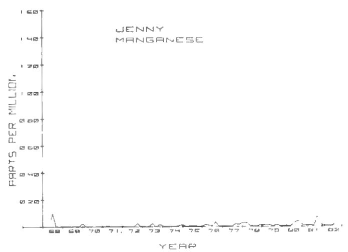

FIG. 19. Manganese concentration in Jenny Fork.

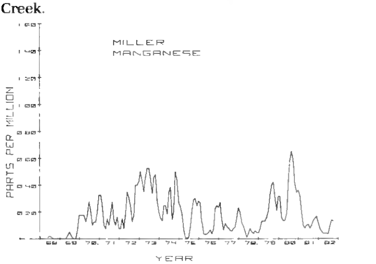

FIG. 20. Manganese concentration in Miller Branch.

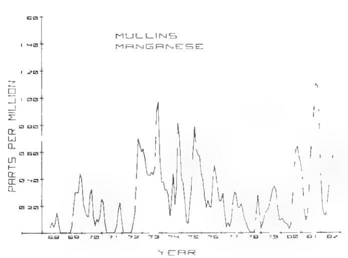

FIG. 21. Manganese concentration in Mullins Fork.

During mining or other surface disturbances such as haul-road construction and use, sulfates are readily produced, often in the form of calcium, magnesium and iron complexes (22). Hence measurements of those substances as well as of specific conductivity are important to an understanding of the degradation process. Figures 6-9 illustrate an initial increase from less than 0.5 ppm of iron in the study streams to approximately 1.0 ppm in Leatherwood Creek and Miller Branch and to over 2.0 ppm in Mullins Fork following the onset of mining with a sharp decline post 1972. A second peaking occurred in Mullins Fork in 1978-1981. Jenny Fork, never mined and only moderately disturbed otherwise, experienced no marked increases in iron content. Concentrations of iron by itself at these levels probably do not pose any threat to aquatic bota in eastern Kentucky. The same type of unqualified statement cannot be made concerning calcium, magnesium and sulfates. The composition of the macrobenthos, because of limited mobility, may reflect long-term, cumulative responses to degrading influences (22). In this regard, it has been observed that, following surface mining, calcium, magnesium, manganese and sulfate concentrations tend to increase in a systematic fashion with the passage of time (23, 6). Thus, the streams discussed herein exhibited a nearly classical picture with regard to magnesium (Figs. 10-13), calcium (Figs. 14-17) and manganese (Figs. 18-21) concentrations during mining and up to the present. Unmined Jenny Fork exhibited only normal seasonal cycles.

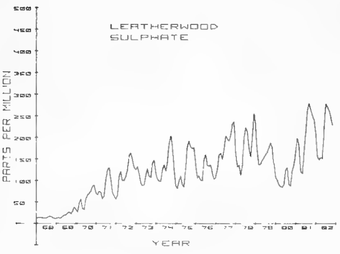

FIG. 22 Sulphate concentration in Leatherwood Creek.

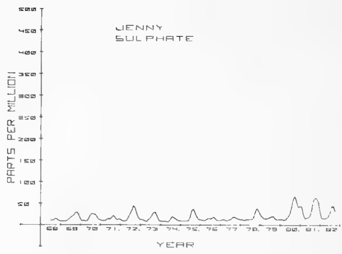

FIG. 23. Sulphate concentration in Jenny Fork.

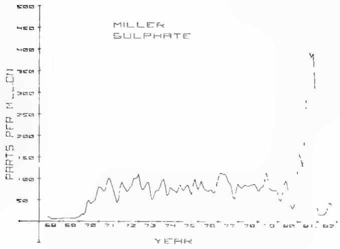

FIG. 24. Sulphate concentration in Miller Branch.

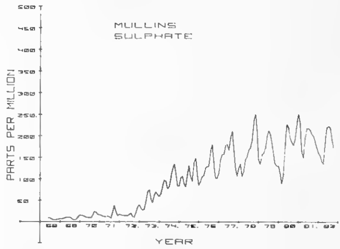

FIG. 25. Sulphate concentration in Mullins Fork.

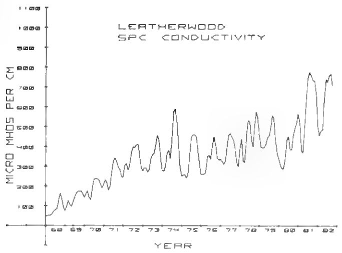

FIG. 26. Specific conductivity in Leatherwood Creek.

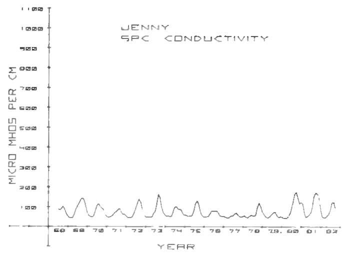

FIG. 27. Specific conductivity in Jenny Fork.

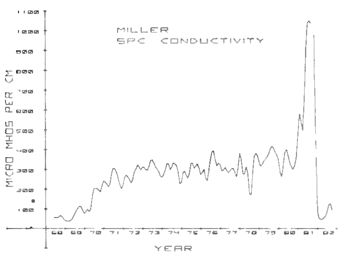

FIG. 28. Specific conductivity in Miller Branch.

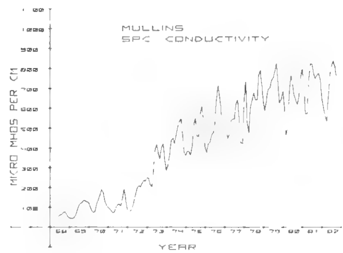

FIG 29. Specific conductivity in Mullins Fork.

Sulfate is probably the most useful indicator of the condition of a stream and its concentration reflects the extent of watershed disturbance. Following a log phase of sulfate generation at the onset of mining, a long-term production of the substance continues from disturbed watersheds (23). In general, high sulfate and hardness components are associated with poor biotic populations (22).

As can be seen in figures 22-25, again with the exception of Jenny Fork, there was a significant increase in sulfate production with the onset of mining and a continuous generation of the substance thereafter. However, sulphate concentrations seldom exceeded the levels established for drinking water standards. Specific conductivity measurements covering the same period reflect a similar trend (Figs. 26-29).

All of these components demonstrated periodic variations of relatively large magnitude, a feature also reported by other investigators (23). This phenomena may be, in part, correlated with peak and mean daily discharge of the streams involved. In that regard, figures 30-33 are of specific interest.

Discharge is also of importance when dealing with erosion and subsequent stream sedimentation. Disturbed soil materials are usually very susceptible to erosion, especially during storms (5, 6, 24, 25, 26). Curtis (5) measured 9,600 to 46,400 ppm of suspended solids in one of the tributaries to Leatherwood Creek following the onset of mining as contrasted with 150 ppm for unmined watersheds in the same general area. The sediment remained high after cessation of mining, as indicated by Branson and Batch (1).

Although this study does not report new measurements of settleable solids, field visual observations indicate that the study streams are still heavily silted; the bottom and sides of the streams have silt deposits that are in many areas more than 45 cm deep.

Periodic turbidity measurements of the study streams give little insight into the sediment problem. Though the measurements spike at 600-700 JTU (Jackson Turbidity Units) following rain storms (Figs. 34-36), the readings quickly return to low levels. Jenny

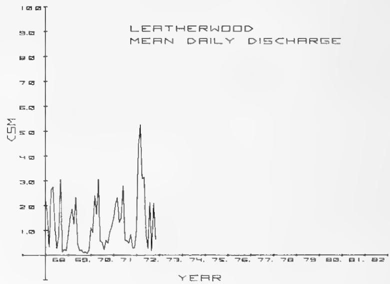

FIG. 30. Mean daily discharge in Leatherwood Creek.

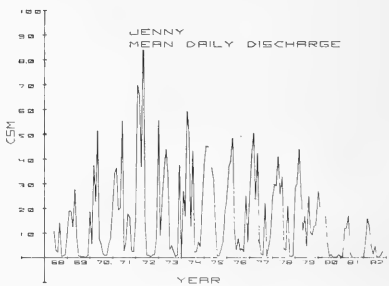

FIG. 31. Mean daily discharge in Jenny Fork.

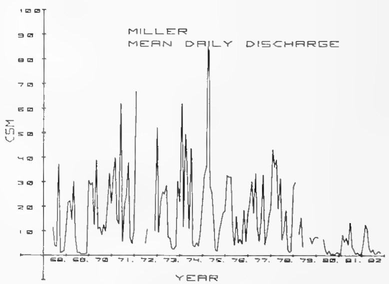

FIG. 32. Mean daily discharge in Miller Branch.

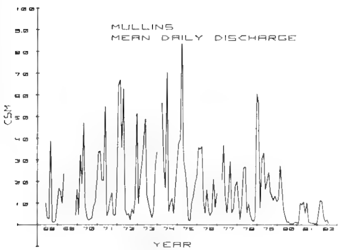

FIG. 33. Mean daily discharge in Mullins Fork.

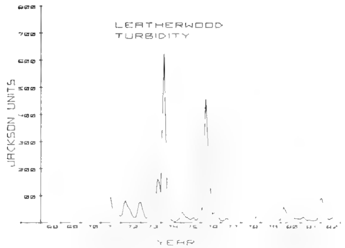

FIG. 34. Turbidity measurements in Leatherwood Creek.

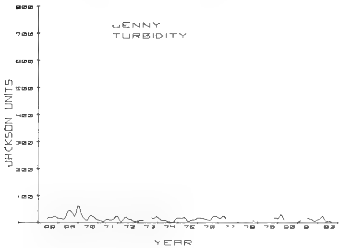

FIG. 35. Turbidity measurements in Jenny Fork.

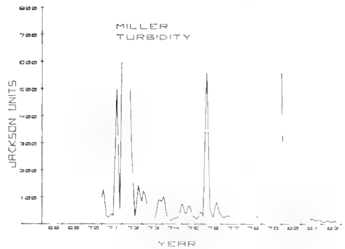

FIG. 36. Turbidity measurements in Miller Branch.

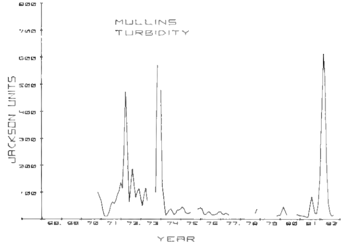

FIG. 37. Turbidity measurements in Mullins Fork.

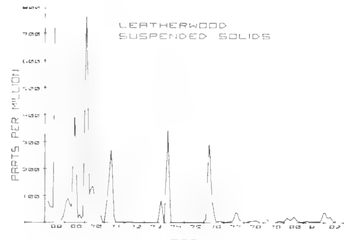

FIG. 38. Suspended solids in Leatherwood Creek.

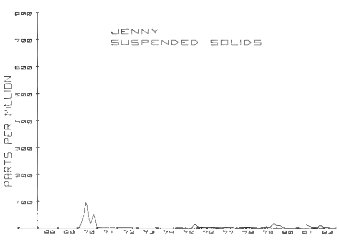

FIG. 39. Suspended solids in Jenny Fork.

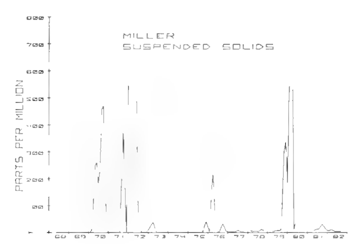

FIG. 40. Suspended solids in Miller Branch.

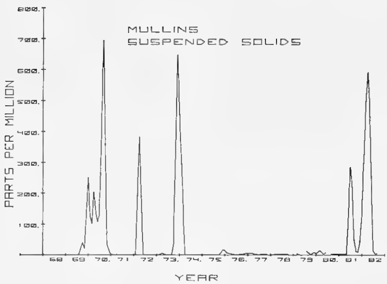

FIG. 41. Suspended solids in Mullins Fork.

Fork (Fig. 37), however, did not exhibit the degree of fluctuation exhibited by the other streams.

Suspended solids also exhibited fluctuations associated with rain storms during the study period (Figs. 38-41) but each stream quickly returned to pre-storm conditions as the transported materials settled to the bottom.

Many of these physical and chemical conditions adversely affect stream biotas. Matter, Ney and Maughan (22) reported a general trend toward poor biotic populations associated with streams impacted by high sulfate and hardness concentrations produced by mining. In addition, siltation often severely affects aquatic biota and its microdistribution in relation to stream velocity, substrate particle size, silt and detritus (27). Fishes are usually displaced downstream or eliminated by heavy siltation (1). Both suspended solids and sediments cause negative responses in macroinvertebrate populations.

Most species, however, are more or less uniformly affected; hence, diversity indices may not be altered (28) although abundance may be greatly lowered (22). There are, of course, exceptions. For example, certain mayflies (*Tricorythodes*) and beetles (*Stenelmis*) are resistant to siltation and tend to increase any time competitors are removed (28). Particle size of sediments is apparently of importance in considering the impact upon the benthos, with sand and fine silt having the greatest impact (27, 15). Most of the sediments deposited in our study areas are in the sand and silt categories. Siltation influences may often be long-term. Vaughan, Talak and Anderson (29) indicated that aquatic invertebrate populations in Tennessee may require 20 or more years to return to a predisturbance level. In other instances following drastic land disturbance, the benthos have remained disturbed for 50 years (30).

Recolonization of disturbed portions of streams comes from 4 principal sources: drift, 41%; upstream migration in the water, 18%; upstream migration in the substrate, 19%; and aerial migration with subsequent reproduction, 28% (31, 32, 33). If the disturbance occurs downstream from a non-impacted headwater where the substrate is suitable, drift may allow rapid recolonization. Headwater disturbance significantly increases drifting downstream of invertebrates which may serve to hasten recolonization of previously disturbed downstream sites (28, 34). If a whole drainage is disturbed, other mechanisms must effect the repopulation of a stream. This is essentially the situation in the case of the streams herein discussed.

Fishes

Table 1 summarizes the fish data from the first two study periods (1, 2) and those gleaned during the present investigation. It is not intended that the data from similar numbered stations be compared by watershed and to do so could be misleading. For example, Station 4 on Leatherwood represents a point well downstream draining some 1200 acres while Station 4 on Bear Branch represents a headwater drainage of less than 300 acres. Stations 3, 5, and 6 are somewhat comparable. Study of the table indicates no change in the fish fauna at Station 1 in either stream, and no change at Station 2 in Bear Branch. However, in Leatherwood Creek *Semotilus, Campostoma, Ericymba*, and *Etheostoma flabellare* have all successfully invaded or reinvaded the area even though the last 3 species are present in small numbers only. *Semotilus*, which is more or less resistent to sedimentation of its habitat (1, 35), is the dominant species at

TABLE 1.—FISH DATA FOR SIX SITES EACH IN LEATHERWOOD CREEK AND BEAR BRANCH, BREATHITT COUNTY, 1968-1982. UPPER ROW OF SYMBOLS FOR EACH SPECIES REPRESENT LEATHERWOOD CREEK OBSERVATIONS, THE LOWER ROW REPRESENTS BEAR BRANCH OBSERVATIONS - INDICATES LACKING; + INDICATES PRESENT. THE LAST ENTRY IN EACH ROW IS THE 1982 OBSERVATION; THE OTHER ENTRIES REPRESENT THE OBSERVATIONS MADE PREVIOUSLY (1, 2).

TABLE 1.—COLLECTING STATIONS

SPECIES	1	2	3	4	5	6	SPECIES	1	2	3	4	5	6
Semotilus	------	++-+--+	+++++-+	++++++++	++++++++	++++++++	*Percina*	------	------	------	------	---- -	------
atromaculatus	++++++	++++++	++++++	+--+-	+-++++	++++++	*maculata*	------	------	-+---	------	------	------
Campostoma	------	+----+	+----+	++++++++	++++++++	++++++++	*Etheostoma*	------	+----+	++----+	++++--++	-+++-++	++++--++
anomalum	------	------	++++--	------	++++-+	+++-++	*flabellare*	------	------	++----	--+--	+-+++-	++++++
Ericymba	------	-----+	+----+	-++++-++	+--++++	++++++++	*Etheostoma*	------	------	+-----	++-----	-----+	++++++++
buccata	------	------	+-++-	------	++++-+-	+++--+	*caeruleum*	------	------	------	------	--++-	++++++
Notropis	------	------	------	------	------	------	*Etheostoma*	------	------	+-----	-+----	------	++----
ardens	------	------	+-----	------	------	++-+++	*nigrum*	------	------	------	------	++---	+++++
Notropis	------	------	------	+-----	+---+-	+++-+++	*Etheostoma*	------	------	------	------	------	+-----
chrysocephalus	------	------	------	------	+---+	+++-++	*variatum*	------	------	--+--	------	------	++++++
Notropis	------	------	------	------	+-----	+-----	*Etheostoma*	------	------	+-----	-+----	--+--+-+	---+---
photogenis	------	------	------	------	------	---+-	*sagitta*	------	------	+-----	------	--++-	++--+-
Notropis	------	------	------	------	+-----	++--+-	*Etheostoma*	------	------	------	------	------	------
volucellus	------	------	------	------	------	--+--	*blennioides*	------	------	------	------	------	+-++-
Notropis	------	------	------	------	------	-----+	*Etheostoma*	------	------	------	------	------	------
rubellus	------	------	------	------	------	----+	*baileyi*	------	------	------	------	------	--+++-
Pimephales	------	------	------	------	+-----	++-+++++	*Catostomus*	------	------	------	------	------	-----+
notatus	------	------	--++-	------	--++-+	++++++	*commersoni*	------	------	------	------	---+	------
Nocomis	------	------	------	------	------	------	*Micropterus*	------	------	------	------	------	-----+
micropogon	------	------	------	------	--++-	++++++	*dolomieui*	------	------	------	------	------	----+
Hypentelium	------	------	------	------	-----+	-----+	*Lepomis*	------	------	------	------	------	------
nigricans	------	------	------	------	------	++--+	----	------	------	------	------	------	----+
Percina	------	------	------	------	------	------							
caprodes	------	------	------	------	------	+-----							

all stations in both streams.

At Station 3 on Bear Branch, *Campostoma, Ericymba, Pimephales notatus, Percina maculata, Etheostoma flabellare, E. variatum,* and *E. sagitta* have not returned to the fauna. *Semotilus, Campostoma, Ericymba,* and *E. flabellare* were present at Leatherwood Creek Station 3, but *Etheostoma caeruleum* continues to be absent.

Water volume, current, and oxygen content is higher at stations 5 and 6 than at the other stations, resulting in a slightly better habitat at these stations, and while large quantities of sediments are present, particularly along the margins of the streams and in pools, recovery in the fish faunas have been modest. For example, at Station 5 in Bear Branch, *Catostomus commersoni* was observed for the first time and *Notropis chrysocephalus* rejoined the fauna. *Etheostoma flabellare,* a clean-water fish dropped out of the fauna and *Nocomis micropogon, Etheostoma caeruleum, E. nigrum,* and *E. sagitta* continue to be absent. Similarly, at Leatherwood Station 5 *Notropis chrysocephalus* has apparently dropped out of the fauna, and *N. photogrenis, N. volucellus,* and *Pimephales notatus* are still missing. At the same station, *Hypentelium nigricans* and *Etheostoma caeruleum* were observed for the first time since the onset of mining, and *E. sagitta* has rejoined the fauna.

Stations 6, located at the mouth of the respective watersheds, are under the influence of normal longitudinal succession which reflects expansion of the habitat. Normally, such sites are kept relatively clear of sediments because of the higher flows, especially during storms. However, in both streams there are some thick bars and lens-shaped deposits of sediments.

At these two sites, some piscine changes were evident. In Bear Branch Station 6, *Lepomis megalotis, Micropterus dolomieui* (2 juveniles), and *Notropis rubellus* were collected for the first time, and *Ericymba* and *Hypentelium nigricans* have rejoined the fauna. However, *Notropis photogenis, Etheostoma sagitta,* and *E. baileyi* dropped out of the fauna, giving a net positive change of one species. *Notropis volucellus, Percina caprodes,* and *Etheostoma blennioides* continue to be absent.

In Leatherwood Station 6, 3 species—

Catostomus commersoni, Notropis rubellus, and *Micropterus dolomieui* — were observed for the first time, and *Hypentelium nigricans* has rejoined the fauna. However, *Notropis ardens, N. photogenis, N. volucellus, Etheostoma nigrum, E. variatum,* and *E. sagitta* apparently have not been able to reinvade the stream.

Many of these species, such as the bass, suckers, and some of the minnows and darters, are usually found at the mouths of small streams because of the proximity of the larger streams into which the tributaries flow. In this case, however, the larger streams have also been heavily impacted by mining. South Fork of Quicksand Creek, receiving Leatherwood Creek, and Buckhorn Creek, to which Bear Branch is tributary, are both choked with sediments and fine silt. Both streams' faunas have also been decimated, so they are no longer capable of providing parent populations of fishes for repopulation of the study streams. Since Bear Branch has recently been redisturbed (see Figs. 2-1) the faunal recovery of that stream has been slower than that of Leatherwood Creek.

Stations 1 and 2 of both watersheds and Station 4 of Bear Branch are on small, first order streams that may be ephemeral. Thus, the diversity and populations of fishes found in larger streams are not to be expected here.

Macrobenthos

None of the Leatherwood Creek and Bear Branch data on macrobenthos have been published previously (Tables 2 and 3). Thus, these data provide us with considerable new insight into the long-term influences of surface mining on the aquatic fauna in eastern Kentucky.

TABLE 2.—MACROBENTHOS OBSERVATIONS IN LEATHERWOOD CREEK, BREATHITT COUNTY, KENTUCKY, 1968 - 1982. COLLECTING DATES HEAD EACH COLUMN BELOW WHICH ARE GIVEN THE NUMBER OF SPECIMENS COLLECTED (COLLECTION SITE(S)) IN PARENTHESES). TOTAL TAXA, TOTAL NUMBER COLLECTED, MEAN DIVERSITY INDICES, MAXIMUM DIVERSITY INDICES, AND EQUITABILITIES ARE PRESENTED AT THE END OF EACH COLUMN

TABLE 2.—LEATHERWOOD CREEK

	6/1/68 NO. (STA)	10/26/68 NO. (STA)	5/17/69 NO. (STA)	11/1/69 NO. (STA)	10/3/70 NO. (STA)	8/14/71 NO. (STA)	12/2/72 NO. (STA)	7/31/82 NO. (STA)
Ephemeroptera								
Baetis			27 (2,3,4,5,6)	4 (1,4		1 (5)		10 (4,5)
Epeorus	1 (2)		13 (2,3,4,5)					
Stenacron			4 (1,2)	3 (2)		6 (3)	2 (3)	3 (4)
Stenonema	9 (1,2,4)	49 (3,4,6)	19 (4,6)	74 (2,4,5,6)	14 (3,4,6)	11 (3,5,6)	58 (3,4,5,6)	4 (4,6)
Isonychia		22 (6)	5 (6)	2 (6)	2 (6)	7 (3,6)	2 (3,4)	26 (4,5,6)
Paraleptophlebia			4 (2)					
Ephemera	1 (2)			1 (6)				1 (4)
Dannella			1 (4)	1 (1)				
Drunella	13 (1,2,4)		1 (5)					
Ephemerella			3 (2,6)					
Odonata								
Boyeria	9 (1,2,4)	1 (6)						
Lanthus			1 (4)				·	1 (6)
Cordulegaster	1 (1)							
Calopteryx								1 (3)
Plecoptera								
Amphinemura	1 (1)		3 (3,5)					
Allocapria							2 (3,4)	
Leuctra	1 (1)							
Peltoperla			1 (1)					
Isoperla			3 (5,6)					
Remenus	2 (1,2)							
Yugus	11 (1,2)	1 (6)		3 (4)		2 (3)	1 (4)	1 (5)

TABLE 2.—LEATHERWOOD CREEK (CONTINUED)

	6/1/68 NO. (STA)	10/26/68 NO. (STA)	5/17/69 NO. (STA)	11/1/69 NO. (STA)	10/3/70 NO. (STA)	8/14/71 NO. (STA)	12/2/72 NO. (STA)	7/31/82 NO. (STA)
Plecoptera (Continued)								
Acroneuria	1 (3)							
Acroneuria carolinensis	18 (1,2,3)	54 (3,4,5,6)	10 (2,4,5,6)	13 (4,5,6)	2 (4)			5 (4,5)
Eccoptura	4 (1,4)							
Heteroptera								
Gerris								9 (4,5)
Trepobates						3 (3,6)		4 (4,5)
Microvelia								1 (5)
Rhagovelia					9 (3)			
Megaloptera								
Corydalus cornutus		3 (6)			1 (6)	2 (3,6)	2 (3)	9 (3,4)
Trichoptera								
Diplectrona	9 (1,2)	18 (3,4,6)	2 (2,5)	1 (1)				
Cheumatopsyche	2 (2)	21 (3,4,6)		7 (4,5,6)		12 (3,4,6)	10 (3,4)	58 (3,4,5)
Hydropsyche		4 (3,6)		7 (4,5,6)		12 (3,4,6)	10 (3,4)	58 (3,4,5)
Ceratopsyche						3 (3)	4 (3)	5 (5)
Chimarra								70 (4,5)
Hydroptila								1 (4)
Rhyacophila		1 (6)						
Neophylax	1 (1)							
Coleptera								
Haliplus		1 (6)		2 (6)				
Hydrophilus				1 (6)				
Hydroblus								1 (4)
Psephenus		2 (3,6)						
Helichus	1 (2)	2 (3,6)	1 (2)	4 (4,5,6)	1 (6)	1 (6)	1 (3)	
Optioservus								1 (4)
Diptera								
Tipula	12 (1,2,3,4)	26 (1,3,6)	2 (3,4)	4 (4,5,6)			40 (4,5,6)	4 (3,4)
Eriocera	3 (1,2)							
Dixa				2 (1)				
Chironomidae								2 (4)
Pentaneura			1 (5)				3 (4)	
Simulium				1 (1)		1 (6)		3 (3,4)
Hemerodromia								1 (4)
Decapoda								
Cambarus bartonii	27 (1,2,3,4,5)	18 (1,3,4,6)	30 (2,3,4,5,6)	13 (2,3,4,5,6)	4 (4,6)	3 (5,6)	2 (5,6)	15 (3,4)
Orconectes putnami	55 (3,4,5)	18 (3,4,6)	13 (4,5,6)	26 (4,5,6)	13 (4,5,6)	29 (3,4,5,6)	6 (4,5,6)	48 (3,4,5,6)
Total Taxa	21	16	20	18	8	13	14	27
Total Number	182	241	144	162	46	81	135	293
Diversity Index (Mean)	3.371	3.181	3.478	2.790	2.438	2.940	2.439	3.463
Diversity Index (Max.)	4.392	4.000	4.322	4.170	3.000	3.700	3.807	4.755
Equitability	.705	.804	.800	.535	.923	.828	.528	.586

In general, analysis of the benthos demonstrated a decrease in total taxa and mean diversity index in Leatherwood Creek between June 1968 and October 1970 with an increase in both from October 1970 to July 1982, with the exception of a slightly lowered diversity index in December 1972. Concomitant changes in equitability were also obvious (Table 2).

Similar changes were noted in Bear Branch (Table 3) from March and April 1969 to November 1970, i.e., decreases in total taxa and mean diversity index, with a tendency toward an increase in total taxa and mean diversity index and equitability from November 1970 through October 1982.

In both watersheds, however, the numbers of individuals within given taxa tended to be lower in 1982 than previously. The population diversity remains lower in Bear Branch than it was in 1969, but in Leatherwood it is higher (Tables 2 and 3). Mayflies (Ephemeroptera) tend to be microhabitat specialists (36), the nymphs often burrowing deeply into the substrata (37) where they are subject to decimation by heavy siltation. Furthermore, the feeding activities, i.e., shredding/chewing of vegetation, collecting, or scraping/grazing, are often depreciated by sediments. Certain mayflies, like the various species of *Stenonema*, are moderately resistant to sediment pollution (38). Although some genera of mayflies (*Baetis, Stenonema, Isonychia,* and others) were able to persist during and after mining, others like *Ameletus, Leptophlebia, Paraleptophlebia, Ephemera, Dannella* and *Ephemerella* were apparently eliminated from the fauna of Bear Branch. Some of these same genera, mostly the collector/gatherers or deposit feeders, are also still missing from Leatherwood Creek. The Odonata were likewise seriously decimated by mining pollution in both streams. In fact, in Leatherwood Creek only *Lanthus* and *Calopteryx* were found in the fauna; both are lotic climbers and detritus feeders. In Bear Branch, *Boyeria, Lanthus, Progromphus* and *Cordulegaster* have returned, probably because of the increased amount of sediments suitable for burrowing.

The Plecoptera are, in general, particularly sensitive to sedimentation as demonstrated by Tables 2 and 3. Many genera eliminated from the fauna during mining have not yet successfully recolonized. The genera *Yugus, Peltoperla* and some *Acroneuria* have become re-established at low levels.

Megalopterans (*Corydalus, Nigronia, Sialis*), living among coarse rubble and stones, are active hunters and, hence, are resistant to sediment and acid pollution (38). Our data confirm this.

The Heteroptera (water strides and associated genera) poses an interesting phenomenon. From 1968 through 1970, intensive collecting failed to turn up specimens of any member of this order. It is doubtful that this is an artifact of collecting since the gerrids, at least, are a very obvious member of the fauna when present. We hypothesize that the influence of sedimentation, by slowing the current, producing several sluggish, ooze-filled pools, and otherwise disturbing the normal conditions changed the habitat enough to allow these organisms to colonize both streams. In any case the addition of these organisms to the fauna of both streams helped to counteract the tendency toward lowered diversity indices created by the absence of mayflies, stoneflies, and other insects.

Most streams show a consistently lower abundance and diversity of Trichoptera when impacted by mining pollution (22), although genera like *Cheumatopsyche* and *Hydropsyche* appear to be resistant to sedimentation pollution (38). These facts are supported by the data in Tables 2 and 3.

Although trichopterans often form a major component of invertebrate drift, especially at night, very little is known about their upstream migrations. Poole and Stewart (39) observed that various trichopterans use the loosely packed materials of the hyporheic zone as refuges from sedimentation and associated bottom scouring and thus are able to quickly recolonize streams following abatement of the sediment pollution.

The aquatic beetles (Coleoptera), though not abundant in Leatherwood Creek at the onset of the study, have been severely decimated in both streams. *Helichus* persisted in Leatherwood Creek through the mining period but was not found 10 years later. *Hydrobius* was the main genus observed in Bear Branch in 1982. It was not found in previous surveys.

TABLE 3.—MACROBENTHOS OBSERVATIONS IN BEAR BRANCH, BREATHITT COUNTY, KENTUCKY, 1968-1982. ALL OTHER DETAILS AS IN TABLE 2.

TABLE 3.—LEATHERWOOD CREEK

	3/21 & 4/26/69 NO. (STA)	12/12/69 NO. (STA)	11/7/70 NO. (STA)	9/4/71 NO. (STA)	9/9/72 NO. (STA)	8/1/82 NO. (STA)
Ephemeroptera						
Baetis	7 (3,4,5)			1 (6)	2 (3,6)	1 (6)
Centroptilum						1 (2)
Epeorus	48 (1,2,3,4)					
Stenacron	37 (1,2,4)	2 (1)	16, (1,4,5)	40 (1,2,3,4,5,6)	13 (3,4,6)	
Stenonema	48 (1,2,3,4,5)	53 (1,3,4,5,6)	40 (3,4,5)	24 (1,2,4,5,6)	29 (3,4,5,6)	1 (6)
Isonychia		1 (6)		7 (6)	2 (5,6)	2 (5,6)
Ameletus	7 (1,3,4)					
Leptophlebia	11 (2)	14 (1,2,4)	3 (4,5)			
Paraleptophlebia	3 (1,3)					
Ephemera	11 (3,4,5,6)	9 (3,4,6)	24 (2)			
24 (2,4)	2 (1,4)					
Ephemerella	21 (3,5)					
Odonata						
Boyeria	5 (1,3,5)	3 (1,3,6)		3 (3,5,6)		2 (2,6)
Hagenius					1 (6)	
Lanthus	1 (6)					4 (1,3)
Progomphus						1 (6)
Cordulegaster	1 (4)	2 (2)		1 (6)		1 (2)
Pantala					1 (2)	
Calopteryx	3 (3,6)	3 (1,4)	2 (2)	1 (2)	1 (6)	
Argia				1 (6)	2 (6)	
Plecoptera						
Ostrocerca		1 (6)				
Brachypterinae	3 (3)	6 (6)				
Allocapnia	2 (2)	3 (3,5)	2 (3,5)			
Leuctra	1 (1)					
Peltoperla	3 (4,5)			3 (3,5)		5 (4)
Isoperla	23 (1,2,3,4,5)	1 (6)				
Yugus	15 (1,2,3,4,5)	4 (6)	2 (4)			1 (4)
Alloperla	3 (6)					
Acroneuria				1 (3)	4 (6)	3 (1,2)
Acroneuria carolinensis	5 (1,3,4,5)	1 (5)	3 (3)			5 (3,5)
Eccoptura	2 (1)		1 (1)			
Heteroptera						
Gerris				2 (2,6)	4 (3,5)	9 (3,5)
Rheumatobates				1 (6)		
Trepobates					1 (3)	3 (5)
Microvelia						3 (3)
Rhagovelia				4 (3,6)		5 (1,2,3,6)
Megaloptera						
Corydalus cornutus	4 (6)			5 (1,6)	4 (5,6)	1 (5)
Nigronia	1 (4)					
Sialis						1 (3)
Trichoptera						
Diplectronia	9 (1,2,4)		1 (1)			1 (2)
Cheumatopsyche	14 (1,3,4,5)	5 (3,4,5)	38 (1,3,4,5)	8 (3,4,5,6)	19 (3,5)	13 (1,5,6)
Hydropsyche	2 (1,4)	1 (6)	2 (1,3)	2 (1,6)	1 (6)	1 (6)

TABLE 3.—MACROBENTHOS OBSERVATIONS IN BEAR BRANCH, BREATHITT COUNTY, KENTUCKY, 1968-1982. ALL OTHER DETAILS AS IN TABLE 2.

TABLE 3.—LEATHERWOOD CREEK (CONTINUED)

	3/21 & 4/26/69 NO. (STA)	12/12/69 NO. (STA)	11/7/70 NO. (STA)	9/4/71 NO. (STA)	9/9/72 NO. (STA)	8/1/82 NO. (STA)
Trichoptera (Continued)						
Ceratopsyche			2 (3)			
Chimarra				24 (6)	25 (3,6)	1 (1)
Wormaldia	1 (1)					
Polycentropus	1 (1)		1 (1)			
Rhyacophila	2 (1,4)					
Pychopsyche						1 (4)
Neophylax	97 (1,3,4)			4 (5)		6 (2,4)
Pseudostenophylax	17 (3,4,6)	7 (6)	1 (6)			
Coleoptera						
Laccophilus					3 (1,2,5)	
Tropisternus				1 (3)	1 (1)	
Hydrobius						6 (1,3,4)
Psephenus	11 (1,2,3)		4 (1,5)	4 (3,6)	2 (5)	6 (1,3,4)
Ectopria	7 (1,4,5)			4 (5,6)		
Helichus	1 (1)	1 (6)	2 (1,3)	13 (3,5,6)	24 (1,5,6)	1 (2)
Diptera						
Tipula	40 (1,2,3,4,5,6)	16 (2,3,4,5,6)	22 (1,3,4,5,6)	1 (6)	1 (3)	4 (3,6)
Dicranota						2 (3,4)
Hexatoma		2 (3,6)				
Bittacomorpha	1 (4)		1 (2)			
Dixa						1 (4)
Chironomidae						4 (1,24)
Pentaneura	1 (4)	1 (4)	4 (4)		11 (6)	
Simulium	6 (1,2)			1 (6)		
Atherix				1 (6)		
Heterondonta						
Sphaerium striatinum	2 (6)	8 (6)				
Mesogastropoda						
Pleurocera acuta	4 (6)	8 (6)		6 (6)	9 (6)	
Goniobasis semicarinata				4 (6)	6 (6)	
Basommatophora						
Ferrissia fragilis					1 (6)	
Helisoma anceps	1 (6)				2 (6)	
Decapoda						
Cambarus bartonii	44 (1,2,3,4,5,6)	5 (1,5,6)	9 (1,2,3,6)	29 (1,3,4,5,6)	2 (2,5)	21 (1,3,6)
Orconectes putnami	10 (5,6)	10 (6)	3 (5,6)	33 (2,3,5,6)	38 (2,5,6)	32 (1,2,3,5,6)
Total Taxa	45	26	22	29	27	32
Total Number	560	169	183	231	209	143
Diversity Index (Mean)	4.427	3.737	3.389	3.880	3.793	4.090
Diversity Index (Max.)	5.492	4.700	4.459	4.858	4.755	5.000
Equitability	.706	.743	.681	.739	.745	.779

In many instances, aquatic diptera, particularly chironomids, become dominant in streams following decimation by pollution (38). However, this tendency was not observed in the Leatherwood and Bear Branch drainages. Although genera like *Tipula, Simulium,* and the *Chironomidae* persist in Leatherwood and Bear Branch in small numbers, genera such as *Hexatoma, Bittacomorpha, Pentaneura, Simulium, Atherix* are generally absent Tables 2 and 3 . Anderson and Dicke (40) found that sediment-laden waters are unfavorable to dipterans, particularly simulids, because the suspended matter clogged their primary fans and digestive tracts. *Bittacomorpha,* found at Bear Branch Station 2 and at Jenny Fork Station 4 (Table 3), lives in stagnate shallow water (less than 4 cm deep) in substrates that are rich in organic matter (41). Both of our collection sites are of this nature.

Mollusks have been eliminated from the Bear Branch fauna; they were never observed in Leatherwood Creek (Tables 2 and 3). The decapod crustaceans *(Cambarus bartonii* and *Orconectes putnami)* remain abundant in both streams, adding significantly to the biomass and diversity indices.

DISCUSSION

Although the computation of total taxa present, diversity indices, and equitability during the evaluation of stream biotas and their tolerance to pollutants is very important (42), these parameters taken alone may be misleading with regard to pollution impact. The shifting of biotic elements (losses and gains of genera or family) may cause the diversity and total numbers to remain high, as demonstrated by results in our study. Each component group in the fauna must be studied individually. The present study makes it clear that the biota of both streams have been affected by the influences of surface mining and that recovery is often very slow.

The fish fauna has made only minor advances toward recovery, many species and groups of species being absent from the streams after more than 10 years. Success in recolonization by genera of macrobenthos has been varied, some have returned; others have not, and a number of genera never observed before are present now.

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NOTES

Preliminary survey of the Mussels of Elkhorn Creek, Northcentral Kentucky—The major tributaries of Elkhorn Creek, North and South Fork, originate in Fayette County east and west of Lexington, Kentucky, respectively. The North Fork meanders across Fayette and Scott counties while the South Fork flows through Fayette and Woodford and into Franklin County where the two forks converge, just east of Frankfort, to form main Elkhorn Creek. The total length of the creek, including both major forks, is Ca. 170 km. Elkhorn Creek discharges into the Kentucky River approximately 16 km due north of Frankfort. For the majority of its course, Elkhorn Creek flows through the rich farm lands of the bluegrass region in the proximity of Lexington, Georgetown, and Frankfort.

During May and June, 1982 mussels were collected from 6 localities along Elkhorn Creek. The stream rarely exceeds 1 m in depth, so handpicking from the water and shore line were used as the collecting techniques. Only fresh-dead shells were collected for voucher material. These specimens are in the Marshall University Malacological Collections. Specimens were also accessioned to the Ohio State University Museum of Zoology.

Nineteen species of unionacean clams plus the Asiatic clam *Corbicula fluminea* were found in Elkhorn Creek during this survey (table 1). Although 6 sites were designated for intensive collecting, good numbers of mussels were found throughout the entire stream. The more commonly found species included *Elliptio dilatata, Fusconaia flava, Lampsilis radiata luteola,* and *Lasmigona costata*. Only single specimens of *Anodonta imbecillis, Lasmigona complanata,* and *Quadrula quadrula* were found. The Asian clam *Corbicula fluminea* was found in large numbers at all stations.

TABLE 1.—SPECIES OF FRESHWATER MUSSELS FOUND IN ELKHORN CREEK, KENTUCKY. THE TOTAL NUMBER OF SHELLS FOUND IS ENCLOSED IN PARENTHESES

Scientific Name	Site Number 1	2	3	4	5	6
Anodonta imbecillis Say, 1829 (1)		X				
Anodonta g. grandis Say, 1829 (8)	X			X		X
Strophitus u. undulatus Rafinesque, 1820 (3)	X					
Alasmidonta marginata Say, 1818 (5)				X		
Alasmidonta viridis (Rafinesque, 1820) (9)	X	X				X
Lasmigona complanata (Barnes, 1823) (1)		X				
Lasmigona costata (Rafinesque, 1820) (24)	X	X		X	X	X
Magnonaias nervosa (Rafinesque, 1820) (2)						X
Quadrula quadrula (Rafinesque, 1820) (1)						X
Amblema p. plicata (Say, 1817) (16)	X	X	X	X	X	X
Fusconaia flava (Rafinesque, 1820) (27)	X	X	X		X	X
Elliptio dilatata (Rafinesque, 1820) (34)		X	X	X	X	
Ptychobranchus fasciolaris (Rafinesque, 1820) (10)		X			X	X
Leptodea fragilis (Rafinesque, 1820) (4)				X	X	
Potamilus alatus (Say, 1817) (8)		X		X	X	X
Villosa i. iris (Lea, 1829) (20)		X	X	X	X	
Lampsilis r. luteola (Lamarck, 1819) (39)	X	X	X	X	X	X
Lampsilis ventricosa (Barnes, 1823) (16)	X	X	X		X	X
Lampsilis fasciola Rafinesque, 1820 (16)		X		X	X	X
Total Number of Species Per Site	8	11	6	10	11	14

The Asiatic clam *Corbicula fluminea* occurred at all stations.

Station Localities: 1. North Fork Elkhorn Creek, Scott County. At bridge on White Oak Road, 3.2 km S of Stamping Ground, KY off U.S. 227; 2. North Fork Elkhorn Creek, Franklin County. Along County Road 1689, 8 km W of Switzer, KY; 3. South Fork Elkhorn Creek, Franklin County. Along Scruggs Road at the Village of Forks of Elkhorn, 2.4 km N of U.S. 421; 4. Elkhorn Creek, Franklin County. Along County Road 1900, .6 km N or Frankfort, KY; 5. Elkhorn Creek, Franklin County. Along County Road 1262 at Peak's Mill, KY; 6. Elkhorn Creek, Franklin County. At the Frankfort Federal Fish Hatchery, Ca. 14.5 km N of Frankfort, KY on Indian Gap Road.—Ralph W. Taylor, Dept. Biol. Sci., Marshall U., Huntington, W. Va. 25701.

The Blacktail Redhorse, *Moxostoma poecilurum* (Catostomidae), in Kentucky, with Other Additions to the State Ichthyofauna.—Since publication of the most recent checklist of Kentucky fishes (Burr, Brimleyana 3:53-84, 1980), 5 additional species have been found. These include the introduced alewife, *Alosa pseudoharengus* (Clupeidae), now present in the Ohio River (Trautman, *The Fishes of Ohio*, 782 pp., 1981), the introduced lake trout, *Salvelinus namaycush* (Salmonidae), now present in Dale Hollow Lake (Ronald R. Cicerello, pers. comm.), the introduced brook stickleback, *Culaea inconstans* (Gasterosteidae), formerly known from Levisa Fork of the Big Sandy River (John MacGregor, pers. comm.) and as a bait-bucket release in Meadow Creek, Owsley County (Branson and Batch, Proc. Southeast. Fishes Council 4:1-15, 1983), and the native greater redhorse, *Moxostoma valenciennesi* (Catostomidae), now extirpated from the Ohio River (Jenkins, *in* Lee, et al., *Atlas of North American Freshwater Fishes*, p. 434, 1980). Two exotics have recently been captured in Kentucky waters, but are not considered a part of the state fauna. They include the silver carp, *Hypophthalmichthys molitrix* (Cyprinidae), collected in the Ohio River below Uniontown Dam in 1982 (David Bell, pers. comm.) and a species of piranha (*Serrasalmus:* Characidae) discovered in Lighthouse Lake near Louisville (Anonymous, T.F.H. Magazine 31(#220):64, 1981).

Another species expected to occur in Kentucky, but which until now had not been reported, is the blacktail redhorse, *Moxostoma poecilurum*, which commonly occurs on the Gulf slope from Galveston Bay tributaries, Texas, to the Choctawhatchee drainage, Florida (Jenkins, *in* Lee, et al., *Atlas of North American Freshwater Fishes*, p. 430, 1980). Two recent collections, the most northern record for the species, from Terrapin Creek, Graves County, Kentucky, included juveniles of *M. poecilurum*. Both were taken from sandy-bottomed pools upstream from the Tenn. Hwy. 69 bridge, one on 6 March (SIUC 7720, 41 mm SL) and the other on 18 June 1983 (SIUC 7852, 62 mm SL). This fish is extremely rare in Terrapin Creek as evidenced by its absence in over 40 other monthly collections made in the watershed in the past 4 years.

The closest reproducing population of *M. poecilurum* occurs in the Obion River, Tennessee (Jenkins, 1980); however, the species is never common this far north of its main range. Of 25 collections made in suitable redhorse habitat in the Obion River drainage in the past 5 years, only 2 have yielded specimens of *M. poecilurum*. One large juvenile (SIUC 7828, 186 mm SL) was collected on 14 July 1980 in North Fork Obion River at Hwy. 69 bridge, Henry County, Tennessee, about 4.5 air km from the Kentucky state line and a tuberculate male (SIUC 5053, 250 mm SL) with running milt was collected at night on 25 May 1982 in Middle Fork Obion River at Hwy. 22 bridge, Weakley County, Tennessee. In addition to the Terrapin Creek records, the North Fork Obion River record is a significant range extension not previously reported (see Jenkins, 1980).

The recent additions to the Kentucky fish fauna brings the total number of species reported in the state to 234 (this number does not include the exotics), only 13 or 14 being the result of introduction by man. The presence of *M. poecilurum* in Terrapin Creek emphasizes once again the unusual diversity of fishes found in this creek and nowhere else in the state (Burr, 1980; Walsh and Burr, Brimleyana 6:83-100, 1981). Other fishes known in Kentucky only from Terrapin Creek include the least madtom, *Noturus hildebrandi;* the brown madtom, *N. phaeus;* the gulf darter, *Etheostoma swaini;* the banded darter, *E. zonale lynceum;* and the lowland snubnose darter, *E. (Nanostoma)* sp. (an undescribed species). Reproducing populations of other unusual Kentucky fishes with small ranges in the state occur in Terrapin Creek and include the dwarfed, partially neotenic population of the least brook lamprey, *Lampetra aepyptera* (Walsh and Burr, loc. cit.); the central mudminnow, *Umbra limi;* the bluntface shiner, *Notropis camurus;* the banded pygmy sunfish, *Elassoma zonatum;* the dollar sunfish, *Lepomis marginatus;* and the goldstripe darter, *Etheostoma parvipinne*. Appropriately, Terrapin Creek was included in the list of Oustanding Resource Waters by the Kentucky Nature Preserves Commission and was recognized for the diverse aquatic biota it supports (Hannan, et al., *Recommendations for Kentucky's Outstanding Resource Water Classifications with Water Quality Criteria for Protection,* 459 pp., 1982). The unusual aquatic biota in Terrapin Creek deserves protection from future modifications that could result in the loss of a unique Kentucky resource.—Brooks M. Burr and Douglas A. Carney, Department of Zoology, Southern Illinois University, Carbondale, Illinois 62901.

Observations on *Anguispira kochi* (Mollusca: Gastropoda) in Kentucky.—Taylor (Trans. Ky. Acad. Sci. 43:155-157, 1982) stated that the present distribution of the land snail *A. kochi* (Pfeiffer) is limited to areas north of the Ohio River east of the Mississippi with "relictual populations south of the river." Pilsbry (Proc. Acad. Nat. Sci. Philad. II:1-1113, 1948) and LaRocque (Bull. Ohio Geol. Surv. 62:1-800, 1970) indicated that habitats for the species were vanishing, and Pilsbry (loc. cit.) thought the prime habitat consisted of mature forests, second-growth forests being avoided. Admittedly, distributional records for *A. kochi* are scanty in Kentucky (Branson and Batch, Sterkiana 43:1-9, 1971; Branson, Bull. Ky. Dept. Fish Wildl. Res., 1973:1-67, 1973), but that is doubtless a reflection of inadequate collecting. Previously published records include the following Kentucky counties (Branson loc. cit.): Fulton, Hickman, Meade, Hardin, Taylor, Green, Rockcastle, Jessamine, Mercer, and Franklin.

Recent field work disclosed relatively large populations of this rather secretive snail at 3 localities in Franklin Co., Kentucky: in and under rock fences at Frankfort; in young, second-growth woodlots at the Kentucky Fish and Wildlife Resource Commission Game Farm, Frankfort; and in a relatively undisturbed woodlot 16.8 km N Frankfort (all in Sept. 1980). Two additional sites with healthy populations were: second-growth woods around the confluence of Goose Creek with Salt River, Spencer Co. (9 Sept. 1980); and a sparse, second-growth woodlot at the U. S. 62 Kentucky River bridge, Woodford Co. The last two sites are new distribution records in Kentucky.

All these sites had in common loose soil that was rich in humus, a feature that allowed the snail to burrow, and microhabitats that maintained a high relative humidity. One of the reasons this snail is easily missed during general collecting is its tendency to burrow deeply into the soil during cold or hot weather, and its marked crepuscular or nocturnal behavior.

The author acknowledges the assistance of S. P. Rice, Kentucky Department of Highways, and John MacGregor, Nongame Species Program, Ky. Dept. Fish Wildl. Res. Comm., for their assistance in collecting—Branley A. Branson, Dept. Biol., Eastern Ky. Univ., Richmond, Kentucky 40475.

***Rhopalosoma nearticum* Brues in Kentucky**[1]—The wasp, *Rhopalosoma nearticum* Brues (Hymenoptera: Rhopalosomatidae), is considered a rare species. It is known from the southeastern states and is a larval parasite of crickets of the subfamily Eneopterinae.

Ashmead (Proc. Ent. Soc. Washington 3:304, 1896) was the first to record this species from Kentucky. He stated he saw a single male collected by H. Garman from Louisville. This specimen was not from Louisville (as recorded) but from Jessamine County. The specimen is in the University of Kentucky Collection labeled "No. 1723, Jessamine Co., Ky., August 15, 1894, H. Garman, from sweeping." It also has an identification label stating *"Rhopalosoma poeyi:* Cresson, by Ashmead." This was a misdetermination but was the name used by Ashmead at that time. As far as I know this species

[1]The investigation reported in this paper (83-7-90) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director.

has never been collected in Louisville.

Townes (Contributions Amer. Ent. Institute 15 (1): 34 pp., 1977), in his revision of this family, gave the most recent information on this species. He also recorded an additional Kentucky locality, Golden Pond. He recently gave me the following data on the specimens involved: Trigg Co. — 4 males, 8 females, Golden Pond, June 10 to August 10, 1964, S. G. Breeland; 3 males, 3 females, Golden Pond, August 1965, S. G. Breeland, (Townes Collection).

My new records are as follows: Jessamine Co.—5 females, July 23-30, 1974, Paul H. Freytag; 1 female August 1-8, 1974, Paul H. Freytag; 1 male, 5 females, August 8-15, 1974, Paul H. Freytag; 11 females, August 15-22, 1974, Paul H. Freytag; 8 females, August 22-29, 1974, Paul H. Freytag; 4 females, August 29 - September 2, 1974, Paul H. Freytag. Mercer Co. — 1 female, July 19-26, 1976, Paul H. Freytag. Wayne Co. — 1 male, July 11-18, 1972, Chris Sperka. All were collected in Malaise traps. One parasitized cricket has been collected with the following data: Nicholas Co. - September 25, 1982, Rudy A. Scheibner.

This species has now been collected in 5 counties in Kentucky, three of which are new records. The data also indicate adults can be collected in Kentucky from mid-July to early September.

I thank Henry K. Townes for his help on the data for Kentucky specimens, Charles V. Covell, Jr. (University of Louisville), and Arnold S. Menke (U. S. National Museum) for checking their collections for Kentucky records.—Paul H. Freytag, Department of Entomology, University of Kentucky, Lexington, KY. 40546-0091.

Notes on Various Growth Features of the Paddlefish in the Ohio River.—Fisheries managers have been interested in the biology of the paddlefish, *Polyodon spathula*, for many years. However, with the recent development of sport fisheries for the species and the modification of it's habitat by dam construction, a need for it's management has been realized. The purpose of this paper is to document some growth features of the species in the Ohio River.

Adult paddlefish were collected with gill net tackle from the Louisville hydroelectric discharge pool downstream from the Falls of the Ohio at River km 976. Larval specimens were collected in April and May 1975 by TVA biologists with 0.5 and 1 m ichthyoplankton nets with 0.5 mm mesh, set in the intake basin of the Shawnee steam electric plant intake canal, located on the lower Ohio River at River km 1523. First and second year paddlefish, impinged on 1 cm^2 traveling screens in the Shawnee plant intake canal, were collected from October 1974 through October 1975. Growth features were compared by combining the fish into 3 groups: fish up to 7 months of age (less than 250 mm TL), fish aged seven to 24 months (greater than 260 mm but less than 800 mm TL), and adult fish (greater than 850 mm TL). The length-weight relationship and coefficient of condition were based upon standard body length measurements from the tip of the tail to the nostrils.

A total of 161 paddlefish were collected, 8 larvae, 130 first and second year specimens, and 23 adults. Recently hatched paddlefish were first observed on 23 April 1975 (water temperature 12.8 C); two specimens were collected (10 and 11 mm TL). Six larvae ranging from 11 to 15 mm TL were taken on 21 May (21 C). Growth of 0 Age Class individuals averaged 2.0 mm/day from 23 April to 26 July, but from 26 July to 31 October decreased to an average of 0.3 mm/day (Fig. 1). The average total length of paddlefish at the end of the first year's growth was approximately 300 mm. During the second year, growth averaged 2.3 mm/day from 25 April to 3 July. The average total length of fish at the end of the second year was approximately 540 mm. Three Age Classes, O, I, and II, were indicated by growth curves (Fig. 1). Adult paddlefish sampled ranged from 875 to 1262 mm TL, but because ages were not estimated, growth rates could not be determined.

Although growth in length was similar during the first 2 summers, weight increases were much greater during the second summer than the first. During their first summer, paddlefish gained approximately 0.16 g/day (23 April - 26 July). In their first fall, weight gain decreased to 0.04 g/day, with the fish averaging 39 g at the end of their first year. During the second summer, the average weight gain increased to 2.04 g/day, decreased to 0.4 g/day during the second fall, and totaled 310 g at the end of the second year. The standard length-weight relationship for 85 paddlefish was $\log W = -4.879 + 2.92 \log SL$. The average coefficient of condition (K_{SL}) for the 3 size groups varied considerably: 0.99 (0.64 to 1.55) for small fish N = 48, 0.74 (0.62 to 0.89) for medium size fish N = 14, and 0.87 (0.45 to 1.36) for adults N = 23.

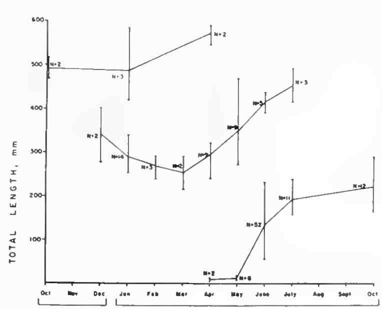

FIG. 1. Number of fish, average total length, and range of total lengths of paddlefish by month from the Ohio River, 1974-1975.

The collection of paddlefish larvae on 23 April and 21 May 1975 indicated spawning occurred in early to mid-April and May at water temperatures of 9 - 14 C and during periods of marked water level fluctuations. The Ohio River varied from 98.4 m above mean sea level on 14 March 1975 to 94 m on 18 April, back to 98 m on 2 May, and down to 94.3 m on 22 May.

Early growth of paddlefish in the Ohio River was similar to that of the fish from Barkley Reservoir and Mississippi River (Pasch et al., Trans. Amer. Fish. Soc. 109:157-167, 1980) and Lewis and Clark Lake (Unkenholz, South Dakota Dept. Game, Fish and Parks, D-J Project F-15-R-12, 1976). However, the average total length of Ohio River fish at the end of the first year's growth was less than that reported by Purkett (Prog. Fish. Cult. 25:31-33, 1963) and Pasch et al. (loc cit., 1980), but greater than that reported by Robinson (Proc. Montana Acad. Sci. 26:33-44, 1966). Estimates of growth made in this report have been biased by small sizes and because larger individuals may not have been as susceptible to impingement.

The period of maximum growth for Ohio River fish, March through July, was also observed for the species by Ruelle and Hudson (Trans. Amer. Fish. Soc. 106: 09-613, 1977), Pasch et al. (loc. cit., 1980), and Houser and Bross (Trans. Amer. Fish. Soc. 88:50-52, 1959). Ohio River paddlefish grew at a slightly slower rate than those sampled by Ruelle and Hudson (loc. cit., 1977) in the Missouri River. This difference also may be a function of the bias introduced by using fish impinged on screens.

Weights of Ohio River paddlefish were generally similar to those compiled by length group by Carlander (Handbook Freshwater Fishery Biology, Iowa State Univ. Press, 1969). Adams (Amer. Mid. Nat. 28:617-630, 1942) and Unkenholz (South Dakota Dept. of Game, Fish and Parks, D-J Project F-15-R-15, 1980), however, indicated lengths and weights to be considerably greater for first and second year specimens than those observed in this study or listed by Carlander (loc. cit., 1969). No condition values for young paddlefish were observed in the literature.—Robert D. Hoyt, Dept. Biol., Western Kentucky Univ., Bowling Green, Ky. 42101.

New Distributional Record for *Mustela nivalis* in Kentucky.— On November 26, 1981, a weasel was collected at a private residence in Woodford County, Kentucky. The specimen had been killed and cached with several rodents by a domestic house cat. The weather at this time was unseasonably warm and the specimen was in advanced stages of decay; the tail was missing.

The collecting site is 0.2 km north of U.S. 421 on CR 1685, approximately 8 m west of the road. The elevation of the area averages approximately 244 m with a maximum of 259 m. The site was less than a km from South Elkhorn Creek. The area is typical of the central Kentucky Bluegrass area, with gently rolling hills of open pasture land and cultivated fields. There is abundant vegetational cover in the fence and ditch lines and along stream banks.

Neither tail or foot measurements were made. Observations included total body length (including an estimate of tail length), about 152 mm; pelage, brown from the dorsal area to the sublateral area and white ventrally (junction very irregular); and the sex, which was male. The head was removed and the skull cleaned for further identification purposes and preservation. The skull is in the museum collection at the University of Kentucky in Lexington. The skull, 29.4 mm long with a cranial breadth of 13.5 mm, was adult and bore a full set of teeth. These observations confirmed that the specimen was *Mustela nivalis*.

The only other record of *M. nivalis* in the state is from Letcher County in SE Kentucky (Davis and Barbour, Trans. Ky. Acad. of Sci. 40:111, 1979). That specimen was collected in February 1976 at an elevation of 310 m. This animal was thought to be a northern species, occurring in Kentucky only in the eastern Appalachian region. The present report from Woodford County may indicate a population that ranges from the Bluegrass area into the SE coal fields. The nearest collecting sites outside Kentucky are from eastern Tennessee, southern Ohio, and eastern Illinois (Hall, Mammals of North Americal, Wiley and Sons, Sec. ed., Vol. II, 1981). The southern-most record from Indiana is from Muscatatuck National Wildlife Refuge in Jennings County (Mumford and Whitaker, Mammals of Indiana, Univ. Press, 1983). The general distribution of *M. nivalis* in the United States is from northern Montana to southwest Nebraska to southern Ohio and down the Appalachian Chain from Pennsylvania to western North Carolina (Blair, Blair, Brodkorb, Cagle, and Moore, Vertebrates of the United States, McGraw-Hill, 1968).

I thank Dr. Wayne Davis for confirming my identification and for executing the skull measurements, and John MacGregor for confirmation and assistance. Thanks is also given to the David Adkinson family for bringing the specimen to our attention.—Kerry W. Prather, Kentucky Depart. Fish Wildlife Res., Prestonsburg Community College, Prestonsburg, Kentucky 41653.

An Improved Method for the Preparation of Steryl *N*-Methylcarbamates.—The synthesis of carbamates is usually a straightforward addition of the isocyanate to the alcohol in a suitable inert solvent with or without the addition of catalytic amounts of pyridine. $CH_3NCO) + ROH \rightarrow CH_3NHCO_2R$. References to such syntheses are numerous and this simple reaction has been incorporated in college textbooks for the identification of organic compounds (Shriner, Fuson and Curtin, Systematic Identification of Organic Compounds, 4th Ed. John Wiley, NY, p. 211, 1956). References to the synthesis of *N*-methylcarbamates of sterols are, however, very scarce and with one exception, when these carbamates have been synthesized at all they were obtained from the reaction of the steryl chloroformate with methylamine (Campbell, Sheperd, Johnson and Ott, J. Am. Chem. Soc., 79:1127, 1957, McKay and Vavasour, Can. J. Chem., 31:688, 1952). Only stigmasterol *N*-methylcarbamate is reported to have been synthesized from the direct reaction of methyl isocyanate and stigmasterol, but no information is given regarding the yield or the purity of the crude product (Campbell *et al*, loc. cit., 1957).

The lack of literature references to the synthesis of sterol carbamates by direct reaction of methyl isocyanate with the appropriate sterol appears to be an indication that this direct reaction is unsatisfactory. Our own experience, in which the synthesis of the *N*-methylcarbamates of cholesterol, stigmasterol and sitosterol by direct reaction of methyl isocyanate with an ethereal solution of the sterol (even in the presence of catalytic amounts of pyridine) was unsuccessful, confirming this conclusion.

However, we have found that the use of pyridine as a solvent has a pronounced effect on this reaction. Thus, almost quantitative yields of analytically pure steryl *N*-methylcarbamates are obtained when sterols of various structures are dissolved in pyridine and allowed to react with a pyridine solution of methyl isocyanate. The results are summarized in Table 1.

TABLE 1. STERYL *N*-METHYLCARBAMATES

Sterol	mp(C°)	Yield (%)	Calculated C	Calculated H	Calculated N	Found C	Found H	Found N
cholesterol	183-6	93	78.50	11.13	3.16	78.54	11.17	3.16
stigmasterol	200-2	91	79.26	10.94	2.98	79.22	10.94	2.98
sitosterol	205-7	95	78.92	11.32	2.97	78.89	11.32	2.93
testosterone	162-3	93	73.01	9.04	4.05	72.98	9.07	4.01
androsterone	161-2	91	72.58	9.57	4.03	72.51	9.60	4.02
ergosterol	200-2	95	79.42	10.44	3.09	79.35	10.46	3.07

Procedure for the preparation of steryl *N*-methylcarbamates: a solution of 0.02 mol of methyl isocyanate in 2 mL of pyridine was added dropwise at room temperature to a stirred solution of 0.01 mol of sterol in just enough pyridine to cause complete dissolution. After addition was complete, stirring was stopped and the reaction flask was allowed to stand at room temperature for 24-48 h, at the end of which time the crystalline steryl methylcarbamate was collected by filtration and washed 3 times with ice-cold ether. The methyl carbamate obtained was analytically pure and needed no recrystallization.

This investigation was supported by the University of Kentucky Tobacco and Health Research Institute Project No. KTRB 22142.—Walter T. Smith, Jr. and John M. Patterson, Department of Chemistry, University of Kentucky, Lexington, Kentucky 40506 and Nabeel F. Haidar, Beirut University College, Beirut, Lebanon.

A New Kentucky Record for the Minnow, *Clinostomus elongatus* (Kirtland).—The redside dace, *Clinostomus elongatus*, is herein reported from the Kentucky River basin. A single individual, 52.1 mm in standard length was caught April 19, 1982 in Edward Branch about 0.5 km upstream from its juncture with North Fork, Red River in Menifee Co., Kentucky. The specimen has been deposited in the fish collection at Southern Illinois University, Carbondale. Collecting assistance from my ichthyology class is gratefully acknowledged.

A record of *C. elongatus* was reported from the Licking River basin based on an earlier unpublished checklist of fishes in that river system (Clark, unpubl. mimeo. list, Ky. Game & Fish Comm., Frankfort, 1940; Clay, The Fishes of Kentucky, Ky. Dept. of Fish & Wildlf. Res., Frankfort, 1975). Specimens were not found later and the most recent state list (Burr, Brimleyana 3:53-84, 1980) can only indicate the possibilities of misidentification, rarity, or extirpation of this species in Kentucky. My record verifies the presence of *C. elongatus* in Kentucky and adds support to the validity of the earlier record.

Edward Branch is a second-order stream of moderate gradient. Substrates vary from sand to coarse gravel and rubble, temperatures are cool, water clarity is exceptionally high for the region, the stream is well shaded by forest canopy and shrubs such as alder and buttonbush, and the watershed is uninhabited. These conditions are essentially those favored by this minnow in Ohio (Trautman, The Fishes of Ohio, Ohio State Univ. Press, Columbus, 1981).

Frequent collecting by me in the Red River basin and an extensive fish survey published on the system never produced records of the redside dace (Branson and Batch, Fishes of the Red River Drainage, Eastern Kentucky, Univ. Press of Ky., Lexington, 1974). The possibility exists that this species was released as a bait minnow and that my collection simply records such an event. It is more probable that *C. elongatus* is a rare native species at this southern margin of its range and that Clark's record and mine verify the presence of two relict populations, others of which might persist in northeastern Kentucky. Even toward the heart of its range the redside dace may be approaching a relict status. Trautman (1981) says that many populations of this minnow have disappeared from Ohio or have been drastically reduced in abundance since 1925.

Even species thought perhaps to have become extinct may persist locally and in very small numbers, as illustrated by the darters, *Etheostoma acuticeps*, *E. sellare*, and *E. trisella*, all rediscovered after long periods of unsuccessful attempts at capture. Thinking that *Etheostoma sagitta* would be as common in Red River as it is in the upper forks of the Kentucky River, I released an adult female caught there in 1959. Despite almost yearly collecting, I never took this darter again in Red River, nor did Branson and Batch (1974) in the most extensive survey conducted in that basin. That the species persists has been verified recently (Greenberg and Steigerwald, Trans. Ky. Acad. Sci., 42:37, 1981). I suggest that *C. elongatus*, like *E. sagitta*, occurs in limited numbers in the protected watersheds of the Red River Gorge Unit of Daniel Boone National Forest. This and similarly well managed portions of the Federal lands in eastern America provide refugia for such threatened elements of our ichthyofauna. Robert A. Kuehne, Biological Sciences, Univ. of Kentucky, Lexington, Ky. 40506.

Additional Kentucky Records of the Yellow Perch, *Perca flavescens* (Mitchill).—On July 6, 1978 Kuehne and John Kuehne seined a yellow perch, 79.1 mm in standard length, from Little Yellow Creek (Upper Cumberland R. basin), about 1 km below the dam of Fern Lake, city water supply for Middlesboro, Kentucky, Bell County. It seemed unlikely that a native population would exist there and subsequent discussions with officers of the lake's fishing club revealed that several species had been introduced. Mr. Larry Brooks checked club records and verified a single stocking of yellow perch in 1972 from some source in Ontario, Canada. He indicated that specimens were caught regularly since that year and that yellow perch were well-established in the lake. The reservoir is clear and cool, lying in a heavily forested basin at about 370 m elevation. Since the upper end of the reservoir and most of its catchment is in Claiborne Co., Tennessee, yellow perch presumably are found there as well. Tennessee populations are already reported for the Hiwasee River basin (Timmons, J. Tennessee Acad. Sci. 50:101-02, 1975). Future records from the Yellow Creek drainage in Kentucky are likely to occur.

On November 3, 1973 Branson was given a specimen of the yellow perch by Mr. Oral Brooks, an employee of the Jellico Coal Company. The fish was caught in a small company impoundment, Wilton Lake, near Woodbine, Whitley Co., Kentucky. Mr. Brooks indicated that yellow perch were apparently stocked in the lake during the 1940's and were plentiful. Escapees from Wilton Lake may exist locally in that portion of the Upper Cumberland basin. Introduced populations of yellow perch may do quite well in suitable waters far south of the natural range of the species.

Records of the yellow perch near the mouth of the Little Kentucky River (Charles, project progress report F-13-R-2, Ky. Dept. Fish and Wildlife Res., Frankfort, 1959), at intake screens of the Louisville water treatment plant (Clay, The Fishes of Kentucky, Ky. Dept. Fish and Wildlife Res., Frankfort, 1975), and from the Lower Cumberland River (Burr, Brimleyana No. 3:53-84, 1980) may be viewed as isolated, introduced populations but alternatively might represent natural, relict populations. Trautman (The Fishes of Ohio, Ohio State Univ. Press, Columbus, 1981) states that most yellow perch in the southern part of Ohio are stocked or have invaded from the north via canals. A few records, however, particularly old ones, cannot be discounted as possibly natural populations. Two old records from southeastern Indiana may also represent native stock (Gerking, Invest. Indiana Lakes and Streams 3(1), 1945). Reinvasion of northern habitat as Pleistocene ice fronts retreated must have initiated in the Ohio and middle or upper Mississippi river basins and the yellow perch, like so many other fishes, probably left behind locally persistent, relict populations. Stream habitat deterioration and corresponding losses in yellow perch stocks is known for Illinois (Smith, The Fishes of Illinois, Univ. of Illinois Press, Urbana, 1979). Similar changes elsewhere probably add to the difficulty of determining the natural southern limits of the yellow perch.

Research support for Kuehne was given by the National Park Service, Contract C X 5000 71 232.—
Robert A. Kuehne, Biological Sciences, Univ. of Kentucky, Ky., 40506 and Branley A. Branson, Dept. of Biological Sciences, Eastern Kentucky Univ., Richmond, Ky., 40475.

Characteristics of Mine Roof Falls in Selected Deep-Coal Mines of Kentucky: A Pilot Study.—A common ground-control problem is the occurrence of mine-roof falls. In fact, the "... roof fall is so common that many consider it to be part of mining operations" (Peng, Coal mine ground control, John Wiley & Sons, 1978, p. 28). Large roof falls cause production losses and, thus, increase the maintenance cost of entries. "Unfortunately, there is no systematic documentation of the characteristics of roof falls in American coal mines" (Peng, loc. cit. p. 29). Roof-fall fatalities have accounted for more than half of the yearly underground coal-mine deaths since fatality records were established. Statistical studies of mine roof-fall investigations over the last decade have established some general correlations among roof-fall fatalities and location, size of the roof falls, seam thickness, immediate roof characteristics, roof-control plans, and roof-testing methods (Barry, U.S. Bureau Mines, 1:1-298; Caudle, *in*, Ground control aspects of coal mine design, U. S. Bur. of Mines, JC 8630:79-85, 1971; Doughterty, A study of fatal roof fall accidents in bituminous coal mines, M.S. thesis, West Virginia Univ., Morgantown, WV, p. 1-77, 1971).

A pilot study was undertaken to investigate selected factors associated with roof falls, as derived from an intensive review of the literature. Specifically, the purposes of the study were to: (1) study in a systematic and empirical fashion selected parameters that may be capable of differentiating characteristics of roof falls and (2) obtain some predictive indices based on selected physical and management-related variables so that predictions of potential future problems associated with mine-roof falls can be made. The achievement of these goals would result in valuable guides to the mining engineer in scheduling exploration work and determining economic feasibility of certain ground-control and mining projects and practices. Table 1 lists the parameters investigated in this pilot study and their coding for analysis purposes. Although a large number of other more detailed parameters associated with mine-roof falls, such as the petrology and petrography of the immediate roof bed or secondary bedding features, which are a function of the sedimentary environment of deposition and consequent erosion and compaction can be studied, the parameters listed in Table 1 represent a good starting point from the mine engineer's perspective.

The dependent variables chosen from Table 1 to be studied were: (1) surface area of the roof fall (roof-fall length (x roof-fall width); (2) assumed condition of the roof before the mine roof fall, using categorical analysis techniques; (3) length of time the mine-roof fall occurred after the coal excavation; (4) type of support before the fall, assuming resin-coated or non-resin-coated roof bolts; (5) presence of water and cracks before the fall; and (6) selected pillar dimensions. The independent variables selected included selected physical and geological parameters associated with rock failure, once properly coded for discriminative or categorical analyses. Multiple linear regression techniques and corrections for multiple comparisons were employed in the testing process of 18 major research hypotheses. Table 2 illustrates the tenth hypothesis or model comparison tested, for illustrative purposes, using standard multiple regression terminology. Table 3 represents a summary of the models tested, dependent and independent parameters tested, R^2 values, degrees and

TABLE 1.—DESCRIPTION AND LISTING OF PHYSICAL AND MINE MANAGEMENT PARAMETERS ASSOCIATED WITH MINE ROOF FALLS AND THEIR CODING FOR ANALYSIS

Variable Label	Description of Variable
MINE	Name of Mine
WORKING	Working Section (1 if roof fall occurred in working section, 2 if not)
INVEST	Name of Investigator or Mine Foreman
COUNTY	County of Mine (1 if Perry, 2 if Pike, 3 if Hopkins, 4 if Muhlenberg, 5 if Union, 6 if Martin, 7 if Floyd)
SPAN	Mine Roof Span (feet)
ORIENT	Orientation of Mine (degrees)
PILWID	Pillar Width (feet)
PILLEN	Pillar Length (feet)
THICK	Thickness of Coal Seam (inches)
ROOFLN	Length of Mine Roof Fall (inches)
ROOFWID	Width of Mine Roof Fall (inches)
ROOFHT	Height of Mine Roof Fall (inches)
SURFACE	Surface Area of Mine Roof Fall ($feet^2$)
SHAPE	Shape of Mine Roof Fall (1 if arch, 2 if dome, 3 if other shape)
THINLAY	Thickness of the Thinnest Immediate Layer (inches)
THICK 1	Thickness of the First Immediate Layer (inches)
TYPE 1	Lithology of the First Immediate Layer in Mine Roof (1 if shales, 2 if bone coal, 3 if shales, 6 if coal, 7 if laminar shales, 8 if black shales, 9 if laminer sandstone) In the analysis, all shales were coded 1, while the others were coded 0 for discriminative analysis purposes
TYPE 2	Lithology of Second Immediate Layer in Mine Roof (coded same as TYPE 1)
TYPE 3	Lithology of Third Immediate Layer in Mine Roof (coded same as TYPE 1)
TYPE 4	Lithology of Fourth Immediate Layer in Mine Roof (coded same as TYPE 1)
THICK 2	Thickness of Second Immediate Layer (inches)
THICK 3	Thickness of Third immediate Layer (inches)
THICK 4	Thickness of Fourth Immediate Layer (inches)
SUPPORTB	Type of Support of Roof Before Mine Roof Fall (1 if resing bolts, 2 if anchor bolts, 3 if posts, 4 if bars, 5 if cribs, 6 if nonsupported, 7 if cribbed off, 8 if canopy) For discriminative analysis purposes, resin bolts were coded 1, and 0 if other.
SPACING	Spacing of Roof Bolts Before the Mine Roof Fall (feet)
LENGTHB	Length of Roof Bolts Before th Mine Roof Fall (inches)
SUPPORA	Type of Support of Roof After Mine Roof Fall (coded same as SUPPORB)
LENGTHA	Length of Roof Bolts After the Mine Roof Fall (inches)
WATER	Presence of Water Before the Mine Roof Fall (1 if yes, 2 if no)
TIME	Length of Time Fall After Coal Excavation (weeks)
DISTANCE	Distance to the Nearest Face (feet)
INJURY	Physical Injury due to Mine Roof Fall (1 if yes, 2 if no)
OPERAT	Operation During the Time of the Mine Roof Fall (1 if continuous miner, 2 if bolting, 3 if other, 4 if conventional, 5 if hand, 6 if abandon) For discriminative analysis purposes continuous mining operations were coded 1 and 0 if other operation.
LOCATIO	Location of the Mine Roof Fall (1 if entry, 2 if crossection, 3 if intersection, 4 if haulage way, 5 if beltway, 6 if airway) For discriminative analysis purposes, if entry, coded 1, and coded 0 if not
DAY	Day of the Mine Roof Fall (1 if Monday, 2 if Tuesday, 3 if Wednesday, 4 if Thursday, 5 if Friday, 6 if Saturday, 7 if Sunday)
SHIFT	Working Shift During the Mine Roof Fall (1 if morning, 2 if noon, 3 if evening)
CRACKS	Presence of Cracks Before the Mine Roof Fall (1 if yes, 2 if no)
CONDIT	Assumed Condition of the Mine Roof Fall Before the Roof Fall (1 if excellent, 2 if very good, 3 if good, 4 if poor, 5 if very poor)
SLOUGH	Presence of Sloughing Before the Mine Roof Fall of the Coal Ribs (1 if yes, 2 if no)
FLOOR	Presence of Floor Heave Condition Before the Mine Roof Fall (1 if yes, 2 if no)

TABLE 2.—RESULTS OF THE TESTING OF SPECIFIC RESEARCH HYPOTHESIS TEN

Explanation of Models	Models	R^2	df	Alpha	F-Value	Prob	Sign
Model 10: WATER = (0.82759)U + (0.37931) CRACKS + E	Full	0.41724					
			1 11	0.05	7.87574	0.0171	S
Model 99: WATER = (0.82759)U + E	Restr.	0.0					

Hypothesis 10:

The variable Cracks in the Roof Before the Fall does not account for a significant amount of variance in predicting the variable Presence of Water

Where: E denotes error vector of residuals
U denotes unit vector
(x xxxx) denotes partial regression weights
R^2 denotes proportion of variance accounted for
df denotes degrees of freedom for both numerator and denominator

Note. See list of parameter descriptions, see Table 1 statistical significance for each hypothesis. Although only 13 mine-roof falls were mapped and measured from 7 counties, mostly in eastern Kentucky, the present results should provide valuable input into structuring a larger study in the future.

TABLE 3.—SUMMARY OF MODELS TESTED, DEPENDENT AND INDEPENDENT PARAMETERS, R^2 VALUES, DEGREES OF FREEDOM, F-RATIOS, PROBABILITY LEVELS, AND STATISTICAL SIGNIFICANCE FOR THE SPECIFIC RESEARCH HYPOTHESES TESTED.

Parameters Dep.	Indep.	Hypoesis No.	R^2-Full	R^2-Restr.	df_n/df_d	F-Ratio	Prob.	Sign.
CONDIT	FLOOR	1[a]	0.04224	0.0	1/9	0.39694	0.5443	NS
CONDIT	CRACKS	2[a]	0.39485	0.0	1/9	5 87235	0 0384	NS
CONDIT	SLOUGH	3[a]	not testable, due to constant or invariance of data					
CONDIT	PILWID	4[a]	0.2993	0 0	1/9	3 84484	0.0815	NS
CONDIT	PILLEN	5[a]	0 00084	0 0	1/9	0 00758	0 9325	NS
SUPPORTB	ROOFLN	6[b]	0 03228	0 0	1/11	0 36697	0.5570	NS
SUPPORTB	ROOFWID	7[b]	0 01229	0 0	1/11	0 13684	0.7185	NS
SUPPORTB	ROOFHT	8[b]	0.53386	0.0	1/11	12.59811	0.0046	S
SUPPORTB	CRACKS	9[b]	0 01006	0.0	1/11	0 11176	0.7444	NS
WATER	CRACKS	10	0 41724	0 0	1/11	7.87574	0.0171	S
CRACKS	THINLAY	11	0.18978	0.0	1/6	1 40536	0.2806	NS
ROOFHT	SPAN	12	0 07452	0.0	1/11	0 88576	0.3668	NS
TIME	SPAN	13	0 01266	0 0	1/8	0 10262	0.7569	NS
PILWID	SPAN	14	0 04347	0 0	1/11	0 49995	0.4942	NS
PILLEN	SPAN	15	0.1674	0.0	1/11	0.18729	0 6736	NS
ROOFLN	SPAN	16	0 02851	0 0	1/11	0.32279	0.5813	NS
ROOFWID	SPAN	17	0 00546	0 0	1/11	0 06037	0.8104	NS
SURFACE	SPAN	18	0 02385	0 0	1/11	0 26566	0.6165	NS

Note. An F-test was utilized to test for significant relationships between various parameters associated with roof falls. The assigned alpha level for a two-tailed nondirectional test was considered statistically significant. However, the employment of a correction for multiple comparisons was necessary in several cases. The corrected alpha was used before the specific research hypothesis was considered significant.
[a]denotes corrected alpha equal to 0.010
[b]denotes corrected alpha equal to 0.012

Tables 4 and 5 list descriptive statistics and frequencies for selected parameters which could be collected for most of the roof falls measured in the study. The typical roof fall had an average roof span of 20.8 feet, 406 feet depth to coal seam, occurred 136 feet from nearest face, coal seam thickness of 56 inches, pillar width of 45 feet, surface area of roof fall 1160 ft², mainly laminar-shaped, previously rated roof before the fall between good and very good, little floor heave, cracks before the fall in about 40% of reported cases, shales in most of the immediate layers, and usually located in an entry of intersection.

The model comparisons and hypotheses testing yield several important conclusions, based on the limited data. As illustrated in Table 3, only 2 hypotheses were found to be statistically significant at the 0.05 alpha level, once adjusted for multiple comparisons. The remaining 15 hypotheses were not found to be significant. The presence of cracks were found to be related to the presence of water in the mine roof-fall areas. As shown in Table 2, 41.72% of the explained variance in presence of water was accounted for by evidence of cracks in the mine roof before the actual

TABLE 4.—DESCRIPTIVE STATISTICS FOR SELECTED CONTINUOUS PREDICTOR AND CRITERION PARAMETERS.

Variable	Mean	Range	Variance	Standard Deviation	Kurtosis	Skewness
DEPTH (ft.) (N = 13)	405.7	620.0	37174.4	192.81	1.373	1.351
SPAN (ft.) (N = 13)	20.8	22.0	34.36	5.86	12.081	3.424
ORIENT (degrees) (N = 9)	111.1	105.0	1479.85	38.47	-1.137	-0.314
PILWID (ft.) (N = 13)	44.6	20.0	60.26	7.76	-0.155	-1.114
PILLEN (ft.) (N = 13)	51.8	48.0	258.97	16.09	-0.411	0.864
THICK (in.) (N = 13)	55.9	14.0	27.91	5.28	-1.261	-0.594
ROOFLN (in.) (N = 13)	713.5	1223.0	151022.77	388.62	-0.731	9.321
ROOFWID (in.) (N = 13)	235.4	84.0	519.92	22.74	5.433	1.961
ROOFHT (in.) (N = 13)	84.1	182.0	3406.74	58.37	0.566	1.286
THINLAY (ft.) (N = 8)	4.7	17.0	34.28	5.86	3.262	1.809
THICK1 (ft.) (N = 11)	4.5	15.5	19.76	4.445	4.325	1.880
THICK2 (ft.) (N = 10)	2.9	9.2	8.31	2.883	3.146	1.700
THICK3 (ft.) (N = 5)	17.2	79.9	1233.97	35.128	4.962	2.226
THICK4 (ft.) (N = 3)	0.7	0.7	0.13	0.361	0.0	-1.152
SPACING (ft.) (N = 13)	4.2	1.0	0.14	0.376	3.223	2.179
TIME (hrs.) (N = 10)	4115.0	26276.0	.	7989.274	8.658	2.879
DISTANCE (ft.) (N = 10)	136.0	460.0	16782.22	129.546	9.340	3.003

·denotes number exceeding 10^9.

failure of the roof (p = 0.0171). In addition, the roof fall height was significantly related (p = 0.0046) to the type of roof support system in use before the actual fall. In general, the greater the use of resin bolts, the greater the occurrence of large heights of fall material from the mine roof (R^2 = 0.534). Hence, even using a limited sample size, interesting relationships among selected physical and geological parameters may give some clue to understanding the mechanism behind roof falls and their occurrence. Of course, a larger and more representative sample is needed before any conclusive decisions can be inferred.

The author extends gratitude to A. B. Szwilski, Associate Professor of Mining at the University of Kentucky, for his original input to the selection of important mining parameters associated with mine roof falls in eastern Kentucky.—Alan D. Smith, Coal Mining Administration, Department of Business Administration, Eastern Kentucky University, Richmond.

TABLE 5.—FREQUENCY COUNTS, RELATIVE FREQUENCIES, AND CUMULATIVE FREQUENCIES FOR SELECTED PARAMETERS ASSOCIATED WITH MINE ROOF FALLS.

Parameter	Variable Label	Absolute Frequency	Relative Frequency (%)	Adjusted[a] Cumulative Frequency (%)
SHAPE	Arch	2	15.4	16.7
	Dome	1	7.7	25.0
	Laminar	6	46.2	75 0
	Other (Combination)	3	23 1	100.0
	MISSING CASES	1	7.7	100 0
	TOTAL VALID CASES	12		
CONDIT	Excellent	1	7.7	9 1
	Very Good	5	38.5	54.5
	Good	2	15 4	72 7
	Poor	3	23 1	100 0
	Very Poor	0	0.0	100 0
	MISSING CASES	2	15 4	100 0
	TOTAL VALID CASES	11		
FLOOR	Yes	1	7.7	7.7
	No	12	92 3	100 0
	TOTAL VALID CASES	13		
CRACKS	Yes	4	30 8	30 8
	No	4	30 8	61.5
	Unknown	5	38.5	100.0
	TOTAL VALID CASES	13		
SURFACE (ft²)	0 0 - 500 0	3	23 1	23 1
	500 0 - 1000 0	2	15.4	38.5
	1000.0 - 1500 0	5	38.5	76.9
	2000 0 - 2500 0	1	7.7	100 0
	TOTAL VALID CASES	13		
WATER	Yes	5	38.5	38.5
	No	8	61.5	100 0
	TOTAL VALID CASES	13		
SUPPORTB	Resin Bolts	6	46 2	46 2
	Anchor Bolts	7	53 8	100 0
	TOTAL VALID CASES	13		
TYPE1	Shales	11	84 6	100.0
	MISSING CASES	2	15 4	100 0
	TOTAL VALID CASES	11		
TYPE2	Shales	6	46.2	54.6
	Sandstones	4	30.8	90 9
	Coal	1	7 7	100 0
	MISSING CASES	2	15 4	100 0
	TOTAL VALID CASES	11		
LOCATIO	Entry	7	53.8	53.8
	Crosscut	2	15 4	69.2
	Intersection	4	30.8	100 0
	TOTAL VALID CASES	13		

[a]adjusted for missing cases.

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ACADEMY AFFAIRS

The Sixty-Ninth Annual Business Meeting of the Kentucky Academy of Science

University of Louisville, Louisville, Kentucky

11-12 November 1983

Host: Dr. Charles Covell, Jr.

Minutes of the Annual Business Meeting

The meeting was called to order by President Rodriguez at 0920, 12 November in Middleton Auditorium of Strickler Hall with approximately 95 members in attendance.

After a motion by Secretary Creek and a second from the floor, the minutes of the 1982 annual business meeting at Ashland Oil, Inc., as recorded in the *Transactions* Vol 44 (1-2), were approved. Secretary Creek made a motion that all new members for 1983 be accepted by the Academy. Following a second from the floor the motion passed. Dr. Creek reminded the members that in order to receive the 1984 *Transactions* their 1984 dues must be paid by February 1, 1984.

The Treasurer's report was made by Dr. Taylor.

Treasurer's Report to the Audit Committee

Kentucky Academy of Science

November 1, 1982—November 3, 1983

Cash in Madison National Bank (Nov 1, 1983)		$ 8131.34
RECEIPTS:		
Registration - Fall Meeting	$ 3204.93	
Membership dues	6320.00	
Library subscriptions *Transactions*	1200.00	
Institutional affiliations	2671.75	
Page charges	1300.00	
TOTAL	$14696.68	
Total Cash and Receipts		$22828.02
DISBURSEMENTS:		
Junior Academy of Science	$ 500.00	
Floristic Grant	1237.00	
Operating Expenses	1635.56	
Transactions (Vol 43, #3-4)	5490.39	
Transactions (Vol 44, #1-4)	10683.07	
Ashland Oil Company	2250.00	
TOTAL	$21796.02	

BALANCE:	
Total Cash and Receipts for 1983	$22828.02
Total Disbursements	21796.02
Cash on Hand	1032.00
KENTUCKY ACADEMY OF SCIENCE FOUNDATION:	
Botany Foundation	$10000.00
Interest Earned in 1983	1078.12
Savings Account (Working)	1181.50
Savings Account (Accumulation)	1153.04
Reserves Subtotal	$13412.66
Grants 1983	1900.00
Total Reserves	$11512.66
Floristic Grant Fund	$ 1237.00
Grants 1983	1237.00
Total Reserves	$ 00.00
Marcia Athey Foundation	$55645.30
Interest Earned 1983	4638.88
Total Reserves	$60284.18

Following a motion and a second from the floor the report was approved. The report was audited by Dr. Douglas Dahlman and Dr. Thomas Strickler and found to be in order.

Dr. Taylor presented the following proposed budget for 1984.

RECEIPTS:	1983	1984
Individual Memberships (400 at $15)	$ 6000.00	$ 6000.00
Institutional Affiliations	1700.00	1700.00
Library Subscriptions	1800.00	1800.00
Page Charges	1400.00	1400.00
Miscellaneous	1000.00	1000.00
	$11900.00	$11900.00
DISBURSEMENTS:		
Transactions	$12000.00	$ 6000.00
Operating Expenses	1400.00	2000.00
Junior Academy of Science	500.00	500.00
Approved Projects	00.00	3000.00
	$13900.00	$11500.00

He indicated that the Academy almost reached a zero balance during 1983 but with the change in the publishers there should be a sufficient balance to begin considering various projects.

1. **BOARD OF DIRECTORS.** Dr. Joe Winstead presented the following report.

The Board of Directors met three times this year: 15 January at the University of Kentucky, 23 April at Western Kentucky University and 27 August at the University of Louisville. Guidelines were developed and approved concerning the Marcia Athey Fund which includes an endowment of $50,000 to support Science in Kentucky. Utilization and management of the assets of the Foundation were outlined with three categories which are:

Utilization of Management of Assets of the Foundation of the Kentucky Academy of Science

I. Gifts, Donations or Bequests designated as Unrestricted:

To be used for betterment and operation of the Kentucky Academy of Science as determined by the Board of Trustees.

II. Kentucky Academy of Science Endowment Fund:

Earnings from this Endowment to be used for the operation of the Kentucky Academy of Science as specified by the Board of Trustees.

III. Special Endowment Funds:

Specified for use by the donor or donors with restrictions developed and approved by agreement between the donor(s) and the Board of Trustees.

Special Endowment Funds, each with specified restrictions, are:

A. Botany Research Fund

B. Marcia Athey Fund

Bylaws of the Foundation were changed to allow expansion of the Board of Trustees of the Foundation to include an advisory council and subsequently the new advisory council, consisting of individuals from principally the private sector, met with the Board of the August meeting. A continuing goal of the Board will be expand the base of income for the Academy to allow the organization to have a greater impact on the development of science in Kentucky.

2. **COMMITTEE ON PUBLICATION.** Dr. Branley Branson made the following report.

A. Volume 44 (1-2), March 1983, consisted of 94 pages that included 15 papers, 5 notes, Academy Affairs, Program, the abstracts some papers presented at the annual meeting, and News and Comments. Volume 44 (3-4), September 1983, consisted of 83 pages that included 12 papers, 6 notes, News and Comments, and the annual index. The cost for printing 44 (1-2) was $5,192.68 and that for 44 (3-4) $5,490.39, for a total of $10,683.07, a decrease of $805.39 over the previous year, even though more papers were published. The savings reflect previously reported format changes.

The subjects of the 27 papers and 11 notes were distributed among 6 diciplines as follows: Zoology and Entomology, 19 papers, Botany and Microbiology, 6 papers, Physiology, 1 paper, Geology and Geography, 10 papers, Genetics, 1 paper, and Physics and Mathematics, 1 paper.

B. During the past year, the Board of Directors, officers of the Academy, and the Editorial Board have wrestled with the problem of finances. It has become patently clear that the Academy will be unable to increase its income unless a massive and successful membership drive is mounted. Since that is highly unlikely, the Board voted favorably upon President Rodriguez' recommendation that we change printers. President Rodriguez, accompanied by the Editor, Dr. Jerry Baskin, and other members of the Editorial Board, met with John Barker, manager of the University of Kentucky Printing Services in order to ascertain how best to effect a change to that firm. Manager Barker assured us that he could print the *Transactions* without a loss of quality, using essentially the same quality of paper stock, print stock, and covers, at a cost substantially lower than charged by Allen Press. The Board voted to accept the University Kentucky Press offer. Thus, starting with 45 (1-2), the *Transactions* will henceforth be printed at the University of Kentucky Press.

This change in printers, of course, has involved more than merely saving money. For one thing, the University of Kentucky Press can not provide technical editing and copy marking; those will fall upon the shoulders of the Editor. Therefore, it becomes highly necessary that *all* authors use even more caution than usual in critically correcting galley proofs. Furthermore, the press has no means whereby they may mail or collect for reprints. Thus, the Editor will have to assume that duty and the associated bookkeeping job.

All this brings to mind a famous admonition: "NON COMPOS MENTIS".

3. **MEMBERSHIP COMMITTEE.** Dr. Larry Elliott presented the report.

The membership committee sponsored a membership contest with the winners receiving a free meal at the banquet. The winners were Tom Despard of the Forestry Service at Berea and Charles Covell, Jr. from the University of Louisville. Since August there had been 41 new members giving a total of 70 new members for the year. Dr. Elliott urged all members to take posters back to their school and use them for advertisement of the Academy.

4. STATE GOVERNMENT/SCIENCE ADVISORY COMMITTEE. Dr. Charles Kupchella made the following report.

During 1982-83, this committee did not meet in formal session; however, several items of business were conducted via telephone and letter exchanges between the chairman and various committee members.

On March 3, 1983 we solicited position statements from candidates for governor and for state superintendent of public instruction. We received replies from Stumbo, Collins, and Grahm in time to provide summaries of their responses to the membership as part of the March 1983 newsletter. Subsequently, we also received a reply from Sloan. We have yet to hear from Ms. McDonald in direct answer to our inquiry; however, committee member Boggess received a response to a similar inquiry made in September.

Copies of our letters to Collins and McDonald are attached to the official copy of this report. Copies of the *responses* by Collins and McDonald are attached here.

In light of Ms. Collin's and Ms. McDonald's elections, and in light of their acknowledgement of problems in science education and research support, it would seem advisible that KAS follow up by seeking face-to-face audiences with both Collins and McDonald as soon as possible—even before they take office.

The following letters are the responses of Governor Collins and Superintendent of Public Instruction Alice McDonald.

Dear Dr. Kupchella:

As a former mathematics teacher, I share the Kentucky Academy of Science's high standards for instruction and research in mathematics and science and appreciate the opportunity to address some of the Academy's concerns.

The shortage of qualified math and science teachers and declining SAT scores by high school students in these subject areas are two very disturbing trends that must be corrected if the United States is to maintain its position as a world leader. The first step needed was to make the public recognize and accept that there is a problem. This has been done. The next step is action at the national, state, and local levels.

During the last three years, I have served as Kentucky's representative on the Task Force on Higher Education and the Schools, appointed by the Southern Regional Education Board. One of the topics we discussed frequently was the shortage of qualified math and science teachers in our public schools. Recommendations 7 and 8 on page 13 of our report, a copy of which I have enclosed, address this problem.

7. *States should develop an array of incentives to attract math teachers, including scholarships or loan programs for prospective teachers tied to the teaching of these subjects within the state, following the established pattern of state subsidies to train medical personnel in short supply.*
8. *States should modify certification requirements to permit graduates in mathematics and science who lack professional education preparation to teach at the secondary levels, with safeguards to insure the quality of instruction. Certification should also accommodate teachers in related surplus fields to teach mathematics and science, with refresher courses as needed.*

As you know, one of the Task Force's recommendations, scholarships for prospective math and science teachers, has been implemented in Kentucky. And Congress is looking at funding scholarships and research on a national level. These proposals are a good start, but may not be enough. A possibility is salary differentials for teachers in shortage areas, but one must consider the effect that would have on the morale of teachers in other subjects. As Governor, I would not rule out proposing salary differentials or stipends, but would want to consider other alternatives first.

Part of a short-term solution could be to provide programs for our marginally qualified math and science teachers and unemployed teachers through summer workshops and institutes, similar to the University of North Carolina at Chapel Hill's Middle School Math and Science Program. Middle School Math and Science teachers, most of whom are not certified in that field, receive daily instruction during the summer and weekly instruction throughout the school year. Tuition was paid for the participants who received credit for renewal of their teaching certificate.

Our long-term solution rests with encouraging more of our gifted students to consider careers in math and science. Information about the shortage of math and science teachers needs to be brought to the attention of high school and college students. The materials designed to attract students should emphasize the availability of teaching jobs. The state boards of education and higher education, professional guidance associations, and local school boards could help prepare and distribute the materials.

Another area that demands attention is the quantity and quality of our math and science courses in our public schools. The recently adopted pre-college curriculum will strengthen math and science requirements at the high school level. Instruction at the elementary and middle school levels could be improved by increasing the number of hours in science courses required for an elementary certificate. As Governor, I will ask the Kentucky Council on Teacher Education and Certification to consider an increase or restructuring of present requirements.

As we increase our science requirements, we must also provide adequate laboratories and equipment. One of my priorities in the education budget for local schools will be capital outlay and current expenses, from which schools pay for laboratory equipment. Because these two line items of the minimum foundation program have received minimal increases the last few years, many schools have not had the funds to purchase equipment.

I have reviewed the articles on Federal Funding for Research and Development in Kentucky, *which points out the need for our institutions of higher education to commit greater efforts toward obtaining federal research funding support. With the arrival of the Reagan Administration, lessened federal support for higher education research has resulted. This makes institution support and the attainment of private support for research that much more critical. I will encourage the institutions to support faculty research efforts whenever possible.*

It is important and encouraging to note that the current draft formula funding proposal under consideration by the Council on Higher Education does not recognize research in the calculations. Additional funding for research also can be requested outside the formula with the understanding that any agreement reached regarding the need for additional support would be added to the formula.

Thank you for writing. Be assured that my commitment to quality education at all levels is solid. As the only candidate with experience as a teacher, I have the background and statewide understanding to give education the priority it deserves. I look forward to working for you and with you as Governor in making Kentucky's future even brighter by providing our youth with a quality education today.

Sincerely,

Martha Layne Collins

Dear Dean Boggess:

Thank you for your letter of September 7 concerning the need to escalate statewide efforts to improve science. The Science Advisory Council should be helpful in that regard, and I appreciate your recommendation that this group of advisors continue to function.

I also appreciate your comments on the "Incentive Loan" program. The Kentucky Academy of Sciences can be very influential in the promotion of science for Kentucky schools. I am glad to have your offer of help.

Sincerely yours,

Alice McDonald

5. COMMITTEE ON DISTRIBUTION OF RESEARCH FUNDS. Dr. Joe Winstead made the following report.

The Botany Fund which operates from a $10,000 endowment in the KAS Foundation awarded five grants totaling $1900 for the 1983 year. Recipients and their funded projects were: Mr. Kelly Carter, and undergraduate at Pikeville College, $400.00 to support his study on *Silphium mohrii;* Miss Donna A. Godbey, MS student at Eastern Kentucky University, $300.00 for her project on the vascular flora of Maywoods; Mr. Harry Woodward, graduate student at the University of Louisville, $400.00 to help in his anatomical study of the Magnoliacae native to Kentucky; Mr. Max Medley, graduate student at the University of Louisville, $400.00 financing his verification of new and rare species of vascular plants in Kentucky; and Mr. George F. Buddell, student at Northern Kentucky University, $400.00 to help underwrite his floristic survey of Lewis County, Kentucky.

The committee was please to note that two former recepients, Mr. Jay Jones, graduate student at Indiana University and Mr. Charles Tarrents, graduate student at Syracuse University are listed on the program in the Botany and Microbiology section with presentations on their work.

The original endowment continues to grow as 10% of the annual earnings are added to the principal each year. Applications for 1984 awards should be sent to the Chairman of the Botany Fund prior to 1 April. It is anticipated that approximately $1400.00 will be available for 1984 awards.

Grants are open to undergraduates or graduate students enrolled in a college or university program within the Commonwealth or applicants may be enrolled in institutions of higher learning located outside the political boundaries of the state if the individual's research program involves a study that would be conducted primarily within the state of Kentucky. Grant applications must involve research projects within the generally accepted boundaries of the field of botany. As a general outline this encompasses: Plant Taxonomy or Systematic Botany, Plant Ecology, Plant Genetics, Plant Anatomy, Plant Morphology, Plant Cytology, Phycology, Mycology, Plant Physiology and Paleobotany.

Applications should include a brief description of the proposed research, references to appropriate literature and an outline of anticipated costs. Research projects are expected to be completed within a two year period from initiation of funding and the applicant will be expected to present a summary of his/her results before an appropriate sectional meeting of the Kentucky Academy of Science.

Dr. Winstead reported that all of the money had been distributed from the Floristic Fund and no more applications would be accepted.

Dr. Rodriguez reported the Marcia Athey Fund had received only one grant application which had been withdrawn for changes and would be resubmitted at a later date. He said that applications were available from the chairman of the Committee, Dr. Paul Freytag, or the secretary, Dr. Robert Creek.

6. SCIENCE EDUCATION COMMITTEE. Mrs. Anna Neal made the report.

Ray Barber, Superintendent of Public Instruction appointed a Science Advisory Council to report directly to him with recommendations for science education. The Kentucky Academy Committee has worked closely with the Council to coordinate activities and also because several members of KAS were also members of the Council.

Following is a list of activities of the Science Advisory Council.

1. Standards for preparation and Certification of elementary teachers were formulated. This recommendation varied little from the 1977 one jointly formulated by the KAS, KAPS and Science Advisory Council. Also influenced by the AAAS guidelines of 1970.
2. It was recommended that the State Department of Education establish Regional Science Resource Teachers for each of twelve regions in the state to work with, and under the direction of, the State Science Consultant.
3. Guidelines should be developed so that science teachers, utilizing a laboratory approach could be provided the opportunity for extended employment.
4. We requested that the State Science Consultant be relieved of several "paper work" assignments unrelated to science education, and that he be encouraged and funded to participate actively in state and national science organizations.

The Advisory Council also explored the possibilities for developing closer ties between Business/Industry/ and Science Education. A pilot program began in Fayette County Schools this year.

In addition to these tasks the Science Education Committee has worked on the following projects:

1. Helped develop Minimum Standards of Compliance as a check list to examine secondary schools for State Accreditation.
2. Helped develop a Minimum Standards Equipment List as a further check on accreditation.
3. Dr. Truman Stevens took on an individual task with Frank Howard to develop a Profile of Kentucky Science Teachers, Grades 7-12. This will show science teachers by district and school, their certification, and whether or not they are teaching within field. It will also show elementary teachers who are teaching 7th and 8th grade science.
4. A major accomplishment of the committee has been the publication of a brochure *Choices of Today Will Count Tomorrow* - Guidelines to Choosing Science Courses. This brochure is being disseminated to principals, counselors and teachers by the Higher Education Coordinator at the state universities.

7. KENTUCKY JUNIOR ACADEMY OF SCIENCE. Mr. Herb Lespold made the following report.

Our annual symposium was hosted by Eastern Kentucky University at Model Lab School on April 29-30, 1983. Three paper sections were conducted with thirty papers from ten schools. Our speaker was Dr. Wm. H. Martin, who spoke on "Endangered Species." Other activities included the Science Bowl and the Lab-Skills Competitions. Five papers from this symposium are scheduled for this meeting of K.A.S.

Efforts toward regional organization have not been successful to date, but several groups have expressed a continued interest and indicate that they will be able to develop active organizations.

During the year we had 16 clubs with a total of 500 members.

Two scholarships were again made available through the Ogden Foundation for use at Western Kentucky University, with the requirement that they be used only for science or mathematics programs. Also of major importance, Murray State University provided one of their best scholarships for another of our "Outstanding Science Graduates." This makes a current total of four students with scholarships that resulted from our scholarship-recognition program.

This year's annual meeting is scheduled for April at Western Kentucky University. It is our 50th Anniversary and plans are underway to properly recognize fifty years of the Academy's service to science education.

Dr. Stephen Hendersson presented the KJAS Treasurer's report.

Balance on Hand, September 1, 1983	$886.06
DISBURSEMENTS	
Research Grants, Fall 1983	$525.00
Robert Elder - St. Charles Junior High	20.00
Toni Miles - St. Charles Junior High	25.00
Duane England - Deming High School	75.00
Kimberly Sale - Deming High School	75.00
Terri Dietz - Notre Dame Academy	40.00
Trina Wagner, Karen Vormbrock, Debbie Teisl - Notre Dame Academy	150.00
Robin Wigelsworth - Harrison County High School	65.00
Tommy Wade - East Hardin High School	75.00
Total Disbursements	$525.00
RECEIPTS	
Club Dues (Since April 30, 183)	$100.50
Total Receipts	$100.50
Balance on Hand, November 8, 1983	$461.50

The report was audited by Dr. Morris Taylor and found to be in order.

8. RESOLUTION COMMITTEE. Dr. John Philley presented the following resolution.

Whereas, the University of Louisville has served as the host institution for the Sixty-ninth Annual Meeting of the Kentucky Academy of Science, and whereas Charles Covell, Jr., Varley Wideman, and their colleagues at the University of Louisville have given graciously and freely of their energies to assist the Academy for this meeting and in other ways in a very successful manner,

Therefore, be it resolved that the Kentucky Academy of Science expresses its deep appreciation to the host institution and to those individuals who were involved in the arrangements to provide the Academy a most successful annual meeting.

A motion was made and seconded from the floor to accept the resolution. Motion was passed.

9. AD HOC COMMITTEES.

A. Rare and Endangered Species Committee. The report was made by Dr. Branley Branson.

I. RECOMMENDATION: Following considerable communication and discussion with John MacGregor, Commonwealth Wildlife Biologist, and the Kentucky Nature Preserves Commission and committee members, it is recommended that a meeting—to include MacGregor, the Kentucky Nature Preserves Commission, and the Kentucky Academy of Science Committee on Rare and Endangered Species—be convened at an early date in order to establish regular procedures (listing packets, etc.) for adding species to the list and for changing the status of species. This meeting would also examine the present designations, discuss revision of the list, and examine the possibility of establishing an official state list.

II. The Kentucky Academy of Science Committee should serve as an advisory committee to the Kentucky Nature Preserves Commission and to the Kentucky Fish and Wildlife Resources Commission.

III. The following crayfish species are recommended for the designations indicated below on the strength of Burr's and Hobbs' (Trans. Ky. Acad. Sci. 1984: *in press*) report:

Cambarellus puer Hobbs: Special Concern
Cambarellus shufeldtii (Faxon): change from Undetermined to Special Concern
Orconectes palmeri palmeri (Faxon): Threatened
Procambarus viaeviridis (Faxon): Special Concern

VI. The following gastropods (snails), based upon the recommendations of John MacGregor, are recommended for Special Concern:

Bulimulus dealbatus (Say)
Mesodon mitchellianus (Lea)
Mesodon chilhoweensis (Lewis)

V. Wayne H. Davis, committee member, recommends *Sorex longirostris* and *Microsorex hoyi* for a status change from Threatened to Special Concern, and that the status of *Mustela nivalis* be changed from Endangered to Special Concern.

VI. Jerry M. Baskin, committee member, recommends the addition to the Kentucky list of *Trifolium stoloniferum* Muhl. ex. A. Eaton as Rare, and that *Lesquerella lescurii* (Gray) Watson be added to the list as Rare.

Dr. Branson further recommended that Rich Hannon and John MacGregor be made permanent members of this committee. It was suggested from the floor that the list of endangered species be sent to the legislature and ask for a bill to be passed concerning the endangered species of Kentucky. Dr. Branson replied that more work was needed on the list by the committee along with interaction with state organizations.

B. Meeting Location and Time Committee.

Dr. John Philley reported that the Academy had received an invitation to hold its 1984 annual meeting at Kentucky State University at Frankfort, Kentucky on November 9-10, 1984. A motion was made and seconded to accept the invitation from Kentucky State University. The motion was passed.

C. Committee on Legislatively Mandated Programs.

Dr. Creek reported that the committee recommends an additional statements to the KAS Science Policy Statement which was passed at the 1981 Annual Meeting. The statement which was published in the September Newsletter and would be paragraph five of the Policy Statement reads as follows:

> It is further recommended that the Kentucky Academy of Science encourage its members and other professional scientific groups to give support and aid to those classroom teachers who present the subject matter of evolution fairly and encounter community objection. We also encourage administrators and individual teachers to oppose the inclusion of non-scientific concepts in the science classroom.

A motion was made and passed to add the additional paragraph.

Dr. Creek reported that Dr. Wallace Dixon would continue to serve as chairman of the Committee to Study Legislatively Mandated Educational Programs and anyone wishing information, particularly on scientific creationism, should contact him.

D. Awards Committee.

Dr. Debra Pearce reported on the awards that were presented the previous evening at the annual banquet. The award for the Outstanding Teacher in Science at the college-university level was presented to Dr. Sam L. Cooke, Department of Chemistry, at the University of Louisville. The Outstanding Teacher in Science at the secondary education level was awarded to Steve Zimmer of Warren East High School. Mrs. Anna Neal was presented a plaque for her contributions in science education. Dr. Pearce urged that all members begin to consider possible nominations for the 1984 Distinguished Scientist Award. The award was not presented this year.

10. UNFINISHED BUSINESS. There was no unfinished business.

11. NEW BUSINESS.

A. Dr. Rodriguez moved that the ad hoc Science Education committee be changed to a standing commitee as announced in the September issue of the Newsletter. This would be paragraph five in Section 2 of Article VIII of the Bylaws and would read as follows: Committee on Science Education that consist of at least three members will be appointed by the President. Following a second from the floor the motion was passed.

B. Dr. Creek announced that a Speaker's Bureau was going to be set up that would enable elementary and secondary teachers and other interested parties to draw upon the expertise of scientists throughout the state. Dr. Creek indicated that the necessary forms were available and should be returned to him as soon as possible. A booklet will be put together listing pertinent information about the scientists and the areas about which they will speak. The bulletin will be made available throughout the state.

12. NOMINATING COMMITTEE. Dr. Gertrude Ridgel offered the following nominations and moved their acceptance.

Charles V. Covell, Jr.	Vice President
Robert Creek	Secretary
Morris Taylor	Treasurer
James Sickel	Board of Directors
Lawrence Boucher	Board of Directors
David Prior	AAS Representative

The motion was seconded from the floor and, with no further nominations, was passed unanimously.

President Rodriguez then presented President-elect Boggess with the gavel and welcomed him as President of the Kentucky academy of Science for 1984.

President Boggess presented Dr. Rodriguez a plaque for his service as President and his contributions to the Academy. Following a brief address by Dr. Boggess, the meeting was adjourned at 1030.

Robert Creek, Secretary
Kentucky Academy of Science

KENTUCKY ACADEMY OF SCIENCE
69th ANNUAL MEETING
PROGRAM

Friday, November 11, 1983

1030-1200	*Community College Faculty Meeting* - Middleton Auditorium Strickler Hall
1130-1300	*Executive Committee Luncheon* - Dining Room C, North Dining Room, University Center
1200-1600	*Registration* - Lobby, Strickler Hall
1200-1700	*Scientific Exhibits* - Lobby, Strickler Hall
1300-1500	*Sectional Meetings* -(See Following Pages)
1500-1530	*Coffee Break* - Lobby, Strickler Hall
1530-1700	*Plenary Session* - Middleton Auditorium, Strickler Hall
1800-1900	*Hospitality Hour* - Mastersons Restaurant
1900 - ?	*KAS Annual Banquet* - Mastersons Restaurant

Saturday, November 12, 1983

0800-1000	*Registration* - Lobby, Strickler Hall
0800-1200	*Scientific Exhibits* - Lobby, Strickler Hall
0800-0900	*Sectional Meetings* -(See Following Pages)
0900-0915	*Coffee Break* - Lobby, Strickler Hall
0915-1015	*Annual Business Meeting* - Middleton Auditorium, Strickler Hall
1030-1200	*Sectional Meetings* -(See Following Pages)
1300- ?	*Sectional Meetings* - (As Needed)

KENTUCKY ACADEMY OF SCIENCE

The Sixty-Ninth Annual Meeting

At The

University of Louisville

November 11-12, 1984

Arrangements: Dr. Charles Covell, Jr.

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PLENARY SESSION

Friday, November 11

1530 THE INTERFACE OF SCIENCE AND INDUSTRY

Speakers: Dr. Paulette G. Lankford, Director of Technology, Humana, Inc.

Mr. Al Turchick, Manager, U.S. Steel Mining Corp. Research

ANNUAL BANQUET

Saturday, November12

1900 Mastersons Restaurant
Speaker: Dr. Mounir M. Kamal, Director of Technology, General Motors Research Labs
"GAPS AND BRIDGES BETWEEN INDUSTRY AND UNIVERSITY"

BOTANY AND MICROBIOLOGY
Session I—Room 109, Natural Science Bldg.
Ralph L. Thompson, Chairman, Presiding
Ronald L. Jones, Secretary

Friday, November 11, 1983

1500 Coffee Break.

1530 Plenary Session.

Saturday, November 12, 1983

0800 A taxonomic analysis of *Dryophyllum* (Fagaceae) leaf forms from the Claiborne Fm. (Eocene) of Graves Co., Kentucky. Jay H. Jones, Indiana University.

0815 Seed germination patterns in the woodland perennial, *Maianthemum canadense* Desf. (Liliaceae). Cindy Williams, Centre College.

0830 Population dynamics of sweet buckeye. Foster Levy, Pikeville College.

0845 The present aims and prospects of the Plant Resources Center of the University of Kentucky. Willem Meijer, University of Kentucky.

0900 Coffee Break.

0915 Annual Business Meeting.

1030 Seed bank development on a series of abandoned lead-zinc mine dumps in southwest Wisconsin. Robin Kimmerer, Transylvania University.

1045 Observations of *Amelanchier arborea* (Michx. f.), Fernald, Sarvis, on the Kentucky River Palisades. Ron Houp, Department for Environmental Protection.

1100 Clone patterns and sexual expression in sumac. Charles Tarrants, Syracuse, New York.

1115 Recovery of trampled bryophyte communities near Mountain Lake, Virginia. Susan M. Studlar, Centre College.

1130 Leaf length/width differences in the geographic distributions of *Euonymus americanus*. *Paul E. Bayer* and Joe E. Winstead. Western Kentucky University.

1145 A decade of change in Bonayer Woods, Barren County, Kentucky: a climax woodlot of the Western Mesophytic Forest. Joe E. Winstead, Western Kentucky University.

1200 Lunch Break.

1300 *Carex texensis* (Cyperaceae): Species, Variety, or Synonym? Dan K. Evans, Marshall University (sponsored by Ralph Thompson).

1315 Plant communities of the Cincinnati Region—an updating of Braun. William S. Bryant, Thomas More College.

1330 Floristic affinities of the vascular flora of Shiloh National Military Park, Tennessee. Ronald L. Jones, Eastern Kentucky University.

1345 A mesophytic Kentucky River ravine forest in Franklin County, Kentucky. Hal Bryan, Frankfort, Kentucky.

1400 The vascular flora of Calloway County, Kentucky. *Michael Woods* and Marian J. Fuller, Murray State University.

1415 New and rarely reported plants in Kentucky. Max Medley, University of Louisville.

1430 Catalogue of vascular plants of Kentucky. Max Medley, University of Louisville.

1445 Election of Sectional Officers.

Session II—Room 110, Natural Science Bldg.
Ronald L. Jones, Presiding

Saturday, November 12, 1983

0800 Changes in the phosphorus and organic matter content in the sediments of McNeely Lake, Jefferson County, Kentucky. James D. Mayfield, University of Louisville.

0815 Investigation of nonpoint source pollution problems associated with karst aquifer systems. *W. D. Green*, N. C. Crawford, L. P. Elliott, and J. T. Riley, Western Kentucky University.

0830 Microbial ecology of two Kentucky caves. *James Greer* and James Dyar, Bellarmine Colleg.

0845 Factors affecting diatom immigration onto substrates. R. Jan Stevenson, University of Louisville.

0900 Coffee Break.

0915 Annual Business Meeting.

1030 Periphyton variability in stream systems. Stephen D. Porter, Department for Environmental Protection.

1045 Growth and differentiation of white pine tissue cultures. *Karen Kaul* and T. S. Kochhar, Kentucky State University.

1100 Isolation, cell wall regeneration, and cell division of barley protoplasts. M. M. Rahman, Kentucky State University.

1115 Characterization of SGP147 as a soil additive. Pamela Rust, Notre Dame Academy. (Sponsored by Herb Leopold)

1130 The effects of biological and chemical control agents on *Galleria mellonella*. Mary T. Kramer, Notre Dame Academy. (Sponsored by Herb Leopold)

1145 Toxicity of coal liquification compounds to *Spirodela polyrrhiza*. Karen Coley, Murray State University. (Sponsored by Joe King).

1200 Algae of Kentucky Lakes. Lisa Barnese, Murray State University.

1445 Election of Sectional Officers in Rm. 109, Natural Science Bldg.

CHEMISTRY SECTION

Samuel L. Cooke, Chairman
Carl D. Slater, Secretary

Session I, Carl D. Slater, Presiding
Room 100—Education Bldg.

Friday, November 11, 1984

1300 The Design of Reaction Mechanisms. P. L. Corio, Department of Chemistry, University of Kentucky.

1315 Analysis of Insoluble Portions of Environmental Air Particulate Samples. *William D. Schulz*, Department of Chemistry, University of Kentucky.

1330 Determination of Choline Using Non-suppressed Cation Exchange Chromatography with Conducting Detection. *Melissa Newhall* and Preston Miles, Division of Science and Mathematics, Centre College.

1345 Enzymatic-Flourometric Trace Analysis of Lactose. *Susan Hargan* and Preston Miles, Division of Science and Mathematics, Centre College.

1400 Buffer Catalysis in the Hydrolysis of N-Methyl-2-fluoropyridinium Iodide. *Denise R. Taylor* and Oliver J. Muscio, Jr., Department of Chemistry, Murray State University.

1415 Cloneing of DNA Fragments from Pathogenic Bacteria. *Christopher E. Rickman*, Ricky A. Jackson, and Vaughn Vandegrift, Department of Chemistry, Murray State University.

1430 Heats and Entrophies of Fusion of n-Alkyl 3,5-Dinitrobenzoates. *Hattie Murphy*, G. L. Shoemaker, S. L. Cooke, Department of Chemistry, University of Louisville.

1445 Solubility Parameter Spectroscopy of Polymers. *James M. Poole* and Joan Reeder, Department of Chemistry, Eastern Kentucky University.

1500 Coffee Break.

1530 Plenary Session.

Session II, James H. Niewahner, Presiding
Room 102—Education Bldg.

Friday, November 11, 1983

1300 Abis(Aminopropionitrile)hydroxidoperchloratozinc(II): A Novel Compound. Harry M. Smiley, Department of Chemistry, Eastern Kentucky University.

1315 On the Preferred Site for Hydrogen Atoms in bcc Transition Metals. *Audrey L. Companion*, Frank Liu, Department of Chemistry, University of Kentucky, and David P. Onwood, Department of Chemistry, IUPU-Fort Wayne.

1330 Implantation of Hydrogen Atoms in and on Titanium Metal Clusters. *Frank Liu* and Audrey L. Companion, Department of Chemistry, University of Kentucky.

1345 The Synthesis and Characterization of Some Novel Group VIII Metal Derivatives Incorporating the Pentaphenylcyclopentadienyl Ligand. *Joan L. Cmarik*, Danny Garland, and David A. Owen, Department of Chemistry, Murray State University.

1400 Mass Spectra of Transition Metal Complexes Incorporating the Pentaphenylcyclopentadienyl Ligand. *Thomas H. Pritchett* and David A. Owens, Department of Chemistry, Murray State University.

1415 Dithioacetal Complexes of Palladium. Phillip E. Fanwick and *Gary B. Kaufmann*, Department of Chemistry, University of Kentucky.

1430 Heterobimetallic Compounds with Early to Late Transition Metal Bonds. *William Sartain* and John P. Selegue, Department of Chemistry, University of Kentucky.

1445 Synthesis of Molybdenum Vinylidene Complexes. *Peter Nickias* and John P. Selegue, Department of Chemistry, University of Kentucky.

1500 Coffee Break.

1530 Plenary Session.

Session III, Carl D. Slater, Presiding
Room 100-Education Bldg.

Saturday, November 12, 1983

0800 An Evlauation of Computer Simulated Experiments in the Freshman Chemistry Labs. *Joan Lewis* and Howard Powell, Department of Chemistry, Eastern Kentucky University.

0815 Instructional REVIEW Programs for Introductory Chemistry. Version for the Apple II-plus Microcomputer. Darnell Salyer, Department of Chemistry, Eastern Kentucky University.

0830 Computer Drill on Chemical Equations. John Chamberlin, Department of Chemistry, Western Kentucky University.

0845 Computer Aided Drills in Organic Reactions. Victor I. Bendall, Department of Chemistry, Eastern Kentucky University.

0900 A Microcomputer Program to Assist Instruction on Reaction Energetics. John L. Meisenheimer, Department of Chemistry, Eastern Kentucky University.

0915 Annual Business Meeting.

1030 Computer Models for Calculating Pore Size Distributions in Catalysts Supported on Spherical-Particle Substrates. *Bruce D. Adkins*, Burton H. Reucroft, Materials Engineering Department, University of Kentucky.

1045 Use of the Apple II+ Computer with the Adalab Card for the Acquisition of Chromatographic Data and for the Determination of Separation Quality Parameters. Shayne Green and Thomas H. Pritchett, Department of Chemistry, Murray State University.

1100 Software for Acquisition and Evaluation of Spectrometric First-Order Kinetic Data. *Thomas H. Pritchett*, David E. Theobald, and Oliver J. Muscio, Jr., Department of Chemistry, Murray State University.

1115 Direct Shearch Optimization of the Infinite Time Value in First-Order Kinetic Studies. Oliver J. Muscio, Jr. and Jeffrey E. Anderson, Department of Chemistry, Murray State University.

1130 Electrochemistry with the Apple Microcomputer. Jeffrey E. Anderson, Department of Chemistry, Murray State University.

1145 Laboratory Microcomputing with FORTH. *Robert Shoemaker* and S. L. Cooke, Department of Chemistry, University of Louisville.

1200 Automated Conductometric Titrations. *Mark Hail* and F. J. Holler, Department of Chemistry, University of Kentucky.

1215 Election of Section Officers.

Section IV, William R. Oliver, Presiding
Room 102—Education Bldg.

Saturday, November 12, 1984

0915 Business Meeting.

1030 Supported Cobalt Phthalocyanines as Catalysts in the Hydrogenation of Nitrogen Containing Heterocycles. *Terry L. Matthews* and Laurence J. Boucher, Department of Chemistry, Western Kentucky University.

1045 Determination of Moisture in Coal Using Pulsed 10 and 20 MHz and NMR Instruments. John T. Riley, Department of Chemistry, Western Kentucky University.

1100 Acid Leaching of White Coal for the Rapid Determination of Elements by Atomic Absorption Spectrometry. *J. Daniel Pawley* and James E. O'Reilly, Department of Chemistry, University of Kentucky.

1115 ANALYTICAL PYROLYSIS: A Novel Approach to Coal Plasticity. *John W. Reasoner*, William G. Lloyd, Department of Chemistry, Western Kentucky University, and James C. Hower, Linda P. Yates, Institute for Mining and Mineral Research, University of Kentucky.

1130 Chromatographic Determination of Methyl Mercury in Seafood: Use of Sodium-Halide-Loaded Columns. Jafariah Jaafar and *James E. O'Reilly*, Department of Chemistry, University of Kentucky.

1145 Furnace AA Determination of Chromium in Urine and its Relationship to other Urinalysis Tests. *David Bugg* and B. E. McClellan, Department of Chemistry, Murray State University.

1200 Oxidation of Ascorbic Acid with Thallium (III). *Ann M. Snepp*, Rita K. Hessley, and Robert D. Farina, Department of Chemistry, Western Kentucky University.

1215 Election of Section Officers in Room 100 - Education Bldg.

GEOGRAPHY SECTION
Room 221—Bingham Humanities BLDG.

William A. Withington, Chairman, Presiding
John L. Anderson, Secretary

Friday, November 11, 1983

1300 North America's Rift Valley, The Salton Trough of California. Anthony O. Clarke, University of Louisville.

1315 The Seasonal Relationships Between Clouds and Precipitation. L. Michael Trapasso, Western Kentucky University.

1330 Seasonal Changes in Kentucky Precipitation Patterns. Glen Conner, Western Kentucky University.

1345 A Local Example of Structural Control in the Kentucky Pennyroyal. Ronald R. Dilamarter, Western Kentucky University.

1400 Estimates of the Flux of Latent Energy in the Southern Hemisphere. David Howarth, University of Louisville.

1415 The Significance of Topography to the History of Tight Hollow. C. A. Leuthart and H. T. Spencer, University of Louisville.

1430 The Effects of Altitude and Latitude on the Distribution of the Normal Mean Annual Temperatures in Kentucky. Robert M. Simpson and Clifford S. Hardin, Western Kentucky University.

1445 The Geography Section, Kentucky Academy of Science, 1971-1983. William A. withington, University of Kentucky.

1500 Coffee break.

1530 Plenary Session.

Saturday, November 12

0800 Mediterranean Seas and the United States of America. E. E. Hegen, Western Kentucky University.

0815 Reorientations of Kentucky Resort Visitors: Impact of the 1982 World's Fair. John L. Anderson, University of Louisville.

0830 Male-Female Differences in Industrial Commuting Patterns Within Non-Metropolitan Kentucky. Roberta Haven Webster, University of Kentucky.

0845 The Geography of Local Government Debt in Kentucky. Gerald R. Webster, University of Kentucky.

0900 Coffee Break.

0915 Annual business Meeting.

1030 Milledot Method for Kentucky's Population Distribution. Reza Ahsan, Western Kentucky University.

1045 Geography Texts in Kentucky: A Historical Perspective. Edwin T. Weiss, Jr. and Rebecca Sturm, Northern Kentucky University.

1100 Beyond Gingerbread and Monumentality? A Chi Square Analysis of Preservation Consciousness. Karen Koegler, University of Kentucky.

1115 Modeling Desegregation of Jefferson County Schools. A William Dakan, University of Louisville.

1130 Spatial Dimensions of Racial Segregation. Mark Lowry II, Western Kentucky University.

1145 Foreign Medical Graduates in Small Towns; Pikeville, Kentucky. Matrini Nathalang, University of Kentucky.

1200 Breweries in Louisville: The Passing of an Era. Dennis Spetz, University of Louisville.

1215 Prehistoric Settlement Patterns in Meade Co., Ky. John Hale, University of Louisville.

1230 A Geographic View of Education in Kentucky. Dennis E. Quillen, Eastern Kentucky University.

1245 Migration from Appalachian Kentucky: 1965-1970. Claudia Craig, University of Cincinnati.

1300 Election of Sectional Officers.

GEOLOGY

Room 16—Chemistry Bldg.

Roy VanArsdale, Chairman
Peter W. Whaley, Secretary, Presiding

Friday, November 11, 1984

1330 Low Altitude Remote Sensing of Fracture Patterns in Western Kentucky, Related to Coal and Oil Production. *Bruce R. Moore*, Department of Geology, University of Kentucky. Sponsored by William C. MacQuown.

1345 The Plaeozoic History of the Rockcastle River Uplife in Eastern Kentucky. *Gregory K. Maynor* and William C. MacQuown, Department of Geology, University of Kentucky.

1400 The Subsurface Lithology, Structure and Stratigraphy of the Middle and Upper Ordovician Rocks in the Cumberland Saddle Region of South-central Kentucky. *Gary Jacobs*, Department of Geology, University of Kentucky. Sponsored by William C. MacQuown.

1415 The August 17, 1983 Earthquake and Its Relationship to Past Seismicity of the Area. *David Couch*, Department of Geology, University of Kentucky. Sponsored by William MacQuown.

1430 Post-Pleistocene Deformation Within the Kentucky River Fault System. Roy B. VanArsdale, Department of Geology, Eastern Kentucky University.

1445 Investigation of Late Tertiary to Recent Movement Along the Kentucky River Faul System in Northwest Madison and Southeast Jessamine Counties, Kentucky. J. Macklin Cox, Eastern Kentucky University. (Sponsored by Roy VanArsdale)

1500 Coffee Break.

1530 Plenary Session.

Saturday, November 12, 1983

0800 Influence of Support Systems on the Occurrence and Distribution of Roof Falls in Selected Coal Mines of Eastern Kentucky. *Alan D. Smith*, Coal Mining Administration, Eastern Kentucky University, and Richard T. Wilson, Department of Geology, Eastern Kentucky University.

0815 Cost-sensitive Mine Planning of Proposed Pillar Dimensions: A Case Study. *Alan D. Smith*, Coal Mining Administration, Eastern Kentucky University.

0830 The Results of Refraction Studies of Pre-cambrian Basement Rock in Southeastern Kentucky. *Alexander Zekulin*, Department of Geology, University of Kentucky. Sponsored by William C. MacQuown.

0900 Coffee Break.

0915 Annual Business Meeting.

1030 Selected Aerial Photography of Kentucky Geological Features. D. K. Hylbert, *J. C. Philley*, and M. Esham, Department of Physical Sciences, Morehead State University.

1045 A Paleo-channel System Above the Springfield Coal of Western Kentucky. D. A. Williams and *A. D. Williamson*, Kentucky Geological Survey.

1100 Fast Foods, Fossils, and You. *Peter W. Whaley*, Department of Geosciences, Murray State University.

1115 Discriminative Analysis of Selected Rock Strength and Geological Parameters Associated with Basic Lithologies Derived from the Eastern Kentucky Coal Field. *Alan D. Smith*, Coal Mining Administration, Eastern Kentucky University, and James C. Cobb, Kentucky Geological Survey, University of Kentucky.

1130 Election of Sectional Officers.

PHYSICS SECTION

Room 13—Natural Science Bldg.

Marshall Wilt, Chairman, Presiding
Raymond McNeil, Secretary

Friday, November 11, 1983

1500 Coffee Break.

1530 Plenary Session.

Saturday, November 12, 1983

0800 The Old and the New Danger to High School Physics. *Mohammad Shams*, Bardstown High School.

0815 Experiments for an Undergraduate Nuclear Laboratory. *P. J. Ouseph*, University of Louisville.

0830 Internal Positron-Electron Pair Detection. *Zoltan Gacsi*, University of Kentucky.

0845 ^{56}Fe(n,n) Reaction - New Levels and Lifetimes in

^{56}Fe. *J. L. Weil*, J. Sa, and S. O'Brien, University of Kentucky.
0900 Coffee Break.
0915 Annual Business Meeting.
1030 A Capsule History of AAPT Involvement in the Crisis in Science Education. *Jack M. Wilson*, Executive Officer, American Association of Physics Teachers.
1045 The Society of Physics Students and Sigma Pi Sigma in Kentucky. *Bernard D. Kern*, University of Kentucky.
1100 VUV Emissions from Krypton - A Kinetic Model. *Jerry D. Cook*, Eastern Kentucky University.
1115 Autokinetic Effect. *Joel Gwinn*, University of Louisville.
1130 Strong Circumstellar SiO Maser Flux Peaks. *F. O. Clark*, University of Kentucky.
1145 An Atari-800 Data-Analysis Program for the Resolution of the Mixed Decay Curves for ^{108}Ag and ^{110}Ag. *R. M. Brengelman*, Morehead State University.
1200 Lunch.
1300 A Low Cost Data Acquisition System for Apple II. *William S. Wagner*, Northern Kentucky University.
1315 Thoroughly Modern Millikan. *D. L. Humphrey*, Western Kentucky University.
1330 Student Conceptions of Forces and Motion; Questionnaire Results and Conclusions. *Jerry Moulder*, Transylvania University.
1345 Carrier-Mediated Transport in Liquid Membrane Systems. Terri Dietz, Notre Dame Academy. (Sponsored by Herb Leopold)
1400 Physics Section Business Meeting.

PHYSIOLOGY, BIOPHYSICS, AND PHARMACOLOGY SECTION

Strickler Hall—Cochran Auditorium—Room 102

Thomas E. Bennett, Chairman, Presiding
Raymond E. Richmond, Secretary

Friday, November 11, 1983
1300 Changes in Fatty-Acid Content of *Pisolithus tinctorius* Due to Common Soil Phenolic Compounds. *J. H. Melhuish, Jr.* and Gary L. Wade, United States Department of Agriculture.
1315 Butylated Hydroxytoluene Inhibits Herpes Simplex Viral Infection of Rabbit Corneas. Thomas P. Coohill, Blaine R. Ferrell, Donald Carson, and Bobetta Bentley. Western Kentucky University.
1330 Physiological and Behavior Correlates of Plasma Caffeine as Determined by HPLC. Andrew Keisker, *Brent C. White*, and *J. Preston Miles, Centre College*.
1345 *Levels of Glycolytic Enzymes in the Housesparrow Flight Muscles and Heart Lactate Dehydrogenases. W. W. Farrar* and Y.J.K. Farrar. Eastern Kentucky University.
1400 Comparative Physical and Chemical Properties of Housesparrow Flight Muscles and Heart Lactate Dehydrogenases. *W. W. Farrar* and Y.J.K. Farrar. Eastern Kentucky University.
1415 Motilin and the Interdigestive Migrating Motor Complex. T. L. Peeters, *D. K. Pearce*, J. Janssens, and G. Van Trappen. Northern Kentucky University.
1430 A Preliminary Evaluation of the Role of Glycosaminoglycans in the Gastrointestinal Ulceration Associated With Trauma. *Karla Guess*, and Charles E. Kupchella. Murray State University.
1445 An Evaluation of Control Tissue in Glycosaminoglycan Histochemistry. *Bradley T. Bryan*, and Charles E. Kupchella. Murray State University.
1500 Coffee Break.
1530 Plenary Session.

Saturday, November 12, 1983
0800 The Effect of U.V. Radiation on Colchicine Binding to Microtubules. *F. R. Toman* and M. Tino Unlap.
0815 Ultraviolet Action Spectroscopy Using A Tunable Dye Laser. John Calkins, Ed Colley, and John Wheeler. University of Kentucky.
0830 Reactivation of Lethally Injured *Tetrahymena pyriformis* by Subsequent Doses of Radiation or Carcinogenic Chemicals. John Calkins, and Ed. Colley. University of Kentucky.
0845 Fractures and Fracture-Dislocations in a Prehistoric Kentucky Indian Population. Elizabeth Finkenstaedt. University of Kentucky.
0900 Coffee break.
0915 Annual Business Meeting.
1030 A Survey of VonWillebrand's Disease in Doberman Pinschers of Clark and Floyd Counties, Indiana. *Laura M. Howard* and Thomas E. Bennett. Bellarmine College.
1045 Election of Sectional Officers.

SCIENCE EDUCATION

Room 102—Life Sciences Bldg.

Dan Ochs, Chairman, Presiding
Jane Sisk, Secretary

Friday, November 11, 1983
1500 Coffee Break.
1530 Plenary Session.

Saturday, November 12, 1983
0815 Using Aerial Photography to Enhance the Teaching of Physical Science. *Maurice Esham*, David Hylbert and John C. Philley, Physical Science Department, Morehead State University.
0830 Report from the Science Advisory Council to the State Department of Education. *Frank Howard*, Science Consultant, State Department of Education and Anna Neal, Science Coordinator, Fayette County Schools.

0900 Coffee Break.
0915 Annual Business Meeting.
1030 Analysis of Student Achievement in the Creative Inquiry Science Program. Donald L. Birdd, Model Laboratory School, Eastern Kentucky University.
1045 The Effect of Microwave and Heat on *Escherichia Coli* and *Staphylococcus* Aureus. Stephanie Pack, Summit Jr. High School. (Sponsored by Herb Leopold)
1100 Election of Sectional Officers.

PSYCHOLOGY SECTION
Strickler Hall—Middleton Auditorium

Steve Falkenberg, Chairperson
Terry R. Barrett, Secretary

Friday, November 11, 1983
1300 The Effects of Presentation Time on Delayed Free Recall. Anne E. Polk, Murray State University. Sponsored by Terry R. Barrett.
1315 Hostility and Self-Esteem in Human Subjects. Daniel R. Evans, Eastern Kentucky University. Sponsored by William H. Watkins.
1330 Factors in the Happiness of Lesbians. Starla Cravens, Murray State University. Sponsored by Terry R. Barrett.
1345 Manipulation of Subject Imputed Velocity in the Tau and Kappa Effects. Kelly Layne Hendrickson, Murray State University. Sponsored by Terry R. Barrett.
1400 The Effects of Relevant and Irrelevant Information on Organization of Prose Passages. Barney Beins and *Chris Perrino*, Thomas More College.
1415 Friendship Patterns in Divorced Men and Women. Cecilia Edwards, Murray State University. Sponsored by Terry R. Barrett.
1430 Religiousity, Locus of Control, and Intelligence. David Walter, Eastern Kentucky University. Sponsored by William H. Watkins.
1445 The Role of Target Muscle in the Efficacy of EMG Biofeedback Training. *Beth Gibson* and Jack G. Thompson, Centre College.
1500 Coffee Break.
1530 Plenary Session.

Saturday, November 12, 1983
0800 Social Facilitation, Social Impairment and Social Loafing: A Self-Attention Theory Integration. Brian Mullen, Murray State University.
0815 An Examination of Death Anxiety, Locus of Control, and Other Variables. William J. Humes, Eastern Kentucky University. Sponsored by William H. Watkins.
0830 When Age Differences in Free Recall Disappear. *Terry R. Barrett* and Brenda B. Estes, Murray State University.
0845 Social Reinforcement vs. Cooperation-Competition as a Mediator of Locus of Control. David Futrell, Murray State University. Sponsored by Terry R. Barrett.
0900 Coffee Break.
1030 Sex-Role Stereotypes of Four- and Eight-Year Olds. Sherri L. Farmer, Eastern Kentucky University. Sponsored by William H. Watkins.
1045 Cognitive Patterns of Hardcore and Softcore Inmates. Frank Kodman, Murray State University.
1100 Generational Stereotyping Across the Adult Life Span. Mark Thompson, Murray State University. Sponsored by Terry R. Barrett.
1155 Differences in Self-Asteem Among Only Children, First Borns, and Later Borns. Tyra J. Taylor, Murray State University. Sponsored by Terry R. Barrett.
1130 Attitudes Toward the Aged Among College Students. Bill McLaurine, Eastern Kentucky University. Sponsored by Steve Falkenberg.
1145 The Generation of Asch-Type Conformity in a Line Generation Task. Barney Beins, John William Porter and *Patty Hoeper*, Thomas More College.
1200 Lunch.
1300 Interracial Dating on Campus Between Blacks and Whites. Dagmar R. Rains, Murray State University. Sponsored by Terry R. Barrett.
1315 The Full Moon and Aggressive Behavior. Chet Overstreet, Murray State University. Sponsored by Terry R. Barrett.
1330 Children's Perception of Sex-Roles. Teresa J. Patterson, Eastern Kentucky University. Sponsored by William H. Watkins.
1345 The Efficacy of Group and Individual Treatment of Mild and Moderate Depression in College Students. *Jack G. Thompson* and Angela G. Kirkland, Centre College.
1400 Apathy Versus Empathy: The Influence of Social Background. *Andrea Galjan*, Murray State University. Sponsored by Terry R. Barrett.
1415 Attitudes of Eastern Kentucky University Students Toward Seeking Professional Psychological Help. *Dana Ward*, Rebecca Sebastian, and Steve Falkenberg, Eastern Kentucky University.
1430 Effectiveness of the Horne-Ostberg Morningness-Eveningness Questionnaire as a Predictor of Circadian Rhythms in Motor Performance. *Mark V. Lathem*, Murray State University. Sponsored by Terry R. Barrett.
1445 Selection of Intellectually Gifted Children: Do Achievement Tests Bias Selection? Walton, H., Thompson, G., Rogers, P., and *Thompson, J. G.*, Centre College.
1500 Juror Decision Making: The Effect of Juror Race and Gender on Decisions Regarding Defendant Race and Gender. *Cathy J. Crawford*, Murray State University. Sponsored by Terry R. Barrett.
1515 Interactions Among Various Types of *Planaria*. *Jennifer Fry, Notre Dame Academy. (Sponsored by Herb Leopold)*

1530 *Election of Sectional Officers.*

ZOOLOGY AND ENTOMOLOGY
Room 101—Life Science Bldg.

Gertrude C. Ridgel, Chairperson
Douglas L. Dahlman, Secretary, Presiding

Friday, November 11, 1983 — Tour Meet at 139 Life Science Building (outside Department of Biology Office).

1300-1400 *Tour of the insect collection, University of Louisville, Charles V. Covell, Jr. presiding.*

Friday, November 11, 1983

1300 *Distribution of Fishes in the Rolling Fork River. William L. Fisher, Water Resources Laboratory, University of Louisville.*

1315 *Fishes and Their Distribution in the Tradewater River System, Knetucky. Lewis G. Miller* and Michael M. Mills, Natural Resources and Environmental Protection Cabinet, Frankfort.

1330 Longitudinal Zonation in the Niche Relations of Ozasrk Stream Minnows. David L. McNeely, Dept. Biological and Environmental Sciences, Morehead State University.

1345 Biological and Water Quality Investigation of the Ross Creek Drainage—A System Impacted by Oil Well Brines. *Samuel M. Call,* Michael R. Mills, Stephen D. Porter, Robert W. Logan, Ronald E. Houp, Donald K. Walker and Clifford C. Schneider, Div. Environ. Services, Dept. Environ. Protection, Frankfort.

1400 The Life History of the Banded Darter, *Etheostoma zonale lynceum* (Jorden), in Kentucky. *Diana L. Bell* and Thomas J. Timmons, Hancock Biological Station, Murray State University.

1415 Age, Growth, and Condition of White Crappie, *Promoxis annularis* (Rafinesque) in Kentucky and Barkley Lakes. *Donna L. Parrish,* Hancock Biological Station, Murray State University and Thomas D. Forsythe, U.S. Tenn. Valley Authority, Land Between the Lakes, Golden Pond.

1430 Mussell Investigation at Green River Dam Number and Barren River Dam Number 1. James B. Sickel, Dept. Biological Sciences, Murray State University.

1445 Role of Aquatic Surface Respiration in the Adaptation of Two Species of Fishes to Headwater Environments. *K. Elkins* and M. Barton, Div. Science and Mathematics, Centre College.

1500 Relative Abundance of Mosquito Species Collected in Jefferson County, Kentucky, over a Fifteen-year Period. *Barbar K. Bollinger* and Charles V. Covell, Jr., Dept. Biology, University of Louisville.

1515 Coffee Break.

1530 Plenary Session.

Saturday, November 12, 1983 - Gertrude C. Ridgel, Chairperson, Presiding.

0800 Stoneflies (Plecoptera) of Kentucky. *Donald C. Tarter* and Dean A. Adkins, Dept. Biological Sciences, Marshall University and Charles V. Covell, Jr., Dept. Biology, University of Louisville.

0815 Life History Features of *Dibusa angata* (Ross) (Hydroptilidae-Trichoptera), in a Central Kentucky Limestone Stream. Ron Houp, Div. Environ. Services, Dept. Environ. Protection, Frankfort.

0830 The Bluegrass Region Effects on Amphibian and Reptile Distribution. John MacGregor, Non-game Wildlife Program, Kentucky Department of Fish and Wildlife Resources, Frankfort.

0845 Rare Species and Subspecies of Amphibians and Reptiles in Kentucky. John MacGregor, Non-game Wildlife Program, Kentucky Department of Fish and Wildlife Resources, Frankfort.

0900 Coffee Break.

0915 Annual Business Meeting.

1030 Ovipositional Selection and Percentage Eclosion of the Potato Leaf-hopper on Soybean at Selected Growth States, *A. M. Simmons,* L. D. Godfrey and K. V. Yeargan, Dept. Entomology, University of Kentucky.

1045 Breeding Success of Starlings *(Sturnus vulgaris)* Using Nest Boxes in Warren County, Kentucky. Daniel J. Twedt, U.S. Fish and Wildlife Service, Denver Wildlife Research Center, Bowling Green.

1100 Consequences of Artificially Inducing Spring Conditions in Starlings in Winter on the Timing of Their Breeding Season. Blaine R. Ferrell, Dept. Biology, Western Kentucky University.

1115 Learning Centers: An Alternative to Auto Tutorial and Computer Assisted Instruction in Entomology. John D. Sedlacek, Dept. Entomology, University of Kentucky.

1130 Vocal Behavior of Cardinal, *Cardinalis cardinalis.* Gary Ritchison, Dept. Biological Sciences, Eastern Kentucky University.

1145 Survivable Atmospheric Alternatives for *Drosophila melanogaster.* Gerrit Kloek, Dept. Biology, Kentucky State University.

1200 Preliminary Investigation of the Allelochemical Effects of the Terpenes of *Liquidambar styraciflua L. W. Blaine Early, III* and Kathy R. Spears, Dept. Biology, Cumberland College.

1215 Election of Sectional Officers.

ABSTRACTS OF SOME PAPERS PRESENTED AT THE ANNUAL MEETING

BOTANY AND MICROBIOLOGY

A taxonomic and evolutionary analysis of *Dryophyllum* leaf forms from the Eocene of Kentucky. JAY H. JONES* and DAVID L. DILCHER, Department of Biology, Indiana University, Bloomington, IN 47405.

Leaves of the genus *Dryophyllum* have been thought to play an ancestral role within the Fagaceae. The forms occurring in western Kentucky were examined to assess their taxonomic position and evolutionary significance. The fagaceous affinities of these fossils were confirmed, but the fossils could not be allied with any modern genus. Leaf architectures characteristic of both the Castaneoideae and Quercoideae were found among these intergrading forms. The cuticular features of all forms are closest to those of modern oaks yet distinct from all extant Fagaceae. The intergradation and unique complement of foliar characteristics suggests that these leaf forms are part of an extinct interbreeding complex from which modern oaks and chestnuts may have evolved.

Seed germination patterns in the woodland perennial *Maianthemum canadense* Desf. (Liliaceae). CYNTHIA L. WILLIAMS*, Division of Science and Mathematics, Centre College, Danville, KY 40422.

Seed germination and establishment of *Maianthemum canadense* were studied under laboratory conditions and at four vegetationally different field sites in northern Wisconsin. Ninety percent of seeds were viable and able to germinate after 6 months stratification. Rates of germination varied significantly for seed from different sources, but total germination did not. In the field, most of the seeds remained dormant for several years. Seedling success varied significantly from site to site and was dramatically influenced by weather, local environmental factors, and microhabitat. No differences in total percent germination among seeds from different sources or between seeds of the two varieties were seen.

ENGINEERING

Cost-sensitive mine planning or projected pillar dimensions: a case study. ALAN D. SMITH, Coal Mining Administration, College of Business, Eastern Kentucky University, Richmond, KY 40475.

The coal-sensitive mine-planning process involves spatial projection of conditions that will have the greatest impact on cost and coal quality for a particular mine site. A comparison of actual piller dimensions, factors of safety, and pillar dimensions, based on the theories of Salamon (1968), Salamon and Munro (1967), Bieniawski (1973), Bieniawski, Rafia, and Newman (1980), and Skelly, wolgamott, and Wang (1977), which cover a broad spectrum of mining conditions, was made for a small coal mine in Whitley County, southeastern Kentucky. A series of five zones, based on topography, were mapped over the proposed mine layout, and comparative results indicate that the present pillars' dimensions in initial development of the mine are too large and, as in zone 2, result in loss of clean coal revenue of approximately $4,295 per pillar.

Discriminative analysis of selected rock strength and geological parameters associated with basic lithologies derived from the eastern Kentucky coal field. ALAN D. SMITH*, Coal Mining Administration, College of Business, Eastern Kentucky University, Richmond, KY 40475, JAMES C. COBB, Kentucky Geological Survey, University of Kentucky, Lexington, KY 40506, and KOT F. UNRUG, Department of Mining Engineering, University of Kentucky, Lexington, KY 40506.

Approximately 1,000 tests were performed on cores derived from the Eastern Kentucky coal field using slake durability, direct shear, Brazilian tensile, punch shear, and ultimate and compressive strength testing. Statistical analyses were performed on the generated data. Multiple linear regression, hypothesis testing, power analysis, stepwise regression, and model building were the statistical methods applied to the Title III data base. Statistically significant relationships were found among the parameters: slake durability, direct shear test mean and standard deviation, punch shear stress mean and standard deviation, Brazilian tensile test mean and standard deviation, and the criterion gross overburden lithology. No predictive relationships with the various engineering and geological tests were found associated with depth of core sampling.

Influence of support systems on the occurrence and distribution of roof falls in selected coal mines of eastern Kentucky. ALAN D. SMITH*, Coal Mining Administration, College of Business Eastern Kentucky University, Richmond, KY 40475, and RICHARD T. WILSON, Department of Geology, Eastern Kentucky University, Richmond, KY 40475.

The vast majority of 250 measured falls occurred in the entry of intersection, had spans of approximately 20 feet, portrayed some presence of water before the fall, occurred less than 30 weeks after initial coal extraction, located usually greater than 100 feet from the nearest coal face, gave evidence of cracks in mine roof before fall, generally presented a stable roof profile before fall, and showed presence of sloughing of coal ribs and little evidence of floor heave. Most roofs were either originally supported by mechanical bolts (57.2%) or resin bolts (38.8%). Sloughing of the coal ribs were associated with a greater occurrence of resin roof bolts.

GEOGRAPHY

Kentucky geography textbooks: a historical perspective. EDWIN T. WEISS, JR.*, Department of History and Geography, and REBECCA STURM, Steely Library, Northern Kentucky University, Highland Heights, KY 41076.

Kentucky is one of twenty states that has a state-wide adoption law for textbooks. We examined geogrpahy textbook adoption since 1914 when the present Kentucky system was instituted. Before WW I, geography texts in the Commonwealth were oriented toward physical and "commercial-economic" geography. During and after the war there was an abrupt shift to world regional geography texts; geography textbooks change since WW II has been far less frequent. A cluster analysis revealed that Kentucky's list remained separate until the 13th grouping, indicating a relatively low degree of similarity with the geography lists of other adoption states.

The geography section of KAS, 1971-1983. WILLIAM A. WITHINGTON, Department of Geography, University of Kentucky, Lexington, KY 40506.

Since 1922 Academy members with spatial research interests have presented a published papers, notably Burroughs (1922-1958), Kennamer (1932-ca.1960), and Schwendeman (1946-ca.1976). Only in 1971 was the separate Geography Section established in the Academy of Science. This section's 13-year history was involved: (1) 15 geographers from eight universities as officers; (2) 160 papers read, only 5 in 1975 but 22 in 1981; and (3) 70 papers of their abstracts printed in eight volumes of *The Proceedings of the Geography Section, KAS, 1973-1982*. A continuing challenge is encouragement of greater involvement of government and business, as well as academic, members in section affairs.

Paleozoic history of the Rockcastle River Uplife in eastern Kentucky. GREGORY K. MAYNOR* and WILLIAM C. MACQUOWN, Department of Geology, University of Kentucky, lexington, KY 40506.

The Rockcastle River Uplift is a southwest-northeast trending, doubly-plunging anticline in Pennsylvanian strata exposed in Laurel, Clay, and Owsley counties of the Appalachian Plateau of eastern Kentucky, 50 miles east of the Cincinnati Arch. Subsurface work indicates that the uplift existed throughout most of the Paleozoic Era as an area of less subsidence between the Rome trough to the northwest and the Appalachian Basin to the southeast. The local extent of the uplift has been controlled by growth faulting and a complex pattern of differential subsidence, local erosion, deltaic lobe build-up, and draping of overlying units.

PHYSIOLOGY, BIOPHYSICS, BIOCHEMISTRY, AND PHARMACOLOGY SECTION

A survey of vonWillebrand's Disease in Doberman pinschers of Clark and Floyd counties, Indiana. LAURA M. HOWARD and THOMAS E. BENNETT,* Department of Biology, Bellarmine College, Louisville, KY 40205.

VonWillebrand's Disease (VWD) is one of the most prevalent inheritable bleeding disorders present in humans, swine, and dogs. VWD is an autosomal dominant trait with variable clinical expression. Of the 25 breeds of dogs affected by VWD, the highest incidence is found in Doberman pinschers. In a two-county servey, 14 of 42 (33%) purebred Doberman pinschers were diagnosed as having the VWD gene. The primary purpose of genetic screening is to reduce the frequence of VWD through selective breeding practices. It is only through owner awareness and voluntary adherence to breeding guidelines that canine vonWillerbrand's Disease will be eradicated.

Changes in fatty-acid content of *Pisolithus tinctorius* due to commong soil phenolic compounds. J. H. MELHUISH* AND G. L. WADE, Northeastern Forest Experiment Station, Forest Service, U. S. Department of Agriculture, Berea, KY 40403.

Mycorrhizal development on surface mine spoils may be inhibited by compounds produced by some herbaceous covers. Ferulic, p-coumaric, and vanillic acids inhibited in vitro growth of *Pisolithus tinctorius.* All these compounds are produced by some grasses. Concomitant effects included an increase in total lipids and the conversion of 18:1 fatty acid to 18:2. Changes in concentration of phenolic compounds influenced leakage of materials form the mycelium into the media. This suggests that allelopathic effects inhibit *P. tinctorius* early in ecosystem development. Increasing media nutrient content, although itself toxic to fungal growth, nullified the effects of ferulic acid.

The effect of U.V. radiation on colchicine binding to microtubules. F. R. TOMAN* and M. TINO UNLAP, Department of Biology, Western Kentucky University, Bowling Green, KY 42101.

Tubulin-^{3}H-colchicine complex was prepared from bovine microtubules. The study included the effect of U.V. radiation on the stabliity of the tubulin-^{3}H-colchicine complex and the capacity of the complex to bind to intact microtubules. The complex was found to dissociate upon exposure to U.V. radiation, the amount of dissociation increasing with increased exposure time. When tubulin-^{3}H-colchicine complex was bound to intact microtubules prior to U.V. radiation exposure, it showed no increased stability. Tubulin-^{3}H-colchicine complex exposed to U.V. radiation showed decreased binding activity to intact microtubules.

ZOOLOGY AND ENTOMOLOGY

Role of aquatic surface respiration in the adaption of two species of fishes to headwater environments. KIM ELKINS* and MICHAEL BARTON, Division of Science and Mathematics, Centre College, Danville, KY 40422.

The role of aquatic surface respiration (ASR) was investigated for two headwater species, the northern studfish *(Fundulus catenatus)* and the striped shiner *(Notropis chrysocephalus)*. Oxygen consumption and survival times were measured in respirometers without an air space and compared with those achieved in respirometers with an equal volume of water but including an air space. Fishes not permitted ASR had mean survival times of 8.4 hours for *Fundulus catenatus* and 3.5 hours for *Notropis chrysocephalus;* those permitted ASR had mean survival times of 68.4 hours and 83.0 hours, respectively. Acquatic surface respiration is presumed to be an adaptation permitting continued aerobic metabolism in environments that experience periodic oxygen deficiencies.

GEOLOGY

Low altitude infrared remote sensing of faults and fractures, western Kentucky coalfields, Morganfield, Kentucky. BRUCE R. MOORE, Department of Geology, University of Kentucky, Lexington, KY 40506.

A low altitude scanning system was developed for obtaining infrared images from light aircraft. The images were processed in an analog and digital computer television system for edge enhancement, false color, and lineament analysis. The area processed is portion of the Rough Creek fault zone of western Kentucky and adjacent to an active deep mining area. The study confirmed the existence of previously mapped faults, corrected their accurate position, and disclosed extensions and new lineaments. The main method utilizes the temperature difference between groundwater from the fractures and the surrounding rock and soil. Results can predict future mine roof conditions.

PHYSIOLOGY, BIOPHYSICS, AND PHARMACOLOGY

Motilin and the interdigestive migrating motor complex. T. L. PEETERS, J. JANSSENS, and G. VAN TRAPPEN, Labo Gastroenterology, University of Leuven, Leuven B-3000, Belgium, and D. K. PEARCE*, Department of Biological Sciences, Northern Kentucky University, Highland Heights, KY 41076.

The site of origin of the interdigestive migrating motor complex (MMC) vs. blood motilin level was determined in 11 normal subjects. Only MMC's originating in the stomach were preceded by a significant peak of plasma motilin. Upon infusion of stomatostatin (supresses the release of motilin), gastric MMC's were abolished, but no effect was seen on those originating in the small bowel. It was concluded that motilin has a physiological role in initiation of gastric activity during the interdigestive cycle but not in regulation of the small bowel.

NEWS AND COMMENTS

70TH MEETING OF THE KENTUCKY ACADEMY OF SCIENCE

The 70th annual meeting of the *Kentucky Academy of Science* will be held at the Kentucky State University, Frankfort on 9-10 November 1984. Additional information will be forthcoming in the Newsletter.

MEMBERSHIP

The Membership Committee has been successful in effecting an appreciable increase in our membership during 1983. However, the Academy is still far under what it should be for a state of this size. Let us all continue to solicit new members and urge all old members to pay their dues.

CHANGE IN PRINTERS

Because the change in printers has eliminated technical editing, one of the reasons for cost saving, it is imperative that authors be extremely careful in reading and marking proof and in returning same as quickly as possible to the editor. Since the University of Kentucky Printing Office has no mechanism for billing authors for reprints, that task has to be assumed by the editor's office. Henceforth, all billing will come from the Editor on publication-associated matters.

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TRANSACTIONS OF THE KENTUCKY ACADEMY OF SCIENCE

Volume 45
Numbers 3-4
September 1984

Official Publication of the Academy

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TRANSACTIONS of the KENTUCKY ACADEMY of SCIENCE

September 1984
Volume 45
Numbers 3-4

Changes in the Adult Caddisfly *(Trichoptera)* Community of the Salt River, Kentucky

K. H. HAAG, V. H. RESH[1], and S. E. NEFF

Water Resources Laboratory, University of Louisville
Louisville, KY 40292

ABSTRACT

A series of one-hour light trap collections was made between 4 June—30 July, 1979, from the Salt River and Brashears Creek, Spencer Co., Kentucky. Since 1971, both streams have received increased loads of suspended solids as a result of road and dam construction. Comparison of adult caddisflies collected in 1979 from the Salt River with 1971 Salt River samples revealed an increase in species richness (mean number of species per collection: 1971 = 24 ± 3; 1979 = 35 ± 7) and species diversity (1971 $\bar{H}$ = 2.0—3.0, $\bar{X}$ = 2.3 ± 0.3; 1979 $\bar{H}$ = 2.2—3.2, $\bar{X}$ = 2.7 ± 0.5). Changes also occurred in the seasonal pattern of species diversity values, from a mid-summer peak in 1971 to a mid-summer low in 1979. Major shifts occurred in relative abundance of net-spinning species. *Chimarra obscura* declined from 7.0% of all individuals in 1971, to 0.3% in 1979, possibly because *C. obscura's* capture net has small irregular pores that become occluded by the increased suspended solids. Comparison of changes in the Salt River fauna between 1971 and 1979 with data on annual variability (AV) from other localities revealed that fluctuations in the caddisfly community of the Salt River exceed those expected in the absence of sediment pollution. Comparison of 1979 Salt River and Brashears Creek collections emphasizes the similarity of sediment influences on the two streams.

INTRODUCTION

During a preimpoundment survey of the portions of the Salt River in Spencer and Anderson counties, Kentucky, extensive collections of benthic invertebrates were made from 1968 through 1975 (1, 2, 3). As a part of this survey, light-trap samples were taken during the summer of 1971. From these collections, the adult caddisfly community was studied, and a summary of the adults collected, their relative abundance, and their diversity was reported (4). From more than 87,000 specimens, 56 species, distributed in 11 families, were identified.

Beginning in 1975, construction of the outlet works for the Taylorsville Lake impoundment, along with a visitors' center and new access roads, resulted in the removal of much of the vegetational cover around the damsite, which exposed soil surfaces to erosion. Within the drainage basin, 4 sections of secondary road (Fig. 1; a, b, c, d) and a main highway with a bridge (Fig. 1, KY. 55) were relocated or modified. These construction and road projects contributed to the increased loads of suspended solids in surface runoff and, ultimately, in the Salt River and Brashears Creek. During the 1979 light-trap collections described below, some construction was still in progress. The dam and its appurtenances were completed in June 1981, and filling of the reservior began on January 4, 1983.

[1]Department of Entomological Sciences, University of California, Berkeley, CA 94720

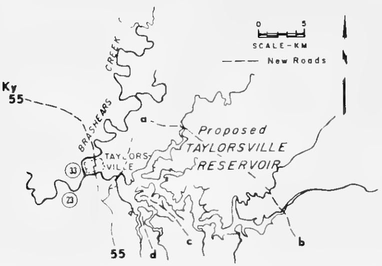

Figure 1: Map indicating the location of Brashears Creek, the Salt River, sampling sites (Station 23 and Station 33), and the proposed impoundment. Also shown are four sections of relocated secondary road (a - d) and KY Hwy. 55. See Resh et al. (4) for complete map of drainage basin.

Benthic sampling from 1968-1975 indicated that the freshwater sponge *Spongilla lacustris* (Linnaeus) was distributed widely in the Salt River, as was the sponge-feeding caddisfly, *Ceraclea transversa* (Hagen). Benthic collections in 1977-1978 indicated that sponge populations had been extirpated in the localities where they had been abundant. Since the sponge declined drastically, we speculated that abundance of the sponge-feeding caddisfly, along with other cadissfly populations, might be affected by the factors that reduced sponge abundance. Thus, a study was designed to compare the caddisfly community of the Salt River, 1979 with the community present in 1971, and to compare the caddisfly fauna of the Salt River with the fauna of Brashears Creek, a tributary stream below the damsite, that had been influenced by silation from bridge and road construction. In addition, we examined certain water-quality parameters to ascertain whether changes in caddisfly community structure may be related to the effects of dam construction and road relocation.

Materials and Methods

Site Description

The Salt River and its tributaries drain 7,563 km^2 in north-central Kentucky. The basin encompasses gently rolling topography of the outer Bluegrass Region, and the area above the damsite is characterized by steep ridges and narrow valleys. Slopes are generally heavily wooded, but the cleared areas are subject to heavy erosion and high runoff with little infiltation (5). Water-quality data for the Salt River, including physical, chemical, and biological parameters, have been reported (1,2,3, and 6).

Resh et al. (4) reported collecting results from a site (Fig. 1, Station 23) on the Salt River which is located 4.5 km downstream from Taylorsville. Here the river is approximately 30 m wide and 4 m deep during average flow conditions. A riffle is bordered by two pools, and substrate ranges from gravel to boulders over bedrock. A second site (Fig. 1, Station 33), located on Brashears Creek at Taylorsville and approximately 0.8 km from its confluence with the Salt River, also was examined in 1979. At this site, the creek is a meter or less in depth and averages 20 m in width. Several large beds of water willow grow in the stream channel on small gravel bars, and the stream bed is covered with gravel and small boulders.

Collection Procedures and Data Analysis

Rather than attempting to encompass the entire season of adult emergence, light-trap collections in 1979 were confined to the period of greatest flight activity, previously determined (4) as June through July. Adult insects were sampled biweekly at both Station 23 and Station 33 with the type of trap used in the 1971 collections — a modified Texas light trap equipped with an 8-watt fluorescent blacklight bulb. The traps were hung approximately 2.5 m off the ground on the steam bank and each collection began 20 minutes after sunset and continued for 1 hour. Insects were collected directly into 70% ethyl alcohol. Species diversity per individual ($\bar{H}$) was calculated using Brillouin's (7) equation. The collecting methods and statistical analyses of species diversity outlined here paralleled methods used in the 1971 light trap collections (4). This was done to permit comparison between the 2 studies.

Water samples were collected on each sampling date and analyzed to determine dissolved solids, suspended solids, and total solids. Other water quality parameters measured included pH, conductivity, alkalinity, hardness, and turbidity.

Results

Water Chemistry

The Salt River and Brashears Creek flow over limestones and shales of Clays Ferry and Calloway Creek Formations (Upper Ordovician) and alluvium derived from these deposits (8). The streams drain farm and pastureland and receive no industrial effluents. They are similar in type of substrate, water chemistry, macrophytic vegetation, and benthic fauna (9).

A comparison of water quality data collected in 1979 with data collected in 1971 indicates that changes have occurred in these streams.

Krumholz (1) described water chemistry characteristics of the Salt River at that time and reported the following ranges: pH (6.3—7.5), total dissolved solids (40-160 mg/1), and conductivity 100—300 umhos/cm). Data from the Salt River in 1979 indicate changes in pH (7.7—8.5), and increases in total dissolved solids (223—272 mg/1) and conductivity (270—440 umhos/cm.) Data from Brashears Creek in 1979 show pH from 7.4—8.6 conductivity from 340—530, and turbidity from 3.8 to 35 NTU. Although a continuous profile of water quality is not available for the seven-year period, these data and others (6,10) suggest that the changes in stream conditions are attributable to increased sediment load.

A comparison of the 1979 water quality data from Brashears Creek and the Salt River suggest that sediment pollution levels are somewhat higher in the Salt River. Suspended solids ranged from 23 to 88 mg/1 in the Salt River ($\bar{x}$ = 55 mg/1), and from 5 to 76 mg/1 in Brashears Creek ($\bar{x}$ = 33 mg/1). Turbidity levels in the Salt River ranged from 16-72 NTU ($\bar{x}$ = 36). Levels of alkalinity and hardness were quite similar in the two streams in 1979, ranging from 87 to 172 mg/1 in the Salt River, and 130 to 250 mg/1 in Brashears Creek.

Species Richness

In 1971, the collections made from the Salt River between 4 June and 30 July yielded 77,458 individuals and 44 species (Table 1). Salt River collections from this same time period in 1979 yielded 45,784 individuals and 49 species. The increase in species richness in the Salt River is reflected by the change in mean number of species per collection. The 1979 collection from the Salt River averaged 35 ± 7 species per collection, whereas collections from 1971 averaged 24 ± 3 species per collection.

Table 1. Species present, number of inviduals, and their abundance as percentage of total caddisflies collected in 1971 and 1979, from the Salt River and Brashears Creek, Kentucky.

	Salt River 1971		Salt River 1979		Brashears Cr. 1979	
	Number Collected	% of Individuals Collected	Number Collected	% of Individuals Collected	Number Collected	% of Individuals Collected
Family GLOSSOSOMATIDE						
Protoptila maculata (Hagen)	6,205	7.91	4,207	9.19	4,584	19.72
Family PHILOPOTAMIDAE						
Chimmara obscura (Walker)	5,816	7.41	104	0.23	100	0.40
Family POLYCENTROPODIDAE						
Nyctiophylax affinis (Banks)	246	0.31	7	0.02	5	0.02
Polycentropus cinereus (Hagen)	787	1.00	75	0.16	48	0.20
Polycentropus sp.	0	0	0	0	3	0.01
Cyrnellus fraternus (Banks)	118	0.15	237	0.52	172	0.70
Family PSYCHOMIIDAE						
Cernotina sp.	7	0.01	1	<0.01	0	0
Psychomyia flavida (Hagen)	0	0	3	<0.01	1	<0.01
Family HYDROPSYCHIDAE						
Hydropsyche betteni Ross	34	0.04	7	0.02	3	0.01
Hydropsyche cheilonis Ross	0	0	2	<0.01	2	0.01
Hydropsyche dicantha Ross	5	0.01	643	1.40	443	1.90
Hydropsyche incommoda Hagen	0	0	6	0.01	0	0
Hydropsyche orris Ross	8	0.01	0	0	0	0
Hydropsyche simulans Ross	202	0.26	119	0.26	26	0.11
Cheumatopsyche pettiti (Banks)	3.057	3.91	2,349	5.13	942	4.05
Cheumatopsyche campyla Ross	6,143	7.83	20,684	45.18	5,676	24.42
Cheumatopsyche pasella Ross	9	0.01	33	0.07	0	0
Cheumatopsyche speciosa (Banks)	9	0.01	0	0	0	0
Potamyia flava (Hagen)	13	0.02	12	0.03	3	0.01
Family HYDROPTILIDAE						
Hydroptila ajax Ross	7	0.01	16	0.03	0	0

continued

Table 1 continued

Hydroptila angusta Ross	82	0.10	119	0.26	80	0.34
Hydroptila armata Ross	23,106	29.45	647	1.40	1,044	4.49
Hydroptila consimilis Morton	6	0.01	10	0.02	6	0.02
Hydroptila hamata Morton	0	0	6	0.01	6	0.02
Hydroptila perdita Morton	12,170	15.51	4,503	9.84	6,172	26.56
Hydroptila waubesiana Betten	11	0.01	32	0.07	35	0.15
Hydroptila sp.	0	0	5	0.01	0	0
Ithytricia nr *mazon* Ross	16	0.02	2	◄0.01	2	0.01
Neothrichia okopa Ross	10	0.01	1	◄0.01	2	0.01
Neothricia vibrans Ross	0	0	701	1.53	756	3.25
Neotrichia riegeli Ross	0	0	0	0	1	◄0.01
Ochrotrichia spinosa (Ross)	7	0.01	1	◄0.01	0	0
Ochrotrichia tarsalis (Hagen)	6	0.11	466	1.02	61	0.26
Orthotrichia aegerfasciella (Cham.)	39	0.05	28	0.06	15	0.05
Orthotrichia cristata Morton	12	0.02	18	0.04	2	◄0.01
Oxyethira pallida (Banks)	284	0.36	148	.032	146	0.63
Stactobiella palmata (Ross)	62	0.08	25	0.05	1	◄0.01
Family LEPTOCERIDAE						
Ceraclea ancylus (Vorhies)	822	1.05	120	0.26	22	0.09
Ceraclea transversa (Hagen)	175	0.22	89	0.19	86	0.37
Ceraclea maculata (Banks)	804	1.02	244	0.53	119	0.51
Ceraclea tarsipunctatus (Vorhies)	10	0.01	735	1.61	311	1.33
Ceraclea cancellata (Betten)	15,604	19.89	7,049	15.40	1,781	7.66
Nectopsyche candida (Hagen)	0	0	1	◄0.01	0	0
Nectopsyche exquisita (Walker)	723	0.92	1,031	2.25	186	0.80
Nectopsyche sp.	10	0.01	20	0.04	41	0.18
Oecetis cinerascens (Hagen)	91	0.12	7	0.02	29	0.12
Oecetis ditissa Ross	24	0.03	105	0.23	4	0.02
Oecetis inconspicua (Walker)	890	1.13	230	0.50	188	0.80
Oecetis nocturna Ross	545	0.69	289	0.63	50	0.22
Oecetis persimilis (Banks)	26	0.03	614	1.34	61	0.26
Triaenodes connatus Ross	2	◄0.01	17	0.04	17	0.07
Triaenodes ignitus (Walker)	0	0	13	0.03	8	0.03
Triaenodes melacus Ross	180	0.23	0	0	0	0
Triaenodes tardus Milne	68	0.09	0	0	1	◄0.01
Triaenodes sp.	0	0	2	◄0.01	0	0
	78,458		45,784		23,240	

Species Diversity

In contrast to species richness, changes in species diversity values were less pronounced. Species diversity ranged from 2.0-3.0 ($\bar{x}$ = 2.3 ± 0.3) in 1971 Salt River collections, and 2.2—3.2 ($\bar{x}$ = 2.7 ± 0.5) in 1979 Salt River collections (Fig. 2). In 1971, the peak in species diversity values occurred in mid-July, with lowest diversity found in June. However, in 1979, diversity estimates were highest in early June and much lower in mid-July. These peaks are related to the phenology and population size of selected species in the community.

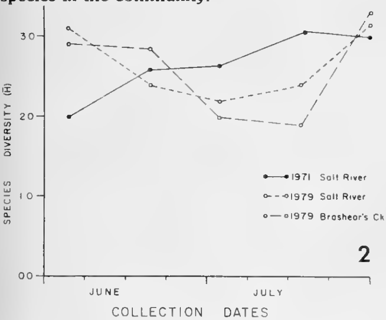

Figure 2: Comparison of species diversity in 1971 and 1979 from the Salt River and in 1979 from Brashears Creek adult caddisfly collections.

For example, in 1971, early June collections contained large numbers of *Hydroptila perdita, Cheumatopsyche pettiti,* and *Ceraclea cancellata,* which raised redundancy and lowered diversity to 2.0 (Fig. 2). Mid-July collections showed highest diversity values (3.0) which reflected peak emergence of the majority of the species and a decline in numbers of *C. cancellata.* Diversity remained relatively constant through July and did not decrease until early August when *Protoptila maculata* became more abundant and most other species declined in numbers.

In 1979, early June collections from the Salt River displayed highest diversity, with an estimated value of 3.1 (Fig. 2). Diversity values from mid-June to mid-July were lower, ranging from 2.2 to 2.4. During this period, *Cheumatopsyche campyla* comprised 45 to 55% of each hour's catch. *Ceraclea cancellata was abundant in mid-June (19% of total catch), but was surpassed in numbers by H. perdita* and *P. maculata* (emerging earlier than in 1971) in July. During most of July, these two species contributed 25 to 50% of each hour's collection and along with *C. campyla,* they constituted approximately 80% of each hour-long collection. The end of July brought a return to the higher diversity values seen earlier in the season. Numbers of *C. campyla, P. maculata,* and *H. perdita* decreased, along with the total number of individuals collected.

Populations

In terms of numbers of species present in 1979, the family Hydroptilidae was highest with 17 species; collections in 1971 contained 14 species. Although 45% of all caddisflies collected in 1971 were hydroptilids, only 15% were of this family in 1979. This decrease is due primarily to a reduced mid-July emergence in the number of *Hydroptila armata.* This species had only a brief emergence peak in 1971 (4). Since the sample collected on 28 May 1979, contained a very large number of *H. armata,* we believe that this species did not substantially decline in numbers from 1971 to 1979, but simply emerged earlier in 1979. The second most abundant hydroptilid in the Salt River in 1979 was *Neotrichia vibrans,* a species not found in the 1971 Salt River collections.

The family Leptoceridae had the second highest species richness with 16 species in the Salt River 1979 collections; the 1971 samples had 15 species. Species of the genus *Ceraclea* were numerically dominant in both 1971 and 1979. Within this genus, some changes in relative abundance of individual species did occur. *Ceraclea tarsipunctata* increased markedly in abundance, from 0.05% of all leptocerids in 1971 to 9.0% in Salt River 1979 collections. Although the sponge populations declined dramatically, abundance of adults of the sponge-feeding caddisfly, *C. transversa,* were similar in 1971 and 1979 (0.2%). Changes also occurred within the leptocerid genus *Triaenodes. Triaenodes melaca* and *T. tarda* were both present in 1971 collections but were completely absent in 1979 collections.

In the family Hydropsychidae, we found 9 species in both 1971 and 1979. Numerical dominance of this family is attributable to the very high numbers of *C. pettiti* and *C. campyla* collected, although the relative proportions of these 2 species changed dramatically. In 1971, the ratio of *C. pettiti* to *C. campyla* was 2:1, whereas, in 1979, the ratio was 9:1.

Examination of the various families of net spinners reveals other changes in their relative abundance between 1971 and 1979. Most notable was a shift in the ratio of Hydropsychidae to Philopotomidae, which was less than 2:1 in 1971 collections, but increased to more than 229:1 in 1979 collections. The ratio of Hydropsychidae to Polycentropodidae also increased from 4:1 in 1971 to 75:1 in 1979.

Comparison of Salt River and Brashears Creek Faunas

Brashears Creek collections between 4 June and 30 July contained 23,240 individuals and 44 species (Table 1). The caddisfly fauna of the Salt River and Brashears Creek in 1979 shared 41 species in common; 3 were present only in the Salt River and 3 were present only in Brashears Creek (Table 1). In most cases these unique species were represented by only 1 or 2 individuals, with the exception of *Cheumatopsyche pasella* which was represented by 33 individuals in the Salt River.

Species diversity estimates in Brashears Creek (range = 1.9—3.3, $\bar{X}$ = 2.4 ± 0.7), were slightly lower than those of the Salt River, although the pattern of these estimates showed the same general trend (Fig. 2). Diversity values were approximately 3.0 in early June but fell in late June to about 2.0 due to the numerical dominance of *C. campyla, H. perdita*, and *P. maculata*. The lowest diversity value of the season, 1.9, occurred when *P. maculata* and *H. perdita* comprised 58% and 19%, respectively, of the sample. Diversity values again rose at the end of July and returned to approximately 3.2, as total catch declined in numbers.

Individuals of the caddisfly family Hydroptilidae were more common in Brashears Creek (36% of all individuals collected) than in the Salt River (15%), and *N. vibrans* was also abundant in Brashears Creek collections. As in the Salt River, 15 species of leptocerid caddisflies occurred in Brashears Creek, making it the second highest family in species richness.

Examination of the net-spinning species in Brashears Creek in 1979 shows that the ratio of *C. pettiti: C. campyla* was 6:1 Hydropsychidae: Philopotamidae was 71:1, and Hydropsychidae: Polycentropodidae was 75:1. Although each of these ratios was higher than 1971 Salt River collections, they were lower than 1979 Salt River collections.

Protoptila maculata, a glossosomatid, was abundant in 1979 Brashears Creek collections, where it contributed almost 20% of the season's total. In the Salt River, it was also common (9.2%) and its relative abundance changed very little from 1971 to 1979.

Discussion

Within the Salt River drainage basin, paterns of land use and population distribution did not change appreciably from 1971 to 1979. The only significant activities to occur over the 8 year period were those associated with construction of the proposed dam outlet-works, visitors' center with access roads, bridges, and the construction of Kentucky State Hwy. 55. Beginning in 1975, these activities generated chronic low levels of suspended solids which eventually entered the Salt River.

In 1979, both Brashears Creek and the Salt River were characterized by moderate levels of suspended solids and turbidity, with levels in the Salt River usually higher than those in Brashears Creek. The caddisfly fauna was similar in these 2 streams, and species diversity values were comparable at the 2 sites with both communities demonstrating a mid-season low in species diversity. Four species, *P. maculata, C. campyla, H. perdita*, and *C. cancellata*, made up approximately 70% of the season's total at both sites. Ratios among the various net spinners suggest that the fauna of Brashears Creek and the Salt River in 1979 is more similar than that of the Salt River in 1971 and 1979.

An evaluation of the Trichoptera community in the Salt River based solely on collections in 1979 does not indicate a greatly stressed community; however, a comparison of the caddisfly community in 1979 with that present in 1971 does suggest that changes have occurred.

Ten species were collected in 1979 from the Salt River which were not found in collections in 1971 (Table 1). Included among these is *N. vibrans*, which was found in substantial numbers (1.5% season's total in 1979), and is apparently a new state record for Kentucky (11, 12). The remaining 9 species collected from the Salt River in 1979 that were absent in 1971 collections, were present in very low numbers, often as single specimens. Variations in emergence synchrony may be responsible for failure to collect these species in 1971; alternatively, these rare species may be inhabiting a marginal habitat in the collecting area or may represent immigrants from other breeding habitats, e.g., Crichton (13).

We found that species diversity did not change greatly from 1971 to 1979 (Fig. 2), although the season patterns of species diversity values is appreciably altered. For example, a midsummer low was present in 1979 Salt River collections, whereas in 1971 highest diversity values occurred in midsummer. The very large numbers of *C. campyla* collected in 1979 raised redundancy and consequently lowered diversity at this time, even though in both years the number of total species collected was highest in midsummer. Sorensen et al. (14) and others have noted that benthic communities are often maintained through succession of species; individual taxa may differ as sediment pollution persists, but estimates of diversity remain constant. We would expect this type of response in the benthos to be reflected in light-trap collections of adults (15).

Although we did not see a decrease in species diversity values in the Salt River, and species richness in fact increased, major shifts in species composition and abundance were observed within several families from 1971 to 1979. For example, the underlying reason for the dramatic change in the ratio of hydropsychids to philopotamids (2:1 to 299:1) is the decline in abundance of *Chimarra obscura*, from 7.0% of the season's total in 1971 to less than 0.3% in the Salt River in 1979. Turbidity and suspended solids levels in the Salt River frequently exceed the upper limits of tolerance observed for this species (2.5 to 51 NTU: 178—198 mg/1 total solids) that were reported by Harris and Lawrence (16).

Chimarra obscura has a small net mesh size (Fig. 3). In addition, near the middle and posterior end of the net shelter, the mesh is covered with a sticky, gelatinous secretion that apparently aids in capturing small particles. The strands of the net, rather than forming a regularly arranged network, appears to serve as a support structure for the gelatinous material. This secretion is also susceptible to occlusion of fine, suspended sediments, which probably accounts for this species' decline in the Salt River.

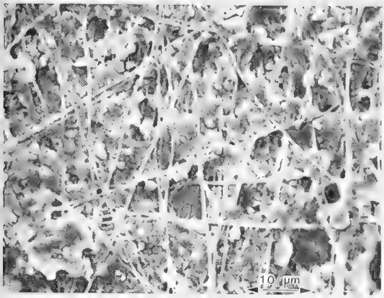

Figure 3: Chimarra obscura collecting net, inner surface at posterior end. Roughness of some strands due to dried secretion. 2000X.

Hydroptila perdita also showed a decline in relative abundance, from 15% in 1971 to 9% in 1979. Although little is known about the ecological requirements of species in the genus, it is generally thought that larvae feed on attached diatoms as well as on the contents of algal cells (17). Shading and abrasion of exposed surfaces by suspended solids may be particularly detrimental to larvae dependent on periphyton food sources.

Ceraclea cancellata appears to be proportionately less abundant in Salt River 1979 collections (15% of total catch) than in 1971 (20%). This species showed a 1979 emergence peak in June, similar to the peak seen in 1971, indicating that a difference in sampling schedules is not the source of the apparent change in abundance. Data on tolerance of this species to suspended solids are not available (16), but Resh and Unzicker (18), in their discussion of the genus *Ceraclea* (= *Arthripsodes*), suggested that some species in the genus may be more tolerant of pollution effects than others.

Although the freshwater sponge *Spongilla lacustris* is fairly pollution tolerant, it is intolerant of sediment pollution (19). Thus, siltation changes are probably responsible for its decreased abundance. The similarity in relative abundance of *C. transversa* in 1971 (0.22%) and 1979 (0.19%) probably also reflects the ability of this species to function as a detritus feeder (20).

Flynn and Mason (21) observed a decrease in the species number of hydropsychids in response to nonpoint sources of sediment pollution. In contrast, the number of species in the Salt River did not decline from 1971 to 1979, although relative proportions of species of *Cheumatopsyche* varied. For example, *C. campyla* was more abundant in 1979 than in 1971, whereas *C. pettiti* remained relatively constant. However, patterns of seasonal emergence for those 2 species remained similar in 1979 to those seen in 1971, with *C. campyla* more abundant earlier in the summer than *C. pettiti. Cheumatopsyche* spp. had been found in conditions of relatively high suspended solids (22). Thus, the population of *C. campyla* may be expanding in numbers to fill habitat vacated by other, less sediment-tolerant, net-spinning species.

An examination of observed changes in the caddisfly community from 1971 to 1979 raises the question of what can be expected in terms of temporal variability in the absence of perturbations. Wolda (23), in research with tropical insects, used a parameter called Annual Variability (AV) to measure fluctuation in numbers of individuals from one year to the next. McElravy et al. (24). applied this statistic to other data on temperate insect communities and found a range of values for AV from 0.080 to 0.325. Using AV to measure fluctuations seen in the Salt River from 1971 to 1979, we obtained a value of 0.925, which is several times greater than the maximum value reported above. The magnitude of this value suggests that, even though the data are not for successive years, the changes exceed those expected in the absence of increased siltation.

Further changes are anticipated once the Taylorsville project is completed and flow augmentation for improving potable water quality if begun. Although construction-related sediment generation will abate, suspended material will still enter the streams as runoff after precipitation. In the Salt River, as stream flow is regulated, the scouring effects of high flow conditions will no longer be available to help remove this accumulated material from the stream bed. Consequently, sediment may begin to fill in and cover over much of the benthic habitat. Continuing studies will examine further change in the Salt River caddisfly community.

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Geometry and Physical Characteristics of Mine-Roof Falls: A Case Study In The Upper Freeport Coal Seam

Alan D. Smith

Coal Mining Administration, College of Business
Eastern Kentucky University, Richmond, KY 40475

Abstract

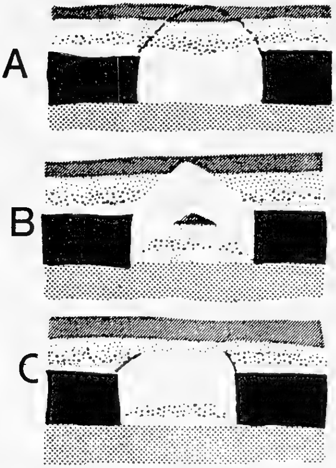
An initial data based in the Upper Freeport Coal Seam (Pennsylvanian age) was established, describing basic geometric and physical characteristics of coal-mine roof failure areas. Multiple linear regression analysis techniques were employed without correcting the decision criteria for multiple comparison, in order to maximize the possibility of detecting significant relationships. A total of 21 mine-roof falls were measured for 15 geologic or engineering parameters associated with roof failure. The averages for the parameters studied were: thinnest immediate roof layer is (0.427 cm) maximum roof height about roof edge or top of surface originally cut (2.86 m), height to second horizon or break-plane above roof lie (1.83 m), third horizon (p. 65 m), fourth horizon (0.41 m), length of roof bolts used during resupport (1.75 m), span of mine entry (5.59 m), and vertical opening of entry (2.71 m). The majority of falls showed no presence of water, occurred mainly in intersections or entries, used resin bolts during resupport, dome-shaped roof falls, no presence of cracks in roof top after fall occurrence, and showed presence of rib sloughing. In terms of the hypothesis testing and model building, only 6 out of a total of 45 hypotheses were found to be statistically significant. Both parameters, presence of water and height to second break-horizon of roof strata were found to be significant in predicting maximum roof height. Location of falls in intersections and length of roof bolts accounted for a significant amount of explained variance in discriminating dome-shaped roof falls.

Introduction

Roof control is one of the most important phases of underground mining and, coupled with mine ventilation requirements, is a major determinant of width of working spaces, operations at the mining face, and eventual subsidence. Mine roof control is a nonending task that must be continued for the life of the mine. Hence, ground control measures may frequently be the largest single cost item in the development and actual production of underground coal mines (1). In order for mine roof predictive models to be effective, in-situ studies associated with the geology of the immediate roof and floor, strength properties, and stress states are needed as basic inputs. The basic thrust of this study is to examine the geometry and associated failure parameters of roof falls in a West Virginia coal mine, mining in the Upper-Freeport Coal Seam (Pennsylvanian age), to establish such a basic data bank and to determine if predictive relationships exist between roof fall geometry and associated mine roof failure parameters.

Geometry of Roof Falls

The basic geometry or shape of a roof fall depends greatly upon the stresses placed on the roof and floor (2,3,4). Laminar and dome-shaped falls are basically the result of tensile stresses and associated geological features or deficits in the roof strata (Fig. 1). These geometries are characterized by low horizontal stresses, incompetent floor and ribs as compared to the mine roof, jointed roof and ribs, and beds in the roof sagging independently of one another. A major difference between laminar and dome-roof falls is the location of the intersection of the separation planes. If the separation planes intersect on a bedding plane, laminar roof falls may develop; if separation planes intersect inside a bed, a dome-shaped roof fall geometry may develop as a result of high compressional stresses (Fig. 1). They are usually characterized by high horizontal stresses, which are common in the Eastern Kentucky Coal Field, large amounts of overburden, thin immediate roof beds, and very competent floor and ribs as compared to the immediate roof. Under these conditions the separation planes usually will intersect at some point in the immediate roof and form arched-shaped roof falls.



1. Basic Geometrics Associated with Common Roof Falls, in Appalachian Coal Mines. Note, the Letters A, B, and C Denote Dome, Arch, and Laminar Shaped Roof Falls, Respectively. Modified from Caudle (2).

Methods

A total of 21 roof falls were described at a particular mine site in the Upper Freeport Coal Seam located in West Virginia. Propriety purposes prevent disclosure of the exact location of the mine site. Basic descriptive statistics, relative, absolute, and cumulative frequencies and multiple linear regression analysis techniques were utilized to describe the relationship of selected parameters associated with mine roof falls with the size and geometry of coal mine roof failures.

Results and Discussion

Tables 1 and 2 summarize the descriptive statistics and frequency counts, relative frequencies and cumulative frequencies, respectively, for selected engineering or geological parameters studied. Figures 2 through 8 graphically portray distributions of selected variables. As illustrated in Table 1, the averages

TABLE 1. Descriptive Statistics for Selected Mine Roof Fall Parameters Studied.

Parameter	Mean	Variance	Standard Deviation	Kurtosis	Skewness
THINLAY (inches) N = 21	0.168	0.045	0.212	12.542	3.337
ROOF HT (feet) N = 21	9.390	69.166	8.317	5.243	2.316
STRATA 2 (feet) N = 19	6.020	38.563	6.210	13.771	3.544
STRATA 3 (feet) N = 10	2.144	0.639	0.799	0.437	0.559
STRATA 4 (feet) N = 2	1.340	0.003	0.057	0.000	0.000
LENGTHA (inches) N = 19	68.842	29.474	5.429	-0.718	-1.170
SPAN (feet) N = 21	18.340	3.619	1.902	1.593	1.156
OPENVER (feet) N = 21	8.884	1.155	1.075	-0.525	-0.651

Note. N denotes number of valid statistics used in arriving at the stated descriptive statistics.

TABLE 2. Frequency Counts, Relative Frequencies, and Cumulative Frequencies for the Engineering or Geological Parameters Associated with Mine Roof Falls Studied.

Parameter Label or Value		Absolute Frequency	Relative Frequency (%)	Adjusted[a] Cumulative Frequency (%)
WATER CONDITION				
YES		7	33.3	33.3
NO		14	66.7	100.0
	TOTAL	21	100.0	

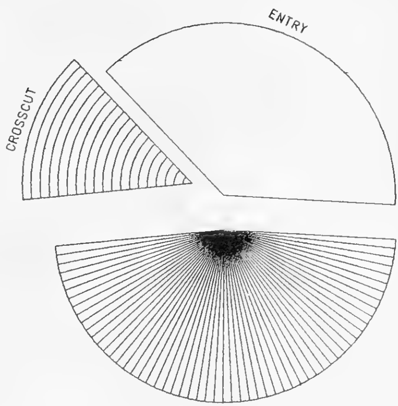
[a] Adjusted cumultive frequency for the exclusion of missing cases or data values.

Continued)

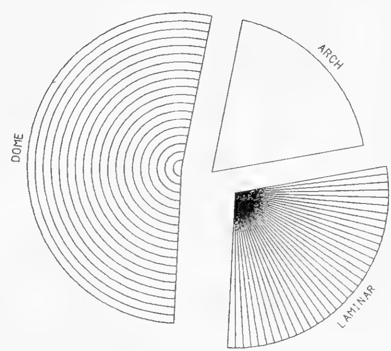
Table 2 continued

LOCATION OF MINE ROOF FALL			
ENTRY	8	38.1	38.1
CROSSCUT	3	14.3	52.4
INTERSECTION	10	47.6	100.0
TOTAL	21	100.0	
TYPE OF ROOF SUPPORT SYSTEM BEFORE ROOF FALL OCCURRENCE			
RESIN BOLTS	19	90.5	90.5
NOT SUPPORTED	2	9.5	100.0
TOTAL	21	100.0	
TYPE OF ROOF SUPPORT SYSTEM AFTER INITIAL ROOF FALL OCCURENCE			
RESIN BOLTS	12	57.1	57.1
CRIBBS	3	14.3	71.4
CANOPY	6	28.6	100.0
TOTAL	21	100.0	
SHAPE OR GEOMETRY OF MINE ROOF FALLS			
ARCH	4	19.0	19.0
DOME	11	54.4	71.4
LAMINAR	6	28.6	100.0
TOTAL	21	100.0	
PRESENCE OF CRACKS IN ROOF TOP			
YES	5	23.8	23.8
NO	16	76.2	100.0
TOTAL	21	100.0	
PRESENCE OF SLOUGHING OF COAL RIBS			
YES	16	76.2	76.2
NO	5	23.8	100.0
TOTAL	21	100.0	

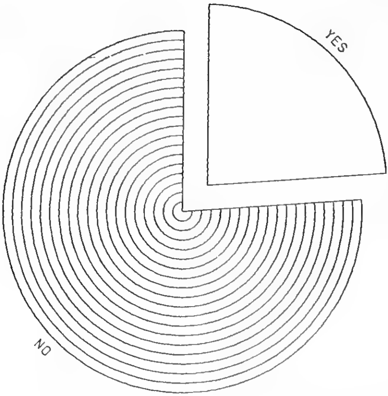
for the parameters studied are: thinnest immediate roof layer is 0.168 in. (0.427 cm), maximum roof height (9.39 ft, 2.86 m), height to second roof horizon or break-plane above the roof line (6.02 ft., 1.83 m), vertical height to fourth roof horizon or break-plane above the roof line (1.34 ft., 0.41 m), length of roof bolts after the roof fall (68.84 in., 1.75 m) span of mine entry (18.34 ft., 5.59 m), and vertical opening of entry (8.88 ft., 2.71 m). Presented in Table 2 and graphically presented in Figures 2 through 8 are the frequencies of selected parameters studied in association to roof falls. The majority of falls showed no presence of water (66.7 per cent), occurrence in intersections (47.6 per cent) and entries (38.1 per cent), used resin bolts after roof fall (57.1 per cent), dome-shaped roof falls (54.4 per cent), no presence of cracks in roof top after fall occurrence (76.2 per cent), and presence of rib sloughing (76.2 per cent).



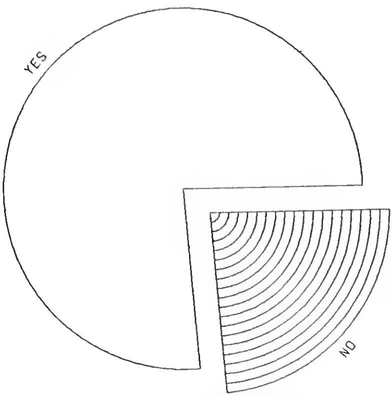
2. Graphically Depicted Distribution of Location of Mine Roof Falls Studied (Entry, Crosscut, and Intersection).



3. Graphically Depicted Distribution of Geometry of Mine Roof Falls Studied (Dome, Arch, and Laminar Shaped).



4. Graphically Depicted Distribution of Presence of Cracks in Mine Roof Falls Studied After Initial Failure (Yes or No).



5. Graphically Depicted Distribution of Sloughing of Coal Ribs Associated with Mine Roof Falls Studied (Yes or No).

Table 3 is the explanatory summaries of the full and restricted regression models, with accompanying regression coefficients and related hypotheses the models test, for the statistically significant relationships found in the present study. Summaries of the hypothesis testing among selected roof-fall parameters and the criterion variables of maximum roof fall height, height to second horizon from roof line, and

TABLE 3. Summary of Results of Selected Hypothesis, Illustrating Basic Multiple Linear Regression Terminology, Testing for Relationships Among the Mine Roof Fall Parameters Studied.

Explanation of Models	Models	df n/ df d	R^2	Alpha	F-Ratio	Prob.	Sing.
Model 1:							
ROOFHT = 22.22500U -7.70071 WATER + E	Full		0.20005				
		1/19		0.05	4.75155	0.0421	S*
Model 99:	Restr.		0.0				
ROOFHT = 22.22500U + E							
Hypothesis: The variable presence of water accounted for a statistically significant amount of variance in predicting maximum roof fall height.							
Model 2:							
ROOFHT = 2.94592UU + 1.10594 STRATA 2 + E	Full		0.05131				
		1/17		0.05332	1710455	0.0000	S**
Model 99:	Restr.		0.0				
ROOFHT = 2.04592U + E							
Hypothesis: The variable height to second horizon of roof strata accounted for a statistically significant amount of variance in predicting maximum roof fall height.							
Model 3:							
STRATA 2 = 0.8895U + 1.53267 STRATA 3 + E	Full		0.39433				
		1/8		0.05	5.20851	0.0519	S*
Model 99:							
STRATA 2 = 0.88895U + E	*Restr.*		*0.0*				
Hypothesis: The variance height to third horizon of roof strata accounted for a statistically significant amount of variance in predicting height to second horizon of roof strata.							

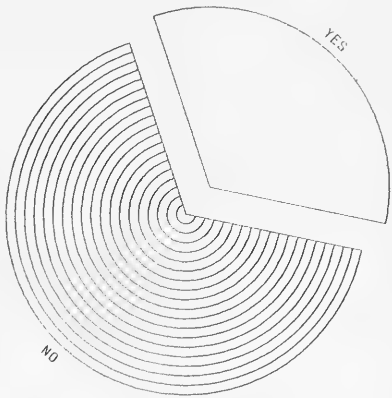
Table 3 continued

Model 4:						
SHAPE =						
7.4545U	Full	0.27802				
+ .42727						
LOCATION + E						
	1/19		0.05	7.31639	0.0140	S**
Model 99:						
SHAPE =		0.0				
0.74545U						
+ E Restr.						
Hypothesis:						
The variance location of roof fall in intersections accounted for a statistically significant amount of variance in predicting dome-shaped roof falls.						
Model 5:						
SHAPE =						
0.042866U	Full	0.21039				
-1.37143						
LENGTHA + E						
	1/17		0.05	4.52961	0.0482	S**
Model 99:						
SHAPE =		0.0				
0.04286U						
+ E Restr.						
Hypothesis:						
The variable length of roof bolts after the initial roof fall for resupport accounted for a statistically significant amount of variance in predicting dome-shaped roof falls.						

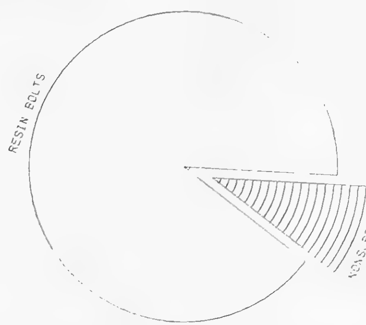
* Significant at the 0.05 level for a two-tailed, nondirectional test.

** Significant at the 0.01 level for a two-tailed nondirectional test.

shape or geometry of mine-roof falls studied are found in Table 4. As evident in the tables, only 6 hypotheses out of a total of 45 were found to be statistically significant for a two-tailed, non-directional test at 0.05 or 0.01. Both parameters, presence of water and height to second break horizon of roof strata above the roof edge were found to be statistically significant in predicting maximum roof height. However, no corrections were made to correct he decision criteria for multiple comparisons, since it was decided to maximize the possibility of detecting difference if they occurred. The parameter, presence of water, accounted for 20 per cent of the explained variance ($p = 0.0421$) in discriminating maximum roof height above the roof line. In general, a greater presence of water was associated with higher roof falls, as is to be expected, due to the greater hydrostatic pressure causing roof layers to separate and eventually fail. In addition, height above the roof line to the second horizontal strata of the roof fall accounted for over 95 per cent of the explained variance in predicting maximum roof fall height ($p = 0.0000$). Thus, higher vertical heights to the second roof strata were associated with greater overall roof heights. However, there appeared to exist no statistically significant relationships in discriminating or predicting maximum roof height and the following variables: location of the roof fall, vertical height to third roof strata in mine roof, spacing of the bolts before the fall, type of support before fall, spacing of the bolts after the fall, type of support after fall, length of bolts before the fall, length of bolts after the fall, span of mine entry, cracks, sloughing of coal ribs, vertical opening of the entry, and thickness of thinnest, immediate, mine roof-rock layer.



6. Graphically Depicted Distribution of Presence of Water Associated with Mine Roof Falls Studied (Yes or No).



7. Graphically Depicted Distribution of Type of Roof Support System in Use Before Failure of Mine Roof Falls Studied (Resin Bolts and Non-Supported or Failed during Cutting).

Table 4 summarizes F-ratios, probability levels, R^2 for both full and restricted models, degrees of freedom-numerator, degrees of freedom-denominator, and significance for each research hypothesis testing discriminative relationship among height to second horizon or break-plane from roof line and associated parameters. Of the 15 hypotheses tested, only 2 were found to be statistically significant. Again, maximum roof height above roof line was found to be significant. However, the height to the third break-plane or roof rock strata was found to account for a statistically significant amount of explained variance (39.43 per cent), in predicting height to second strata of mine roof fall (p = 0.0519). Both variables were found to be positively correlated. The other parameters, similar to those tested with the other dependent variables, were also not found to be statistically significant.

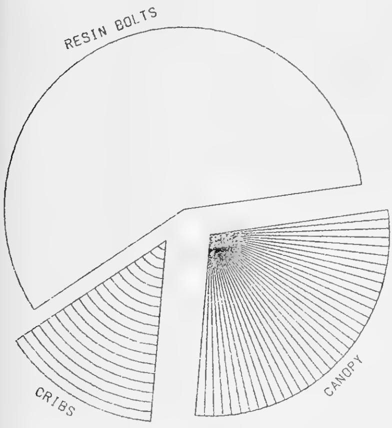
TABLE 4. Summary of F-Ratios, Probability Levels, R^2 for Both the Full and Restricted Models, Degrees of Freedom-Numerator, Degrees of Freedom Denominator, and Significance for Each Research Hypothesis Testing Discriminative Relationships Among Selected Failure Parameters and Geometry of Mine Roof Falls.

Independent Variable(s)	R^2_f	R^2_r	df	F	Probability	Sig.
Dependent Variable = MAXIMUM ROOF FALL HEIGHT						
WATER	0.20005	0.0	1/19	4.75155	0.0421	S*
LOCATION	0.04062	0.0	1/19	0.80437	0.3810	NS
STRATA2	0.95131	0.0	1/17	332.17104	0.0000	S**
STRATA3	0.32173	0.0	1/8	3.7943	0.0873	NS
SPACINB	NOT TESTABLE DUE TO INVARIANCE					
SUPPORB	0.06475	0.0	1/19	1.31540	0.2657	NS
SPACINA	NOT TESTABLE DUE TO INVARIANCE					
SUPPORA	0.14715	0.0	1/19	3.27835	0.0860	NS
LENGHTA	0.00020	0.0	1/17	0.00338	0.9543	NS
LENGTHB	NOT TESTABLE DUE TO INVARIANCE					
SPAN	0.00175	0.0	1/19	0.03330	0.8571	NS
CRACKS	0.02283	0.0	1/19	0.44382	0.5133	NS
SLOUGH	0.00001	0.0	1/19	0.00017	0.9897	NS
OPENVAR	0.10162	0.0	1/19	2.14919	0.1590	NS
THINLAY	0.00014	0.0	1/19	0.00274	0.9588	NS
Dependent Variable = HEIGHT TO SECOND BREAK HORIZON ABOVE ROOF LINE						
WATER	0.08409	0.0	1/17	1.56082	0.2285	NS
LOCATION	0.05477	0.0	1/17	0.98511	0.3349	NS
STRATA3	0.39433	0.0	1/8	5.20851	0.0519	S*
ROOFHT	0.95131	0.0	1/17	332.17104	0.0000	S**
SPACINB	NOT TESTABLE DUE TO INVARIANCE					
SUPPORB	0.01028	0.0	1/17	0.17657	0.6796	NS
SPACINA	NOT TESTABLE DUE TO INVARIANCE					
SUPPORA	0.05702	0.0	1/17	1.02804	0.3248	NS
LENGHTA	0.06623	0.0	1/16	1.13485	0.3026	NS
LENGTHB	NOT TESTABLE DUE TO INVARIANCE					
SPAN	0.00085	0.0	1/17	0.01438	0.9059	NS
CRACKS	0.09725	0.0	1/17	1.83127	0.1937	NS
SLOUGH	0.07592	0.0	1/17	1.39661	0.2536	NS
OPENVER	0.05081	0.0	1/17	0.91000	0.3535	NS
THINLAY	0.00437	0.0	1/17	0.07459	0.7715	NS
Dependent Variable = GEOMETRY (DOME SHAPED) OF MINE ROOF FALL						
WATER	0.00455	0.0	1/19	0.8676	0.7715	NS
LOCATION	0.27802	0.0	1/19	7.31639	0.0140	S**
STRATA2	0.11779	0.0	1/17	2.26980	0.1503	NS
STRATA3	0.09275	0.0	1/8	0.81788	0.3922	NS
SPACINB	NOT TESTABLE DUE TO INVARIANCE					
SUPPORB	0.11579	0.0	1/19	2.48810	0.1312	NS
SPACINA	NOT TESTABLE DUE TO INVARIANCE					
SUPPORA	0.00303	0.0	1/19	0.05775	0.8127	NS
LENGTHA	0.21039	0.0	1/17	4.52961	0.0482	S*
LENGTHB	NOT TESTABLE DUE TO INVARIANCE					
SPAN	0.02203	0.0	1/19	0.42797	0.5208	NS
CRACKS	0.01920	0.0	1/19	0.37203	0.5491	NS
SLOUGH	0.13136	0.0	1/19	2.87336	0.1064	NS
OPENVER	0.06487	0.0	1/19	1.31803	0.2652	NS
THINLAY	0.05389	0.0	1/19	1.08221	0.3113	NS

*Denotes statistical significance of 0.05 level for a nondirectional test.

**Denotes statistical significance of 0.01 level for a nondirectional test.

Also found in Table 4 is a summary of the hypothesis testing and model comparisons in discriminating the shape of mine roof falls (dome-shaped) and selected parameters. Only 2 of the 15 hypotheses were found to be statistically significant at the 0.05 level. The parameters location of the roof fall (intersections) and length of bolts used after the fall were found to be significantly correlated to the geometry of the falls. As illustrated in Table 3, location of the falls in intersections accounted for a significant amount of explained variance (27.80 per cent) in discriminating dome-shaped roof falls. Hence, a greater occurrence of dome-shaped falls are associated with intersections. When considering the nature of intersections and the stress concentrations equally spaced on the abutments, this conclusion is supported by previous findings (3,5). In addition, the length of bolts used after the fall were significantly related ($p = 0.0482$) in discriminating dome-shaped falls (Table 3). The relationship is negatively correlated, thus shorter length of roof bolts used to resupport the fall were associated with a greater occurrence of dome-shaped roof falls. Since many of the falls are several generations in reoccurrence, shorter bolts used to resupport the fall may cause a more uniform and relatively shallow roof horizon to fall, forming an equidimensional, dome-shaped geometry. The other 13 parameters previously tested in Table 4 were not found to be statistically significant in discriminating roof fall geometry.



8. Graphically Depicted Distribution of Type of Roof Support System used After Initial Failure of Mine Roof Falls Studied (Resin Bolts, Canopy, and Cribs). Note, Usually the Use of Canopy or Cribs also Entail the Combined Use of Roof Bolts.

Conclusion

Hence, as evident in an inspection of the overall findings, a basis for a profile of mine-roof falls associated with the Upper Freeport Coal Seam, located in West Virginia, can be established. With this data base established, coupled with future studies of mine roof falls describing similar characteristics, predictive models for use in forecasting and eventual prevention of major ground control problem areas may be attempted in Appalachian coal mines.

Acknowledgements

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Dimensional Analysis of Coal Pillars: An Application of Cost-Sensitive Mine Planning Principles to a Southeastern Kentucky Mine

Alan D. Smith

Coal Mining Administration, College of Business
Eastern Kentucky University, Richmond, KY 40475

ABSTRACT

The cost-sensitive mine planning process involves spatial projection of the geological and economical conditions that will have the greatest impact on cost and coal quality for a particular mine site. A comparison of actual, maximum safety, and recommended pillar dimensions and their associated factors of safety, based on the theories of Salamon, Salamon and Munro, Bieniawski, Bieniawski, Rafia, and Newman, and Skelly, Wolgamott, and Wang, which cover a broad spectrum of mining conditions, were made for a small coal mine near Leatherwood, Kentucky in southeastern Kentucky. From a preliminary and economic forecasting viewpoint, the traditional 40-foot square pillar appears to be too large, at least from the standpoint of overburden thickness and common lithologic characteristics found in the eastern Kentucky coal fields. The alternative system of room-and-pillar mining with 34-foot pillars and conservative 20-foot entries would allow for 5 entries to be developed in the same area of coal, which would result in an increase of 320 tons of raw coal per move up. Assuming the price of coal is $32 per ton and standard coal preparation losses at 20 per cent, additional revenue of about $8,200 per move up would be realized. This increase in cash flow is especially important in developmental stages of underground mining, due to the shortage of cash flows.

INTRODUCTION

Cost-Sensitive Mine Planning

Cost-sensitive mine planning systems have been developed to help coal companies design underground mines that will recover coal reserves in the most profitable method. Information obtained from borehole logs, local mines, mining equipment manufacturers, and previous mining experience should be used in the mine planning process. According to Ellison and Scovazzo (1), cost-sensitive mine planning assumes that the physical and economic conditions that will have the greatest impact on cost and coal quality can be predicted accurately enough to assist mine planners in making decisions. In the planning process, many maps, such as coal seam thickness, expected roof caving conditions, geologic lineaments, roof shale thickness, distance to the first sandstone, overburden thickness, underclay thickness, as well as a host of other factors, can be generated as overlays on each other to assist planners in selecting appropriate locations and orientations for the portal, mains, submains, and longwall panels. The thrust of the present study is to examine overburden and strength characteristics of a small mine in southeastern Kentucky and determine minable pillar widths, according to 3 popular pillar strength theories, based upon depth of overburden over the proposed mine layout. Assuming other factors are predictable in the location of pillars, a generalized plan of anticipated pillar widths can be spatially oriented and according costs or benefits be assessed.

Pillar Design Theory

Coal pillars are solid coal left in-situ to support entires, sections, panels, and prevent surface subsidence. Since pillars are left for support, their failure greatly contributes to ground control problems. Although pillars are extensively used for many purposes as part of the multiple design elements in underground mining, no single design method or pillar strength formula has been accepted in the United States. As suggested by Babcock, Morgan, and Haramy (2), several equations for mine pillar design have been developed since the 1830s. Most of these equations are essentially of the same nature, using pillar width to height relationships. Yet, in spite of considerable research conducted, especially since the 1900s, mine pillar dimensions in this country continue to be predominately selected on the basis of precedent or practical experience. While pillars in coal mines are mainly associated with room-and-pillar systems, their use as support elements in development entries for longwall and shortwall systems are an integral part of their design. In fact, these development entries, being service entries for such vital services as ventilation, power distribution, escapeways, haulage avenues, are the main pulse of the daily routine in underground mining and, hence, must be maintained in a safe and adequate manner (3).

The design of pillars involves the determination of proper size pillars for certain locations in line with the expected load history. The data generally required in the design of pillars are: (1) the expected load history, including premining pillar loading and mining-induced abutment pressure; (2) stress distribution within the pillar; (3) pillar strength; (4) interaction between roof, pillar, and floor.

Some types of mining, compared to mining bedded-deposits, require different shapes of pillars and some differences in the pillar geometry. Bedded deposits, such as coal and limestone, may require the height of pillars to vary over a considerable range, from as low as 2 to a high of 80 feet. However, in ore bodies, the height variation may even be greater. In addition, nearly all materials show a creep effect with time when placed under varying magnitudes of stress. In many cases, the ultimate effect of creep in coal is difficult, if not impossible, to forecast. However, the technology of designing coal pillars is presently further advanced than similar technology in designing pillars for other minerals. For these and other reasons, 3 pillar formulas have been selected for use in this study in relating pillar strength to its geometry and structural material in the mine site. The 3 pillar formulas cover a broad enough spectrum of conditions to be of general applicable value. The formulas to be used in the present study were derived by Salamon (4), Salamon and Munro (5), Bieniawski (6), Bieniawski, Rafia, and Newman (7), and Skelly, Wolgamott and Wang (8).

The design of a room and pillar layout necessitates the knowledge of the size of coal pillars that will act as a permanent support to the immediate roof strata until the depillaring operation stage, if any. Many investigations have been carried out in studying the most stable dimensions of a pillar. Salamon (4), Salamon and Munro (5) developed an empirical formula by which the approximate strength of a pillar may be determined. Salamon et al. (loc. cit.) based this formula upon back-analysis derived from underground information and performance of stable and collapsed, or failed, pillars:

$$Sp = \frac{1320\ W^{0.46}}{H^{0.66}}$$

Where Sp is the pillar strength, W is the width of the pillar, and H is the height of the coal seam in inches. Of course, stable coal pillars are likely to deteriorate due to weathering or creep; therefore, it is necessary to take into account the strength and time dependent properties of the coal seam and surrounding strata. This process of coal pillar deterioration may be accelerated if undermined by previous room and pillar workings. In addition, the stability of the immediate roof strata may be lessened by deterioration. Room and pillar designs are particularly sensitive to the ability of the roof of the entries to be self-supporting (9). According to Bieniawski (6) and Bieniawski, Rafia, and Newman (7), the strength of a coal pillar may be approximated by:

$$Sp = 650\,(0.64 + 0.36\ W/H)$$

Again, the symbols are the same as previously defined for Salamon's equation. Skelly et al (8) developed the following equation for predicting the strength of the pillar:

$$Sp = 650\,(0.78 + 0.222\ W/H)$$

This formula is fairly similar to Bieniawski's, but reflects more of an attempt to modify Bieniawski and Salamon's work to suit the conditions found in the Appalachian coal fields.

Upon computing a pillar strength by the above formulas, they can be compared to the actual calculated stress applied to a particular pillar, and a factor of safety can be determined. A factor of safety is simply the stress on the pillar divided into the strength of the pillar. Salamon recommended a factor of safety ranging from 1.3 to 1.9, with 1.6 being associated with a stable pillar; Bieniawski et al. and Skelly et al. collectively recommended 1.0 to 3.0, with 2.0 being the factor of safety associated with a stable pillar. Of course, there are ranges in the factors of safety, since different mining conditions may warrant more conservative or more liberal pillar dimensions. However, the smaller the factor of safety, the smaller the coal dimension, and the greater overall coal recovery.

The determination of the actual stress on the pillar can easily be determined, assuming tributary loading and not pressure arch theory, by the following formula:

$$\sigma_p = \frac{\gamma\ d\ (We + Wp)^2}{Wp^2}$$

Where σ_p is the actual stress on the pillar, γ is the weighted density of overburden over the coal pillar, d is the depth to the top of the coal seam, We is the width of the entries or roof between pillars, and Wp is the width of a square pillar.

The above formula can be modified for a rectangular pillar by using the length of the pillar as well:

$$\delta_p = \frac{\gamma\, d\, (We + Wp)\, (We + Lp)}{(Wp)\, (Lp)}$$

Where the only new term, Lp, is simply the length or longest dimension of the rectangular pillar.

METHOD

Study Area

A small southeastern Kentucky coal mine near Leatherwood, Kentucky is owned and operated by a large mining company that will remain unidentified for proprietary purposes, was studied to apply the cost-sensitive mapping procedures suggested by Ellison and Scovazzo (1). A typical small Kentucky coal mine is usually shallow (between 200 to 500 feet (60 to 150 m) of vertical overburden) and of relatively short duration. Therefore, the motive is to derive as much minable coal in as short a time as possible. This small mine is operated in a thin coal seam, ranging between 40 and 72 inches, with a sandstone/siltstone partition of approximately 12 inches in parts of the mine. The coal seam is essentially flat-lying, with some gentle folds causing a maximum in the seam's elevation of 25 feet above and 20 feet below the seam's elevation at the driftmouth or mine entrance. In addition, the seam dips slightly to the west. The overburden is very shallow in that the deepest cover is 350.2 ft. (106.74 m) in thickness and the average depth is 265.6 ft. (80.95 m). The immediate roof is sandstone, which is considered a hard and competent strata; unfortunately, in this mine it is highly fractured and weakened. The mine has a predicted life expectancy of 3 to 5 years for development mining and 3 to 5 years of retreat mining.

Mining Methods to Produce Coal

A large mining company that owns and operates the small mine uses the continuous mining method in the room-and-pillar system. Continuous mining reduces the mining cycle compared to that of the conventional method by removing some pieces of the equipment and associated miners to operate it, thus increasing productivity. The continuous mining method uses one machine to break the coal loose where the conventional method uses several machines, such as the horizontal drill and front-end loader or load-haul-dumpers (LHD). The continuous miner has teethed drums that rotate against the coal and breaks it up. The broken coal then travels to the tail of the miner via a chain conveyor and is loaded onto a shuttle car. The shuttle car then travels to a belt conveyor and unloads the coal. The beltline then take the coal to the driftmouth. However, the shuttle car must travel a route which is designed to minimize the number of corners turned and, hence, the total distance traveled. Since the continuous miner can cut coal fast enough to keep 2 cars busy, these cars must be scheduled to cut down on idle time and avoid potential accidents. Once the miner moves on to its next cut, a roof bolter is moved in to install immediate roof supports. Usually, 2 roof bolters are required to keep up with the continuous miner in this mine. The bolting machine drills holes into the immediate roof to a depth which reaches a stronger layer of rock or anchor horizon. Roof bolts vary in lengths from 28 inches (0.71) to 8 feet (2.44 m) and come in 2 general types. The first type uses an expanding shell that flares out as the bolt is torqued against the roof. This flaring creates the pressure that causes the bolt to hold up the immediate roof through tension. The second type of bolt uses resin to create the hold between it and the rock strata. As the resin flows into the cracks in the rock it solidifies and this contact creates the tension needed. Of course, the resin bolt is more expensive, and is employed in very bad roof top areas for better ground control.

The mining system used is that of room-and-pillar. The room-and-pillar mining method is traditionally used in the many small coal mines of southeastern Kentucky. In room-and-pillar mining, entries are driven into the coal seam at its outcrop. As the entries develop, crosscuts are made to join the entries for ventilation and coal haulage purposes. The number of entries varies in typical room-and-pillar mines from 2 to 8 or more. Two entries are minimally required to get proper ventilation flow with one entry being used for intake air and the other for exhaust air. However, most mines in the area, and including the one under study, use one entry for a track to take in men and supplies and another for the beltline to come out. These entries require the presence of workers and, hence, cannot be exposed to exhaust from the coal face, 3 intake entries are usually used. The number of entries increases once the mine develops further to increase productivity through the prevention of delays in the mining cycle. The action of driving entries and crosscuts leaves pillars or columns of coal to support the roof. Room-and-pillar mining assumes the tributary load concept, although the pressure arch theory can be applied in selected areas to relieve part of the load on main and submain pillars. Under the tributary load concept, each pillar is assumed to uniformly support the weight of the rock overlying the pillar and midway the span of the entry or room on each side of the pillar.

Pillar Dimensional Design

An average depth of overburden was assumed to be 265.6 feet (80.95 m), average density of overburden of 160 lbs/ft^3 ($2.86\ g/cm^3$, the standard often used in association with sedimentary lithologies found in Kentucky), coal seam height of 5 feet (1.52 m), width of entries to be 20 feet (6.10 m), a calculated overburden or geostatic pressure of 657.36 lbs/in^2 on a 40 ft. (12.19 m) pillar in performing a pillar dimensional analysis. Factors of safety and recommended pillar sizes were also calculated, using the theories of Salamon et al. (5), Bieniawski (6), Bieniawski et al. (7), and Skelly et al. (8).

RESULTS AND DISCUSSION

Pillar Dimensional Analysis and Associated Factors of Safety

Once having the mean, actual stress on the pillars presently used in the mine near Leatherwood, Kentucky calculated, the pillar strength can then be calculated, according to the previously discussed design equations. The corresponding factors of safety can be calculated, since, as stated earlier, the factor of safety is simply the relationship of pillar strength, whether based on ultimate strength or progressive failure criteria, to the mean, actual vertical stress acting on the pillar. Table 1 summarizes the various factors of safety associated with a 40-foot square pillar, maximum safety, and recommended for safe-rigid pillar according to the theories of Salamon (4), Salamon and Munro (5), Bieniawski (6), Bieniawski, Rafia, Newman (7), and Skelley, Wolgamott, and Wang (8). The figures in the table were based on the qualifying assumptions previously stated in the methods section. As evident from a quick inspection of the table, the 40-foot pillar is overdesigned, since the associated factors of safety are noticeably larger than the factors of safety for a pillar of maximum safety for all but one theory (8). The factors of safety for a recommended safe-rigid pillar, based on the tributary load concept is lower than the actual pillars' factors of safety for all 3 theories. Since there is a direct relationship between pillar width and factors of safety, the larger factors of safety represent unnecessary waste of coal that could have been mined, instead of left for support and ground control. Of course, this means that by using a standard and oversized pillar, based on precedent or practical experience, a much reduced coal recovery results and, hence, diminished profits. To find the proper size pillars under these conditions, the pillar dimensions should be recalculated at the recommended factors of safety for each theory explored and back-calculated the optimum pillar dimensions to maximize coal recovery.

TABLE 1. Factors of Safety Associated with 40 Foot Square Pillars, Maximum Safety, and Recommended for Safe-Rigid Pillars.

Pillar Design Theory	Factors of Safety For a 40-Foot Square Pillar[a]	Factors of Safety For Maximum Safety Pillar	Factors of Safety For Recommended Safe-Rigid Pillar
Salamon (4), Salamon and Munro (5)	3.79	1.9	1.6
Bieniawski (6), Rafia, and Newman (7)	3.48	3.0	2.0
Skelley, Wolgemott, and Wang (8)	2.53	3.0	2.0

[a]Factors of safety is equal to the ultimate strength of the pillar (S_p) divided by the actual stress of the pillar δ_p), assuming the ultimate strength approach as defined by Peng (10).

The trial and error solutions for pillar dimensions, using the factors of safety for maximum safety and recommended dimensions can be found in Table 2. The recommended pillar dimensions range from a high of 34 feet (10.36 m) for Skelly et al. (8) and a low of 21 feet (6.40 m) Salamon (4) and Salamon and Munro (5). Of course, these pillar dimensions may be enlarged to counter the effects of deterioration resulting from exposure to moisture in the ventilated air as well as other factors. However, this mine, as well as similar mines in southeastern Kentucky are of limited duration, therefore the deteriorating effects of moisture in the atmosphere will have minimal effect. However, from a preliminary and economic forecasting viewpoint, the traditional 40-foot square pillars that this mining company is using in this particular mine appears to be too large, at least from the standpoint of overburden thickness. This statement is further evidenced by the absence of noticeable numbers of mine roof falls; thus, this is another indication that the pillar dimensions are too conservative in the overall mine layout.

TABLE 2. Comparison of the Actual, Maximum Safety, and Recommended Dimensions for a Square Pillar at the Leatherwood Mine.

Pillar Design Theory	Square Pillar Dimensions in Feet (Meters)		
	Actual	Maximum Safety	Recommended
Salamon (4), Salamon and Munro (5)	40 (12.19)	24 (7.32)	21 (6.40)n
Bieniawski (6), Rafia, and Newman (7)	40 (12.19)	36 (10.97)	28 (8.53)
Skelley, Wolgemott, and Wang (8)	40 (12.19)	45 (13.72)	34 (10.36)

Extraction Ratio Comparison and Cost/Benefit Sensitive Analysis and Planning

A simple cost/benefit analysis can be performed to illustrate the amount of money involved in applying the principles of cost-sensitive planning. Presently, based on 40-foot pillars, the coal extraction ratio is approximately 56 percent. The extraction ratio for a 34-foot pillar, based on the largest recommended pillar dimension from the calculations utilizing Skelley et al. (8), is 60 percent. Of course, if the width of span of the entries between pillars were allowed to increase, then the corresponding extraction ratio would increase drastically.

Although the percentage increase appears to be small, the tonnage of coal recovered will have a significant impact on tonnage produced. The 40-foot pillar has a volume of coal of 8,000 ft.^{3} (226.53 m^3) while the 34-foot pillar has a volume of 5,780 ft.^{3} (163.67 m^3). Thus, a difference of 2,220 ft.^{3} (62.86 m^3) in the 40-foot pillar that could be mined by utilizing a system of 34-foot pillars. Assuming coal has a unit weight or density of 80 lbs/ft^3 (1.43 g/cm^3) and multiplying this by the difference of 2,220 ft.^{3}, a total weight of raw coal of 177,600 lbs. or 88.8 tons per pillar is available, if the entries are allowed to expand. However, if using the original entry system of 40-foot pillars and maintaining the same 20-foot entries with a four-entry system means 200 linear feet (61 m) of coal from rib to rib is being mined. The alternative system of 34-foot pillars would allow for 5 entries of 20 feet each in the same area of coal. The 4-entry system will provide 1,120 tons per move up and five-entry system will provide 1,440 tons per move up which results in a difference of 320 tons per move up. Assuming the price of coal is approximately $32 per clean ton and a standard coal preparation recovery of 80 percent, this would bring in $8,192 per move up during development mining. Once the development mining is finished the remaining coal is partially removed where possible by a process known as robbing or retreat mining. However, it is during development stage of mining that cash flows are a major problem, especially in the fluctuating coal markets of today. Hence, the additional revenue during this stage is of extreme importance, especially to the owners and operators of small coal mines, such as this one in Leatherwood, Kentucky.

CONCLUSIONS

As demonstrated in the preliminary analysis and discussion of recommended pillar dimensions, based on overburden thickness and common properties of rocks contributed to the eastern Kentucky coal fields, the mining company may be too conservative in its approach to its Leatherwood Mine. This point is well taken, since results obtained from all 3 diversed pillar-dimensional theories point to the same conclusion of oversized pillars. The overdesigning of pillars may be costly, as evident by the simple cost/benefit analysis previously illustrated, utilizing the principle of cost-sensitive planning. Hence, the current design of coal mine pillar pillars in southeastern Kentucky can be significantly improved by selecting a more appropriate pillar strength formula and more realistic safety factors. The state of rock mechanics and mining engineering is such that mine planners can be more effective in the overall desing of the pillar dimensions in advance of mining operations, development, and eventual production.

ACKNOWLEDGEMENTS

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Sunset as an Orientational Cue for a Nocturnal Migrant, the White-throated Sparrow (*Zonotrichia albicollis*).

James R. Pauly[2] and Blaine R. Ferrell

Western Kentucky University, Bowling Green, Kentucky 42101

Abstract

The possibility that nocturnal migrants use sunset as an orientational cue was explored using the white-throated sparrow (*Zonotrichia albicollis*) in a series of experiments conducted between 1 April and 24 April, 1981. Orientation tests were performed on the roof of the biology building at Western Kentucky University with birds assumed to be in proper physiological condition for migration. Birds exposed only to the night skies, birds isolated from all visual cues, and birds exposed to both day and night skies did not exhibit the northward directional preference appropriate for the spring season. However, white-throated sparrows exposed only to the sunset and tested in the absence of visual nighttime cues exhibited significant orientation northward. These data support the hypothesis that white-throated sparrows can use the sunset as an orientational cue.

Introduction

Various environmental cues are available for the orientation of migrating birds (1,2,3). The use of several orientational cues may increase the accuracy of a migrant's heading but confounds efforts to establish which cues are actually utilized. The possibility that nocturnal migrants use the position of the setting sun as an orientational cue was first suggested by Kramer (4). The casual observations of Kramer were followed by several field experiments that more strongly implicated the sunset as an important orientational cue to nocturnal migrants (5,6,7). In 1978, Frank Moore (8) provided more direct evidence that directional information derived from the sunset was used by a nocturnal migrant, the savannah sparrow (*Passerrulus sandwichensis*). Bingman and Able (9) performed similar experiments using white-throated sparrows (*Zonotrichia albicollis*) tested in an autumnal migratory condition. Although the data presented by these authors are supportive of the hypothesis of sunset as an orientational cue, their experimental protocol did not measure the orientational response of birds exposed only to the sunset and tested in the absence of night sky orientational cues. Therefore, the present study was carried out in order to investigate more rigorously the possibility that sunset is an important directional cue used by white-throated sparrows during spring migration.

Materials and Methods

During January and February, 1981, 38 winter-resident white-throated sparrows were captured by mist net or live traps in the vicinity of Bowling Green, Kentucky. Orientation tests were conducted on the roof of the biology building on the campus of Western Kentucky University from 1 April to 22 April, 1981. All birds were maintained indoors under 14L:10D before the test periods and were judged to be in a migratory seasonal condition based upon easily observed criteria, such as enlarged gonads, increased fat stores, and nocturnal unrest (*Zugunruhe*) (10). Locomotor activity was monitored using perches that rested on microswitches interfaced with an Esterline-Angus event recorder. Subcutaneous fat stores were examined visually weekly and gonad size was determined monthly by unilateral laparotomy.

Four treatment groups were established. Birds in one experimental group were exposed to the open night sky during the test period but were maintained in photoperiod chambers on the roof at all other times. In another experimental group, birds were placed in holding cages where they were exposed to the sun beginning one hour before sunset. Birds in this same group were denied exposure to the nighttime sky during the test period and maintained in photoperiod chambers at all other times. A third group of birds (Control Group 1) was ex-

[2]Present Address: Department of Biology, Marquette University, Milwaukee, Wisconsin 53233

posed to both sunset and the nighttime sky. Birds in the fourth group (Control Group II) were maintained in photoperiod chambers during the day and were denied exposure to the nighttime sky by a black plastic cover during the test period. In order to provide a stimulatory photoperiodic schedule, 15-watt fluorescent bulbs were attached to the holding cages located on the roof. Twelve Emlen funnels (i.e., 3 from each test group) were placed in an orientation chamber on each test night. The walls of the test chamber were lined with black plastic and extended 12 inches above the Emlen funnels, thus denying the test birds a view of landmarks on the horizon. Birds housed in one-half of this chamber were denied exposure to the night sky by an opaque black plastic cover. The half of the chamber that housed birds allowed exposure to the night sky was covered with a clear plastic in order to keep the treatments as consistent as possible. Birds were tested for two hours beginning at 1930 hours (i.e., approximately one hour after sunset), a time of night appropriate for the initiation of spring migratory flights.

The footprint method described by Emlen and Emlen (11) was used in tests for orientation. The test unit consisted of a blotter paper funnel which was supported by a cardboard funnel. The small ends of these funnels were placed in two-quart aluminum pans and the entire apparatus was covered by quarter-inch hardware cloth fastened to the aluminum pan. A slit cut in the lower side of each aluminum pan facilitated the insertion of foam ink pads into the test funnels. The pads were saturated with india ink on each night of use. A bird placed in the funnel thus was standing on an ink pad surrounded by outwardly sloping walls of blotter paper. The forward movement of a bird resulted in black footprints on the paper. It was the accumulation of these footprints that created the orientation record of a bird. A total of 144 bird-nights (i.e., 36 replications from each test group) of orientational data was generated. For statistical purposes, footprint records were quantified according to a method reported previously (11). Mean angular directions of activity were calculated and tested for significance according to the method described by Zar (12). Since white-throated sparrows breed throughout the northern United States and southern Canada, mean angular directions between 270 and 90 degrees were considered appropriate orientational choices for the spring season. Zero degrees represented due north.

Results and Discussion

Birds exposed to sunset only were the only ones that exhibited an appropriate directional choice that was statistically significant (Table 1 and Figure 1). The activity of this group was the lowest among all groups tested but this activity was precisely oriented.

Table 1. Analysis of orientation in White-throated Sparrows exposed to different celestial cues in spring.

Treatment	N[2]	R[3]	Total Footprint Activity (N_t) in Activity Units	Mean Angular Direction in Degrees	Compass Direction
Nighttime sky only					
Total	17	.093	89	185	SW
trial 1[1]	6	.338	96	289	NW
trail 2	11	.334	86	108	SE
Both sunset and nighttime sky (control I)	16	.237	132	105	SE
Neither sunset nor nighttime sky (control II)	9	.283	179	241	SW
Sunset only					
Total	11	.613	56	58*[4]	NE
trial	3	.756	43	37*	NE
trial 2	8	.529	61	28*	NE

[1] Orientation tests conducted prior to April 11, 1981 (trial 1) and orientation tests conducted after April 11, 1981 (trial 2).

[2] The number (N) of birds showing significant orientational activity.

[3] The length of the vector (R) determined from the sample mean of measurements (in degrees) on a circular scale.

[4]* Indicates significant directionality of orientation and significant footprint activity as determined by Raleigh's Test (Zar 1974).

The fact that birds exposed to daytime and nighttime skies did not orient consistently in the appropriate direction is not in accordance with reports of previous studies (9). Although we attempted to exclude extraneous light sources, such as horizon glow, through the orientation test chamber architecture, it is possible that these birds were directing their activity toward the glow created by the city lights of Bowling Green located southwest of the orientation test site. This supposition is supported by the fact that many birds exposed only to the night sky also chose this direction. Birds denied exposure to the night sky by a black plastic cover showed little tendency to orient in this direction.

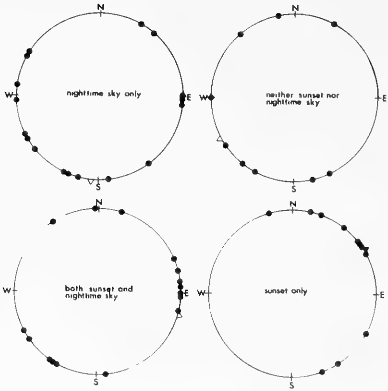

Figure 1. The mean angular directions of individual birds (closed circles) plotted about a circular scale with compass directions indicated by E (east), S (south), W (west), and N (north). Triangles represent group mean angular directions. Open triangles represent a non-significant directional choice and the shaded triangle (sunset-only group) represents a significant directional choice.

Results of this study do not indicate the use of magnetic cues in orientation by white-throated sparrows. If the earth's magnetic field was a source of orientational information, then correct orientational responses should have occurred consistently in all treatment groups. The fact that Emlen funnels are too small for a response due to geomagnetic fields might account for the observed lack of response. It has been reported that birds exhibit a weak response to geomagnetic cues when placed in Emlen funnels (13). Although results of this study do not support the concept that nocturnal migrants can use magnetic fields as orientational cues, our results do indicate that the position of the sun at sunset is in fact an important orientational cue used by a nocturnal migrant, the white-throated sparrow.

Acknowledgements

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A Convenient Apparatus for Microbiological Sampling of River Waters

John T. Lisle[1] and David N. Mardon[2]
Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

A compact water sampler for the collection of microorganisms from selected depths in both lentic and lotic waters is described.

INTRODUCTION

A prerequisite to quantitative studies of aquatic microbial populations is a specimen-sampling apparatus suitable for collecting from desired depths (2, 7). Various investigators and organizations have developed samplers according to their specific needs (1, 4, 5, 6, 7). However, each of these samplers has features which can restrict its application. Some problems within the above group of samplers are; capacity limitations, sterility of the sample container, lateral stability in lotic waters, unreliable collection of samples from specific depths, difficulty in the rapid replacement of broken parts, compact storage, and inconvenience or inability for varying the length of the sampler to allow collection at selected depths. The Eastern Kentucky University (E.K.U.) water sampler described below was designed to minimize these difficulties during the collection of microbial samples from the Kentucky River.

CONSTRUCTION OF THE E.K.U. MICROBIAL WATER SAMPLER

The collecting section of the sampler consists of a 0.6 m piece of 31.89 mm by 1.6 mm aluminum frame, bent to accommodate biochemical oxygen demand (B.O.D.) bottles or similar vessels up to 500 ml in capacity (Fig. 1a). This aluminum frame is fastened to one end of a 0.9 m section of polyvinylchloride (PVC) tubing via two 63.1 mm by 4.8 mm round head bolts, lock washers and nuts (Fig. 1c). The bottle is held onto the frame by a stainless steel flask holder and an adjustable stainless steel hose clamp (Fig. 3c and 4c). The removable flask holder, which may be selected for any size flask from 25 ml to 500 ml capacity, is connected to the aluminum frame via a 4.8 mm flat-head bolt (Fig. 3d and 4d).

The shaft of the sampler is made of 0.9 long sections of 25.4 mm diameter PVC tubing with a sleeve glued in place at one end of each 0.9 section (Fig. 1b). This modification of the PVC tubes allows convenient fitting of sections when expansion of the sampler shaft is desired (Fig.2). Near each end of the 0.9 m PVC sections are two holes to accommodate a 63.1 mm by 4.8 mm round head bolt which can be passed through the aligned holes of the joined PVC sections, then secured with a 4.8 mm wing nut and washer (Fig. 2a). Inside each PVC section is a 1.1 m by 4.8 mm threaded rod with a threaded sleeve at one end (Fig. 1d). At the collecting end of the sampler is another 4.8 mm threaded sleeve attached to the initial threaded rod (Fig. 3e and 4e). A 63.1 mm diameter by 4.8 mm adjustable spacer secured by 4.8 mm nuts on each side is located at the desired position on the initial threaded rod above this sleeve (Fig. 3a and 4a). The location of the spacer disk can be adjusted to accommodate the height of the bottle fastened to the collection section of the sampler. Normally, this spacer is adjusted so that when the immersed bottle is opened, the stopper will not be pulled out of the lip of the bottle farther than 1.5 cm thus, allowing the stopper to remain aligned with the bottle opening (Fig. 4). Each bottle is sealed with a separate rubber stopper of appropriate size which has a flat head bolt 50.89 mm long by 4.8 mm inserted through its center (Fig. 3b and 4b). The head of this bolt is at the bottom of the stopper and is covered with a thin layer of silicone to prevent metallic leaching. The threaded bolt protrudes through the top of the stopper and therefore can readily be attached to the sleeve on the end of the initial threaded rod. Each bottle and stopper can be sterilized (autoclaved) as a unit and stored prior to use. Figure 2 shows how each 0.98 m length of PVC tubing and 1.1 m threaded rod may be

[1] Present Address: City of Tampa Water Department, Production Division, 7125 North 30th Street, Tampa, Florida 33610.

[2] Reprint requests should be addressed to this author at: Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475.

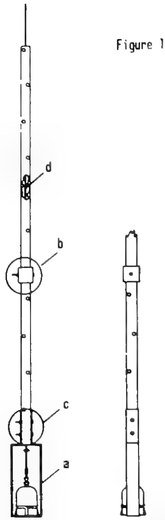

Figure 1 Two Views of the E.K.U. Microbiological Water Sampler. (left to right. Full view of the sampler showing the internal threaded rod and sleeve structure. Side view of the sampler.

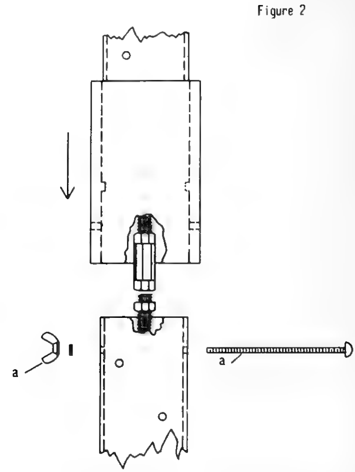

Figure 2 Exploded view of the threaded rod and sleeve component and the male-female fitting of the PVC shaft.

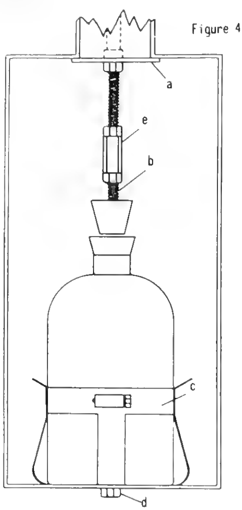

Figure 4 The collection end of the sampler in the open stopper position.

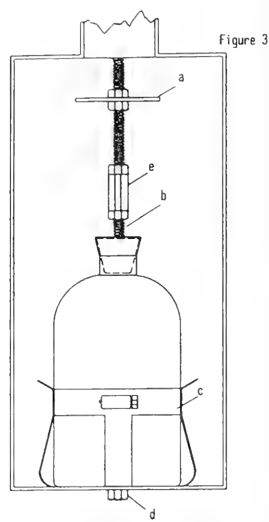

Figure 3 The collecting end of the sampler in the closed stopper position.

added to the sampler shaft to allow lengthening of the sampler as needed.

Collection of Microbial Samples

A sterile stoppered vessel (B.O.D. bottle) is clamped onto the flask holder. The threaded rod at the collecting end of the sampler is fastened to the extended threads of the stopper bolt via a threaded sleeve (Fig. 3b and 4b). The sampler is the lowered to the desired depth and the central threaded rod pulled up until its movement is stopped by the spacer disk. This procedure removes the stopper from the bottle allowing it to fill with water. When the bottle is full the central rod is pushed back down forcing the stopper back into the bottle. The apparatus is then retrieved, the sample bottle removed and either stored temporarily or prepared immediately for microbial counts.

Discussion

The prerequisites for a versatile microbial water sampler are satisfied by the E.K.U. prototype. Its performance was excellent during a six month study on a section of the Kentucky River at sampling depths between 1.0 m and 9.0 m (3). The E.K.U. sampler's simple construction, rugged design and versatility should enhance its usefulness for research, industrial and educational purposes. The ability to use sampling bottles with volumes between 25 ml and 500 ml is an advantage as is maintenance of the integrity of a sample from a particular depth during retrieval. Once at a desired depth the bottle can be readily opened, filled, then closed by an operator on the surface. Furthermore, since the stopper is opened and closed manually and there are no messengers, incomplete samples and broken parts are rare. The rigid shaft construction with its permanent sounding marks allows the sampler to be lowered to a specified depth with minimal lateral drifting in lotic waters. The use of shaft sections 1.1 m in length facilitiates assembly and dismantling of the E.K.U. sampler as well as its storage in a limited space, such as a small vehicle or boat.

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Population Densities of Diurnal Raptors Wintering in Madison County, Kentucky

Nancy J. Sferra
Department of Biological Sciences, Eastern Kentucky University
Richmond, Kentucky 40475*

Abstract

Between December 1980 and March 1981 population densities of wintering diurnal raptors were determined using an automobile strip census. Winter population density estimates/km^2 were 0.19 Kestrels (*Falco sparverius*), 0.09 Red-tailed Hawks(*Buteo jamaicensis*), 0.05 Rough-legged Hawks (*B. lagopus*), 0.05 Northern Harriers (*Circus cyaneus*), 0.004 Red-shouldered Hawks (*B. lineatus*). 0.003 Sharp-shinned Hawks (*Accipiter striatus*), and 0.001 Cooper's Hawks (*A. cooperii*).

Introduction

Winter raptor population studies have been performed in many areas (1,2,3,4,5), but no such research has been conducted in central Kentucky. In Madison County, raptors may be an important part of the winter bird community because extensive areas of pastureland and other open habitats potentially support high prey populations. The purpose of the present study was to determine population densities of diurnal raptors wintering in Madison County, and to record temporal fluctuations in those densities.

Materials and Methods

Diurnal raptor populations were sampled by means of an automobile strip census (6) of the secondary roads in Madison County, Kentucky. The census route was chosen so that it covered each of the 4 physiographic regions of the county: the Hills of the Bluegrass, the Outer Bluegrass, the Knobs Section of the Cumberland Plateau, and the Mountains (7). One census was run per week beginning in late December 1980 and ending in March 1981, for a total of 10 censuses (Table 1). Each census covered 235 km; none was taken whenever visibility was hampered due to fog, snow, or rain.

Table 1. Census dates for winter of 1980-1981.

Census no.	Date
1	28 December to 1 January
2	5 January to 11 January
3	11 January to 18 January
4	22 January to 25 January
5	29 January to 31 January
6	5 February to 6 February
7	12 February to 15 February
8	20 February to 21 February
9	26 February to 28 February
10	6 March to 12 March

A driver/observer and a passenger/observer were present on every census. The routes were driven at speeds between 32 and 48 kph, and all raptors seen on each side of the road were recorded. Craighead and Craighead (6) assumed that all raptors present within 0.40 km of the road could be sighted, and this assumption was used in the present study. Each raptor sighting was plotted on a map of the study area after estimating the distance of the bird from the road. All distance estimates were made by the same person to ensure consistency. Only raptors identified to species were included in density estimates. Although Turkey Vultures (*Cathartes aura*) and Black vultures (*Coragyps atratus*) were present in the area, they were not included in this study. Both species are most common in highly dissected terrain with vertical rock walls (8); they could, therefore, not be accurately counted using an automobile census.

* Present Address: Department of Zoology, Michigan State University East Lansing, Michigan 48824.

Results and Discussion

A total of 585 raptors were sighted during the winter of 1980-1981 (Table 2). The 7 species wintering in Madison County, in decreasing order of abundance, were the American Kestrel (*Falco sparverius*), Red-tailed Hawk (*Buteo jamaicensis*), Northern Harrier (*Circus cyaneus*), Rough-legged Hawk (*B. lagopus*), Red-shouldered Hawk (*B. lineatus*), Sharp-shinned Hawk (*Accipiter striatus*), and Cooper's Hawk (*A. cooperii*).

Table 2. Actual numbers and population densities/km^2 by species of wintering raptors along the census route in Madison County, Kentucky.

	Census no.											
Species	1	2	3	4	5	6	7	8	9	10	Total	$\bar{x}$ ± S.E.
Kestrel/km^2	58	45	36	40	37	28	27	29	21	38	359	35.9 ± 3.34
	0.31	0.24	0.19	0.21	0.20	0.15	0.14	0.15	0.11	0.20		0.19 ± 0.02
Red-tailed Hawk/km^2	6	17	14	16	13	13	26	18	17	28	163	16.8 ± 2.10
	0.03	0.09	0.07	0.09	0.07	0.07	0.14	0.10	0.09	0.09		0.09 ± 0.009
Unidentified buteo/km^2	—	6	3	1	3	1	1	—	2	3	20	2.0 ± 0.59
	—	0.03	0.02	0.005	0.02	0.005	0.005	—	0.01	0.02		0.01 ± 0.003
Northern Harrier/km^2	2	1	2	2	—	1	1	1	—	—	10	1.0 ± 0.26
	0.01	—	0.01	0.005	0.005	0.005	0.01	—	—	—		0.005 ± 0.002
Rough-legged Hawk/km^2	2	—	2	1	1	1	2	—	—	—	9	0.9 ± 0.28
	0.01	—	0.01	0.005	0.005	0.005	0.01	—	—	—		0.005 ± 0.001
Red-shouldered Hawk/km^2	—	—	1	1	1	3	1		—	1	8	0.8 ± 0.29
	—	—	0.005	0.005	0.005	0.02	0.05	—	—	0.005		0.005 ± 0.002
Sharp-shinned Hawk/km^2	5	—	—	—	—	1	—	—	—	—	6	0.06 ± 0.50
	0.03	—	—	—	—	0.005	—	—	—	—		0.004 ± 0.003
Unidentified accipiter/km^2	—	—	2	—	—	—	—	1	—	—	3	0.3 ± 0.22
	—	—	0.01	—	—	—	—	0.005	—	—		0.002 ± 0.001
Cooper's Hawk/km^2	—	—	—	—	—	1	1	—	—	—	2	0.4 ± 0.27
	—	—	—	—	—	0.005	0.005	—	—	—		0.001 ± 0.001

American Kestrels accounted for 61% of the total raptor count, although their numbers steadily declined throughout the winter. The lowest tally occurred during census 9 when only 21 Kestrels were seen. This decline may have been due to winter mortality and behavior changes brought about by unusually cold weather conditions. Mills (5) found a sharp decline in Kestrel populations in central Ohio following the first cold spell of the winter, and Enderson (9) was able to correlate low temperatures and low Kestrel numbers in east-central Illinois. In Madison County, the first cold spell occurred during a 9-day period beginning on 5 January. During that time, the minimum daily temperature was below −12°C for 8 out of the 9 days. Decreasing Kestrel numbers, beginning during census 2, coincided with the period of cold weather.

Mengel (8) states that spring migration is not usually apparent in Kentucky; however, there was a dramatic increase in Kestrel numbers during census 10 (38 sightings), probably due to a wave of migrants moving through the area. Behavior associated with the breeding season could also have contributed to the high count due to the conspicuousness of courtship flights and increased numbers of paired birds.

Mean Kestrel density for the winter was 0.19/km^2 (Table 2). In Colorado, lower estimates were obtained on grazing and wheat lands of the plains immediately east of the Rocky Mountains, where habitats were probably less diverse than in Madison County (10). Far higher estimates were obtained in Florida (11), where Kestrel densities included two subspecies, *F.s. paulus*, a resident race, and *F.s. sparverius*, a winter migrant. Only one subspecies, *F.s.*

sparverius, is present in Madison County (8). In addition, milder weather conditions in Florida could have contributed to higher densities.

The Red-tailed Hawk was the most abundant *Buteo* species during the winter, comprising 29% of all raptors observed. The lowest count occurred during census 1 (6 sightings) which may have been due to inexperienced observers on the initial count. The 2 highest counts were made during census 7 (26 individuals) and census 10 (28 individuals). Spring migration dates for Red-tailed Hawks in Kentucky are not well known, but Mengel (8) states that migrating flocks are seen in February to early March. Present data for census 7 and 10 confirmed the timing of spring migration. During census 10, for instance, 6 Red-tailed Hawks were observed soaring in an area of approximately 2 km², in what appeared to be an aggregation typical of migrating birds.

Red-tailed Hawks generally preferred perch sites along woodlot edges overlooking open areas (12). Madison County habitats are very diverse with plenty of edge habitat; in spite of that, the density was low (0.09/km², Table 2) when compared with areas in Wisconsin comprising mostly open habitat, with a probably lower frequency of perch sites (13). In those areas, it may have been higher prey density which favored larger raptor populations: Ring-necked pheasants (*Phasianus colchicus*), absent in Madison County, were considered an important prey species in Wisconsin especially when snow provided shelter for small mammals. In addition, Madison County estimates were obtained in rolling country with many woodlots; density would therefore, be more easily underestimated than in Wisconsin, where counts were made in open, level terrain with few woodlots (13).

Hawk densities generally may be related to availability of perch sites. Relatively low in the plains of Colorado (10), populations reported for Kansas were comparable to those of Madison County; the areas surveyed in Kansas (14) encompassed a variety of suitable edge habitats such as tree lines along gullies and fields and small stands along stream margins.

Rough-legged Hawks, Northern Harriers, Red-shouldered Hawks, Sharp-shinned Hawks, and Cooper's Hawks were seen in low numbers and together made up 6% of all observations. Northern Harriers and Rough-legged Hawks are found in Madison County primarily during the winter and migrate from the area before the onset of the breeding season (8). Last sightings for both species were made during census 8, which represented the approximate time of northward migration. Both species occurred in mean densities of 0.005/km² (Table 2), which is far below estimates obtained for both in Colorado (10). The Rough-legged Hawk's southern limit of its main winter range is just north of Kentucky, and low densities were expected (8). Both species prefer open areas for hunting, which may account for their high winter density in Colorado. Craighead and Craighead (6) found that Northern Harriers spent up to 57% of their time perched on the ground, whereas Rough-legged Hawks preferred to perch in lone trees or on telephone poles (15). These species do not require wooded areas and can reach high densities in the plains of Colorado where open spaces and isolated perch sites prevail.

Red-shouldered Hawks were present in Madison County in small numbers throughout the winter, the mean density being 0.004 individuals/km² (Table 2). Densities of this species in other areas are not known; in Madison County, they constituted a minor component of the raptor community.

Sharp-shinned and Cooper's Hawk populations (0.0004 and 0.001/km², respectively, Table 2) were probably grossly underestimated. Both species prefer wooded habitats where they are not easily counted by automobile census.

All population estimates must be considered minimum estimates, since some birds were probably obscured by landscape features and buildings, and Northern Harriers, for instance, spend much time on the ground where they may not be visible from a car. The hunting ranges of some raptors frequently the study area undoubtedly covered a larger territory than the width of the census strip. A bird hunting outside of the census strip on any given day would have been omitted from the census.

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Polynomial Modeling and Predictive Evaluation of Tariff-Derived Transportation Costs in Kentucky

Alan D. Smith
Coal Mining Administration, College of Business
Eastern Kentucky University, Richmond, KY 40475

Charles L. Hilton
Department of Business Administration, Eastern Kentucky University
Richmond, KY 40475

ABSTRACT

The analysis of transportation and distribution costs includes careful and accurate calculation of costs. These calculations include rate studies and their adjustments within a particular location that a company or carrier operates. One approach to this problem is to model physical distribution costs, based on carrier tariffs derived from the National Motor Freight Classification for commodity classes, from selected origin and distribution points to the state of Kentucky.

The present study is based on polynomial-surface modeling and spatial analysis, via hypothesis testing and model comparisons of polynomial trend-surfaces, of costs in dollars for 100-pound shipments in commodity classes or ratings of 77.5 and 100. The origin point is Chicago, Illinois, for illustrative purposes, to selected destination points in the state of Kentucky. Significant and predictive trends were established, with R^2s over 83 per cent of explained variance of spatial-oriented, transportation costs in Kentucky. In general, the generated models and their mathematical expression and error analysis may aid the decision maker in setting realistic prices, based on the predictive trends derived from the tariffs studied. These models may be developed for almost any series of origin and destination points that a particular carrier or user wants to establish, assuming certain data and research design constraints are observed.

INTRODUCTION

Transportation enterprises are engaged in producing a composite of heterogeneous groups of services for which precise costs cannot be determined. In addition, transportation or physical removal and replacement of commodities is only one aspect of the total amounts involved in the calculation of physical distribution costs. Physical distribution costs include a large variety of separate and distinct functions that are coordinated together, such as warehousing and related storage, packaging, inventory control, and materials handling. This lack of price control is true for most modes of transport, although the railroads are the most outstanding illustration of this situation (1). Hence, because of the position that the railroads held in the transport structure of this country until relatively recent years, discrimination in some form or another has resulted in the intervention of regulatory bodies. However, discriminatory pricing may contain both competitive and monopoly elements, and it is very difficult to separate the 2 and give them a quantitative content (2, 3). Although this is so, it does not follow that all discrimination would be undesirable and, in fact, it may be necessary for survival.

Along with the desire to establish rates associated with transportation costs is the need to classify all articles of commerce in a uniform fashion. The Standard Transportation Commodity Codes were developed by adhering as closely as possible to the classification system used by the Budget Bureau's Standard Industrial Classification and were initially used by the railroads to accomodate the reporting of carload statistics to the ICC (3).

Transportation rates have traditionally been established using two basic factors: shipping characteristics of the product and the distance factor, which reflects the amount of miles between origin and destination points. Shipping characteristics have been treated in the Uniform Freight Classification for the railroad industry and the National Motor Freight Classification for the motor carrier industry. Class ratings reflect the proportional differences in the carrier's handling of the specific group of commodities - a class rating of 100 commodity would cost proportionally more to handle than a class rating of 77.5. Carrier rates increase as a funditon of distance, but at an overall decreasing rate.

The purpose of this research is to relate the cost of transportation derived from carrier tariffs as a function of physical distance, from centralized locations to particular points for modeling purposes. Hence, by mathematically modeling, for predictive purposes, establishing general trends and its error evaluation, a managerial decision tool can readily be made available.

METHODS

The major research tools used in the present study are polynomial-trend surface analyses, hypothesis testing, and model comparisons of trend surfaces, generated from commercially available computer software, via the line printer (4).

Polynomial Trend Surface Analysis and Model Comparisons

A trend is a statistically derived surface to explain variations in a given set of values, known as Z-values, that have a given geographic position, either regularly or irregularly distributed in the x-y plane. The surface is the representation of an equation using the least-squares criterion. This means that the generated surface will be fitted to the input data in such a way that the sum of the squared deviations between the data at their particular locations and the corresponding value of the computed surface are minimized. Thus, the least-squares criterion calls for the surface to be laid down in such a way that the sum of the squares of these discrepancies is as small as possible, as indicated by: $d^2 = E$, where d^2 = deivation squared and E = minimum value.

The basic reasoning behind minimizing the sum of squares of the deviations, and not minimizing the sum of the absolute magnitudes of the discrepancies are 1) It is extremely difficult to mathematically deal with the absolute discrepancies or deviations; while the treatment of the squared deviations provides the method of practical mathematical developments in the interpretation of the regression equation and 2) Useful and desirable statistical properties follow from using the least-squares criterion (5, 6, 7).

The equation describing the surface can be linear (plane), quadratic (paraboloid), cubic (paraboloid with an additional point of inflection), to higher order degree surfaces. In general, the higher the order of the surface, the more the residuals, or individual deviations will be minimized and the more computation will be required. The higher-order trend surfaces may reflect the variation in Z-values more accurately if the study area is complex, but lower-order surfaces may be more useful in the isolation of local trends. The filtering mechanism allows the upper limit of variability to be determined by the order of the surface. The equation for a linear trend surface, for example, is: $Y = b_0 + b_1X_1 + b_2X_2$, where Y = dependent variable, b = constant value related to the mean of the observations, b_1, b_2 = coefficients, X_1, X_2 = geographic coordinates. This linear equation generates 3 unknowns and 3 equations are needed to determine a solution. These equations are:

$$(1)\quad \sum_{i=1}^{n} Y = b_0 n + b_1 \sum_{i=1}^{n} X_1 + b_2 \sum_{i=1}^{n} X_{2_1},$$

$$(2)\quad \sum_{i=1}^{n} X_1 Y = b_0 \sum_{i=1}^{n} X + b_1 \sum_{i=1}^{n} X_1 + b_1 \sum_{i=1}^{n} X_1 X_2, \text{ and}$$

$$(3)\quad \sum_{i=1}^{n} X_1 Y = b_0 \sum_{i=1}^{n} X_2 + b_1 \sum_{i=1}^{n} X_1 X_2 + b_2 \sum_{i=1}^{n} X_2.$$

where n = number of observations or data collected. Solving these equations simultaneously will give the coefficients of the best-fitting linear surfaces, where best fit is defined by the least-square criterion. As the degree of the trend-surface that is to be used increases, so does the number of equations that must be solved simultaneously.

The significance of a trend or regression may be tested by performing an analysis of variance, which deals with the separation of the total variance of a set of observations into components with defined sources of variation (8). In trend-surface analysis, the total variance in an independent variable may be divided into the trend itself, which is determined by regression analysis, and the residuals, or error vector. An analysis of variance table can be calculated (Table 1). By reducing the sum of squares, derived from the least-square criterion, an estimate of the variance can be computed by using the F-distribution (8). The F-test, like a t-test, is a very robust test and relatively insensitive to violations of the assumptions of random selection of observations and normal distribution of the variables (9, 10). Newman and Fraas (11) and Nunnally (12) looked at a number of investigations that dealt with the F-distribution assumptions and their violation and summarized by suggesting that no appreciable effect on the accuracy of the F-test from skewed sample distribution occurred. In addition, if sample sizes are equal, heterogeneity of variance has a negligible effect.

Table 1 - Typical Analysis of Variance Table for Polynomial Trend Surfaces.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F Ratio
Regression	SS_{Reg}	m	MS_{Reg}	MS_{Reg}/MS_{Res}
Residual	SS_{Res}	n - m - 1	MS_{Res}	
Total	SS_T	n - 1		

Note: In the table, m is the number of coefficients in the polynomial-trend surface equation, not including the constant term, b_0; and n is the number of valid data points used in the regression equation.

The F-test for significance of fit is a test of the null hypothesis that the partial regression coefficients are equal to zero and, hence, there is no regression. If the computed F-value exceeds the F-value having a probability of a set alpha level, (∞ = 0.01 to 0.05) the null hypothesis is rejected. In polynomial trend-surface analysis, it is customary for investigators to fit a series of successively higher degrees to the data without statistically testing the higher order's contribution in additional variance. Davis (8) suggested that an analysis of variance table be expanded to analyze the contribution of the additional partial regression coefficients to give a measure of the appropriateness of each order equation. In regression work, the question often arises as to whether it was worthwhile to include certain terms associated with the order of the polynomial in the model. This question can be investigated by considering the extra portion of the regression sum of squares which arises due to the fact that the terms under consideration were in the model. If this extra sum of squares is significantly large, those terms should be included. However, if nonsignificant, they are judged unnecessary and should be deleted. For example, SS (b_1/b_0) is the extra sum of squares owing to the B_1X_1 term included in a model which otherwise only contained B_0. If the F-test indicated significance, the model should include the B_1X_1 term. The full versus restricted model principle implies that if the null hypothesis, where $H_0:B_1 = 0$ were true, and if this condition is imposed on the model, the result would be that contribution of the β_1X_1 term is zero. This is equivalent to discharging the β_1X_1 term from the model, resulting in the restricted model. Hence, the restricted model is the model which results when the specific null hypothesis, which is assumed true, is imposed or restricted on the full model. The full model is the model which contains all the terms of the lower and higher order polynomial coefficients being tested. The sum of squares of the null hypothesis (SS (H_0)) is equal to the difference of the regression sum of squares of the full less the regression sum of squares of the restricted model. Also, the degrees of freedom of the null hypothesis (df (H_0)) is simply the difference between the degrees of freedom of the full and restricted models.

Study Area

For illustrative purposes, motor carrier transportation costs were computed using commodity classes 77.5 and 100 at the 100 pounds of shipment weight and were selected from an origin point in Chicago, Illinois to destination points in or around Kentucky (Table 2). The costs are in dollars, per 100 pounds of shipment weight.

Table 2. Transportation Costs for Classes 77.5 and 100 from Chicago, Illinois to Selected Points in or around Kentucky.

From Chicago to Points in Kentucky	Zip Code	Rate Group	Costs, in Dollars, per 100 Pounds of Shipment Weight	
			Class 77.5	Class 100
Manchester	409	41	13.15	16.50
London	407	39	12.80	16.05
Somerset	425	37	12.43	15.65
Russell Springs	425	37	12.43	15.65
Columbis	427	34	11.91	14.80
Glasgow	421	40	12.96	16.26
Munfordville	427	34	11.91	14.80
Bowling Green	421	40	12.96	16.26
Morgantown	421	40	12.96	16.26
Greenville	423	33	11.65	14.50
Princeton	424	32	11.35	14.21
Paducah	420	34	11.91	14.80
Wickliffe	420	34	11.91	14.80
Middlesboro	409	41	13.15	16.50
Pineville	409	41	13.15	16.50
Williamsburg	409	41	13.15	16.50
Albany	385	46	14.19	17.91
Tompkinsville	421	40	12.96	16.26
Scottsville	421	40	12.96	16.26
Corbin	407	39	12.80	16.05
Franklin	421	40	12.96	16.26
Russellville	422	34	11.91	14.80
Hopkinsville	422	34	11.91	14.80
Canton	420	34	11.91	14.80
Murray	420	34	11.91	14.80
Mayfield	420	34	11.91	14.80
Hickman	420	34	11.91	14.80
Williamson	412	37	12.43	15.65
Prestonberg	414	39	12.80	16.05

Continued)

Table 2 continued

Salyersville	413	39	12.80	16.05
Irvine	403	34	11.91	14.80
Richmond	404	36	12.27	15.42
Danville	404	36	12.27	15.42
Elizabethtown	427	34	11.91	14.80
Hardinsburg	423	33	11.65	14.50
Owensboro	423	33	11.65	14.50
Henderson	424	32	11.35	14.21
Morganfield	424	32	11.35	14.21
Sebree	424	32	11.35	14.21
Lebanon	400	32	11.35	14.21
Lancaster	404	36	12.27	15.42
Berea	404	36	12.27	15.42
Jackson	413	39	12.80	16.05
Pikeville	415	41	53.15	16.50
Jenkins	418	43	13.72	17.22
Hazard	417	41	13.15	16.50
McKee	404	36	12.27	15.42
Mt. Vernon	404	36	12.27	15.42
Campbellsville	427	34	11.91	14.80
Letchfield	427	34	11.91	14.80
Caneyville	427	34	11.91	14.80
Hartford	423	33	11.65	14.50
Madisonville	424	43	11.35	14.21
Marion	424	32	11.35	14.21
Lynch	408	43	13.72	17.22
Hyden	417	41	13.15	16.50
Covington	410	32	11.35	14.21
Walton	410	32	11.35	14.21
Portsmouth, O.	413	39	12.80	16.05
Vanceburg	411	37	12.43	15.65
Maysville	410	32	11.35	14.21
Falmouth	410	32	11.35	14.21
Williamstown	410	32	11.35	14.21
Carrollton	410	32	11.35	14.21
New Castle	400	32	11.35	14.21
Owenton	410	32	11.35	14.21
Ashland	411	37	12.43	15.65
Grayson	411	37	12.43	15.65
Cythiana	403	34	11.35	14.80
Louisville	400	32	11.35	14.21
Shelbyville	400	32	11.35	14.21
Frankfort	406	34	11.91	14.80
Georgetown	405	34	11.91	14.80
Paris	403	34	11.91	14.80
Morehead	403	34	11.91	14.80
Louisa	412	37	12.43	15.65
Liberty	414	39	12.80	16.05
Mt. Sterling	403	34	11.91	14.80
Winchester	403	34	11.91	14.80
Lexington	405	34	11.91	14.80
Bloomfield	400	32	11.35	14.21
Shepherdsville	400	32	11.35	14.21

Data Collection Techniques

A total of 79 points were selected in Kentucky and their related physical distribution costs from Chicago, Illinois were calculated. All costs, for both commodity classes 77.5 and 100 were derived from tariffs for 100 pounds of shipment weight. The 79 data points were established by selecting points in a straight-line fashion across the state of Kentucky at approximately 20-30 mile-wide bands. Next, the associated transportation costs from Chicago, Illinois, were determined and used as the initial data base, along with spatial coordinates, in the development of the mathematical models. Each destination point was recorded and trend surface analysis techniques, via SYMAP (13) and a computer program suggested by Smith (14), were performed.

Results and Discussion

Tables 3 and 4 illustrate the mechanics and results of the hypothesis testing and model comparisons of polynomial trend surfaces in predicting transportation costs to the state of Kentucky for the commodity classes 77.5 and 100, as well as the differences in changes for the various classes. Table 3 shows the hypothesis testing and modeling comparison results, in traditional analysis of variance (ANOVA) format, to determine if the third-degree, polynomial trend surface of classes 77.5 and 100 differences, from Chicago, Illinois to selected points of destination in Kentucky, accounted for enough explained variance in predicting its spatial distribution over random variation or no trend. The variance accounted for by the third-order surface was substantial (R^2 = 75.20) and was found to be highly significant (p = 0.0000). Table 4 summarizes the same basic information found in Table 3, but restates it in standard multiple linear regression (MLR) terminology. As shown in Table 4, a summary of the F-ratios, probability levels, R^2 for both the full and restricted models, degrees of freedom-numerator, degrees of freedom-denominator, and statistical significance for each trend surface is presented. As evident from a quick inspection of the table, the costs for the two commodity classes studied from Chicago, Illinois to location coordinates in Kentucky, similar results were not evident. Although both the sixth-degree, polynomial trends were found to account for a statistically significant amount of explained variance (R^2 for 77.5 was 83.03 per cent, and R^2 for class 100 was 83.03 per cent as well, representing a constant and proportionate difference in the costs for the two commodity classes), the sixth-degree surface was not found to be statistically the best fit, since it did not account for enough variance for the lower-degree surfaces. the second-order surface was found to be best fit (R^2 = 75.89 per cent, p = 0.0000).

Table 3. ANOVA Table for Third-Degee, Polynomial Trend Surface Predicting the Spatial Distribution of Transportation Costs, Class Differences between 100 and 77.5, from Chicago, Illinois to Points in Kentucky, Over Random Variation.

Source of Variation	SS	df_n/df_d	MS	F-Ratio	Prob.	Sign.
Third Degree[a] Regression	2.77074	9	0.30786	23.2454	0.0000	S**
Error (Residuals)	0.91383	69	0.01324			
Total	3.68457	78				

$R^2_f = 0.7520$, $R^2_r = 0.0$

** Denotes statistical significance at the 0.01 level for a nondirectional, two-tailed test.

[a] Third order regression equation, with geographic coordinates, X and Y, in SYMAP asis system:

TRANSPORTATION COSTS = 5.3764160172 − 0.40624614518X − 0.58931266603Y + 0.01974342150X + 0.5875116076XY + 0.04008445257Y² − 0.00020337758X³ − 0.00167429687X²Y − 0.00126830580XY² − 0.00068289589Y³ + Error (Residuals)

Table 4. Summary of F-Ratios, Probability levels, R^2 for both the Full and Restricted Models, Degrees of Freedom-Numerator, Degrees of Freedom-Denominator, and Significance for each Trend Surface for Predicting Transportation Costs from Chicago, Illinois to Destination Points in Kentucky.

Order of Trend Surface	R^2_f	R^2_r	df_n/df_d	F-Ratio	Prob.	Significance
Class of 100 (N = 79)						
1	0.7229	0.0	2/76	99.1320	0.0000	S**
2	0.7589	0.0	5/73	45.9499	0.0000	S**
3	0.7776	0.0	9/69	26.8038	0.0000	S**
4	0.7894	0.0	14/64	17.1386	0.0000	S**
5	0.8196	0.0	20/58	13.1767	0.0000	S**
6	0.8303	0.0	27/51	9.2432	0.0000	S**
1 vs 2	0.7589	0.7229	3/73	3.6312	0.0168	S*
2 vs 3	0.7776	0.7589	4/69	1.4512	0.2266	NS
3 vs 4	0.7894	0.7776	5/64	0.7200	0.6108	NS
4 vs 5	0.8196	0.7894	6/58	1.6175	0.1587	NS
5 vs 6	0.8303	0.8196	7/51	0.4597	0.8589	NS
Class of 77.5 (N = 79)						
1	0.7229	0.0	2/76	99.1320	0.0000	S**
2	0.7589	0.0	5/73	45.9499	0.0000	S**
3	0.776	0.0	9/69	26.8038	0.0000	S**
4	0.7894	0.0	14/64	17.1386	0.0000	S**
5	0.8196	0.0	20/58	13.1767	0.0000	S**
6	0.8303	0.0	27/51	9.2432	0.0000	S**
1 vs 2	0.7589	0.7229	3/73	3.6312	0.0168	S*
2 vs 3	0.7776	0.7589	4/69	1.4512	0.2266	NS
3 vs 4	0.7894	0.7776	5/64	0.7200	0.6108	NS
4 vs 5	0.8196	0.7894	6/58	1.6175	0.1587	NS
5 vs 6	0.8303	0.8196	7/51	0.4597	0.8589	NS

* denotes statistical significance at the 0.05 level
** denotes statistical significance at the 0.01 level

CONCLUSION

As evident in the spatial modeling and the polynomial surfaces derived and its statistical analyses summarized in Table 4, significant and predictive trends do exist for the transportation costs, as derived from the motor-carrier tariffs, for the commodity classes studied in the state. The models aid the decision maker in setting realistic prices, based on these tariffs, and may be established for almost any series of origin and destination points that a particular company or user may be interested in, provided certain data and research design constraints are observed.

The major benefit of modeling research is to be able to parameterize the actual distributions of important parameters associated with physical distribution costs. Examples illustrated in this research allow the user to mathematically portray selected distributions of parameters in order to take administrative measures in the future to establish reasonable pricing structures. This process can bring the business administrator's "common sense" and judgement into play to determine the best fit. With the increasing use and availability of appropriate software and hardware, computer modeling should be used in conjunction with statistical models in estimating the usefulness and limitations of trend-surface analyses for predictive purposes in generating models with geographic dimensions.

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Role of Selected Corn Insects and Plant Stress in Aflatoxin Production in Kentucky Corn[1]

J. G. Rodriguez, C. G. Patterson, M. F. Potts
C. G. Poneleit, and R. L. Beine
University of Kentucky
Lexington, KY 40546-0091

Abstract

The influence of such prominent ear-damaging insects as the corn earworm, *Heliothis zea* (Boddie), European corn borer, *Ostrinia nubilalis* (Hubner), and the maize weevil, *Sitophilus zeamais* Motschulsky was examined in their capacity to disseminate *Aspergillus parasiticus* and *A. flavus* spores to pre-harvest corn. Corn earworm infestation was simulated (S-CEW) by stabbing the ear through the husk with a knife blade, and this also served to inoculate the kernels with high aflatoxin producing strains of *A. parasiticus* (NRRL 2999) and *A. flavus* (NRRL 3251). European corn borer (ECB) was introduced as egg masses and maize weevils (MW) were introduced as adults. All treatments were introduced singly or in combinations. Rainfall was adequate during the 1982 growing season but drought conditions prevailed during 1983. The highest levels of aflatoxin occurred generally in treatments involving insects or their combinations plus either species of the fungi. In 1983, very high levels of aflatoxin were attributable to the drought stressed corn. A mean production of >54,000 ppb total aflatoxin was elicited from the ECB, S-CEW plus NRRL 2999 and MW combination compared with >24,000 ppb when NRRL 3251 was inoculated instead of NRRL 2999. The untreated control produced a mean of >2,500 ppb aflatoxin in 1983 compared to a mean of 1 ppb in 1982.

Introduction

Only since 1971 has aflatoxin contamination of corn been recognized as mainly a preharvest problem of field corn (1). These workers surveyed the northern, central and southern counties of both Indiana and Kentucky in 1971 and 1972 and found field corn infected with *Aspergillus flavus*. This is not to say that "moldy corn" has not been recognized as a problem for a longer period. Garman and Jewett (2), in studying the life history of the corn earworm, *Heliothis zea* (Boddie) in Kentucky, speaking about corn injured by the corn earworm stated in part: "Injured corn does not sell well, and if badly damaged, can hardly sell at all. If used by the farmer himself, . . . there is the risk of injuring and even killing the animals to which it is fed . . . numerous complaints have come each winter to the Kentucky Experiment Station of loss from feeding such corn. Hundreds of animals . . . have been lost from some cause thought to be the eating of this moldy corn." They also recognized storage problems for they wrote: "Corn is stored in cribs and sold in the husks about Hickman, and farmers state that unless it is thoroughly dried before putting in the cribs it molds badly and that stock often refuse to eat it. They charge the molding to the earworm."

Since then, continued investigation has removed any doubt that *Aspergillus* contamination and aflatoxin production is primarily a problem that begins in the field and it is not nearly the serious storage problem as formerly believed, as drying high moisture grain prevents mold growth. We have been involved in the aflatoxin problem in corn because Kentucky and the southeastern states comprise a region where

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aflatoxin contamination is recognized as a serious problem (3). Research in this area has progressed rapidly and a regional aflatoxin symposium involving the southeastern states was held in 1982 to review and report findings (4).

The role of arthropods in field contamination of *Aspergillus flavus* in corn was thoroughly reviewed at the above symposium (5). Our research has also examined the role of insects and mites in *A. flavus* dissemination and conuomitantly the effect of mycotoxins on the arthropod (6, 7, 8).

The objectives in the work reported here were to examine the influence that some selected insects such as the European corn borer, *Ostrinia nubilalis* (Hubner), maize weevil, *Sitophilus zeamais* Motschulsky, and corn earworm, *Heliothis zea* (Boddie) may exert in combined effects of dissemination, and infection of *A. flavus* and production of aflatoxins under Kentucky conditions. Concomitantly, it was our objective to determine the possible additive effects of plant stress, introduced to the corn plant by the European corn borer, on alfatoxin production.

Materials and Methods

General Methods.

Corn hybrids were planted in 6 replications of a randomized block design with each plot having 20 plants minimum. Four European corn borer (ECB) egg masses were introduced per plant by placement on the leaf immediately beneath the ear at beginning silk and again 3-4 days later. Simulated corn earworm (S-CEW) injury was via a knife wound made by a stab (ca. 3 cm long) about mid-ear, longitudinally through the husk, and this also served to introduce fungal spores to the ear. The fungi were originally obtained from the USDA Northern Regional Research Laboratory, Peoria, IL. *Aspergillus parasiticus* NRRL 2999, a heavy G aflatoxin producer, and *A. flavus* NRRL 3251, a heavy B aflatoxin producer, were inoculated by dipping the knife blade tip into the inoculum, which was standardized to provide a spore count of ca. 2.5×10^5 spores/ml. Inoculation was generally done 15 days after 50% pollination had occurred. Maize weevil (MW) were introduced onto the ear by pulling the husk tip down slightly and placing the weevils on the kernels and then closing the husk and securing with a rubber band. MW adults were randomly selected from a mixed population and placed on established *Aspergillus* cultures of NRRL 2999 and NRRL 3251, and allowed to become contaminated overnight. Five MW adults were then introduced to each ear. Uncontaminated weevils were used as a check. All treatments were made singly or in combination with other treatments (Tables 1-3). The untreated control plants were allowed to grow undisturbed to maturity/harvest. All plots were protected from bird damage by capping the ear with a plastic screen mesh bag. Ears were harvested by hand and placed in nylon net bags for oven drying; this was done for 1 wk at 38°C, lowering the moisture to ca. 13 percent. The ears were then hand-shelled, ground in a Stein mill, the 20-ear sample was split to ca. 1/16 of the original sample, and weighted into a tared bottle.

Table 1. Treatments on Pioneer 3369A planted in the South farm, University of Kentucky, Lexington, 1983. Treatments were replicated 6 times, 1 row of 20 plants per replicate.

TREATMENTS applied 15 days after 50% pollination[a]
1. Knife wound (S-CEW), simulated corn earworm
2. S-CEW with NRRL 2999, *Aspergillus parasiticus*
3. S-CEW with NRRL 3251, *A. flavus*
4. European corn borer (ECB), 1st generation
5. ECB, *2nd* generation
6. ECB, *1st* and *2nd* generation
7. ECB, *2nd* generation plus MW (5/ear)
8. ECB, *2nd* generation plus MW (10/ear)
9. Maize Weevil (MW)
10. MW plus NRRL 2999
11. MW plus NRRL 3251
12. ECB *2nd* generation, S-CEW with NRRL 2999
13. ECB *2nd* generation, S-CEW with NRRL 3251
14. ECB *2nd* generation, S-CEW with NRRL 2999 and MW
15. ECB *2nd* generation, S-CEW with NRRL 3251 and MW
16. Untreated control
Corollary Experiment: S-CEW with NRRL 3251 and MW - Days after 50% pollination
1. 7 days
2. 15 days
3. 28 days
4. 35 days
5. Untreated control (same as 16 above)

[a] ECB treatments: 1st generation made when plants were ca. 0.5 m high; 2nd generation made when corn was beginning to silk.

Table 2. Treatments and results of aflatoxin analyses of corn from two hybrids grown at Quicksand, Kentucky, 1982. Treatments were replicated 6 times, 1 row of 20 plants per replicate.

Treatment	Means, 2 Hybrids (ppb)[a]				
	B_1	B_2	G_1	G_2	Total
1. Untreated control	1c	1c	0c	7c	1c
2. Knife wound (S-CEW)[b]	27b	2b	8c	1c	38b
3. S-CEW with NRRL 2999	610a	39a	153b	10b	811a
4. S-CEW with NRRL 3251	664a	54a	27c	2c	747a
5. European corn borer (ECB)[c]	1c	1c	0c	0c	1c
6. ECB plus S-CEW with NRRL 2999	783a	54a	303a	19a	1159a
7. ECB plus S-CEW with NRRL 3251	742a	58a	0c	0c	800a

Hybrid effect across all treatments (Total aflatoxin, ppb)

C166xFR802W - 266a

FRM017xT232 - 541b

[a] Values with the same letter are not significantly different at 5% level, by Duncan's multiple range test

[b] Simulated corn earworm

[c] ECB egg masses on all second generation treatments

Analysis for aflatoxin was by a proven TLC method of high sensitivity developed by us (RLB), and followed the procedures outlined in Rodriguez, et al. (8).

The data were analyzed using SAS ANOVA, with log transformations, and Duncan's multiple range test. Aflatoxin levels are reported in actual values.

Table 3. Treatments and results of aflatoxin analyses of corn from two hybrids grown at South Farm, Lexington, Kentucky, 1982. Treatments were replicated 6 times, 1 row of 20 plants per replicate.

Treatment	Means, 2 Hybrids (ppb)[a]				
	B_1	B_2	G_1	G_2	Total
1. Untreated control	8c	1c	0d	0d	9d
2. Knife wound (S-CEW)[b]	28c	5c	1d	0d	32d
3. S-CEW with NRRL 2999	723ab	55ab	368b	22c	1058abc
4. S-CEW with NRRL 3251	625b	43b	3d	1d	649c
5. Maize weevil (MW)	4c	2c	1d	0d	12d
6. MW plus NRRL 2999	1643a	93a	1461a	90a	3287a
7. MW plus NRRL 3251	630ab	47ab	24c	1d	802ab
8. European corn borer (ECB)[c]	2c	0d	0d	0d	9d
9. ECB plus S-CEW with NRRL 2999	975ab	59ab	704a	35b	1773ab
10. ECB plus S-CEW with NRRL 3251	603ab	37ab	2d	1d	699bc

Hybrid effect across all treatments (total aflatoxin, ppb)

C166xFR802W - 685a

FRM017xT232 - 1007b

[a] Values with the same letter are not significantly different at 5% level, by Duncan's multiple range test

[b] Simulated corn earworm

[c] Second generation ECB egg masses on all ECB treatments

1982 Studies — Corn hybrids C166xFR802W (white) and FRM017xT232 (yellow) were grown at the Robinson Substation, Quicksand, Kentucky, and at the South Farm of the Kentucky Agricultural Experiment Station in Lexington. The Quicksand treatments are listed in Table 2 and were administered according to procedures described above.

The Lexington treatments included MW introductions which were not made at Quicksand (Table 3).

1983 Studies — The experimental design for the 1983 growing season varied from the previous year in that one corn hybrid (Pioneer 3369A) was planted only at the South farm of the Kentucky Agricultural Experiment Station in Lexington. ECB egg masses were introduced to coincide with first generation moth flight on June 16-21, when the corn plants were ca. 0.5 m high, while the second generation introduction was made at beginning silk. All other treatment procedures followed those outlined in the general test methods and are listed in Table 1.

A corollary experiment was performed to study the effect of kernel maturity on aflatoxin production when exposed to *A. flavus* (NRRL 3251), S-CEW and MW. Five adult MW's were introduced to each ear at 7, 15, 28 and 35 days after 50% pollination had occurred. The samples were harvested and prepared for aflatoxin analysis as described previously.

Results and Discussion

The growing season in 1982 was considered "normal"; precipitation was adequate at both experimental fields in Quicksand and Lexington. Hence, stress factors from abiotic sources were generally absent. In reviewing the conditions leading to fungal invasion of corn kernels with *A. flavus*, Hesseltine (9) enumerated spore inocula quantity, stress factors on the growing plant, insect and mite populations, damage from other fungi, varietal susceptibility or resistance, mechanical damage from farming, storm damage, bird damage, mineral nutrition of the plant, and temperature. Our experimental method involved stressing the growing plant and developing ear with European corn borer (ECB, via inoculation with egg masses), maize weevil (MW) and corn earworm (S-CEW, via simulation by knife wound).

Analyses of the aflatoxins confirmed earlier results demonstrating the high aflatoxin producing characteristics of the NRRL 2999 and NRRL 3251 strains (8). Also, the results pointed up the especially high productivity of aflatoxin G_1 and total aflatoxin by NRRL 2999 (Tables 2-6). Again, this characteristic had been demonstrated earlier (8). In 1982, the Quicksand experiment showed that ECB combined with NRRL 2999 introduced via S-CEW produced the highest levels of B_1, B_2, G_1, and G_2 aflatoxins, but only in the G_1 type was this level significant from the second highest level produced (Table 2). The ECB plus NRRL 2999 with S-CEW treatment also elicited production of the second highest level of the B and G aflatoxins at the Lexington planting, being outproduced only by the MW with NRRL 2999 treatment. The difference, however, was not significant (Table 3). ECB alone did not prove to be significantly different than the untreated control, producing only traces of aflatoxin at either location (Tables 2 and 3). The S-CEW treatment alone promoted significantly higher levels of B_1, B_2 and total aflatoxin than ECB, or untreated control at Quicksand (Table 2) but not at Lexington (Table 3). At Lexington, when MW was introduced in several treatments, it played an important role in influencing aflatoxin production. MW plus NRRL 2999 produced the highest level of total aflatoxin, while ECB plus S-CEW with NRRL 2999, S-CEW with NRRL 2999, and MW plus NRRL 3251 followed in that order. MW alone, however, proved to influence only low level aflatoxin production (Table 3).

Hybrid effect was significant and this was borne out at both locations, with FRM017xT232 giving a significantly higher level of total aflatoxin than CI66xFR802W (Tables 2, 3). This difference, however, should be viewed from the perspective of relative magnitude, and it is apparent that this is not large enough to have a significant impact in host plant resistance towards *Aspergillus* contamination/aflatoxin production. Consequently, we accept the findings that neither hybrid offers genetic sources of aflatoxin resistance. Because of this, Pioneer 3369A was planted in 1983, not only in Kentucky, but in other southern states as part of a regional study.

The summer of 1983 was extremely dry except for the early one-third of the growing season, and the planting at the South Farm in Lexington was under great water stress. Harvest yield in the experimental field was estimated as being ca. 40 percent of normal (Avg. corn yield for Fayette County was estimated at 32 bu/A. by Kentucky Crop and Livestock Reporting Service, compared to 105 bu/A. in 1981). *Aspergillus* infection was readily evident at harvest, and unusually high levels of aflatoxin were produced in all treatments, including the control plots (Table 4). This was attributable to the stressed condition of the growing plant and preharvest corn. The highest levels were found in the treatments involving insects, i.e., ECB, MW, and S-CEW, or their combinations plus either species of the fungi. A mean production of 54,330 ppb total aflatoxin was encountered from the ECB (2nd gen.), S-CEW plus NRRL 2999 and MW (treatment no. 14), compared with 24,760 ppb when NRRL 3251 (treatment no. 15) was substituted for NRRL 2999 (Tables 4, 6). The untreated control produced 2,560 ppb, compared to a mean of 1 ppb in 1982. The insects, or their combinations, contaminated with *Aspergillus*, generally resulted in significantly higher levels of total aflatoxin than the treatments introducing insects without fungi, or the untreated control. The only exception was the ECB, 1st and 2nd generation, treatment no. 6 (Tables 1, 4).

Table 4. Treatment effect: Aflatoxin analyses of corn hybrid grown at South Farm, Lexington, Kentucky, 1983.

Treatment No.[b]	Aflatoxin Mean, ppb[a] B$_1$	B$_2$	G$_1$	G$_2$	Total
14	25,670a	2,330ab	23,330a	3,000a	54,330a
10	17,330abc	2,170ab	14,670ab	2,000ab	36,170ab
12	18,330abc	2,170ab	13,000abc	2,170ab	35,670ab
2	15,570abcd	1,730ab	11,900abc	1,630ab	30,830abc
11	27,670a	2,770ab	170def	100cde	30,700abcd
15	20,050abcde	2,070abc	2,180de	450cd	24,760bcdef
3	21,830abc	2,620a	40g	40e	24,530abcde
13	20,830ab	2,130ab	80fg	60de	23,100abcde
6	10,020cdef	680bcd	2,000de	400c	13,100efg
1	8,120efg	410e	2,340bcd	540bc	11,400fgh
5	7,170bcdef	780abc	1,850cd	230bc	10,030defg
7	7,920abcdef	750abc	1,000d	220bc	9,880cdefg
9	6,470defg	770abcd	920d	230bc	8,380fgh
8	5,350defg	730abcd	970de	180cd	7,230fgh
4	3,450fg	370cd	320def	100cd	4,240gh
16	1,700g	250de	550de	60cd	2,560h

[a]Values with the same letter are not significantly different at the 5% level, by Duncan's multiple range test

[b]Refer to Table 1 for treatments.

The corollary study to examine the influence of plant maturity on aflatoxin production showed that there was no significant difference among the treatments contaminated 7, 15 and 28 days after 50% silking, but the 7-day treatment was significantly higher than the 35-day treatment. All treatments were significantly higher in total aflatoxin production than the untreated control (Table 5). These results point up the role that corn development (maturity) has in the infection and aflatoxin production process. A previous study had shown a maturity effect of 316 ppb total aflatoxin produced when contamination was made 15 days after 50% pollination compared to 105 ppb at 21 days, but levels in that instance were considerably lower (8).

Table 5. Results of corollary experiment, 1983. Effect of maturity on aflatoxin production, with knife wound (S-CEW), NRRL 3251 plus Maize Weevil (MW) treatments and days after 50% silking effects.

Treatment[b] (Days)	Aflatoxin mean, ppb[a] B$_1$	B$_2$	G$_1$	G$_2$	Total
1. 7	18,670a	1,380a	30a	20a	20,100a
2. 15	18,500a	1,270a	200a	70a	20,060ab
3. 28	13,320a	1,250a	550a	150a	15,500ab
4. 35	6,280b	1,070a	670a	200ab	8,210b
5. Control	1,700c	250b	790b	60a	2,560c

[a]Values with the same letter are not significantly different at the 5% level, by Duncan's multiple range test

[b]Refer to Table 1 for treatments.

Table 6. Fungi effects across treatments indicated. Mean of total aflatoxin - ppb[a].

Treatment[b]	NNRL 2999	NRRL 3251
S-CEW	30,830abc	24,530abcde
MW	36,170ab	30,700abcd
ECB (2nd gen), S-CEW	35,670ab	23,100abcde
ECB (2nd gen), S-CEW, MW	54,330a	24,760abcde
Control	2,560d	2,560f

[a]From means, Table 4. Values with the same letter are not significantly different at the 5% level, by Duncan's multiple range test

[b]Refer to Table 1.

In conclusion, the effect of drought in 1983 on aflatoxin production in corn was dramatic as compared with more normal years, and clearly demonstrated that while insect interaction also increased the aflatoxin levels drastically, basically the plant has to be physiologically disposed/stressed to provide the correct ambiance for fungal synthesis of mycotoxin (10). The possibility of Kentucky corn carrying relatively large loads of aflatoxin in the 1983 crop was great. If our untreated control plots were any indication of the condition of the 1983 crop generally, the aflatoxin level exceeded the FDA permitted levels of 20 ppb by a factor of more than 100 x.

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Borehold Determination of Immediate Lithologic Characteristics of Adjacent Stable and Unstable Coal Mine Roofs

Alan D. Smith
Coal Mining Administration, College of Business,
Eastern Kentucky University
Richmond, Kentucky 40475

Abstract

An in-depth study of 4 adjacent mine crosscuts, 2 of which juxtaposed a major beltway, in an underground coal mine located in the Northern Appalachian Coal Field, northeastern West Virginia, was completed to determine if lithologic and geologic parameters of the immediate roof strata could be used to differentiate roof conditions. Three of the crosscuts were extremely unstable and, if they had not been bolted and reinforced with a series of wooden cribs, would have, in most probability, failed. The stable crosscut, which showed no sign of deterioration, is flanked by the unstable areas and is supported by the traditional roof-bolt techniques and patterns common to the Appalachian Coal Field. A study, using diamond coring, borescoping, and X-ray diffraction techniques, was completed. All cores from 4 sites had primarily dark gray shales (124), hard sandstones with rippled shale streaks (563 RIP), and dark gray shales with interbedded sand, rippled sandstone streaks (322 RIP) as the dominant lithologies. The stable crosscut appeared to contain slightly more massive strata of the 322 RIP and 564 lithologies. Drill site 4, classified as extremely unstable, with a previously recorded major roof fall on the belt a few meters away, had evidence of expandable montmorillonite-illite, mixed-layer clay minerals. No evidence of these clay minerals was observed in the stable crosscut. However, the evidence collected does not clearly differentiate among adjacent stable and unstable immediate mine roof profiles; hence, more complex geological and mechanical interactions must be in play to account for the extreme changes in mine-roof quality.

Introduction

The mechanics and geological conditions that result in coal mine roof falls are complex and not completely understood. The measurement, monitoring, and forecasting of mine roof falls involves a continuous process. Several programs can be implemented to improve ground control or underground stability and aid in the prediction of potentially bad areas. As suggested by Tennant (1), some of these various programs that can be implemented in the Appalachian Coal Field include a detailed analysis of satellite imagery to detect structural linements and their correlation with the known areas of mine roof instability. Also, improvement is needed in mine planning, mine projections with in-situ stress measurements are needed, increased emphasis in regard to pillar design, and barrier block design. Other programs, such as utilizing extensometers, television, and traditional optical borescoping should be employed after initial coal extraction to monitor separations in rock layers at various levels in the mine roof. This would aid in the identifying roof failure mechanisms and be useful in formulating appropriate corrective action.

In narrowing down possible causes of roof falls, the influence of tectonic forces, geologic conditions, mine geometry, and roof support techniques all interact to play a vital role that should be considered. Unfortunately, the degree of interaction among these variables is great, difficult to isolate, and highly dependent on the mine's in-situ combination of these conditions. The correlation of topographical features, including such features as the presence of creek beds, water table locations, mountain terrains, and data concerning the high lateral stresses, common to the Appalachian Coal Field, with the actual occurrence and distribution of mine roof falls are generally inconclusive (2).

Probably more important parameters, such as geological disturbances, which include a host of features including paleochannels consisting of sandstones and accompanying slickenslides, clastic dikes, kettle bottoms, joints and axial plane cleavage, and expandable clays, are extremely difficult to assess in the short term, since their occurrence may not be predictable and they are generally not encountered until actual coal extraction. Frequently, mine roof strata will contain geologic and lithologic features that will eventually cause roof failure. Unfortunately these features are not readily identified until after the failure has occurred. The purpose of any comprehensive monitoring program for ground control should be to identify potentially unstable roof strata soon after coal extraction. This enables the mining engineer to take preventive measures before roof convergence becomes uncontrollable and complete failure is likely.

According to research completed by Van Besien (3) in underground mines of the western United States, many roof falls are associated with localized defects in the immediate roof. Factors contributing to roof falls include the type and thickness of the rock strata, slickensides, plant material on bedding planes, burrowed and rotted zones, rider coal seams, kettle bottoms, cracks in the roof, and the presence of water. Dougherty (4) found in his study that roof falls occurred 7 per cent of the time when the roof was sandstone, and 12 per cent of the time when coal was left to protect the shales, while 80 percent of roof falls occurred when the roof consisted of unprotected shales.

The best quality roof strata generally consists of well consolidated graywacke sandstone which are generally about 10 feet thick and laterally continuous for more than 2000 feet (5). However, sandstones also present roof control problems. Orthoquartzitic sandstones may provide high quality roof rock needed, but this sandstone tends to react more brittely than other sandstones or non sandstones (6, 7). Usually orthoquartzitic sandstones are jointed and fractured producing the possibility of a severe roof fall (5).

In roofs where interbedded sandstones and shales or flaggy sandstones exist, roof competence depends on bed thickness (5, 7). When beds are less than 2 feet thick, separation can occur along the bedding plane giving rise to a roof fall that can fall as a single unit. If beds become thicker than 10 feet, slickenside surfaces develop due to differential compaction giving rise to roof falls that may not fall as single units. Hylbert's (3) study also indicates that lithified plant material on bedding lanes is likely to contribute to the incidence of roof falls, because it weakens the cohesiveness of the rock to the next bed. Therefore, the optimum bed thickness is 2 to 10 feet thick producing an optimum bridging strength of the material.

Discontinuous sandstone bodies, such as sandstone channels, often rank as one of the more troublesome roof control problems (6, 8). These bodies also frequently cut out coal beds, are involved in roof falls, and can start water problems. The associated problems with discontinuous sandstones are due to the abrupt change of lithologies, such as the change from shale and standstone, and the differential compaction of sediments along the boundary of the sandstone deposit. These 2 factors create the shears and/or slumps which cause natural zones of weakness and excellent places for roof control problems to develop (7, 9). The field techniques to recognize these problem areas may include the presence of fractures and/or steeply dipping coal beds, slickenside surfaces becoming more numerous, and the observation of a rise in the floor elevation (8, 10). However, the occurrence of sandstone channels is at best difficult to predict.

Studies by Hylbert (7) and Lagather (11), found that thick shale roofs are often characterized by laminated shales, usually coarsening upward to a rider coal seam. Roofs such as these are hazardous because laminated shales tend to separate along bedding planes. Sudden changes in the thickness of shales by either pinchouts or wedging of sediments are sometimes associated with roof falls.

Heavily burrowed shales or siltstones present potential roof control problems. The strength of these fine-grained rocks is reduced by burrowing. Supporting burrowed roof rock by bolting is difficult, if not impossible, due to the nonbeaming support nature of the burrowed rock. Rooted shales and siltstones are another roof control problem with engineering problems similar to burrowed shales. Roots penetrating these rocks often show slickenslides intersecting at angles of 90 to 120 degrees (12). Rooting weakens the rock making bolting to form the roof beam difficult and sometimes impossible.

The occurrence of rider coal seams has been found to have a definite influence on roof stability (7, 9). Hylbert (7) and Horne et al. (5) found that rider coal seams and their associated root zones represent incompetent layers. Rider seams have their worst effects when they are within 6.1 m of the coal seam being mined. It is at the interface between the rider seam and the adjacent roof rock where separation of the strata may occur, causing a mine roof fall. The fall usually begins at the coal seam and falls to the above rider seam. If a higher concentration of water is present along the separation, this may weaken the ability of the roof to support a load, making roof instability a greater likeliood.

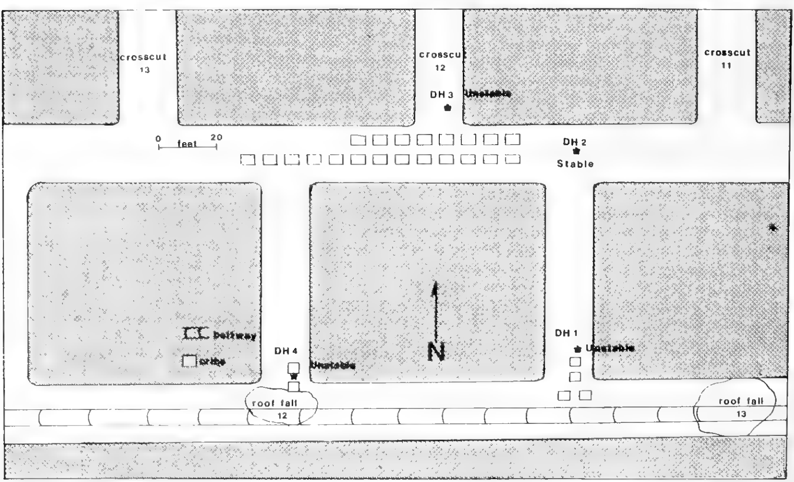
Although the design of a safe mine roof can be quite complex, challenging, and in need of constant surveillance, generally crude and relatively unsophisticated equipment is used to install and to monitor mine roof conditions. Of course, this situation is probably due to the expensive and possible delicate nature of the more advanced equipment (13). In addition, there is usually some resistance to the interfacing of new applications and techniques into the underground coal mining environment by mining personnel, primarily due to tradition and routine of daily operations. The monitor equipment is generally costly, for example a relatively simple optical borescope with a 6 to 9 m cable extension may easily result in a $10,000 to $20,000 expense, depending on the model and attachments. Generally, some training by a specialist is needed for interpretation.

The purpose of the present research is to evaluate the monitoring value of both adjacent unstable and stable mine roof top in a coal mine in the Appalachian Coal Field to determine if detailed borehole scoping, diamond drilling and associated coring, lithologic classification, and dimensional analyses can significantly enhance roof quality assessments. Results from borescope inspection can correlate, in practice, very well with diamond-drill core logs and help resolve the question whether a fracture is the original or resulted from stress induced during the drilling process. The detection and assessment of immediate roof characteristics, if significant, may be monitored in the future through various stations in coal mines, usually during the roof bolting operation to differentiate potentially stable and unstable mine roof conditions in order to estimate proper and cost effective support systems.

METHODS

STUDY AREA

The Upper Freeport coal seam in the mine studied averages about 9 ft. (2.7 m) thick with a variable parting of siltstone and bone thickness from 2.5 ft (0.8 m) to small fractions of an inch. The coal, relatively high in sulfur content which frequently staines the powered limestone utilized in the rock dusting process. A site was chosen to investigate the adjacent stable and unstable areas in the immediate roof in this coal mine in northeastern West Virginia, owned and operated by Island Creek Coal Company. A total of 4 locations were marked and measured, as illustrated in Fig. 1. The lithology of the immediate mine roof consisted of primarily shales. As can be seen in Fig. 1, entry spans adjacent to the roof falls and/or unstable areas are not significantly different precluding differential loading from overburden as a contribution factor in these failures.



1. Planametric view of adjacent stable and unstable areas and positions of drill hole sites 1 through 4.

SAMPLING AND BORESCOPING TECHNIQUES

Diamond drill holes of 2 in. (5.1 cm) diameter resulting in an approximately 0.88 in. (2.2 cm) diameter solid core were completed to varying depths in the immediate mine roof tops in the 4 sites portrayed in Fig. 1. A hydraulic pump was used in connection with the portable drill rig to retrieve the cores. Only water without the benefit of bentonite was used as the drilling fluid. The drill apparatus was sufficiently anchored below the mine floor and above on the mine roof with hydraulic compression rams; in addition a safety chain was used near adjacent wooden cribs to provide an extra margin of safety. A post for safety purposes was always erected near the drilling site and immediately over the hydraulic control box. The cores derived from the drilling of the various sites were boxed, short notes concerning speed of drilling, core recoveries, and lithologic classification, according to Ferm and Weisenfluh's code system (14) were recorded and tabulated (Table 1). Some of the samples from drill site 4 underwent X-ray diffraction to identify the clay minerals present. These samples were selected because of the intermittent water flow characteristics they exhibited during drilling, which may be caused by expandable mixed-layered clays. Finally, standard borescope analysis techniques were employed to locate fractures and gross lithologic changes in the 4 drill sites.

Table 1. Three-digit classification scheme of Ferm and Weisenfluh (14) and their corresponding lithologic descriptions. (see Fig. 3 for actual core logs).

Lithologic Code	Lithologic Description of Actual Cores
124	dark gray shale, extremely limited silt content
322 RIP	dark gray shale, of sandy content, and interbedded sandstone that are rippled in configuration
323	dark gray, sandy shale with sandstone streaks
324	dark gray, massive sandy-shale
325	dark gray, massive churned sandy-shale
563	hard sandstone with shale streaks
563 RIP	hard sandstone with shale streaks that are rippled in configuration
564	gray, hard, massive sandstone

RESULTS

The data summaries and calculation of the per cent core recovery can be found in Table 2. Figure 2 portrays the lithologic description of the 4 drill logs, according to the classification of Ferm and Weisenfluh's (14) classification scheme (Table 1). Figure 3 is the X-ray diffractograms performed on the clay samples collected from drill site 4. Lastly, Table 3 presents the optical borescoping information collected and described for drill sites 1 through 4.

Table 2. - Core sample lengths and recoveries for drill holes 1 through 4.

Drill Hole Number	Cumulative Borehole Length (in)	Cumulative Sample Length (in)	Borehole Drill Length (in)	Borehole Sample Length (in)	Percent Recovery (%)
	96.0	33.5	96.0	33.5	34.9
1					
total recovery = 46.0%	NA	NA	NA	NA	NA
2	50.0	37.0	50.0	37.0	74.0
total	98.0	78.0	48.0	41.0	85.4
recovery	140.0	119.0	42.0	41.0	97.6
= 87.2%	196.0	171.0	56.0	52.0	92.90
3	57.0	51.0	57.0	51.0	89.5
total	116.0	108.0	59.00	57.0	96.6
recovery	154.0	146.0	38.0	38.0	100.0
= 94.9%					
NOTE: Hit very hard sandstone at 80 in into hole. At 84 in., past sandstone into soft shale. At 109 in. entered extremely hard sandstone. No plugging of bit occurred the first 60 in. of drilling in the wet roof.					
4	58.0	48.0	58.0	48.0	82.8
total	96.0	81.5	38.0	33.5	88.2
recovery = 84.9%					
NOTE: During drilling, encountered many thin sandstone sequences of extremely hard nature, which made it very difficult to drill (up to 1400 psi of thrust, which is the maximum allowable on the machine). Drill fluid leaked out through the shale and sandstone sequences toward the exposed roof fall over the belt and flowed out by the bolt header boards. However, this condition was stopped a few weeks later due to the expansive nature of the clay derived from drilling into the shale.					

Discussion

Coring and Borehole Scoping of Drill Sites 1 through 4

Presented in Fig. 2 and Table 3 are the data derived from coring and optical borescoping of drill locations 1 through 4. Due to the relatively poor core recovery of drill site 1 (Table 2), the lithologies of the first few meters are relatively uncertain and extrapolated from the other cores and borescope data. Basically, strata in the diamond cores can be characterized using three lithologic types: 124 (dark gray shale), 563 RIP (hard sandstone with rippled shale streaks), and 322 RIP (dark gray shale of sandy content with interbedded, rippled sandstone streaks). These lithologies are relatively consistent throughout the cores, for both the stable (drill site 2 and unstable (drill sites 1, 3, and 4) areas. The stable roof strata appears, however, to contain a more massive section of 322 RIP and 564 lithologies that are closer to the initially cut roof top, but the variability of lithologies of the adjacent unstable immediate roof beds are relatively high; and, thus, may make this observation invalid.

Table 3. - Borehole scoping information for drill holes 1 through 4.

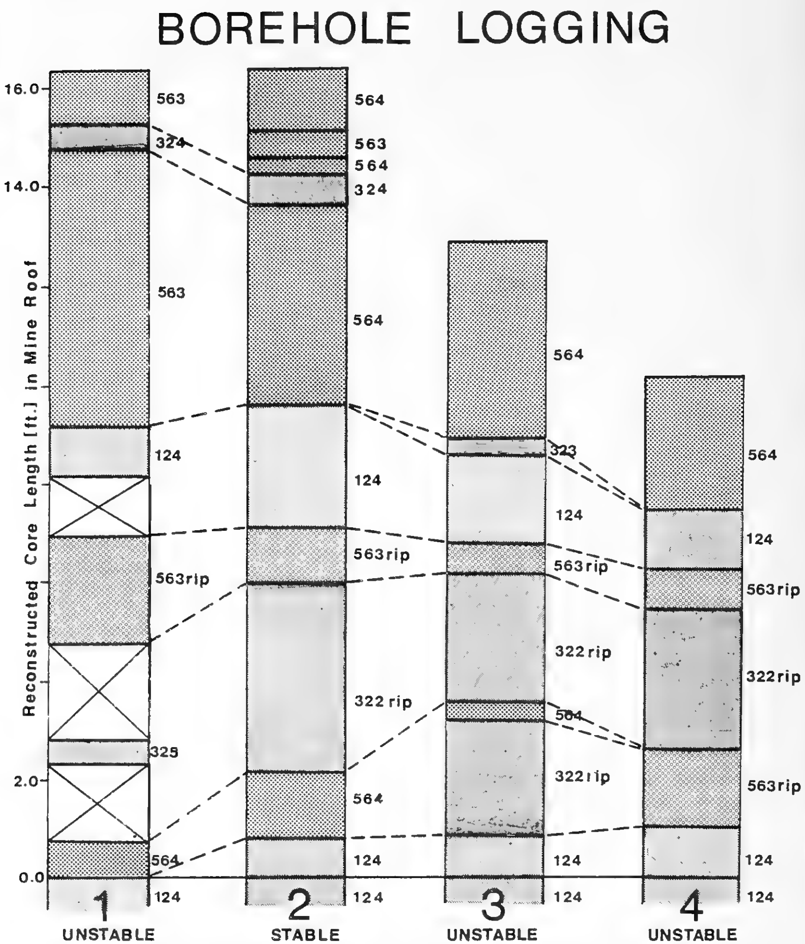
Drill Hole Number	(ft) Beginning of Hole (Roof)	Geologic and Physical Description
1 (7-25-83)	0.42-1.67	Interbedded shale and sandstone, mainly shale, highly fractured and broken zone.
	2.75-6.92	Interbedded shale and-sandstone, highly fractured zone, 2.75 ft. open crack, top of fracture zone at 6.92 ft.

continued

Table 3 continued

	8.00	Sandstone contact begins.
	8.08-8.17	Interbedded shale and sandstone, highly fractured and broken zone.
	8.67	Top of broken zone, 8.08-8.67 fracture zone extent.
2 (7-25-83)	0.00-1.67	Interbedded shale and sandstone, mainly shale with some dark to black color, fracture zone, large fracture at 1.67 ft.
	1.67-5.17	Interbedded shale and sandstone,w ith intermittent thin sandstone layers.
	5.17	Open crack.
	5.17-6.00	Fracture zone, 6.00 ft. end of fracture zone.
	6.75-7.00	Sandstone, massive, begins, very sharp textural contact.
	13.67	Interbedded sandstone and shale contact within massive sandstone.
	13.67-14.25	Interbedded sandstone and shale zone.
	14.25	Sandstone, massive zone continues.
3 (7-26-83)	0.00-0.50	Interbedded shale and sandstone, mainly shale, dark color highly fractured and broken zone.
	1.08-1.58	Interbedded shale and sandstone, mainly shale, highly fractured and broken zone.
	2.00	Interbedded shale and sandstone, sharp, well defined sandstone layers, good intact rock.
	2.00-6.00	Interbedded shale and sandstone, good intact rock.
	6.00	Open crack, approximately 1/16 inch.
	6.42	Open crack, approximately 1/16 inch.
	6.50	Open crack, approximately 1/16 inch.
3	6.75	Open crack, approximately 1/16 inch.
	7.00	Black shale contact, with presence of water.
	8.75	Open crack.
	9.00	Open crack.
	9.17	Sandstone, massive, begins, very sharp textural contact.
	9.17-12.00	Massive sandstone, stop scoping at 12.00 ft.
4 (7-26-83)	1.17	Interbedded shale and sandstone, mostly shale, series of open cracks.
	1.17-1.42	Interbedded shale and sandstone, mostly shale, fracture zone, ends at 1.42 ft.
	1.75	Interbedded shale and sandstone, approximately 1 inch highly broken zone.
	2.17	Highly broken zine, approximately 1 inch.
	5.67	Sandstone, thin laminar contact.
	7.25	Shale bed contact with associated crack.
	7.25	Series of hairline cracks, approximately 0.5 inches apart.
	8.17	Sandstone, massive, contact, at base of sandstone washout zone.

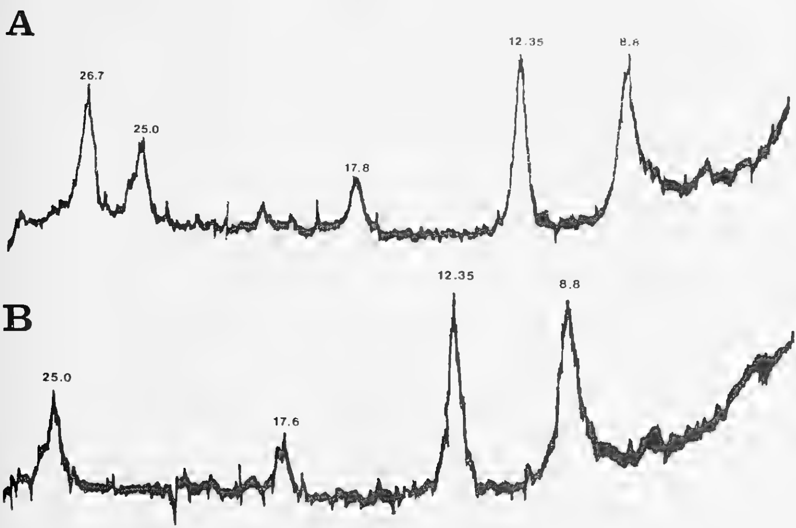
The borehole scoping results (Table 3) prove to be even more inclusive, especially in light of the fact that some measurable convergence has occurred in the unstable areas (drill sites 1, 3, and 4) and fracture zones are expected. The stable crosscut (drill site 2) had a noticeable open crack at approximately 5.2 ft. (1.6 m). However, this same crack, which may have led to the development of fracture zones characterized in the other drill sites, is also represented in the unstable roof top as well. This presence of cracks at this depth into the roof is puzzling, especially since this stable crosscut is flanked by unstable roof tops (Fig. 1).

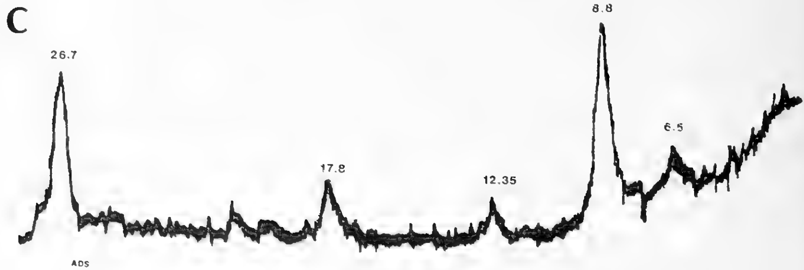


2. Lithologic description, according to Fermand Weisenfluh (14), of the 4 recovered cores from drill hole sites 1 through 4. Please refer to Table 1 for geologic descriptions of classification codes used in the logs.

X-Ray Diffraction of Drill Site 4

It is difficult to make quantitative determinations at mixed-layered silicate structures particularly when layers of the different silicate minerals are interstratified. Figure 3 ABC display X-ray diffractograms of clay sampled from drillhole site 4. As illustrated in Fig. 3, parts A through C, which represent different treatments, some recognizable peaks for qualitative interpretation are evident in the defractogram, using a copper-target element. The quartz peak, represented by the characteristic diffraction of 26.7 2θ angle, appears in all the diffractograms. Standard preparation techniques, as outlined by Cullity (15), Grim (16), and Mitchell (15), using the powdered method of preparation, in which a small sample, giving particles of all possible orientations is placed in a collimated beam of parallel X-rays. As portrayed in Fig. 10A, an untreated powered sample was exposed to X-rays and, based on the basal spacing determined from the first order reflections, kaolinite (12.35 20 angle, d or basal spacing equal to 7.19 Å), and illite (8.8 20 angle, d equal to 10.0 Å) can be identified. However, to identify illite-montomorillonite mixed-layered clays is more difficult, as previously mentioned. Since montmorillonite is characterized by extensive isomophoric substitution, it has a high cation exchange capacity (10-15 times that of kaolinite), causing water molecules and other cations to be attracted between crystal units. This attraction results in expansion of the crystalline lattice, high plasticity, and cohesion properties. Based on these properties, by a combination of glycolation and heating treatments, illite-montmorillonite qualitative identifications can be made (Fig. 3 B-C). However, quantitative determinations of the amounts of the different minerals in the clay sample taken from drill hole site 4 on the basis of simple comparison of diffraction peak heights or areas cannot be made. The reasons for this inability to differentiate the exact amounts of illite and montmorillonite involve the differences in mass absdorption coefficients of different minerals, in particle orientations, in same weights, in surface texture of the powdered sample, in crystallinity in the minerals, in hydration, as well as other factors (17). As shown in Fig. 3C, the prominant feature of this diffractogram is the reduction of the kaolinite peak and a sharpening of a mixed-layer montomorillonite-illite peak at about 13.6 Å; also evident is the illite peak remaining unchanged, as well as the quartz peak. Although a quantitative analysis is complex, as suggested by Moore (18) and Buck (19), a semi-quantitative analysis can be attempted. The montomorillonite peak is usually small on the diffractogram and, when found in conjunction with illite, may be up to a multiple of 7 of that peak actually recorded in the diffractogram compared to the illite recorded peak (15, 17, 18). Therefore, there could be theoretically a 1:1 relationship of illite to montmorillonite, when comparing the two peaks. Although the diffractogram indicates the possible presence of small amounts of montmorillonite, the amount could be significant and, due to its great expansive properties, be a major contributor to mine roof instability. The clay samples were derived from a depth of approximately 1.5 meters (4.8 ft.) into the roof in the 124 coded lithology. In addition, although further tests were not completed due to sampling constraints, similar clay appeared to be present in the relatively unstable drill site 1. However, no evidence of this clay forming during the drilling operation was found in site 2.





3. Prominant features of the diffractogram on clay sample taken from drill site number 4. Numbers are in 2θ. Note, letters symbol various treatments: (A) untreated, (B) heat treated at 300°C for 6 hours, (C) heat treated at 500°C for 2-5 hours according to techniques suggested by Cullity (15) and Grim (16).

CONCLUSION

The results of this study of adjacent stable and unstable immediate mine roofs creates more questions than it solves. Although it appears that the expansive nature of the montmorillonite-illite clay mixtures may be a potential cause in the unstable areas, it does not explain the origin of the source of water or additional cations available to these clays, causing subsequent swelling behavior. The lithologies associated with the clays, especially the interbedded shales and sandstones, and fractures found may act as a conduit for subsurface flow, but these lithologies are associated, according to the cores, with the stable area as well. Indeed, an open crack, according to the borescoping data, was also found in the stable area that could allow for this directional water flow, although no expandable clay was observed during drilling. Generally, the present study illustrated in this case that the immediate lithologic and geologic features corresponding with the stable and unstable area were not clearly different or predictable, in order to base a design approach for ground control in the development of stable entries for the affected coal mine. Hence, other than the results of the X-ray diffraction and identification of expansive layer silicates, many, if not most, mine roof falls occur under a complex set of conditions and subsequent interactions that frequently can not be forecasted on the basis of geological and lithological evidence alone. However, many potential roof problems can be successfully predicted geologically using conventional rock coring and field reconniaissance. The designing of ground control systems must be interdisciplinary in nature, as presented in this study, based on probability of occurrence.

ACKNOWLEDGEMENTS

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NOTES

Break Angle Determination and Contouring of Coal Mine Roof Falls: Suggested Methods and Case Study. —Geometry of mine roof falls and their associated break angles of the strata involved are basic input into many rock mechanics, ground control techniques, and mine-roof fall prevention programs (Karhnak, 1981, An overview of Bureau of Mines ground control research, In Proc. of First Annual Conf. on Ground Control in Mining, Peng (ed.), West Virginia Univ., Morgantown, WV; Obert and Duvall, 1967, Rock mechanics and the design of structures in rock, John Wiley and Sons, Inc., New York; Peng, 1978, Coal Mine Ground Control, John Wiley and Sons, Inc., New York). The geometry of mine-roof falls depends on the lithologic characteristics, strata stresses, progressive failure characteristics, time duration of opening, moisture contents, and degree of competency of the mine-roof beds. A suggested method for gathering basic information for the determination of break angles and the eventual plotting of the basic geometry of mine roof falls was established. The technique for data collection is relatively simple and involves only 15 to 45 minutes to complete, depending on the complexity and areal extent of the fall and the experience of the researchers. The only equipment required specifically for this procedure are string, a small wooden base station with 22.5 degree intervals marked on the side facing up, and an extendable measuring pole to reach the various horizontal strata involved.

The mine-roof fall was mapped, for illustrative purposes, in a coal mine in the Appalachian coal fields located in Bayer, West Virginia. Figure 1 outlines the basic location of the mine roof fall: between the 19th and 20th break or crosscuts inby (inby refers to the direction towards the working face or away from the mine shaft) in 3-Left submain entry. The base station is located 16.7 ft. (5.1m) from the midsection of the crosscut facing the belt entry and the farthest extent to the east of the roofline is 23.3 ft. (7.1 m) from the edge of the 19th break, as shown in the figure. The O-degree interval pointed due east or directly outby (outby refers to the direction towards the mine shaft or away from the mine working face) and the rest of the readings are located in relation to that origin point. Figure 2 is the result of plotting the information found in Table 1 and portrays the elongated geometry of each strata break

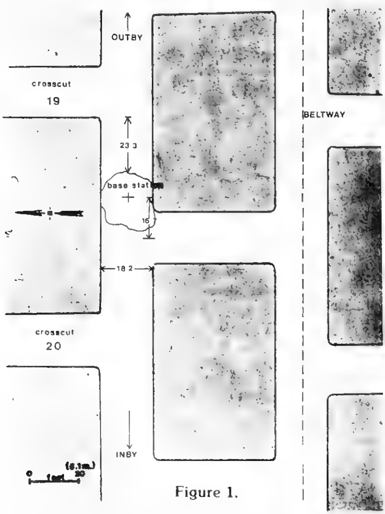

Figure 1.

Planametric view presenting the location of the coal mine roof fall measured and contoured.

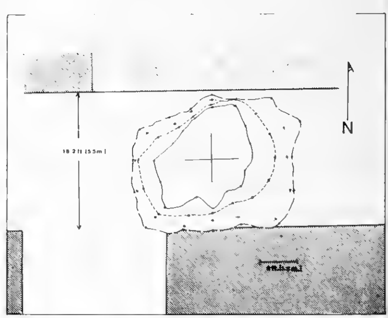

Figure 2.

Final geometrics of coal mine roof fall. Note that the contour interval between strata break horizons are not constant, see Table 1 for more specific information.

horizontal. Of course, it must be remembered that an individual break horizon may be composed of several separate and/or interbedded lithologies. Finally, Table 2 summarizes the break angles of each series of horizons and can be used to compare symmetry of the fall. As evident in Table 2, the mean break angle for all strata horizons in the outby direction was 41.4° ($\sigma = 16.98$), the mean break angle in the inby direction was 61.1° ($\sigma = 15.97$), the average break angle facing north was 66.5° ($\sigma = 14.03$), and the average break angle of the mine roof fall facing directly south was 51.4° ($\sigma = 15.01$). However, its most useful function would be to compare break angles of other falls in the area to the major stress axes to determine if direction of insitu stress was a major determiner of mine-roof falls.

Table 1. Raw data from the survey of break angles of mine roof strata and contouring of basic geometrics of the crosscut located, coal mine roof fall.

Orientation of Base Station (degrees)	Roof Strata Break Horizon in Feet (Meters)							
	Roof Top (1)		Strata Below Roof Top (2)		Strata Above Roof Edge (3)		Roof Edge[a] (4)	
	H	V	H	V	H	V	H	V
0.0 (E)	5.25 (1.6)	3.67 (1.1)	8.42 (2.6	2.08 (0.6)	10.00 (3.0)	1.08 (0.3)	10.50 (3.2)	0.0
22.5	4.67 (1.4)	3.67 (1.1)	7.83 (2.4)	2.08 (0.6)	11.17 (3.4)	1.08 (0.3)	11.33 (3.5)	0.0
45.0	5.17 (1.6)	3.67 (1.1)	7.42 (2.3)	2.08 (0.6)	11.58 (3.5)	1.08 (0.3)	12.33 (3.8)	0.0
67.5	4.67 (1.4)	3.67 (1.1)	6.33 (1.9)	2.08 (0.6)	8.33 (2.5)	1.08 (0.3)	9.42 (2.9)	0.0
90.0 (S)	6.58 (2.0)	3.67 (1.1)	7.08 (2.2)	2.08 (0.6)	8.17 (2.5)	1.08 (0.3)	9.50 (2.9)	0.0
112.5	5.58 (1.7)	3.67 (1.1)	7.92 (2.4)	2.08 (0.6)	9.33 (2.8)	1.08 (0.3)	10.08 (3.1)	0.0
135.0	9.00 (2.7)	3.67 (1.1)	10.08 (3.1)	2.08 (0.6)	10.83 (3.3)	1.08 (0.3)	12.50 (3.8)	0.0
157.5	7.92 (2.4)	3.67 (1.1)	9.75 (3.0)	2.08 (0.6)	10.67 (3.3)	1.08 (0.3)	11.08 (3.4)	0.0
180.0 (W)	7.67 (2.3)	3.67 (1.1)	9.67 (2.9)	2.08 (0.6)	10.00 (3.0)	1.08 (0.3)	10.33 (3.1)	0.0
202.5	5.58 (1.7)	3.67 (1.1)	7.50 (2.3)	2.08 (0.6)	9.17 (2.8)	1.08 (0.3)	10.33 (3.1)	0.0
225.0	5.42 (1.7)	3.67 (1.1)	6.00 (1.8)	2.08 (0.6)	6.08 (1.9)	1.08 (0.3)	7.83 (2.4)	0.0
247.0	5.92 (1.8)	3.67 (1.1)	6.00 (1.8)	2.08 (0.6)	6.92 (2.1)	1.08 (0.3)	7.08 (2.2)	0.0
270 (N)	6.92 (2.1)	3.67 (1.1)	7.08 (2.2)	2.08 (0.6)	7.92 (2.4)	1.08 (0.3)	8.42 (2.6)	0.0
292.5	7.58 (2.3)	3.67 (1.1)	8.42 (2.6)	2.08 (0.6)	8.17 (2.5)	1.08 (0.3)	8.58 (2.6)	0.0
315.0	6.75 (2.1)	3.67 (1.1)	8.25 (2.5)	2.08 (0.6)	11.17 (3.4)	1.08 (0.3)	10.83 (3.3)	0.0
337.5	5.42 (1.7)	3.67 (1.1)	8.33 (2.5)	2.08 (0.6)	10.25 (3.1)	1.08 (0.3)	12.50 (3.8)	0.0

Note. The letters in parentheses next to the orientations of the base stations symbol basic direction, where east represents the mine inby direction and west represents the outby direction. The symbols H and V represent horizontal distance from the base station to the perpendicular dropped directly from the strata break horizon and the vertical distance to each break horizon, respectively.

[a] Denotes that the roof edge or roof line is 9.5 ft. (2.9 m) above the mine floor.

As evident from the break angles listed in Table 2 and the roof fall diagram of Figure 2, the steepest angles are associated with the N-S direction, probably due to the cutter-roof formation along the ribs. Large amounts of stress concentrate along the ribs, causing brittle rupture of roof rock at steeper break angles, which may approach near vertical break angle measurements. In addition, the NW-SE elongaton of break angles may be in line with the major axis of the strain ellipsoid, which may give an indication of major stress direction. In the Appalachian Coal Fields, this direction has been generally measured in a NE-SW direction. Since the major stress and strain axes run perpendicular to each other, the geometry of the fall, if controlled by stress-release mechanisms instead of the lithologic character of the roof, appears to provide additional evidence for the NE-SW direction of the major stress axis.

Table 2. Computed break angles for each strata horizon measured in Table 1.

Orientation of Base Station (degrees)	Break Angles in Degrees: From Roof Top (1) to Strata Below Roof Top (2)	From Strata Below Roof Top (2) to Strata Above Roof Edge (3)	From Strata Above Roof Edge (3) to Roof Edge (4)
0.0 (E)	26.7	32.3	65.2
22.5	26.7	16.7	81.6
45.0	35.2	13.5	55.2
67.5	43.8	26.6	44.7
90.0 (S)	72.5	42.5	39.1
112.5	33.9	35.3	55.2
135.0	55.8	53.1	85.4
157.5	41.0	47.4	69.2
180.0 (W)	38.5	71.7	73.0
202.5	39.6	30.9	43.0
225.0	70.0	85.4	31.7
247.5	87.1	47.4	81.6
270.0 (N)	84.3	50.0	65.2
292.5	62.2	90[b]	69.2
315.0	46.7	18.9	90[b]
337.5[a]	28.7	27.5	25.6

Note. The break angles approaching near vertical slopes close to the north-south direction may be the result of cutter-roof forming along the entry ribs.

[a] Sample calculation using the following formula:

$$\text{slope} = \arctan \frac{\Delta V}{\Delta H / \Delta H}$$

where: H = change in horizontal direction from base station, V = change in vertical direction from floor to strata horizon. For example, from Table 1, the change in horizontal distance for 337.5 degrees reading is 8.33 – 5.42, and the change in vertical distance is 3.67 – 2.08. The arctan of 1.59/2.91 gives a break angle of 28.7 degrees.

[b] Break angle greater than 90 degrees, assumed to be vertical.

Roof control is a never-ending task, not only at the working face and in sections where miners are working, but along haulways and airways that must be kept open. As coal is being excavated, the stresses that are set up and progressively changing in the roof result in fractures and movements that are very difficult if not presently impossible to detect, and may lead to mine-roof falls. The measurement of pre-existing and newly developed falls, through break angle determination and contouring of basic geometrics may add needed data for the establishment of statistical relationships with failure parameters associated with mine roof falls and eventually develop predictive and preventative techniques for mine ground control in underground mining operations.—**Alan D. Smith,** Coal Mining Admin., College of Business, Eastern Ky. Univ., Richomond, KY 40475; **Kot F. Unrug,** Dept. of Mining Engr., Univ. of Ky., Lexington, KY 40506.

Experimental Transplants of Plerocercoids of *Triaenophorus crassus* Forel into the Body Cavity of Whitefish, *Coregonus clupeaformis* (Mitchill). —*Triaenophorus crassus* is a pseudophyllidean tapeworm whose plerocercoid larva is found in the muscles of a variety of salmonid fish. Normally, the parasite occupies the host body cavity only during the first week of infection before migrating from the fish digestive system to the muscles (Rosen and Dick, Can. J. Zool. 62:203-211, 1984). Recently, experimental infections of whitefish fry, *Coregonus clupeaformis* (Rosen and Dick, Can. J. Zool. 62:203-211, 1984), and rainbow trout fry, *Salmo gairdneri* (Rosen and Dick, J. Wild. Dis. 20:34-38, 1984), with *T. crassus* resulted in a small number of incompletely differentiated plerocercoids that reentered the body cavity from the muscles between days 40-60 postinfection (PI) and survived in this site. Considerable pathology, including hemorrhaging and granuloma formation, was associated with these plerocercoids in the body cavity.

It is not known whether fully differentiated plerocercoids (i.e., worms with hooks and at least 3 months old) contained in a host capsule may reenter the body cavity of fish, but several worms with hooks have been observed to penetrate through the host capsule within the muscles of whitefish (Rosen and Dick, Can. J. Zool. 62:203-211, 1984). These worms may represent a long-term source of parasites capable of reentering the body cavity since they may live 4 to 5 years in muscles (Miller, Bull. Fish. Res. Board Can. No. 95, 1952). It is important to determine whether these fully differentiated plerocercoids of *T. crassus* may also survive upon reentry into the host body cavity if the pathology in fish caused by this parasite is to be accurately assessed. The objective of this study was to determine whether or not *T. crassus* plerocercoids can survive in the body cavity of whitefish if they are introduced into this site after they are completely differentiated and encapsulated by the host.

Fully formed plerocercoids of *T. crassus* were removed from capsules in the muscles of cisco, *Coregonus artedii*, obtained from Quigly Lake, Manitoba (54°51'N, 101°04'W). Plerocercoids (4-5/fish) of unknown age were pipetted into the body cavity through an incision made in the ventral hypaxial muscles of nine 4-5 year old laboratory reared whitefish packed in ice and anesthetized with MS-222. The incision was then closed with catgut chromic 310 USP (B. Broun Melsungen A. G., W. Germany), and the revived fish were held in 12°C aerated water. Fish were sacrificed at weekly intervals starting at day 7 PI. Plerocercoids and associated host tissues were removed from the body cavity, placed in a 0.75% salt solution and observed with a Wild M-3 dissecting microscope. Some worms and tissues were then fixed in Bouin's solution, routinely processed for paraffin embedding, sectioned at 10mM and stained with hematoxylin and eosin.

All plerocercoids recovered from the transplants were dead. Worms were stretched along the length of the body cavity or entwined around viscera. Most plerocercoids were completely surrounded by connective tissue at day 28 PI, and all were in a state of degeneration.

These results clearly show that plerocercoids of *T. crassus* have the capacity to survive in the body cavity of whitefish only if they reenter this site from the muscles prior to the completion of their development and encapsulation by the host. Therefore, the pathology associated with plerocercoids of *T. crassus* in the body cavity of whitefish must originate during the two month migratory phase of developing plerocercoids prior to their encapsulation.

This work was supported by a University of Manitoba Fellowship to R. Rosen and grants from the Natural Sciences and Engineering Research Council of Canada and Fisheries and Oceans, Science Subvention Program, to T. Dick.—**Ron Rosen,** Div. Nat. Sci., Union College, Barbourville, Kentucky 40906 and **T. A. Dick,** Dept. Zool., Univ. Manitoba, Winnipeg, Manitoba, Canada R3T 2N2.

Dawson Springs Seep Swamp: Site of Some Significant New Amphibian Records.—Dawson Springs Seep Swamp is a privately owned, forested *Sphagnum* swamp located in the floodplain of Montgomery Creek near its confluence with the Tradewater River, Caldwell County, Kentucky. Its geological and ecological features were described by Quarterman and Powell (Potential ecological/geological landmarks of the Interior Low Plateaus, U.S. Dept. Int., Nat. Pk. Serv., 1978), and Harker et al. (Western Kentucky Coal Field: preliminary investigations of natural features and cultural resources. Vol. I, Part II, Technical Report., Ky. Nature Preserves Comm., Frankfort, 1980) conducted aquatic and terrestrial surveys of the site's flora and fauna. The purpose of this note is to augment the biological findings of these studies and to present new Kentucky distributional data for three species of amphibians whose ranges in western Kentucky are poorly understood. Specimens cited are in the Austin Peay State University Museum of Zoology (Nos. 3487 to 3491).

Two visits were made to the swamp, 7 June 1983, and 24 February 1984. On both occasions the area was thoroughly searched for amphibians by looking under rocks, logs, leaf litter and *Sphagnum*. During the first visit, 2 *Pseudotriton montanus* (snout-vent lengths 65 mm and 57 mm) and *Rana sylvatica* (snout-vent length 50 mm) were taken. All were found under rocks at the edge of a spring located at the base of a low sandstone bluff which borders the swamp. On the second visit, 2 *P. montanus* (snout-vent lengths 78 mm and 75 mm), 2 *R. sylvatica* (snout-vent lengths 56 mm and 53 mm) and 3 *Hemidactylium scutatum* (snout-vent lengths 34 mm, 30 mm, and 31 mm) were obtained. Both *P. montanus* were beneath rocks at the same spring where the species was discovered on the previous visit. One specimen of *R. sylvatica* was found beneath a rotting log; the other was taken from among *Sphagnum* and leaf litter along the swamp's margin. All 3 *H. scutatum* were taken from beneath *Sphagnum* and leaf litter. Other species of amphibians encountered at the swamp were *Ambystoma maculatum, A. texanum, Eurycea bislineata, Plethodon dorsalis, P. glutinosus, Acris crepitans,* and *Pseudacris triseriata.*

The collections of *H. scutatum, P. montanus,* and *R. sylvatica* cited above represent new locality records and document the westernmost known populations of these species in Kentucky. The nearest published localities for each, respectively, are: Edmonson County (Brandon, Trans. Ill. Acad. Sci. 58:149, 1965), approximately 145 km to the east; Todd County (Barbour, Amphibians and Reptiles of Kentucky, Univ. Press of Ky. Lexington, 1971), about 65 km to the southeast; and Henderson County (Barbour, loc. cit., 1971), some 65 km to the north-northeast.

In light of these findings, it seems reasonable to expect these amphibian species in suitable habitats throughout Kentucky as far west as the western edge of the Shawnee Hills Section of the Interior Low Plateaus Province.

The authors wish to thank Mike Wood and Nathan Rutherford for their aid in the field and Lisa Stokes for proofing the manuscript. Field work was supported by an Austin Peay State University Tower Research Grant.—**A Floyd Scott, Dan VanNorman and Ron Rich,** Dept. of Biology, Austin Peay State University, Clarksville, TN 37044.

Range Extensions and Drainage Records for Four Kentucky Fishes—The Kentucky distribution of *Ammocrypta pellucida* includes portions of the Green, Salt, Kentucky, Licking, Little Sandy, Big Sandy, and Ohio rivers (Burr, Brimleyana 3:53-84, 1980; Rice et al., Trans. Ky. Acad. Sci. 44:125-129, 1983; Williams, Bull. Ala. Mus. Nat. Hist. 1, 1975), but this fish was last collected from the Salt River drainage in 1890 by Woolman (Bull, U.S. Fish. Comm. 10:249-288, 1892), who considered the species to be common. Two specimens collected on 1 August 1983 from the Rolling Fork at Gaddy's Ford, 1.7 km S of Howardstown, Nelson County, confirm the persistence of *A. pellucida* in the Salt River drainage. Although historically *A. pellucida* had a wide distribution in Kentucky and may at times be collected in good numbers at certain localities (Rice et al., loc. cit.; per. obs.), the species is considered threatened in Kentucky (Branson et al., Trans. Ky. Acad. Sci. 42:77-89, 1981) and is being evaluated for possible addition to the U.S. endangered and threatened species list (U.S. Fish and Wildl. Serv., Fed. Reg. 47:58454-58460, 1982).

Although Clay (*The Fishes of Kentucky*, Ky. Dept. Fish. Wildl. Resour., Frankfort, 1975) referred to 2 collections (KFW 1352 and 1746) of *Etheostoma maculatum* from the upper Kentucky River, the specimens were not found by the authors in the University of Louisville and Kentucky Department of Fish and Wildlife Resources collections. Etnier (*in* Lee et al., *Atlas of North American Freshwater Fishes*, 1980) and Burr (loc. cit.) noted *E. maculatum* from the Green and Cumberland rivers only in Kentucky. William L. Fisher, University of Louisville, brought to the junior author's attention one juvenile *Etheostoma* (*Nothonotus*), subsequently identified as *Etheostoma maculatum*, from the North Fork of the Kentucky River at the mouth of Rock Lick Creek, Breathitt County, 14 March 1981. This collection represents the first confirmed record of *E. maculatum* from the Kentucky River and lends credence to Clay's (loc. cit.) records for the Middle Fork. It is recommended that adult specimens be sought to help define the species taxonomic affinities and range in the Kentucky River.

Notropis emiliae was previously known in Kentucky from Ohio River tributaries upstream to and including the Green River drainage (Clay, loc. cit.; Burr, loc. cit.). Two specimens, collected on 1 November 1983 from Pottinger Creek, Nelson County, 1.3 stream km upstream from the Rolling Fork confluence, extend the range of *N. emiliae* in the Ohio River valley of Kentucky upstream to include the Salt River drainage. Trautman (*The Fishes of Ohio*, Ohio State University Press, Columbus, 1981) assumed *N. emiliae* was extirpated from Ohio River tributaries in Ohio. The Salt River record represents the farthest upstream extant population in the Ohio River drainage (Gilbert and Bailey, Occas. Pap. Mus. Zool. Univ. Mich. 664, 1972).

Notropis venustus is known in Kentucky from 2 localities each in Bayou du Chien, the Mississippi River, and the lower Ohio River (Burr, loc. cit.) and one locality in Mayfield Creek (Rice et al., loc. cit.). A single specimen of *Notropis venustus*, secured 19 May 1982 from Obion Creek 3.4 km SSW of Milburn and 0.15 km S of the Carlisle-Hickman County line in Hickman County, is the first record of the species from that stream. The specimen was collected with *Notropis lutrensis* and *Notropis lutrensis* x *N. venustus* hybrids. Smith and Sisk (Trans. Ky. Acad. Sci. 30:60-68, 1969) reported *Notropis lutrensis* in their survey of the system. *Notropis venustus* is regarded as of special concern in Kentucky (Branson et al., loc. cit.).

The species reported herein appear to have extremely localized distributions in the Kentucky drainages covered. *Ammocrypta pellucida* and *N. emiliae* each occurred in one of 18 collections made in the Salt River drainage during this survey and were not collected from the drainage during other recent fish surveys (Henley, Ky. Dept. Fish. Wildl. Resour. Bull. 67, 1983; Hoyt et al., Trans. Ky. Acad. Sci. 40:1-20, 1979; W. L. Fisher, pers. comm.) The absence of *E. maculatum* in previous surveys of Kentucky River drainages (Jones, Ky. Dept. Fish. Wildl. Resour. Bull. 56, 1973; Branson and Batch, Southeast. Fishes Council Proc. 4(2):1-15, 1983; and others) suggests an extremely localized distribution. The darter subgenus *Nothonotus* often occurs in habitats which are difficult to sample and members of this subgenus have recently been discovered in rivers in Kentucky and elsewhere after having been missed by previous surveyors (Warren and Cicerello, Brimleyana *in press*; Williams and Etnier, Proc. Biol. Soc. Wash. 91(2):463-471, 1978). The distribution of *Notropis venustus* within Kentucky drainages may also be characterized as localized. This pattern is observed even in drainages where suitable habitat is relatively abundant (Burr, loc.cit.).

Richard R. Hannan, Director of the Kentucky Nature Preserves Commission (KNPC), supported this work and the KNPC staff lent field assistance; Mr. William L. Fisher, University of Louisville, provided the *E. maculatum* specimen; and Dr. B. M. Burr, Southern Illinois University at Carbondale, confirmed the *N. venustus* identification and provided distributional information—RONALD R. CICERELLO, Kentucky Nature Preserves Commission, Frankfort, Kentucky 40601 and MELVIN L. WARREN, Jr., Department of Zoology, Southern Illinois University at Carbondale, Carbondale, Illinois 62901.

REDISCOVERY OF THE RARE KENTUCKY ENDEMIC *SOLIDAGO SHORTII* T. & G. IN FLEMING AND NICHOLAS COUNTIES.—*Solidago shortii* a member of the angiosperm plant family Compositae (= Asteracaea), is one of the two goldenrods endemic to Kentucky. (The other one is *S. albopilosa* E. L. Braun.) Historically, *S. shortii* was known only from 4 counties in Kentucky: Fleming, Jefferson, Nicholas and Robertson (Braun, E. L. 1941. Rhodora 43: 484; Medley, M. 1980. Status report on *Solidago shortii* submitted to the U.S. Fish and Wildlife Service, Unpubl.). This species currently is under status review by the U.S. Fish and Wildlife Service for listing as federally endangered (Federal Register 45 (242): 82538. 15 December 1980).

In a status report on *S. shortii* to the Fish and Wildlife Service, Medley (1980) concluded that the only known extant population of this species in is " . . . Blue Lick State Park along both sides of the Old Buffalo Trace Trail and in edges of a nearby cedar glade." Thus, the purpose of this short note is to report the rediscovery of *S. shortii* in Nicholas and Fleming counties. The localities follow: NICHOLAS CO.: Along east side of U.S. 68, 0.16 km south of the Robertson County line, J. & C. Baskin *#2094* (KY), 11 September 1983; Along east side of U.S. 68, 0.48 km south of Licking River, J. & C. Baskin *#2095* (KY), 11 September 1983. FLEMING CO.: 2.4 km NE of Blue Licks Battlefield State Park on U.S. 68 and 0.8 km E on old U.S. 68, across road from the Assembly of God Church, J. & C. Baskin *#2096* (KY), 11 September 1983.

In addition, we found a second site for the species in Blue Licks Battlefield State Park: ROBERTSON CO.: Blue Licks Battlefield State Park, W of and adjacent to the camping area, J. & C. Baskin *#2093* (KY), 11 September 1983. Medley (1980) reported that the largest population of *S. shortii* in Blue Licks Battlefield State Park recently was destroyed during construction of the camping area. Apparently, the plants still growing adjacent to the camping area are part of a larger population that existed in this part of the park prior to construction of the camping area.

Although the 4 additional extant populations of *S. shortii* reported here extends the known number of individuals in the species population by perhaps a few hundred, we agree with Medley (1980) that the species should be listed as endangered at the federal level.

Specimens of *S. shortii* cited in this note have been annotated as such by Max Medley.—JERRY M. BASKIN and CAROL C. BASKIN, School of Biological Sciences, University of Kentucky, Lexington, KY 40506-0225.

Notes on Kentucky Mammals: *Myotis keenii* and *Sorex longirostris*—*Myotis keenii*, a northern species, is one of the scarcest bats in Kentucky (Barbour and Davis, Mammals of Kentucky, Univ. Press of Kentucky, Lexington, 1974). Most specimens have been taken by netting at caves in summer. All summer specimens previously taken in Kentucky have been males.

On 30 June 1983, Chadwick, in a study to assess potential environmental impact of the proposed Means Oil Shale Project near Jeffersonville, netted a lactating female *Myotis keenii* over West Fork Creek, Menifee Co., Ky.

The nearest locality where this species is known to bear young is Roosevelt Lake, Scioto County, Ohio (Brandon, J. Mammal. 42:400-401, 1961). In Missouri, Caire et al., (Amer. Mid Nat 102:404-407, 1979) netted lactating *M. keenii* in June.

Also of interest is a southeastern shrew, *Sorex longirostris* taken in Foley Hollow, Montgomery Co., Ky. on 15 August 1983. This locality extends the known range of the species into eastern Kentucky 100 km from the Franklin-Scott County line (Caldwell and Bryan, Brimleyana 8:91-100, 1982).

Specimens collected during this project have been desposited in the University of Kentucky collection: JAMES W. CHADWICK, Chadwick and Associates, 5767 South Rapp St., Littleton Co., 80120 and WAYNE H. DAVIS, School of Biological Sciences, University of Kentucky, Lexington 40506.

President's Report to the Kentucky Academy of Science

As the Kentucky Academy of Science celebrates its 70th Anniversary, the objectives of the organization are as relevant as when first written. To refresh your memory, I share with you those objectives as they appear in the KAS Constitution: 1) to encourage scientific research, 2) to promote the diffusion of scientific knowledge, and 3) to unify the scientific interests of the Commonwealth of Kentucky.

Much is being said about the scientific competency, or rather the lack thereof, of the present generation of students both in the Commonwealth and throughout the Nation. It's true that much is being said and written but very little is being done. There is tremendous opportunity for the Academy to significantly impact science and mathematics education for Kentuckians. We must do more than merely offer our services, our combined and individual expertise, and our willingness to provide resources. We must become actively involved in the decision-making process. It is a most opportune time for the scientists of Kentucky to work concertedly in the design and development of an educational construct that is both relevant and futuristic. I ask that you join me in reflecting on best possible solutions to our educational problems and that you than share your ideas with other members of the Academy, the Executive Committee, and me. In turn, we can then interact with other scientific societies in a combined effort to impact state programs.

This year's emphasis on education is a natural progression of the Academy's recent history. Significant gains were made under the presidencies of Dr. Philley, Dr. George, and Dr. Rodriguez in strengthening ties between academe and industry. In 1982 meeting in Ashland was most impressive to those of us in academe. The 1984 annual meeting is scheduled for November 9, 10 in Frankfort and the focus will be the interrelationships of academe/industry/government. Such a theme and place seem appropriate for the times.

I consider it a signal honor to serve as President and am looking forward to working with you in carrying out the objectives of the Academy. Your comments and suggestions will be appreciated.

Sincerely,

Gary W. Boggess

Important Publications by Kentucky Scientists

The long-awaited book, *The American Darters* (University Press of Kentucky), by Drs. Robert A. Kuehne and Roger W. Barbour has appeared. It is a stunning piece of work, full of information of value to field biologists, novice fish-watchers, museum taxonomists, natural history photographers, and biogeographers. The full-color photographs are of excellent quality. Although there is another book presently in print on the American percid fishes called darters, no book on any segment of the North American fish fauna has ever presented so many species in color photography. The book will certainly find a lasting place in the library of anybody with even a remote interest in fishes.

"Distribution and Status of Ohio River Fishes" by William D. Pearson and Louis A. Krumholz, Water Resources Laboratory, University of Louisville (ORNL/SUB/79-7831/1). This 401-page review chronicles the effects of human settlement in the Ohio River Valley on the river and its fishes. Trends in the fish community are outlined, and the effects of navigation projects, pollution, and pollution abatement are described. Distribution maps for the major species are plotted for three time periods. The report was prepared under subcontract 7831 for Oak Ridge National Laboratory (Dr. S. Marshall Adams, project officer) and for the U.S. Environmental Protection Agency—Region V Water Division (Walter L. "Pete" Redmon, project officer).

The report incorporates much of the "grey literature" contained in environmental reports, impact statements, and interagency communications issued in the 1970's; unpublished data from lock chamber rotenone collections made by the Ohio River Valley Water Sanitation Commission (ORSANCO), the U.S. Environmental Protection Agency, and various state agencies; and unpublished original data and museum holdings. The complete data base for the report is available to qualified investigators in the Louis A. Krumholz Memorial Reading Room, Biology Department, University of Louisville. The report is available from the National technical Information Service, 5285 Port Royal Road, Springfield, Virginia, 22161 (NTIS *#DE 84007922).*

A limited number of copies are available from the first author.

– *Committees of the Kentucky Academy of Science: 1983-1984*

President Bogess takes this opportunity to thank all of the individuals listed below for graciously accepting various committee assignments. He expresses special appreciation to those individuals who accepted chairperson responsibilities.

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Gary Boggess (President)
College of Environmental Sciences
Murray State University
Murray, KY 42071
(501) 762-2886

Joe Winstead (President-Elect)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-3696

Charles Covell, Jr. (Vice-President)
Department of Biological Sciences
University of Louisville
Louisville, KY 40292
(502) 588-6771

J. G. Rodriguez (Past-President)
Department of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4902 or 3148

Robert O. Creek (Secretary)
Department 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)
Department of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1537

David Pryor (NAAS Representative)
Department of Biological Sciences
University of Kentucky
Lexington, KY 40506-0225
(606) 257-9302

Herbert Leopold (Director - KJAS)
Department of Health and Safety
Western Kentucky University
Bowling Green, KY 42101
(502) 563-5731

Manuel Schwartz (Chairman, Board of Directors)
Department of Physics
University of Louisville
Louisville, KY 40292
(502) 588-6787 or 588-5235

Board of Directors

Manuel Schwartz (1986) (Chairman)
Department of Physics
University of Louisville, KY 40292
(502)588-6787 or 588-5235

Mary McGlasson (1984)
429 Breck Avenue
Richmond, KY 40475
(606) 623-1585

Joe Winstead (1984)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-3696

Paul Freytag (1985)
Department of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-7452

William A. Baker (1985)
The General Electric Company
Appliance Park AP35-1301
Louisville, KY 40225
(502) 452-4642

Gerrit Kloek (1986)
Department of Biology
Kentucky State University
Frankfort, KY 40601
(502) 227-6095

Lawrence Boucher (1987)
Department of Chemistry
Western Kentucky University
Bowling Green, KY 42101
(502) 745-3457

James Sickel (1987)
Department of Biology
Murray State University
Murray, KY 42071
(502) 762-2786

Committee on Membership

Larry P. Elliott (1985) (Chairman)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-3696

George Coltharp (1984)
Department of Forestry
University of Kentucky
Lexington, KY 40546-0073

Paul Freytag (1985)
Department of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-7452

Rudolph Prins (1984)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-3696

Jerry C. Davis (1985)
President, Alice Lloyd College
Pippa Passes, KY 41811
(606) 368-2701

Ex Officio

Gary Boggess (President)
College of Environmental Sciences
Murray State University
Murray, KY 42071

Jeo Winstead (President-Elect)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-3696

J. G. Rodriguez (Past-President)
Department of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4902

Committee on Publications

Branley A. Branson (Chairman)
Department of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1537

Jerry M. Baskin (1984)
Department of Biological Sciences
University of Kentucky
Lexington, KY 40506-0225
(606) 257-8770

James E. O'Reilly (1985)
Department of Chemistry
University of Kentucky
Lexington, KY 40506-0055
(606) 257-7080

Donald L. Batch (1986)
College of Natural and Mathematical Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1818

Gary Boggess (KAS President)
College of Environmental Sciences
Murray State University
Murray, KY 42071
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Geochemical Analysis of the Providence Limestone Member of the Sturgis Formation (Upper Pennsylvanian)

MARY C. PERKINSON and GARY L. KUHNHENN, Department of Geology, Eastern Kentucky University, Richmond, KY 40475

ALAN D. SMITH, Coal Mining Administration, College of Business, Eastern Kentucky University, Richmond, KY 40475

ABSTRACT

The Providence Limestone Member, Sturgis Formation (Upper Pennsylvanian), cropping out in the western Kentucky coal field, represents 2 transgressive carbonate units deposited in separate and distinct environments. The lower and upper limestone units occur between the Kentucky No. 11 and No. 13 coal beds and are separated by claystone and the Kentucky No. 12 coal bed, or a smut zone where the No. 12 coal is absent. Both limestone units were deposited over broad, relatively flat-lying platforms built upon a deltaic system.

A geochemical analysis of the Providence Limestone Member was conducted to obtain cation information to aid in an understanding of the depositional history of the area. The analysis was determined by atomic absorption spectrophotometry and involved only the carbonate portion of the rock. The results, while adding helpful information about environments of deposition, must be viewed with caution in that the insoluble (noncarbonate) portion of the rock, as well as diagenetic factors, may affect the distribution and amount of elements. The elements analyzed were calcium, magnesium, iron, manganese, strontium, sodium, and potassium.

In reviewing the results, certain variations occur within the limestone units. Both the lower and upper limestone units consist of low-magnesium calcite, which may be considered to be indicative of an environment with normal marine salinity. Slight variations do occur between cores and probably reflect localized conditions within the units.

INTRODUCTION

Glenn (1) assigned the name Lisman Formation to a stratigraphic sequence of upper Pennsylvanian rocks overlying the Carbondale Formation. Lee (2) assigned the term Henshaw Formation to a sequence of rocks overlying the Lisman Formation. Further studies indicated minor variations in the lithology of these units; hence, the names were abandoned and the 2 units were combined and reassigned to the Sturgis Formation (3).

The Providence Limestone was first described by Hutchinson (4), who referred it to the lower limestone unit as the Jelly Limestone. Glenn (1) assigned the name Providence Limestone to a unit of limestone found above the Kentucky No. 11 coal in the vicinity of Providence, Kentucky. Glenn described the Providence as consisting of an argillaceous, impure, irregularly bedded limestone, locally containing shale partings. Glenn found the Providence to be a valuable horizon maker and was able to correlate it with the Brereton Limestone of Illinois. Glenn further defined the Providence as occurring between the Kentucky No. 11 and Kentucky No. 12 coal beds. After extensive mapping it has been shown that Kentucky No. 12 coal beds, referred to by Glenn, is actually the Kentucky No. 13 coal. The Providence Limestone Member of western Kentucky is a Middle-Upper Pennsylvanian (Desmoinesian) marine unit located at the base of the Sturgis Formation. The Providence Limestone lies along the southeastern rim of the Eastern Interior Basin and is regionally persistent throughout the western Kentucky coal fields. The Providence Limestone Member is located between the Kentucky No. 11 and No. 13 coal beds and has been noted to occur as 2 distinct beds referred to as the upper and lower units (3). These 2 beds are separated by the Kentucky No. 12 coal bed, or by a dark clayey shale where the No. 12 coal is absent.

TECTONIC SETTING

Pennsylvanian coal-bearing rocks of the western Kentucky coal fields are exposed in an area of about 11655 km^2 (5). The rocks are, in general, deltaic and tidal flat in origin and extend out over a gentle slope. They consist mainly of shale, siltstone, sandstone, and minor amounts of coal and limestone.

The study area, located in the western Kentucky coal fields, is within the Eastern Interior Basin (Illinois Basin). Although the major portion of this basin is concentrated around the state of Illinois, it does encompass rocks in Kentucky, Indiana, Iowa, and Missouri. The basin is a spoon-shaped depression with its major axis trending in a north-northwest to south-southwest direction with the southern tip of the spoon in Kentucky (6). It is bordered on the west by the Ozark uplift and on the east by the Cincinnati Arch. In Kentucky, the basin is dominated by 3 structural features: (1) the Rough Creek fault system, (2) the Moorman Syncline, and (3) the Pennyrile fault system (Fig.1).

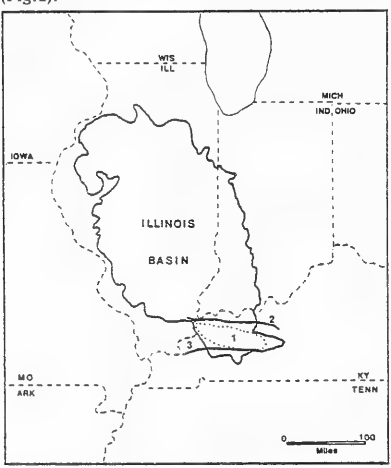

Figure 1: Generalized structural map, illustrating the study area.

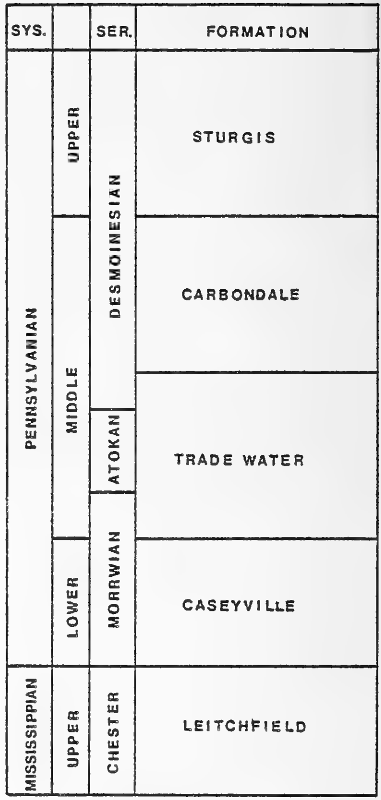

Figure 2: Stratigraphic column of Pennsylvanian strata in western Kentucky.

STRATIGRAPHY

The Pennsylvanian rocks of the western Kentucky coal fields are considered to be an extension of the Eastern Interior Basin and rest unconformably on the Upper Mississippian Chesterian sequence. The Pennsylvanian sequence in western Kentucky is about 1070 m thick (7) and, in ascending order, consists of the following formations: (1) the Caseyville, (2) the Tradewater, (3) the Carbondale, and (4) the Sturgis (Fig. 2). As mentioned previously, the Sturgis Formation contains those rocks formerly belonging to the Lisman and Henshaw formations. Pennsylvanian strata are unroofed in most areas of the Eastern Interior Basin. For this reason the upper limit of the Sturgis Formation was undefined. Douglas (8) has since identified *Triticites* sp. from a drill core located in Union County, Kentucky, indicating the presence of Permian-age material within the southern part of the Eastern Interior Basin. In this area, the Sturgis Formation is estimated to be 610 m thick (5).

With the discovery of Permian-age material in this area, the term Mauzy Formation has been tentatively proposed for these rocks (9). The Mauzy Formation is an estimated 120 m in thickness and is very similar, in terms of lithology, to the underlying Pennsylvanian strata, with the exception of a higher percentage of limestone. Permian rocks in the Eastern Interior Basin have been found only in a small down-faulted area in Union County, Kentucky.

Sturgis Formation

The Sturgis Formation, which overlies the Carbondale Formation, contains all Upper Pennsylvanian strata in the western Kentucky coal field. The lower contact for the Sturgis Formation is placed at the base of the Providence Limestone Member (3). In most of this area, the upper portion of the Pennsylvanian has been removed by erosion, hence, no upper contact has been determined. Permian rocks have, however, been identified from core material in Union County, Kentucky, as previously mentioned.

The Sturgis Formation, containing rocks that were previously assigned to the Lisman and Henshaw formations, consists of sandstone, siltstone, shale, limestone, and coal. Since a large portion of the Sturgis is concealed by loess, alluvium, and collevium, no adequate outcrop for a type section has been designated. Data from two core holes drilled by Cities Service Oil Company, both northeast of Sturgis, Kentucky, have been combined and identified as the type area and composite section for the Sturgis Formation (3). In ascending order, the members of this formation are: (1) the Providence Limestone, (2) the Kentucky No. 12 (Paradise) coal, (3) the Kentucky No. 13 (Baker) coal, (4) the Anvil Rock Sandstone, (5) the Kentucky No. 14 (Coiltown) coal, (6) the Madisonville Limestone, (7) the Carthage Limestone, (8) the Lisman coal, and (9) the Geiger Lake coal.

Sandstone makes up 30 to 50 % of this formation and is the dominant rock type (3). It is commonly light gray, weathering to yellowish-brown, and is fine-to-medium grained except in channel deposits where it is locally conglomeratic.

Siltstone, light to dark gray, is usually interbedded with sandstone and shale. The shale is generally medium to light gray and silty, but when associated with coal beds it is dark gray to black and carbonaceous. It also commonly occurs as olive green and clayey, with slickensides. Kehn (3) notes that the shale contains brachiopods and crinoids only when interbedded with limestone.

In general, the coals of the Sturgis Formation are not as thick or widespread as those of the underlying Carbondale Formation. The lower section does, however, contain the Kentucky numbers 12, 13 and 14 coals which locally are very thick and of economic importance. The Kentucky No. 14 coal has been reported to be more than 4 m thick in some drill holes (3).

Limestone beds of the Sturgis Formation are thicker and more abundant than those of the underlying Pennsylvanian formations, but make up only 5% of the Sturgis (3). They are generally light to dark gray, fine-grained, fairly dense, and usually occur in beds 0.01 to 0.3 m in thickness.

Providence Limestone Member

The Providence Limestone Member consists of all limestone beds located between the Kentucky No. 11 and No. 13 coal beds. Exposures utilized in this study consist of 2 limestone beds, referred to as the upper and lower units (Fig. 3). At some localities as many as 4 different beds, separated by clayey shale and, locally, thin lenses of sandstone, have been described (3). In the area around Sturgis and Providence, Kentucky, the Providence limestone comprises as much as 10 m of strata (3) extending from the top of the No. 11 coal bed to just beneath the No. 13 coal bed. In the study area, however, the Providence consists of only a maximum of 3.4 m within the same interval.

The lower unit of the Providence is generally light gray to dark gray, fine-grained, dense, fossiliferous and averages about 0.6 m in thickness within the study area. Dark zones of argillaceous material are common within the lower unit and tend to contain a greater abundance of fossil material as well as a crystalline texture. The fossil assemblages commonly include brachiopods, pelecyopods, pelmatozoans, bryozoans, foraminifera, and algae.

The upper unit is separated from the lower unit by 2 to 3 m of claystone and shale partings, as well as the Kentucky No. 12 coal bed, or a dark clayey shale where the coal is absent. The Kentucky No. 12 horizon occurs about 0.61 m beneath the upper unit. The upper unit is generally a buff to light brown, very dense, microcrystalline limestone containing calcite blebs and abundant sub-rounded limestone clasts. Weathered portions tend to be extensive-

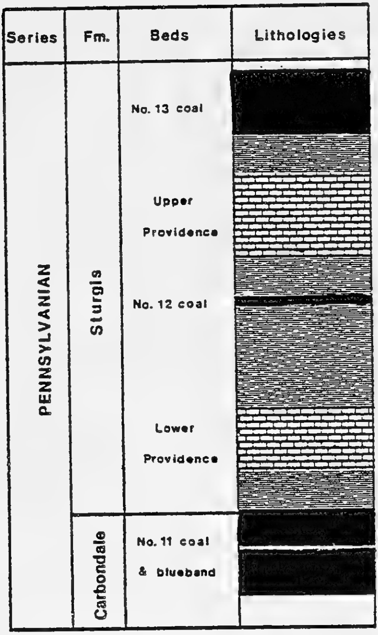

Figure 3: Representative stratigraphic column/section of the study area.

ly stained by iron and display a greater abundance of limestone clasts resulting in a pseudobrecciated appearance. In some localities *Stigmaria* is present along the base of the upper unit where it is interbedded with claystone and shale. Other than the *Stigmaria*, ostracods were the only fossils found in the upper limestone.

The Kentucky No. 13 coal bed generally occurs 0.3-0.6 m above the top of the upper unit within the study area. It averages about 1.0 m in thickness and tends to contain high amounts of sulfur.

In most of the study area, the Pennsylvanian section above the Kentucky No. 13 coal has been removed by erosion. The Madisonville Limestone Member occurs about 61 m above the base of the Sturgis Formation (3) and is light to medium gray, fine to medium crystalline, and fossiliferous. It may contain as many as 4 separate limestone beds, and is usually associated with sandstone, claystone, shale, and coal.

METHODS

The study area is located within the Western Kentucky Coal Field, in Ohio and Muhlenberg counties, and is represented by five 7.5 minute geologic quadrangles (Fig. 4). Nine stratigraphic sequences, including outcrops and cores, were located and sampled at 0.3 m intervals or where a lithologic change occurred. Additional cores were located and studied to provide a better understanding of the unit.

A geochemical analysis of the Providence Limestone Member was conducted to obtain additional information to aid in an understanding of the depositional history of the area. The analysis was determined by atomic absorption spectrophotometry and involved only the carbonate portion of the rock. The core samples were pulverized, then placed in solution by dissolving in hydrochloric acid and distilled water. The results, while adding helpful information about environments of deposition, must be viewed with caution in that the insoluble (noncarbonate) portion of the rock, as well as diagenetic factors, may affect the distribution and amount of elements. The elements analyzed were calcium, magnesium, iron, manganese, strontium, sodium, and potassium.

Many factors govern the distribution of elements in limestones including: (1) the abundance and diversity of the source biomass, (2) environmental effects at the time of deposition, (3) the influence and composition of detrital material, (4) tectonic activity, and (5) diagenetic processes. The presence of these variables will greatly influence the final outcome of the elemental distribution within the limestone. Diagenetic processes alone may play a large role in altering the composition of the original sediment. Hence, it may be impossible to completely interpret the environment at the time of deposition through geochemical studies alone.

RESULTS

The elemental data are summarized in Tables 1 through 3. Table 1 lists the elemental content of each individual sample analyzed, while Table 2 shows the average elemental content of each core. Slight variations do occur between the cores and probably reflect localized conditions within the units. Significant as well as insignificant variations occur between the lower and upper limestone units (Table 3).

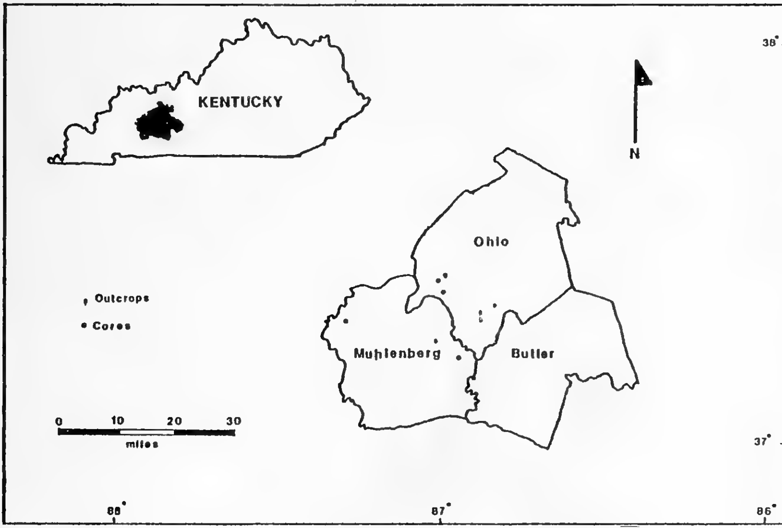

Figure 4: Study area, showing outcrop and core location.

Table 1. Elemental content (expressed in percentage) of the lower and upper units of the Providence Limestone Member. The lower and upper unit samples are designated by L, and U, respectively.

Sample Number	Ca	Mg	Fe	Mn	Sr	Na	K
RO-1-A-L	34.904	4.738	1.002	0.132	0.069	0.044	0.022
RO-1-B-L	35.191	4.639	1.008	0.088	0.077	0.035	0.015
RO-1-C-L	31.775	5.708	2.243	0.174	0.068	0.037	0.020
RO-1-D-L	31.594	5.641	2.807	0.215	0.072	0.040	0.018
HA-1-A-L	37.743	1.032	0.697	0.185	0.036	0.037	0.028
HA-1-B-L	37.030	1.013	0.485	0.195	0.044	0.039	0.017
HA-1-C-L	37.730	0.641	0.453	0.273	0.043	0.044	0.023
HA-1-D-U	32.466	4.544	2.782	0.138	0.043	0.038	0.007
HA-1-E-U	36.666	1.280	0.959	0.188	0.049	0.034	0.009
HA-2-A-L	38.067	1.112	0.424	0.201	0.064	0.042	0.022
HA-2-B-L	37.017	1.418	0.412	0.126	0.097	0.034	0.009
HA-2-E-U	36.906	1.398	1.029	0.180	0.081	0.049	0.044
HA-3-B-U	35.608	2.854	2.131	0.152	0.053	0.044	0.022
HA-3-C-U	35.740	2.835	1.690	0.148	0.047	0.034	0.007
HA-3-D-U	36.991	1.804	1.204	0.158	0.067	0.067	0.040
HA-3-G-L	38.141	0.948	0.365	0.190	0.050	0.034	0.014
HA-3-H-L	38.566	0.957	0.471	0.175	0.061	0.074	0.028
MI-1-A-L	29.784	0.782	0.415	0.083	0.048	0.067	0.055
MI-1-B-L	35.097	4.514	1.559	0.113	0.068	0.056	0.035
MI-1-C-L	30.744	6.861	1.316	0.108	0.062	0.021	0.043
MI-1-D-L	38.033	1.908	0.595	0.090	0.065	0.023	0.012
MI-1-E-L	27.344	7.786	1.229	0.094	0.044	0.047	0.055
MI-1-F-L	34.981	4.366	0.768	0.088	0.061	0.030	0.015
MI-1-G-L	33.368	5.996	0.717	0.094	0.078	0.039	0.028

Table 2. Average elemental content (expressed in percent) of individual cores analyzed.

Core Number	Ca	Mg	Fe	Mn	Sr	Na	K
RO-1	33.366	5.184	1.731	0.151	0.071	0.039	0.019
HA-1	36.327	1.702	1.415	0.196	0.043	0.023	0.017
HA-2	37.330	1.309	0.622	0.169	0.081	0.036	0.013
HA-3	37.009	1.879	1.172	0.164	0.056	0.051	0.022
MI-1	37.019	4.601	0.943	0.096	0.516	0.042	0.040

Table 3. Average elemental content (expressed in percent) of the lower and upper units of the Providence Limestone Member.

	Ca	Mg	Fe	Mn	Sr	Na	K
Lower Unit	34.839	3.305	0.942	0.150	0.061	0.042	0.023
Upper Unit	35.729	2.452	1.632	0.161	0.056	0.044	0.021

Discussion

Sodium, the most abundant cation in sea water (10) is believed to lend information indicating the degree of salinity of fluids during

diagenesis. In sea water, the average concentration of Na+ is 1050 ppm as compared with 25 ppm for fresh groundwater (10). Where the 2 are mixed, the concentration of sodium will be directly proportional to the degree of mixing.

Land and Hoops (10) noted that due to the lack of information on the Na+ /Ca and Na/Mg partitioning coefficient in natural carbonates, no acceptable method for determining paleosalinites at the time of deposition has been found. They do suggest, however, that the salinity of the latest diagenetic solution may be indicated by the bulk sodium content.

The analysis of strontium in carbonate rocks has been the subject of numerous studies. Many of these studies have attempted to show the relation of the concentration of strontium with environmental parameters like salinity, temperature, and organisms. In determining the strontium concentration of precipitated carbonate minerals, the Sr^{+2}/Ca^{+2} ratio has been noted to play an important role (11). Kinsman (11) noted the ability of organisms to incorporate strontium into their shell structures and found that individual organisms may contain up to 20,000 ppm Sr^{+2} when composed mainly of argonite. This association of higher amounts of strontium with argonitic shells than with calcitic shells has also been suggested in other studies by Kulp et al. (12) and Pilkey and Goodell (12). The Sr/Ca ratio, as noted by Lowenstam (14), is thought to be related to the proportions of aragonite and calcite found in tests of organisms where the presence of the organisms are dependent on water temperature. From this he concludes that warmer waters contain higher amounts of strontium. After studying numerous carbonate rocks and associated fossils, Kulp et al. (12) suggest that temperature is not an important factor, but that the presence of organisms is more important. They note the organisms themselves, regardless of shell composition, account for a higher concentration of strontium as compared with that of the surrounding matrix.

The presence of iron in carbonate rocks is believed to have resulted from the influx of detrital material into the environment of deposition (15). This material may have been introduced into the environment by the influx of fresh water as well as from diagenetic alterations of compounds to form siderite (15).

The Ca/Mg ratio in carbonate rocks will decrease as the salinity increases (16). Ingerson (16) noted that widespread marine fossil assemblages occur only in areas where the Ca/Mg ration is greater than 50. The absence of fossils is generally indicative of an environment with increased salinity, hence, a low Ca/Mg ratio.

In reviewing the results, certain variations occur within the limestone units. Both the lower and upper limestone units consist of a low-magnesium calcite. Folk and Land (17) consider this association to be indicative of an environment with a normal marine salinity. The iron content of the upper limestone unit is significantly higher than that of the lower limestone unit. This reflects the presence of the iron-oxide stain abundant in the upper limestone unit. This stain is present in both core and outcrop locations, hence, it is not a result of recent weathering.

Berner (15) noted that the majority of iron present in carbonate rocks has been derived from the detrital materials. The pyrite found in the lower limestone unit is believed to have been introduced into the environment as hematite, and later reduced to pyrite and siderite.

There is a slight variation in the content of manganese between the lower and upper limestone units. Khawlie and Carozzi (18), in their study of the Brereton Limestone, associated the presence of manganese with iron minerals and the influx of fresh water. The occurrence of manganese, along with iron, may be associated with the slight increase of manganese in the upper unit.

Ronov and Ermishkina (19) noted that the presence of manganese in amounts greater than 0.01% is indicative of a humid environment. This may be due to the tendency of manganese to become concentrated in organic acid-rich waters found in a humid environment. All samples analyzed show a manganese concentration significantly over that of 0.01%. This relationship reflects the humid climate present at the time of the formation of the Pennsylvanian coal swamps.

There is a small variation in the strontium concentration between the lower and upper limestone units, with slightly more present in the lower limestone unit. The higher concentration in the lower unit reflects the abundant fossil assemblages that occur in the lower unit while the upper unit is very sparse in fossil content.

Variations in both sodium and potassium that occur within the lower and upper units are insignificant. Although sodium plays an important role in the percentage of salinity (20), there are no adequate methods to determine paleosalinities at this time.

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ENGINEERING AND STRENGTH PROPERTIES OF SELECTED SILTY-CLAY MIXTURES DERIVED FROM MADISON COUNTY, KENTUCKY

ALAN D. SMITH

Coal Mining Administration, College of Business
Eastern Kentucky University, Richmond, KY 40475

ABSTRACT

Engineering properties of 6 representative sites of silty-clay mixtures in and around Richmond, Kentucky were investigated to help understand and qualify functional relationships among common soil strength and consistency measures in this area. Since all the sites are scheduled for future development in terms of a variety of construction projects, and the silty-clay mixtures, classified by the uniform classification system as SC, are common throughout Madison County, extensive laboratory tests were performed. On all sample sites, standard and modified energies of compaction, via the Proctor Compaction Density Laboratory Test, were completed a total of 3 times. In addition each layer, 3 in the standard and 5 in the modified, in the compaction mold was sampled a total of 3 trials for water content, vane shear, and compressive strength, as measured by the penetration test. Atterberg Limits were performed on 3 representative samples to determine the variability of the plastic range.

Multiple linear regression techniques were applied in the hypothesis testing process, which resulted in 13 hypotheses being statistically significant. In general, higher energies of compaction were associated with lower water content, less void space, higher shear and compressive strengths, lower water contents were found to be related to higher maximum dry densities, higher compressive strengths with greater maximum dry densities, and vane shear strengths positively related to compressive strengths as measured by the penetration test.

INTRODUCTION

Problems associated with soil mechanics and foundation engineering are usually solved through a combination of theoretical knowledge, awareness of the precedents in the area, geology, history, and properties of the soil conditions obtained from laboratory and field testing procedures. Only through a combination of these features and an appreciation of the function of the proposed structure can a proper design and construction program be formulated. Characterization of the soil properties and subsequent engineering judgments are based on laboratory tests performed on representative samples taken during a site investigation. The scope, type, and quality of the corresponding site investigation are important and decided upon only after considering the subsequent laboratory test program (1, 2, 3, 4).

The engineering classifications in common use are based on the size composition of the solid constituents and on their interaction with the water substance as evidenced by the resultant volume and consistency changes (5, 6). Hence, relationships between water content, optimal strength, and the soil's volume and consistency behavior should be established before the design and construction of structures are under way. Although each site warrants its own preliminary exploration and investigation of physical parameters, general guidelines concerning strength properties and these parameters for similar soils and environmental conditions would provide valuable aids in engineering design and result in cost savings by not performing repetitive tests.

The principal goals of this research are to help establish ranges of basic soil mechanics and foundation data of representative soil types in the Madison County area, Kentucky, for construction and scientific purposes. In addition, the interrelationships among fundamental laboratory tests of strength and soil consistency for representative soil types need to be established.

METHODS

Laboratory tests, including water contents, Atterburg Limits determination, Proctor density tests with both standard and modified compaction energies, vane shear and penetration tests were performed on representative samples of dominant residual soil complexes of silt-clay. All the samples used in the study were collected from potential building sites on exposed cultivated land in and near Richmond city limits and were classified as SC, using the unified soil classification system (7).

Atterburg Limits

The soil consistency tests, originally established by Atterberg (8), have been further developed and standarized by practicing engineers and scientists. The Atterberg Limits used in the present study included the liquid limit and plastic limit. The liquid limit (LL,W_L) is essentially the water content at which 2 halves of a soil cake prepared in a standarized manner in the cup of a liquid limit device will flow together from a distance of 0.5 inch (1.25 cm) along the bottom of a groove when the cup is dropped 25 times for a distance of 1 cm at the rate of 2 drops per second (ASTM D423). Fang (9) provided a simple procedure for the determination of the liquid limit of soils, which is derived from the flow index:

$$I_f = \frac{LL - W_n}{\log N - \log 25}$$

$$LL = W_n + I_f \log \frac{N}{25}$$

Where I_f is the flow index approximately equal to the slope of the flow curve; N is the number of blows ($17 < N < 36$); and W_n is the moisture content at N blows. As for the plastic limit (PL, W_P), it may be defined as the moisture content as a percentage of the oven-dry weight of a soil to which it can be rolled into threads of 1/8 inch diameter without the threads breaking into pieces (ASTM D424). Through the use of these tests, a measure of soil volume and state of consistency can be established and the range of plastic behavior be measured (10, 11).

Proctor Density Compaction Test

Compaction of soil, usually by mechanical methods, reduces air voids with the primary aim of controlling subsequent moisture-content changes, achieving a state of increased unit weight, increasing the shear strength of the soil, reducing permeability, and making the soil less susceptible to settlement under load (1). Laboratory tests have been developed so that the specification for field compaction can be written and checks can be made on the fill material as placed and compacted. The function of the laboratory compaction tests is to determine the optimum quantity of water and corresponding unit weight to achieve maximum strength in the field. Compaction of cohesive soils has been proven to follow the principles stated by Proctor (12); although there are several laboratory compaction standards and types of compacted fills of compactive efforts used in construction, the effect of the water content of the soil on the resulting dry density is similar for all methods. The standard Proctor test (ASSHTO-99) uses a 5.5 lb. hammer, drop 12 inches, made in a 1/30 ft^3 cylindrical mold, 3 layers each compacted by the hammer by 25 blows for an energy input of 12,375 ft-lbs. per ft^3. Standard Proctor energies are equivalent to light rollers and compaction equipment. The modified tests uses a 10 lb. hammer, 18 inch drop length, 5 layers at 25 blows each for a compaction energy of 56,250 ft-lb per ft^3 of energy (AASHTO-108). Modified is approximately equal to heavy compaction equipment, such as the dual-drum sheepsfoot roller, with several passes over the structural fill.

Vane Shear and Penetration Tests

The purposes of shear-strength tests allow the prediction of soil displacement under working loads and the evaluation of the external forces required to cause shear failure of a soil (1, 7). The vane-shear test gives a rapid estimation of the undrained shear-strength of fine-grained soils. The vane consists of four blades, set at right angles, attached to a central, circular rod. The vane is pushed into the soil until it is embedded and a torque is applied until failure. The Soil Test, model CL-600 was used in the study, performed and recorded 3 times at every layer during both standard and modified energies in the compaction testing. The same procedure was followed for the Soil Test, model CL-700 penetrometer, which quickly measures compressive strength of the soils studied.

Statistical Techniques

Multiple linear regression techniques, once corrected for multiple comparisons, were utilized to test hypotheses concerning compacted dry density, compaction energies, vane shear, penetration or compressive strength, and water content. Since multiple regression is a very flexible technique, a number of hypotheses were established and tested in an attempt to clarify statistical relationships among these important physical parameters.

RESULTS

Table 1 and 2 are summaries of the plastic range determinations and physical characteristics of water content and strength, respectively, of the 6 sites intensely sampled. The sites were representative of the silty-clay (SC) mixtures found in Madison County, Kentucky. As evident from Table 1, the liquid and plastic limits were relatively similar, with a mean plastic range of 18.8 %, an indication of the low compressiblity of this silty-clay mixtures in the area. Table 2 displays relationships that are not readily apparent without hypothesis testing

Table 1. Plastic range determinations for typical Richmond's silt-clay mixtures.

Sample Number	Liquid Limit (%)	Plastic Limit (%)	Plastic Range[a] (%)
1	44.8	22.8	20.0
2	39.0	26.2	12.8
3	44.3	22.8	21.5
Means	42.7	23.9	18.8

[a]Plastic range or plastic index is equal to liquid limit minus plastic limit.

Table 3 lists the models tested, R^2, degrees of freedom, F-ratio, probability levels, statistical significance, and associated statistics for the various hypotheses tested in the course of the study. As evident from a quick inspection of Table 3, a total of 13 hypotheses were found to be statistically significant. Proctor compaction energies, both standard and modified, were discriminated from each other by the parameters water content, dry density, vane shear, and compressive strength, as measured by the penetration test. The explained variance in differentiating standard and modified energies of compaction by the engineering characteristics of the silty-clay samples ranged from a low of 24.2 per cent (vane shear) to a high 48.4 per cent (dry density). In general, the results of the hypothesis testing illustrated the following: lower water contents measured during the compaction of the soil samples were associated with higher energies of soil compression; greater maximum dry densities were associated with modified energies of compaction; higher shear strengths, as measured by vane shear, were associated with higher energies of compaction; increased compressive strengths were found to be directly related to modified compaction efforts. These results are reflected in the Pearson correlations among engineering parameters of silty-clay mixtures listed in Table 4.

The other engineering characteristics were also found to be related with each other in predictive functions. Maximum dry density accounted for 29.6 per cent of the common variance in predictive water contents sampled after laboratory compaction of the soil samples ($p = 0.0006$). As expected, a decrease in water content and compression of the void space in

Table 2. Summary of water contents, dry densities, vane shear and penetration strength results associated with the standard and modified Proctor laboratory tests performed on the Richmond's silt-clay mixtures.

Sample Location Number	Proctor Laboratory Test	Water Content (%)	Dry Density (lbs/ft)	Vane Shear (kg/cm)	Penetration (kg/cm)
1	S	24.8	149.6	4.1	4.6
	S	20.8	147.1	5.7	3.5
	S	24.5	144.4	4.1	3.8
	M	21.3	148.3	2.6	2.9
	M	20.1	152.0	4.3	4.6
2	S	17.1	139.5	4.7	3.7
	S	18.0	137.5	3.5	2.8
	S	19.1	136.0	3.5	2.0
	M	15.7	156.6	4.7	4.5
	M	16.0	150.6	5.0	4.5
	M	15.0	156.8	6.4	4.5
3	S	20.5	143.5	1.7	4.2
	S	19.8	145.4	1.4	3.3
	S	21.9	141.7	1.7	2.4
	M	21.3	140.9	2.6	2.9
	M	21.0	145.1	4.4	4.5
	M	19.9	146.1	4.4	4.5
4	S	20.3	133.3	4.7	3.8
	S	20.3	130.4	3.5	2.8
	S	23.6	128.2	3.5	2.0
	M	18.0	151.0	4.7	4.5
	M	19.0	145.0	5.0	4.5
	M	17.0	151.8	5.2	4.5
5	S	24.8	130.5	4.3	4.0
	S	20.8	137.1	3.8	4.3
	S	24.6	129.8	5.8	3.5
	M	18.4	153.7	5.7	4.5
	M	19.1	148.9	8.3	4.5
	M	20.2	144.7	6.6	4.5
6	S[1]	19.9	144.7	2.5	4.1
	S	21.0	144.4	3.7	3.2
	S	21.7	140.9	3.8	2.8
	M[1]	18.9	144.5	5.6	4.5
	M	19.4	153.3	6.2	4.3
	M	18.5	155.2	5.7	4.5

[1]The symbols S and M correspond to the standard and modified compaction energies of the Proctor density laboratory test, respectively.

Table 3. Summary of models tested, R^2, degrees of freedom for both numerator and denominator, F-ratio, mean square, probability levels, and statistical significance for each research hypothesis that tested for predictive relationships and the engineering parameters associated with SC (silty-clay) samples derived from the Richmond area.

Engineering Parameters Dependent	Independent	R^2	df	MS_{Reg}	F-ratio	Prob.	Sign
Proctor Compaction Energy	Water content, Dry Density, Vane Shear, Penetration	0.5810	4/31	1.3073	10.7470	0.0000	S
	Water Content[a]	0.2499	1/34	2.2498	11.3322	0.0019	S
	Dry Density[a]	0.4836	1/34	4.3522	31.8368	0.0000	S
	Vane Shear[a]	0.2421	1.34	2.1785	10.8582	0.0023	S
	Penetration	0.3513	1/34	3.1619	18.4146	0.0001	S
Water Content	Proctor Compaction Energy, Dry Density, Vane Shear, Penetration	0.3438	4/32	17.9084	4.0611	0.0092	S
	Dry Density[b]	0.2964	1/34	61.7463	14.3214	0.0006	S
	Vane Shear[b]	0.0886	1/34	18.4577	3.3051	0.0779	NS
	Penetration[b]	0.10236	1/34	21.38773	3.8773	0.0521	NS[e]
Dry Density	Proctor Compaction Energy, Water Content, Vane Shear, Penetration	0.6289	4/31	334.3553	13.1371	0.0000	S
	Vane Shear[c]	0.1055	1/34	224.3704	4.0108	0.0532	NS[e]
	Penetration[c]	0.4063	1/34	864.0287	23.2711	0.0000	S
Vane Shear	Proctor Compaction Energy, Water Content, Dry Density, Penetration	0.3426	4/31	7.0604	4.6025	0.0049	S
	Penetration[d]	0.2911	1/34	22.0668	13.9639	0.0007	S
Penetration	Proctor Compaction Energy, Water Content, Dry Density, Vane Shear	0.5458	4/31	3.1177	9.3118	0.0000	S

Note: An F-test was utilized to test for statistically significant relationships among the various engineering parameters associated with the silty-clay samples derived from the Richmond area. The assigned alpha for a two-tailed, nondirectional test was used before each specific hypothesis was considered significant. However, a correction for multiple comparisons was deemed necessary in a number of cases in the hypothesis testing process. The alpha level was corrected using the Newman and Fry (13) Method. The following are corrected alpha levels:

a 0.0125 d 0.05
b 0.0167 e denotes hypothesis approaching statistical significance at the 0.05 alpha level for a two-tailed test
c 0.025

the soils were significantly related to an increase in dry density. However, although approaching statistical significance at the 0.05 alpha level, uncorrected for multiple comparisons, no such relationship was found for vane shear and compression strengths. This lack of significance on the strength characteristics as a function of water content is probably related to the complex interparticle interaction of cohesive materials. As demonstrated in Table 3, penetration test results accounted for a significant amount of explained variance (40.6 per cent) in differentiating dry density of the silty-clay mixtures ($p = 0.0000$). Increased compressive strengths were associated with greater maximum dry densities. Lastly, vane shear characteristics were significantly predicted by the compresssive strength tests (29.1 per cent of the explained variance, $p = 0.0007$). Hence, as expected, higher shear strengths are related to higher strengths in the cohesive soil samples.

Table 4. Pearson correlations among engineering parameters of silty-clay mixtures (SC) derived from the Richmond area.

Engineering Parameters	Proctor Compaction Energy	Water Content	Dry Density	Vane Shear	Penetration (Compressive Strength)
Proctor Compaction	1.000	0.500*	0.695*	0.492*	0.593*
Water Content		1.000	-0.544*	-0.2977	-0.3199
Dry Density			1.000	0.325	0.637*
Vane Shear				1.000	0.540*
Penetration (Compressive Strength)					1.000

Note: All the correlations were found to be statistically significant at the two-tailed, nondirectional alpha level of 0.05.

* denote highly significant at the 0.01 level.

CONCLUSIONS

The data collected and summarized in Tables 1 and 2, and the statistical analysis presented in Tables 3 and 4 for representative silty-clay samples derived from the Richmond area establish several important and fundamental relationships. Although the strength properties of cohesive soil mixture, such as the silty-clays studied, are characterized by complex cation interactions and variable properties, which make quantitative correlations difficult to obtain, several predictive functions were established. Due to the complexity of soil mechanics and foundations, exploratory site investigations are still needed in Madison County, but the correlations among field and laboratory water contents measured during the development and construction of structural fills and the soil's associated parameters of maximum dry density strength measurements, plastic ranges, and energies of compaction to obtain specified construction requirements should provide useful guides in engineering design in this area.

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STATISTICAL METHODS IN MINING ENGINEERING: EXPANDED ANOVA TECHNIQUES FOR THREE-DIMENSIONAL CHARACTERIZATION OF MINE-ROOF PARAMETERS

Alan D. Smith
Department of Business Administration
Eastern Kentucky University
Richmond, KY 40475

ABSTRACT

Recent years have shown profound advances in applying quantitative approaches to mining geology and engineering. These approaches, better known as geostatistical methods, have provided a theoretical basis for formal statistical tests in the designing and planning aspect of mine development and production, especially in sampling schemes and drilling plans. Most of the statistical methods center around calculting best-fits of response surfaces over spatially-distributed samples with explained variances as the central theme. Expanded analysis of variance (ANOVA) techniques were developed and calculated for two important parameters used in designing proper ground-control practices to minimize the occurrence of mine roof falls: maximum height of fallen material from roof, measured from the roof edge to top of failed area in roof, and height above roof line to second rock-break horizon. A total of 21 roof falls were examined from a coal mine in the Northern Appalachian Coal Field, Upper Freeport Coal Seam, to develop the statistical techniques to differentiate between three-dimensional models predicting spatial distributions of these 2 variables. Fourteen expanded ANOVA tables were developed in the hypothesis-testing process among the response surfaces studied. A fourth-degree surface accounted for 98 percent of explained variance in predicting height to second-break horizon as a function of spatial location. No regional trend was determined to be statistically significant in projecting maximum height of mine roof falls.

INTRODUCTION

Statistical Methods in Mining Engineering

Geostatistics is a common term associated with the application of statistical methods to geology, mining, and geographic problems. However, as indicated by Davis (1) and Clark (2), most of the techniques of quantitative geology may be regarded as "quasistatistical" or "protostatistical" procedures. Since few of the commonly used methods in geostatistics are sufficiently developed to be used in rigorous tests of statistical hypotheses, and there is a general lack of general theory about the nature of geologic population parameters about which sample statistics can be used to infer. Hence, geomathematical techniques are based on the concept that information concerning the geologic phenomenon can be inferred from an in-depth examination of a small sub-sample collected from the vast pool of potential observations that, due to time, cost, or physically difficult to examine constraints, prevent measurement.

Mining geologists and engineers (2-10) have used statistical techniques for many years. These techniques were found to be especially useful in mine development and production stages. In fact, many geologists and engineers design sampling schemes and drilling plans according to statistical designs and eventually subject their observations to hypothesis testing and detailed statistical analysis (1, 6, 9, 10). Several statistical theories and associated distributions have been proposed to account for variation in mine values (grade, continuity, strength), providing the theoretical basis for statistical modeling and inferrence (2). However, as warned by Davis (1), geologists and engineers frequently deal with data over which they had no influence with regard to where the sample is taken, "Here, the well-developed tests of hypotheses do not exist, and the best we can hope from our procedures is help in what ultimately must be a human decision" (p. 7). Geostatistics, by its very nature, deals with the application of statistical procedures to data that lack the degree of control required by the tests. According to convention, there are some basic assumptions in geostatistics, including: differences among collected samples and their magnitudes are determined by the relative spatial orientation of those samples; since the mean and variation are extremely important in establishing relationships with geological and mining phenomena, their corresponding orientation is extremely important; in establishing trends or predictive relationships, an assumption of random variation or no trend is made in order to emphasize the variance of the difference in values between samples (1, 9, 10).

The thrust of the present study is to expand analysis of variance techniques (ANOVA) in testing selected hypotheses of the predictive trends of important parameters used in mine development and design. One of the goals of mine planning is to three-dimensionally characterize these parameters in such a way that useful maps for decision-making can be implemented. The parameters frequently used in preparing mine plans are associated with mine-roof falls.

Mine-Roof Fall Prediction

Since the first records in 1838 on coal-mine health and safety, more than 130,000 U.S. miners have lost their lives in mine accidents. Death rates in mines of this country are higher than in any other Western industrialized nation engaged in coal mining (11). A major cause of death and physical injury in underground coal mines is roof failure. As suggested by Moebs and Stateham (12), instability in coal-mine roofs is considered to be either the result of defect-related/geological features or nondefect-related, such as the strength-stress state existing in the rock mass. Support of underground entries is based on recommendations of the physical characteristics of geologic structures and the overall effect the structures have on mine roof stability.

The stability of coal-mining tunnels, entries, rooms, and associated openings plays a major role in the success of any major underground project. Hence, if the main access openings to a new coal mine become deformed and damaged by strata movement to the extent of requiring serious repairs, special problems may arise which will have an influence on ventilation, impairment to speed and reliability of transport systems as well as the direct and indirect costs involved with the repair program (13, 14).

The mechanical design of a roof-support system is basically a matter of a working knowledge of statics and dynamics, assuming that the imposed loads and mining conditions are known. However, in the Appalachian Coal Fields the general conditions are known well enough to allow for the majority of mining operations, including traditional room-and-pillar as well as longwall mining techniques and be furnished with standard and commercially available supports. Of course, these support systems and roof control procedures are accompanied by suitable variants and options (15). The overall design of a mining system, which design incorporates not only size and capacity of the equipment to be used, but includes equipment adaptability to the mining scheme; equipment versus human constraints; operation at the designed levels; and coordination of operation, maintenance and support design (15).

Hence, a multitude of factors must be considered in successful underground operations (14). Cost-sensitive mine-planning systems have been developed to help coal companies design underground mines that will recover coal reserves in the most profitable method. Information obtained for borehole logs, local mines, mining equipment manufacturers, and previous mining experience should be used in the mine planning process. According to Ellison and Scovazzo (16), cost-sensitive mine planning assumes that the physical and economic conditions that will have the greatest impact on cost and coal quality can be predicted accurately enough to assist mine planners in making decisions. In the planning process, many maps, such as coal seam thickness, expected roof caving conditions, geologic lineaments, roof shale thickness, distance to the first sandstone, overburden thickness, underclay thickness, as well as a host of other factors, can be generated as overlays on each other to assist planners in selecting appropriate locations and orientations for the portal, mains, submains, and longwall panels (12, 17, 18). As compiled and summarized by Moebs and Stateham (12), a recent study to investigate in a graphic manner, all rock-fall hazards related to geologic conditions in the Pittsburgh Coalbed for a 9-county-area, located in northern West Virginia and southwestern Pennsylvania, resulted in the systematic collection and analysis of field data. A total of 7 geologic and 5 mining-engineering related variables were found to be causally related to roof failure. However, only 3 of the significant geological parameters, namely overburden thickness, roof lithology, and vertical distance to the rider coal seam, were found to be useful in the final map preparation.

Although mine-roof falls are not random events and their occurrence is usually contributed to an interaction of a host of geologic and stress-strength parameters, some of the conditions that cause failure may be frequently continuous in nature. Examples of this continuous nature in mine-roof failure includes, as previously stated, overburden thickness, roof lithology, and vertical distances to selected bedding-plane features. These interactions, both related to rock mechanics and geological phenomena, result in determining the maximum mine roof fall height during a given time interval. Therefore, by modeling the structural contour of maximum mine height after failure, and associated heights of various rock-break planes that are prominent in the failure area, a better understanding of the behavior of mine-roof falls may develop and be useful in projecting potential areas of roof failure.

Expanded ANOVA Techniques for Modeling Predictive Surfaces

Simple analysis of variance and covariance must have a dependent variable that must be measured on at least an interval scale (19). ANOVA techniques can be applied to test relationships among three-dimensional models with spatial coordinates (1). A detailed discussion of testing the significance of these trend surfaces can be found in work completed by Smith (9, 10, 20). The concepts of using the full and restricted models in testing these relationships among trends and the process of determining the best-fit predictive surface have been discussed theoretically (21) and operationalized (20).

The equation describing the surface can be linear (plane), quadratic (paraboloid), cubic (paraboloid with an additional point of inflection), to higher-order degree surfaces. In general, the higher order of the surface, the more the residuals, or individual deviations, will be minimized and the more the residuals, or individual deviations, will be minimized and the more computation will be required. The higher-order trend surfaces may reflect the variation in Z-values more accurately, if the study area is complex, but lower-order surfaces may be more useful in the isolation of local trends. The filtering mechanism allows the upper limit of variability to be determined by the order of the surface. The equation for a linear-trend surface, for example, has the following form: $Y = b_0 + b_1X_1 + b_2X_2$, where Y = dependent variable, b_0 = constant value related to the mean of the observations, b_1b_2 = coefficients, and X_1, X_2 = geographic coordinates.

In addition, model comparison between trend surfaces is also completed. The model comparison directly answers the major question of determining the order of best fit. In the case of trend-surface analysis, the restricted model corresponds to the lower order trend surface, or one order less than the order in the full model. The degrees of freedom and resultant F value are reached as follows: $df_1 = m_1 - m_2$, $df_2 = N - m_1$, where df_1 = degrees of freedom-numerator, df_2 = degrees of freedom-denominator, M_1 = number of coefficients, counting the constant coefficient, in the full model, m_2 = number of coefficients, counting the constant coefficient, in the restricted model, and N = number of observations. These equations, determined by Newman and Thomas (22), are similar in function to those equations suggested by Davis (1), except the addition of the constant term, b_0. In the case of trend-surface analysis, m_1 corresponds to the number of coefficients, including the constant, b_0, in the higher order surface while the term, m_2, is associated with the number of coefficients, plus the constant term, in the lower order surface. For example, in a second order trend surface, the equation is represented by: $Y = b_0 + b_1X_1 + b_2X_2 + b_3X^2_1 + b_4X^2_2 + b_5X_1X_2$. In the hypothesis testing to determine if this second order equation is statistically significant at a set alpha level, this equation becomes the full model, since it contains all the required terms and their coefficients. The restricted model, on the other hand, is defined as no information, since an investigator is asking the question if the second degree surface is predictive of the geographical distribution of the data over no other trend surface.

The typical ANOVA table for polynomial trend surfaces testing, if the surface accounts for a statistically significant amount of explained variance in predicting the criterion by the variance in spatial coordinates of the sample location over random variation or no trend (null hypothesis), can be found in Table 1. Table 2 illustrates the basic ANOVA format required to test or covary lower-order surfaces (restricted models) from higher-degree surfaces (full models), using standard multiple linear regression (MLR) terminology. The concept involved in the calculation of Table 2 is to test if the addition of explain variance or sum of squares of the higher-degree surface is statistically significant over the lower surface (plus the error or residual variance associated with the higher surface).

Table 1. Typical Analysis of Variance Table for Polynomial Trend Surfaces.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F Ratio
Regression	SS^{Reg}	m	MS^{Reg}	MS^{Reg}/MS^{Reg}
Residual	SS^{Res}	n - m - 1	MS^{Res}	
Total	SS^{T}	n - 1		

Note: In the table, m is the number of coefficients in the polynomial-trend surface equation, not including the constant term, b_0; and n is the number of valid data points used in the regression equation.

Table 2. Expanded analysis of Variance Table for Model Comparisons of Polynomial Trend Surfaces Testing for Statistical Significant Amounts of Explained Variance of Higher-Order over Lower-Order, Three-Dimensional Response Surfaces.

Source of Variation	Sum of Squares	df	Mean Squares	F-Ratio
Higher-Regression	$SS^{higher\ Reg.}$	$m_1 - m_2$	$MS^{Higher\ Reg}$	$MS^{Higher\ Reg}/MS^{Combined}$
Low-Order Regression + Error Variance Associated with Higher-Order Regression	$SS^{Lower\ Reg} + SS^{error\ (higher)}$	$N - m_{1-1}$	$MS^{Combined}$	

Note: In the table, m_1 is the number of coefficients in the response surface containing the full model, or model with the most spatially-depicted terms, not including the constant term, b_0; m_2 denotes the number of coefficients in the response surface containing the restricted model, or model with the least spatially-depicted terms of the lower-order surface to be covaried with the full model, not including the constant term, b_0. N represents total number of sampling locations or measured values.

Methods

A total of 21 roof falls were measured and described at a particular mine site in the Upper Freeport Coal Seam, located in the Northern Appalachian Coal Field in West Virginia. The failure parameters of maximum height of roof fall, heights to second and third horizon of roof strata or break-planes, mine span of entries, and vertical height of main opening associated with the roof falls, thinnest immediate roof layer, bolting characteristics, and associated characteristics were collected. In addition, maximum height of the failure zone into mine roof entry and second roof horizon or break-plane was chosen, due to the completeness of the database and the importance of these parameters as cited in the literature review, to develop mathematical models or surfaces and apply expanded ANOVA techniques to determine the best fit in terms of predicting spatial distributions.

Results and Discussion

Descriptive Statistics

The averages for the thinnest immediate roof layer is 0.17 inches, maximum roof height (9.4 feet) height to second roof horizon or break-plane above the roof line (6.0 feet), height to third roof horizon on break-plane above the roof line (2.1 feet), vertical height to fourth roof horizon or break-plane above the roof line (1.3 feet), length of roof bolts after the roof fall (68.8 inches), span of mine entry (18.3 feet), and vertical opening of entry (8.9 feet). The majority of falls showed no presence of water (66.7 percent), occurrence in intersections (47.6 percent) and entries (38.1 percent), used resin bolts after roof fall (57.1%), dome-shaped roof falls (54.5%), no presence of cracks in roof top after fall occurrence (76.2%) and presence of rib sloughing (16.2%) (Table 3.)

Table 3. Descriptive Statistics for Selected Mine Roof Fall Parameters Studied.

Parameter	Mean	Variance	Standard	Kurtosis	Skewness
THINLAY (inches) N = 21	0.168	0.045	0.212	12.542	3.337
ROOFHT (feet) N = 21	9.390	69.166	8.317	5.243	2.316
STRATA2 (feet) N = 19	6.020	38.563	6.210	13.771	3.544
STRATA3 (feet) N = 10	2.144	0.639	0.799	0.437	0.559
STRATA4 (feet) N = 2	1.340	0.003	0.057	0.000	0.000
LENGTHA (inches) N = 19	68.842	29.474	5.429	-0.718	-1.170
SPAN (feet) N = 21	18.340	3.619	1.902	1.593	1.156
OPENVER (feet) N = 21	8.884	1.155	1.075	-0.525	-0.651

Note. N denotes number of valid statistics used in arriving at the stated descriptive statistics.

ANOVA and Mathematical Modeling

Table 4 displays the basic coordinates in SYMAP and SYMUV inch-grid system (a contouring program) (23) and the input data for the hypothesis testing and model comparisons of trend surfaces, as reflected in the ANOVA tables. Tables 5 through 11 illustrate the hypothesis testing and model comparisons of response surfaces via expanded ANOVA techniques for maximum heights of roof failure. Table 12 is a summary table of the F-ratios, probability levels, R^2 for both the full and restricted models, degrees of freedom, and statistical significance for each surface and model comparison in predicting the spatial distribution of failure height into the mine roof. Similar information is displayed in Tables 13 through 20 for height to second break-horizon from roof line for the roof falls studied. In addition, Figure 1 is a three-dimensional, computer-generated, graphical portrait of the measured height above roof edge to second break-horizon for the roof falls studied. Alpha levels of 0.01 and 0.05 were employed for a two-tailed, nondirectional test, and standard statistical criteria were employed to reject or fail-to-reject the null hypothesis, H_0, in order to determine statistical significance.

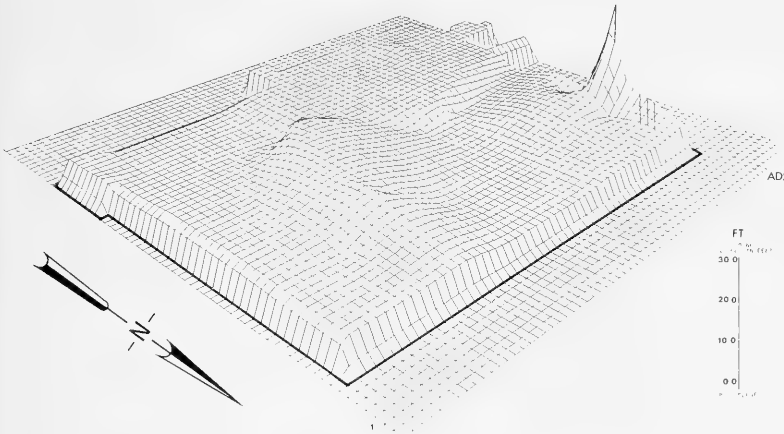

Figure 1. Three-dimensional model displaying spatial distribution of height to second rock-break horizon, from the roof edge, for the present mine layout, as viewed from the northeast direction.

Table 4. Location coordinates (SYMAP) and input data for hypothesis testing and model comparisons of trend surfaces.

Fall Identification Number	Y-coordinate (SYMAP axis system, in)	X-coordinate (SYMAP axis system, in)	Height of roof fall* (ft)	Height to Second Horizon of Roof Strata (ft)*
1	4.6	27.3	4.0	3.58
2	4.9	19.6	3.67	2.08
3	10.7	29.4	7.12	4.45
4	7.4	5.3	3.30	2.30
5	7.2	5.3	30.00	-----
6	6.5	5.3	11.75	7.75
7	5.7	4.9	35.00	30.00
8	4.4	6.3	4.0	2.67
9	4.1	6.5	6.20	4.13
10	18.7	7.8	7.58	5.33
11	19.1	8.6	9.83	7.08
12	6.4	23.4	13.42	4.25
13	6.4	23.0	7.92	6.00
14	4.6	27.0	4.22	3.42
14A (15)	6.4	27.6	11.42	4.75
15 (16)	4.6	26.7	1.83	-----
16 (17)	18.3	29.8	6.08	2.41
17 (18)	18.3	30.2	6.16	4.25
20 (19)	4.2	27.4	4.66	3.41
21 (20)	8.4	29.4	9.20	4.6
22 (21)	19.5	11.4	9.84	4.92

Table 4 continued

*Note: All roof height measurements are in relation to roof edge (vertical height of mine opening) as initial starting point.
The data values are accurate to the nearest tenth, the two digits to the right of the decimal point were used to prevent rounding-off errors in the statistical response surfaces generation and evaluation.

Table 5. ANOVA Table for the First Degree Polynomial Trend Surface for Structure Contour of Maximum Mine Roof Fall Height

Source of Variation	SS	df	ms	F-ratio	Sign
1st Degree Regression	244.6572	2	122.3286	1.6449	NS
Error Residual	1338.6707	18	74.3706		
TOTAL	1383.2379				

R^2 full model (regression) = 0.7686
R^2 restricted model (null hypothesis) = 0.0

Table 6. ANOVA Table for the Second Degree Polynominal Trend Surface for Structure Contour of Maximum Roof Fall Height

Source of Variation	SS	df	ms	F-Ratio	Sign
2nd Degree Regression	429.1304	5	85.8261	1.3492	NS
Error (Residual)	954.1975	15	63.6132		
TOTAL	1383.3279				

R^2 full model (regression) = 0.31026
R^2 restricted model (null hypothesis) = 0.0

Table 7. ANOVA Table for the Third Degree Polynominal Trend Surface for Structure Contour of Maximum Mine Roof Fall Height

Source of Variation	SS	df	ms	F-Ratio	Sign
3rd Degree Regression	771.0737	9	85.6749	1.5393	NS
Error (Residual)	612.2542	11	55.6595		
TOTAL	1383.8279				

R^2 full model (regression = 0.55740
R^2 restricted model (null hypothesis) = 0.0

Table 8. ANOVA Table for the Fourth Degree Polynominal Trend Surface
for Structure Contour of Maximum Mine Roof Fall Height

Source of Variation	SS	df	ms	F-ratio	Sign
4th Degree Regression	954.2024	14	68.1573	0.9529	NS
Error (Residual)	429.1255	6	71.5209		
TOTAL	1383.3279				

R^2 full model (regression) = 0.68979
R^2 restricted model (null hypothesis) = 0.0

Table 9. Model Comparison of the Second Order versus the First Order Trend Surface for Structure Contour of Maximum Mine Roof Fall Height

Table 9 continued

Source of Variation	SS	df	ms	F-ratio	Sign
2nd Degree Regression	184.4732	3	61.4911	0.7694	NS
1st Degree Regression	1198.8547	15	79.9237		
+ Error Residual					

R^2 full model (regression) = 0.31026
R^2 restricted model (null hypothesis) = 0.17686

Table 10. Model Comparison of the Third Order versus the Second Order Trend Surface for Structure Contour of Maximum Mine Roof Fall Height

Source of Variation	SS	df	ms	F-Ratio	Sign
3rd Degree Regression	771.0737	4	192.7684	2.0362	NS
2nd Degree Regression	1041.3846	11	94.6713		
+ Error (Residual)					

R^2 full model (regression) = 0.55470
R^2 restricted model (null hypothesis) = 0.31026

Table 11. Model Comparison of the Fourth Order versus the Third Order Trend Surface for Structural Contour of Maximum Mine Roof Fall Height

Source of Variation	SS	df	ms	F-Ratio	Sign
4th Degree Regression	954.2024	5	190.8405	0.95404	NS
3rd Degree Regression	1200.1992	6	200.0332		
+ Error (Residual)					

R^2 full model (regression = 0.68979
R^2 restricted model (null hypothesis) = 0.55470

Table 12. Summary of F-Ratios, Probability Levels, R^2 for Both the Full and Restricted Models, Degrees of Freedom-Numerator, Degrees of Freedom-Denominator, and Significance for Each Trend Surface for the Variable Structure Contour of Maximum Mine Roof Fall Height.

Order of Trend Surface	R^2f	R^2_r	dfn/dfd	F-Ratio	Significant

Table 12 continued

1	0.17686	0.0	2/18	1.64485	NS
2	0.31026	0.0	5/15	1.34919	NS
3	0.55740	0.0	9/11	1.53927	NS
4	0.68979	0.0	14/6	0.95297	NS
5	0.97518	0.0	N/A		
6	0.76216	0.0	N/A		
1 vs 2	0.31026	0.17686	3/15	0.76937	NS
2 vs 3	0.55470	0.31026	4/11	2.03619	NS
3 vs 4	0.68979	0.55470	5/6	0.95404	NS
4 vs 5	0.97518	0.68979	NA		
5 vs 6	0.76216	0.97518	NA		

(N = 21)

Table 13. ANOVA Table for the First Degree Polynominal Trend Surface for Height to Second Horizon of Roof Strata.

Source of Variation	SS	df	ms	F-ratio	Sign
1st Degree Regression	83.605713	2	41.8029	1.0955	NS
Error Residual	610.530760	16	38.1582		
TOTAL	694.13647				

R^2 full model (regression) = 0.12045
R^2 restricted model (null hypothesis) = 0.0

Table 14. ANOVA Table for the Second Degree Polynominal Trend Surface for Height to Second Horizon of Roof Strata

Source of Variation	SS	df	ms	F-Ratio	Sign
2nd Degree Regression	113.86328	5	22.7727	0.5102	NS
Error (Residual)	580.27319	13	44.6364		
TOTAL	694.13647				

R^2 full model (regression) = 0.16404
R^2 restricted model (null hypothesis) = 0.0

As evident in the ANOVA tables, no predictive trend was discovered to account for a statistically significant amouxt of variance for structure contour ofables, no predictive trend was discovered to account for a statistically significant amount of variance for structure contour of maximum failure zone above roof line or edge. As evident in Table 12, the expanded ANOVA techniques resulted in no significant variance of response surface over/above random variation or covariance of lower-degree surfaces. Hence, the occurrence of maximum roof-failure height above the roof edge cannot be spatially depicted, due to its high spatial variability, at least for the sites measured.

In terms of the expanded ANOVA techniques applied to height, above roof edge, to second break-horizon, a statistical significant amount of explained variance was accounted for by the fourth-degree, polynomial response surface (Table 16 and 20). The fourth-degree polynomial surface accounted for 98.04 percent of explained variance (p 0.01) in predicting the spatial distribution of height of second rock-break horizon. Probably, this significance is related to the continuous nature of the lithologies and geologic structures that resulted in failure, either plastic or brittle deformation, at this level.

Table 15. ANOVA Table for the Third Degree Polynominal Trend Surface for Height to Second Horizon of Roof Strata

Source of Variation	SS	df	ms	F-Ratio	Sign
3rd Degree Regression	444.20947	9	49.3566	1.7774	NS
Error (Residual)	249.92691	9	27.7696		
TOTAL	694.13647				

R^2 full model (regression = 0.63995
R^2 restricted model (null hypothesis) = 0.0

Table 16. ANOVA Table for the Fourth Degree Polynominal Trend Surface for Height to Second Horizon of Roof Strata.

Source of Variation	SS	df	ms	F-ratio	Sign
4th Degree Regression	680.51343	14	48.6081	14.2725	S**
Error (Residual)	13.622908	4	3.4057		
TOTAL	694.136747				

R^2 full model (regression) = 0.98037
R^2 restricted model (null hypothesis) = 0.0

**denotes statistical significance at the 0.01 level for a two-tailed, non-directional test.

Table 17. Model Comparison of the Second Order versus the First Order Trend Surface for Height to Second Horizon of Roof Strata.

Source of Variation	SS	df	ms	F-ratio	Sign
2nd Degree Regression	113.86328	3	37.9544	0.0640	NS
1st Degree Regression	610.53076	13	593.2732		
+ Error Residual					

R^2 full model (regression) = 0.61404
R^2 restricted model (null hypothesis) = 0.12045

Table 18. Model Comparison of the Third Order versus the Second Order Trend Surface for Height to Second Horizon of Roof Strata.

Source of Variation	SS	df	ms	F-Ratio	Sign
3rd Degree Regression	444.20947	4	111.0524	3.0255	NS
2nd Degree Regression	330.34619	9	36.7051		
+ Error (Residual)					

R^2 full model (regression) = 0.63995
R^2 restricted model (null hypothesis) = 0.61404

Table 19. Model Comparison of the Fourth Order versus the Third Order Trend Surface for Height to Second Horizon of Roof Strata.

Source of Variation	SS	df	ms	F-Ratio	Sign
4th Degree Regression	680.51343	5	136.1027	2.1783	NS
3rd Degree Regression	249.92687	4	62.4817		
+ Error (Residual)					

R^2 full model (regression) = 0.98037
R^2 restricted model (null hypothesis) = 0.63995

Table 20. Summary of F-Ratios, Probability Levels, R^2 for Both the Full and Restricted Models, Degrees of Freedom-Numerator, Degrees of Freedom-Denominator, and Significance for Each Trend Surface for the Variable Height to Second Horizon of Roof Strata.

Order of Trend Surface	R^2f	R^2f	dfn/dfd	F-Ratio	Significant
1	0.12045	0.0	2/16	1.09550	NS
2	0.16404	0.0	5/13	0.51018	NS
3	0.63995	0.0	9/9	1.77736	NS
4	0.98037	0.0	14/4	14.27246	S**
5	0.99997	0.0	N/A		
6	0.99981	0.0	N/A		
1 vs 2	0.16404	0.12045	3/13	0.06397	NS
2 vs 3	0.63995	0.16404	4/9	3.02553	NS
3 vs 4	0.98037	0.63995	5/4	2.17828	NS
4 vs 5	0.99997	0.98037	NA		
5 vs 6	0.99981	0.99997	NA		

(N = 19)

Note: The symbols * denote statistical significance at 0.05 level, ** denote statistical significance at 0.01 level, both for a two-tailed, nondirectional test.

Conclusions

As evident in the ANOVA tables, Tables 4 through 20, expanded analysis of variance techniques can be applied to aid geoscientists and engineering in testing certain hypotheses concerning three-dimensional characterization of selected parameters for predictive purposes. As previously mentioned, most mining problems dealing with design and planning, especially for ground control stability and forecasting, are concerned with establishing statistically predictive relationships among measured parameters based on their associated variabilities. As demonstrated in the hypothesis-testing process, expanded ANOVA techniques can accommodate statistical testing of relatively sophisticated research hypotheses concerning spatial distributions in typical mining engineering problems. Although statistically significant trends were not found for one parameter studied, structural contour of maximum roof fall height, but determined for height to second break-horizon above roof line, the technique is readily available and is another tool that may be applicable in the decision-making process.

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Mantle Rock and Alcove Arch, Livingston County, Kentucky

Thomas C. Kind and Lynn Shelby
Department of Geosciences
Murray State University
Murray, Kentucky 42071

Abstract

Two natural arches, Mantle Rock and Alcove Arch, are located in Livingston County, Kentucky. Alcove Arch is at an early stage of development while Mantle Rock is a spectacular feature spanning nearly 58 m. The arches formed in association with physical and chemical weathering processes which have been active along fractures in the Pennsylvanian Pounds Sandstone.

Introduction

The presence of known scenic natural arches in west Kentucky is very limited. Two structures located in Livingston County, Mantle Rock (Fig. 1) and a smaller arch (here named Alcove Arch) (Fig. 2) in Livingston County, Kentucky, are unique to the area landscape. According to Corgan and Parks (1) there have been a total of 20 natural bridges and arches described in Kentucky. The most recent description of bridges within Kentucky was accomplished by these authors in a work on two bridges in Christian County, Kentucky. The bridges were then the two westernmost structures of this type described within the state. An account of many of the other bridges and arches within the state was written by McFarlan in *Geology of Kentucky* (2).

Mantle Rock, with a span of 57.6 m is, in fact, one of the longest bridges in Kentucky although its height, 9.1 m, is not as impressive as others, such as the Natural Bridge of Kentucky, which is 23.7 m high, or Smoky Bridge, which is 15.2 m high (2). Mantle Rock is locally known but Alcove Arch is often overlooked due to a position which is partially obscured by large collapse blocks. Alcove Arch is much younger than Mantle Rock with respect to its development and represents an arch in the early stages of development.

Fig. 1. Mantle Rock, Livingston County, Kentucky

Mantle Rock is a truly oustanding physical landscape feature. Interestingly, it is also mentioned in historical records in conjunction with the Trail of Tears, the trek of the Cherokee Indians from their territory in the southeastern United States to Oklahoma during the 1830's. Property owned by the Cherokee was seized as a result of the Dahlonega goldrush in Georgia. The Cherokee, numbering about 15,000, were removed by force during the fall and early winter of 1838. Their route through west central Tennessee and western Kentucky brought them to the Ohio River near Salem, Kentucky. The river at that time was ice-filled and too dangerous to cross. Hundreds died and were buried near Mantle Rock and the town of Joy, Kentucky, as many were ill and exhausted from travel and could not survive the bitter winter. Nearly one-fourth of the Cherokee died before reaching their destination in Oklahoma (3).

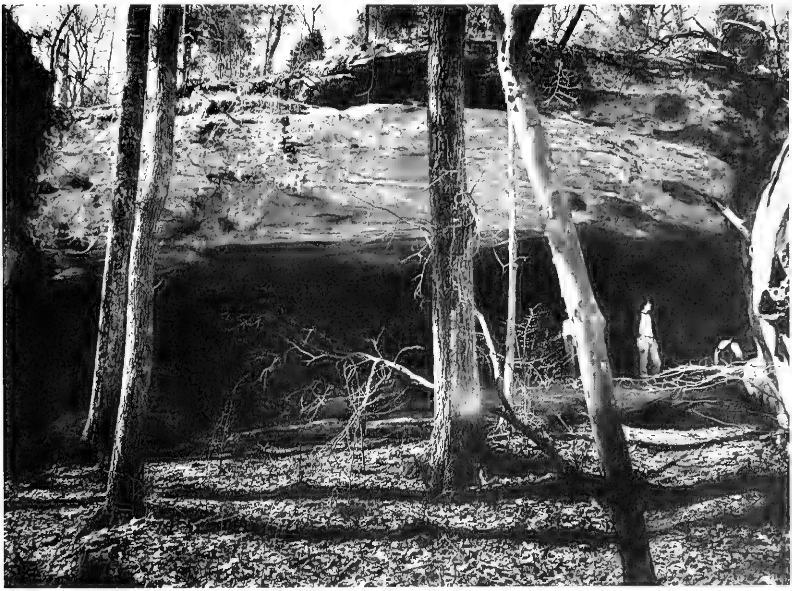

Fig. 2. Alcove Arch, Livingston County, Kentucky

LOCATION

Mantle Rock and Alcove Arch are located on the Golconda Quadrangle, 7.5-minute series (4), approximately 4 km west of the small community of Joy on Kentucky Highway 133 (Fig. 3). The arches are situated on property owned by Reynolds Metals, Salem, Kentucky. Access from Highway 133 is by a trail across the property of Dale Calendar, Ledbetter, Kentucky.

MANTLE ROCK

Mantle Rock trends in a northeast-southwest direction. The span, measured at the base, is 57.6 m (Fig. 4). Maximum height of the span is located to the left of center and is 9.1 m. The minimum thickness of the span is 3.0 m, while the width of the span is 5.8 m at its narrowest point. The opening or window behind the span is 48.8 m long with a maximum width of 5.0 m (Fig. 5). The surface beneath the arch slopes gently from northeast to southwest. A few large pieces of breakdown are partially buried in surficial material near the northeast end of the span. Primary fractures associated with the bridge trend approximately N45°E while a secondary fracture pattern is oriented N78°E.

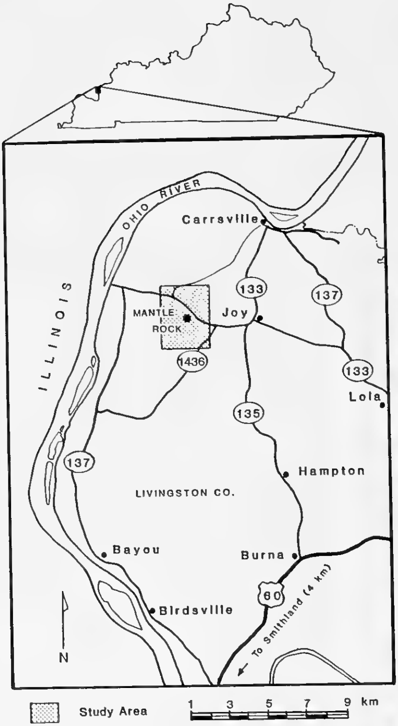

Fig. 3. Location of study area.

ALCOVE ARCH

Alcove Arch is located approximately 300 m northeast of Mantle Rock along the same outcrop. The arch spans 20 m and has a maximum height of 8.5 m (Fig. 6). Minimum thickness of the span is 3.3 m while the width of the span is approximately 5.2 m at its narrowest point. The window of the arch is 5.5 m long and 0.9 m wide (Fig. 7). Two prominent joints are present at this arch. One fracture is oriented N44°E although the window of the arch has formed along a fracture trending N68°E. Large slabs of sandstone that have fallen from the roof of the structure are situated beneath the arch.

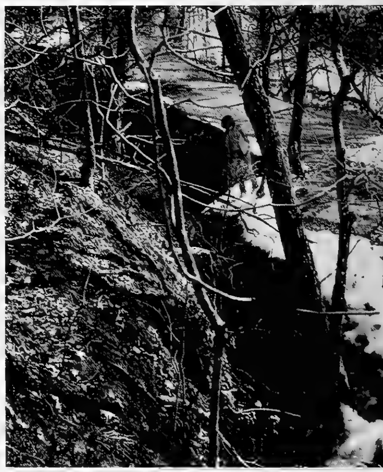

Fig. 5. View of the window above Mantle Rock.

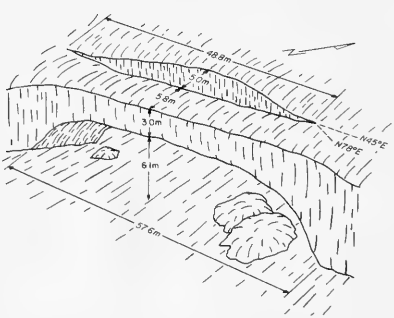

Fig. 4. Dimensions associated with Mantle Rock.

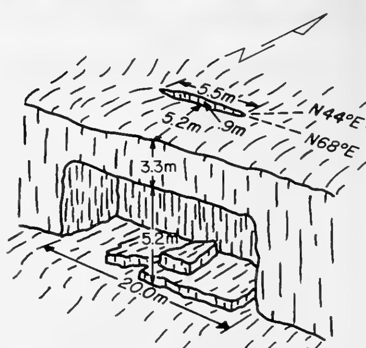

Fig. 6. Dimensions associated with Alcove Arch.

GEOLOGY

The Shawnee Hills section of the Interior Low Plateaus is the physiographic regional setting for the arches (5). The topography of the local area is characterized by rugged to rolling hills and steep-walled valleys. Elevations range from 90 to 250 m. This area is known for its extensive faulting and abundant fluorite deposits. Over 75 per cent of the fluorite production in the United States has been from the surrounding Kentucky-Illinois mining district. Significant lead and zinc deposits associated with the fluorite are currently being investigated by private industry.

Fig. 7. View of the window above Alcove Arch

According to Heyl and Brock (6), "the district is located in the most complexly faulted area in the craton of the United States." Three major fault zones, the Shawneetown-Cottage Grove, the Rough Creek, and the New Madrid, intersect approximately 24. 5 km north of the arches. Some north-trending faults are present as are a small number of east-trending faults; however, the predominant orientation of faults on the Golconda Quadrangle is northeast.

Mantle Rock and Alcove Arch lie within a graben that is approximately 0.9 km wide and 5.3 km long (Fig. 8). Figure 8 is a generalized map modified from Amos (4). Displacement within the graben is estimated to be 46 m. The graben is bounded on the southeast by a fault which trends N39°E. This fault is associated with the Rosiclare Fault System which is located .4 km east of the arches. The graben is also bordered on the northwest by a fault of the Big Creek Fault System which trends N18°E and is situated .8 km west of the arches. The stresses responsible for this post-Pennsylvanian faulting were also of primary importance in the formation of the extensive joint sets of the study area.

The larger arch, Mantle Rock, is oriented N45°E. As previously stated, the major joint in the backwall of this arch strikes N45°E and a secondary joint trends N78°E. The joints in Alcove Arch have bearings of N44°E and N68°E. Joint orientations exemplify conjugate shears that developed approximately 30° east and west of the principal stress orientation in the region.

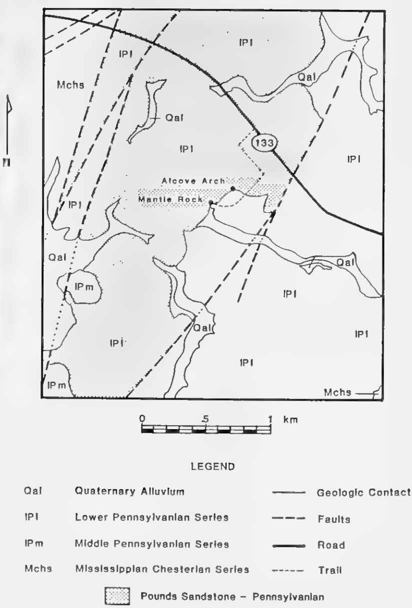

Fig. 8. General geology of the study area [Modified after Amos (4)].

Stratigraphy

The arches have formed in the Pounds Sandstone Member of the Pennsylvanian Caseyville Formation immediately above a regional Mississippian/Pennsylvanian unconformity (Fig. 8). The Pounds Sandstone in the study area varies from 25-40 m thick. The sandstone is medium to coarse-grained with 1.5 cm quartz pebbles. It is generally light gray in color and shows some cross beds that dip to the south and southwest. Honeycomb weathering is very well defined on the northeastern exposures of the outcrops (Fig. 9). some Liesegang layering, the deposition of limonite and hematite in joints and roughly concentric rings, is present at Mantle Rock, but absent at Alcove Arch (7). A local unconformity exists below the Pounds. Beneath the unconformity an unnamed shale, siltstone, and sandstone member of the Caseyville is present. This member is represented at the site by a thin, even-bedded, light gray siltstone which is approximately 9 m thick. In some nearby locations this member is completely cut out by the overlying members (4). The unnamed siltstone is exposed in the stream bed 15 m east of the larger arch and about 0.4 km southwest along another small stream.

Fig. 9. Honeycomb weathering in the Pounds Sandstone Member of the Caseyville Formation.

Mode of Formation

Mantle Rock was formed as a result of physical and chemical weathering activity along the sandstone cliff face and associated joints. It is also possible that an intermittent stream which flows toward the southwestern corner of the span assisted in the removal of material along a small portion of the cliff face. The weathering processes alone or in combination with stream erosion removed material at the base of the cliff to a point where a widened fracture parelleling the face of the cliff was encountered as shown in the cross-sections in Figure 10, Steps 1 through 3. As weathering progressed, another widened fracture was encountered (Step 4). Chemical weathering weakened the bedrock along the joints resulting in the removal of support and gradual collapse of roof material (Step 5). Subsequent weathering and mass wasting has removed more material resulting in the present situation, Step

6. Infiltration of water into the cross strata and Liesegang layering has helped to accelerate the weathering processes.

The smaller arch has formed in essentially the same manner as Mantle Rock except for the lack of any stream erosion due to the elevated entrance of Alcove Arch and a lack of Liesegang layering. The life of this arch may be short geologically due to the presence of a vertical fracture that cuts the northeastern end of the span. As weathering processes continue along this fracture the span will weaken and finally collapse, leaving only a rock shelter.

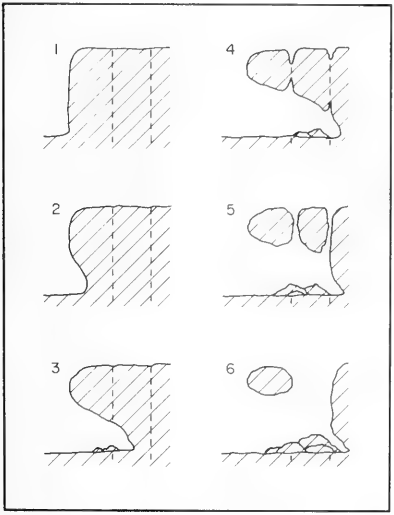

Fig. 10. Mode of arch formation.

SUMMARY AND CONCLUSIONS

Mantle Rock and Alcove Arch are situated farther west in Kentucky than any like structures that have been documented. Both arches have formed in response to chemical solution and physical weathering along widened intersecting joints which are directly related to regional structural trends. Undercutting by stream erosion may have been a factor which influenced the collapse of roof material from the southwest end of Mantle Rock but had no influence on the formation of Alcove Arch. Infiltration along prominent crossbeds and Liesegang layering helped to accelerate the weathering processes at Mantle Rock and may be responsible for a more mature stage of arch development. Although crossbeds which facilitate weathering processes are present at Alcove Arch, visible Liesegang layering is absent.

Numerous other undocumented natural arches and/or bridges may exist along the extensive outcrop of the Pounds Sandstone Member due to the existence of the aforementioned conditions. It should be noted that the scenic area surrounding Mantle Rock and Alcove Arch is perfectly suited for field instruction and extensive geologic investigations on such topics as fracture analyses, differential weathering processes, and sedimentary structures.

ACKNOWLEDGEMENTS

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GROWTH OF PADDLEFISH IN TWO MAINSTREAM RESERVOIRS WITH REFERENCE TO COMMERCIAL HARVEST[1]

Charles R. Bronte[2] and Donald W. Johnson [3]
Hancock Biological Station, Murray State University, Murray, Kentucky 42071

ABSTRACT

Adult and juvenile paddlefish from commercial net catches from Kentucky Lake and Lake Barkley were studied to determine growth and maturation information. Backcalculated lengths at dentary bone annuli revealed rapid growth for the first 4 years with body length of 10 cm or greater attained within the first year. Differential growth in terms of weight at age between the sexes was noted. Males appeared to become sexually mature in their sixth or seventh year. Lengths and weights of mature males sampled by the fishery ranged from 74 to 97 cm and 5.3 to 13.2 kg, respectively. Gravid females sampled ranged from 88 to 102 cm and 16.8 to 22.7 kg; all were 9 years or older. Mesh sizes currently used by commercial fishermen are selecting for mostly immature fish and may have possible negative affects on breeder recruitment under intensive fishing pressure.

INTRODUCTION

Paddlefish *(Polyodon spathula)* have undergone some restrictions in range and declines in numbers since 1900 from overharvesting and destruction of suitable spawning habitat (1, 2, 3, 4). Impoundments throughout the Mississippi River drainage have flooded and/or made inaccessible many spawning areas.

Fifty percent (124 tons) of the total recent commercial harvest (260 tons) of paddlefish comes from the Tennessee and Cumberland Rivers (5) located in southwestern Kentucky and western Tennessee. Recently, commercial fishing pressure has increased in these areas. Reduced imports of Caspian Sea sturgeon eggs have made it necessary for the caviar industry to switch to paddlfish as an alternate egg source. High prices ($65/kg) paid for paddlefish roe provide incentive for increased fishing pressure.

In 1979, Lake Barkley (Cumberland R.) and Kentucky Lake (Tennessee R.) in western Kentucky were reopened to gill and trammel net usage to harvest under-utilized buffalofish *(Ictiobus spp.)* and carp *(Cyprinus carpio)*. Catch data from the first year (1979-1980) revealed that 6 tons of paddlefish were taken as by-catch. With this increase in harvest and potential for spawning stock damage, it became imperative to collect information on growth and maturation of these stocks to ensure responsible management.

METHODS

Paddlefish from the Kentucky and Tennessee portions of Lake Barkley (n = 101) and Kentucky Lake (n = 89) were obtained from commercial net catches between December 14, 1980 and February 5, 1981. Kentucky permits commercial harvest in these reservoirs with 90-115 mm bar mesh gill and trammel nets from November 1 through March 31. A year-round gill and trammel net fishery exists in Tennessee where regulations stipulate that bar mesh sizes must be 76 mm or greater.

Rostrum, body, and total lengths, as well as weight, sex, and condition of gonads were recorded and dentary bones collected from all fish. Body lengths (BL) were measured from the anterior margin of the eye to the base of the hypural bone. Rosen (6) suggested this as a more valid index of paddlefish growth than total length. Only 22% of variation in body lengths was explained by variation in rostrum length.

Ages were estimated by examining dentary bone cross sections (7). Thin sections of dentary bone were cut with a rotary saw where the bone bends mesially. Sections were thinned by grinding on a wet stone and cleared in xylene or methyl salicylate to facilitate identifying annuli. Annuli were counted and backcalculation distances measured on the mesial lobe of the dentary bone section. Only growth bands which extended around the bone were considered true annuli. Most dentaries were read twice with

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[2] Present Address: Red Cliff Fisheries Department, Red Cliff Band of Lake Superior Chippewas, P.O. Box 529, Barfield, WI 54814.

[3] Center for Environmental Studies, Biology Department, Memphis State University, Memphis, TN 38152.

discrepancies settled by assigning the older age estimate.

Backcalculations to estimate length at age were performed by measuring the distance from the middle of the central core to the distal portion of each annulus. All reported lengths are body lengths. Rosen (6) determined that central core development was completed after the first growing season, therefore, the core center provides an appropriate reference point for backcalculation measurements. Fish length at annulus formation was estimated on the basis of direct proportional expansion (8).

RESULTS

The size range of fish sampled resulted from selectivity of the 90-152 mm bar mesh nets used by commercial fishermen and may not be indicative of true population age and size characteristics. Fishermen in Kentucky used 90-115 mm mesh nets which selected for buffalofish, carp and catfish *(Ictaluridae)* with paddlefish incidental to the catch. Larger mesh nets (152 mm) were used by Tennessee fishermen targeting gravid paddlefish. Body lengths (cm) of commercially harvested paddlefish ranged from 32 to 102 and 27 to 139 for Kentucky Lake and Lake Barkley samples, respectively while weights (kg) ranged from 0.4 to 22.7 and 0.6 to 30.2, respectively (Tables 1 and 2).

Table 1. Paddlefish age, size, and sex distribution of commercial catch samples from Lake Barkley (Cumberland River). December 1980-February 1981.

Year			Body Length (cm)		Weight (kg)		Sex (%)		
Class	Age[1]	N	Mean	Range	Mean	Range	F	M	U[2]
1978	2	4	36	26-48	1.2	0.6-1.7	25	25	50
1977	3	7	51	39-63	2.7	1.0-4.6	57	43	
1976	4	7	54	45-59	2.7	1.4-3.4	43	57	
1975	5	13	65	52-79	4.7	2.2-8.9	23	77	
1974	6	24	73	58-84	7.5	3.9-13.6	33	67	
1973	7	12	77	72-83	8.2	5.6-11.8	36	64	
1972	8	17	89	64-97	10.9	6.4-17.5	59	41	
1971	9	14	90	84-97	14.7	5.5-20.1	100	0	
1970	10	2	90	--	--	--	100	0	
1969	11	0	--	--	--	--	--	--	
1968	12	1	132	--	30.2	--	100	0	

[1] Number of growing season completed.

[2] Unable to determine sex.

Table 2. Paddlefish age, size, and sex distribution of commercial catch samples from Kentucky Lake (Tennessee River). December 1980-February 1981.

Year			Body Length (cm)		Weight (kg)		Sex (%)		
Class	Age[1]	N	Mean	Range	Mean	Range	F	M	U[2]
1978	2	1	32	--	0.4	--	0	0	100
1977	3	5	40	35-42	0.8	0.5-1.0	0	20	80
1976	4	8	50	41-56	1.9	1.0-2.7	25	75	
1975	5	4	67	66-68	4.4	4.1-4.7	50	50	
1974	6	16	68	62-72	5.6	3.8-6.6	44	56	
1973	7	12	73	65-88	6.7	4.6-9.3	50	50	
1972	8	20	77	64-87	8.2	5.1-11.4	50	50	
1971	9	16	79	72-90	8.8	6.5-12.4	25	75	
1970	10	4	89	87-93	13.3	11.8-16.8	50	50	
1969	11	1	91	--	14.4	--	100	0	
1968	12	0	--	--	--	--	--	--	
1967	13	1	99	--	22.7	--	100	0	
1966	14	1	102	--	20.1	--	100	0	

[1] Number of growing season completed.

[2] Unable to determine sex.

Interpretation of dentary bones indicated that age classes 2-12 and 2-14 were represented in Lake Barkley and Kentucky Lake samples, respectively. Age at recruitment to the fishery appears to be at six to seven years when mean lengths approach 70 cm. Annual mortality estimated by catch curve analysis of age frequencies of fully recruited fish (>6 yrs) was 44% for Kentucky Lake fish and 45% for Lake Barkley fish.

Growth data from backcalculated lengths were consistent with observed lengths at age in samples (Table 3). Growth was similar in both

Table 3. Growth of Kentucky Lake and Lake Barkley paddlefish determined from dentary annuli backcalculations.

	Length at Annulus Formation (cm)									
	1	2	3	4	5	6	7	8	9	10
Kentucky Lake										
Males	20.4	31.8	42.4	52.3	61.1	67.1	73.4	77.6	83.0	86.5
SD	3.3	3.8	4.2	5.0	5.6	5.5	5.1	4.9	3.5	2.0
Growth (cm)	20.4	11.4	10.6	9.9	8.8	6.0	6.3	4.2	5.4	3.5
Females	20.9	31.9	42.9	51.3	59.2	65.3	70.5	77.3	80.5	85.4
SD	3.5	4.0	5.3	6.1	5.3	5.8	6.6	7.6	9.2	11.8
Growth (cm)	20.9	11.0	11.0	8.4	7.9	6.1	5.2	6.8	3.2	4 9
Lake Barkley										
Males	20.4	33.8	45.4	54.8	63.1	69.5	71.5	77.8	82.0	84.1
SD	3.9	5.5	6.1	6.6	7.1	8.0	8.5	8.4	9.0	4.8
Growth (cm)	20.4	13.4	11.6	9.4	8.3	6.4	2.0	6.3	4.2	2.1
Females	20.7	32.7	44.6	55.3	63.3	71.3	78.3	84.8	90.1	89.0
SD	3.2	6.3	6.0	5.5	6.7	8.2	9.0	10.6	12.3	--
Growth (cm)	20.7	12.0	11.9	10.7	8.0	8.0	7.0	6.5	5.3	--

lakes. Paddlefish grew relatively rapidly during the first four years with annual increases generally greater than 10 cm. Differential growth in length between the sexes was not observed as in other studies (6, 9). Growth in length for all fish was described by von Bertalanffy equations (Table 4).

Table 4. Von Bertalanffy growth equations for Kentucky Lake and Lake Barkley paddlefish (BL = body length in cm); R^2 for all equations = 0.99).

Kentucky Lake

Males $Bl_t = 111.1\,(1\text{-}e^{-0.146(t\,+\,0.355)})$

Females $BL_t = 112.4\,(1\text{-}e^{-0.134(t\,+\,0.534)})$

Lake Barkley

Males $BL_t = 96.7\,(1\text{-}e^{-0.200(t\,+\,0.1.77)})$

Females $BL_t = 116.3\,(1\text{-}e^{-0.153(t\,+\,0.217)})$

Weight at age was estimated using backcalculated lengths in length-weight regressions (Table 5); differential growth in weight between the sexes was observed for Lake Barkley fish. Lake Barkley females were heavier than males after the fifth growing season with differences increasing with age. Kentucky Lake paddlefish failed to show sexual dimorphism by weight. Differences in weight may be due to the development of ovaries and associated fat bodies. Weight differences are further reflected in comparing mean calculated condition factors [K(BL)], for arbitrary length classes (Table 6). Condition generally increased with length for all fish. Lake Barkley females had higher condition values than males for most length classes. Previous to sexual maturity, Kentucky Lake females exhibited lower condition factors than males.

Table 5. Length-weight regressions for Kentucky Lake and Lake Barkley paddlefish samples.

		r
Kentucky Lake		
Males	LOG W = -5.329 + 3.197 LOG BL*	.99
Females	LOG W = -6.308 + 3.534 LOG BL	.98
Lake Barkley		
Males	LOG W = -4.240 + 2.822 LOG BL	.91
Females	LOG W = -5.020 + 3.100 LOG BL	.95

*Body Length

Table 6. Calculated condition values [K(BL)] for Kentucky Lake and Lake Barkley paddlefish.

Body Length	Kentucky Lake Males	Kentucky Lake Females	Lake Barkley Males	Lake Barkley Females
35.0-44.9	1.35	--	1.52	1.66
45.0-54.9	1.51	1.45	1.53	1.70
55.0-64.9	1.68	1.42	1.73	1.87
65.0-74.9	1.84	1.68	1.70	1.72
75.0-84.9	1.65	1.87	1.01	2.09
95.0	--	2.12	--	2.25

Sexual maturity was estimated by visual examination (2, 6). Mature males exhibited expanded and convoluted testes which assumed white mottled appearance and extended into the caudal end of the body cavity. Kentucky Lake mature males ranged from 74 to 90 cm in length and 8.0 to 12.4 kg in weight and were 7 to 10 years old; Lake Barkley mature males were 764 to 97 cm and 5.3 to 13.2 kg with ages ranging from 6 to 8 years. The presence of black or gray-black eggs indicated maturity in females. Although many large females were sampled, few contained eggs. Most had ovaries which were yellow to slightly pink in color extending throughout the body cavity. Gravid females from Kentucky Lake ranged from 93 to 102 cm and 16.8 to 22.7 kg, and were greater than 9 or 10 years old.

Discussion and Conclusions

Age frequencies of Kentucky Lake and Lake Barkley paddlefish samples were similar to samples reported from Mississippi River-Pool 13, Iowa (10); Missouri River below Gavins Point Dam, Nebraska (11, 12); and the Neosho River, Oklahoma (13); however, older fish (20-26 years) have been collected in the Mississippi River-Pool 19, Iowa (14); the Osage River, Missouri (9); Lake Francis Case, South Dakota (15); and a free flowing section of the Missouri River, South Dakota (6).

Paddlefish exhibited large length increases for the first three to four years when compared to other populations (6, 7, 9, 11, 14, 16, 17, 18). Impinged young-of-the-year paddlefish from Cumberland Steam Plant (Lake Barkley, Tennessee), were over 30 cm in total length by late winter (19) and agree well with backcalculated estimates.

As reported by others, gonad examination revealed that these fish mature relatively late in life. Testes indicated males may become sexually mature at the sixth or seventh year. Helms (20) states that at maturity, testes enlarge to sizes greater than the associated fat tissue.

None of these fish showed these characteristics. Testes expansion was limited to 10-20 mm in width as noted by Rosen (6). Gravid females were some of the largest and oldest individuals sampled. However, 91 percent of females of similar or greater size and age contained no mature eggs. It is not unusual to observe few or no ripe females in samples containing old fish (1, 4, 6, 15, 18, 20). This may indicate that only a small percentage of mature individuals spawn each year (14, 16). Rosen (6) suggested that maturation may not be age dependent, but that the formation of large egg masses may be limited by available energy. Appropriate stimuli may not be present in these reservoirs to induce egg maturation. Purkett (4) noted that warming water temperatures and rising water levels are needed to induce spawning migrations. Whether other stimuli are also required for oocyte maturation early in the season is unknown.

Fast growth leading to large sizes during early life can lead to adverse consequences to the population from commercial fishing. This concept was addressed early by Adams (7) and later by Larimore (2) who both recognized that knowledge of growth rates, age at maturity, and spawning habits are imperative for responsible management and protection. Data presented here for Kentucky Lake and Lake Barkley paddlefish suggest that many individuals are being removed before contributing to reproduction. Mean lengths and ages of commercially harvested females are below those observed for mature fish. Absence of older fish and high total mortality rates may indicate fishing has cropped these age classes. Harvests consist of younger fish as they are recruited into the fishery. Mesh sizes (152 mm) commonly used in the Tennessee fishery may be inappropriate for maintaining favorable population structure. Use of larger mesh gill nets that select for fish greater than 80 cm should be investigated.

Sport fishery harvests currently exceed surveyed commercial landings through most of the paddlefish's range and may pose a greater threat to the species' future than the commercial fishery (5). Although current fishing mortality rates associated with commercial fisheries will yield sustained harvests, monetary incentives for roe may increase total harvest levels and lead to population declines. Appropriate regulation is needed to ensure that this commercially and aesthetically valuable resource remains renewable.

Acknowledgements

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An *Azosipirillum lipoferum* Isolate with High Nitrogen-Fixing Capabilities from a Coal Surface-Mined Site

by
David N. Mardon and Frederick M. Rothwell
Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475
and
The Northeastern Forest Experiment Station, U.S. Forest Service, Berea, Kentucky 40403

ABSTRACT

Azospirillum lipoferum was isolated from the rhizosphere soil of *Festuca arundinacea* growing on a coal surface-mined site in Eastern Kentucky. As measured by the acetylene reduction assay, this isolate fixed nitrogen at a substantially higher rate in comparison with other *Azospirillum* cultures. These results demonstrate the potential significance of associative nitrogen-fixation in establishing and maintaining growth of herbaceous vegetation on minesoils when nitrogen is a limiting factor.

INTRODUCTION

Azospirillum is an asymbiotic nitrogen-fixing bacterium characteristically found in close association with the roots of many herbaceous plants, particularly the grasses (1, 3, 4, 15). The genus is composed of 2 species, *A. brasilense* and *A. lipoferum* (14). Both species have been implicated in nitrogen fixation in the rhizosphere soil of the above plants (12).

Asymbiotic nitrogen-fixing microorganisms, including *Azospirillum*, have occasionally been isolated from rhizosphere soil of grasses used in minesoil reclamation (10). However, little information is available regarding the significance of *Azospirillum* in this type of environment. This paper presents evidence that the nitrogen-fixing capacity of an *A. lipoferum* isolated from the rhizosphere soil of a perennial grass, *Festua arundinacea*, growing on a coal surface-mined site was significantly higher than selected *Azospirillum* species tested.

MATERIALS AND METHODS

Microorganisms—The primary microbial isolate in this study has been tentatively identified as *Azospirillum lipoferum* based upon the results of morphological and physiological tests (14). Two morphologically distinct colonies of the original isolate were obtained via the streak-plate method. These cultures were designated Martiki-R (Rough) and Martiki-S (Smooth) in accordance with their respective colonial morphology. Other bacteria used in this investigation were obtained from the American Type Culture Collection as follows: *A. lipoferum* ATCC 29707, *A. brasilense* ATCC 29145 and *Azotobacter paspali* ATCC 23833.

Culture Medium—All bacteria were maintained with bi-monthly transfers on agar slants of a nitrogen-free malate medium similar to that employed by Haahtela et al. (4). Each component of this medium was autoclaved and maintained separately in 10X concentration as a stock solution with the exception of the agar which was dissolved in 880 ml of distilled water and autoclaved. Next, 10 ml of each sterile stock solution was added aseptically to the agar suspension. These additional components of the final medium were: biotin, 100μg; pyridoxine-HCL, 200 μg; $Na_2MoO_4.2H_20$, 0.005 g; KH_2PO_4, 0.4 g; $K_2HPO_4.3H_20$, 0.13 ; NaCl, 0.1 g; $CaCl_2.2H_20$, 0.2 g; $MgSO_4.7H_20$, 0.2 g; $FeSO_4.7H_20$, 0.2 g; DL-malic acid, 5 g; $CaCO_3$, 0.5 g and 40% w/v KOH solution added to a final pH of 6.8-7.0.

Growth and Preparation of Cultures for Ethylene Assays—The microorganisms used in this study were grown at 32°C for 72 h on nitrogen-free agar slants. Cells were washed from the slants using nitrogen-free broth, collected by centrifugation (5000 x g for 10 min) and suspended in fresh nitrogen-free broth. The culture was then adjusted to a density of 100 klett units (approximately 1.2×10^8 cells per ml) using a Klett-Summerson Colorimeter. One-fourth ml of this cell suspension was then inoculated into 6 replicate 13.5 ml serum vials each of which already contained 3.25 ml of nitrogen-free agar medium. While immersed in an ice bath, each vial was next flushed with glasswool filtered nitrogen at a rate of 400 ml/min for 5 min. following this procedure, a specified volume of nitrogen was withdrawn from the vial and replaced with oxygen. In vials containing *A. lipoferum*, 0.85 ml of oxygen was added; in vials with *A. brasilense*, 1.28 ml of oxygen was added; and for vials with

Azotobacter paspali, 0.43 ml of oxygen was used (5, 9). Cultures were incubated at 32°C for selected time periods (Table 1 and 2) after which 1.0 ml of the gas phase in each vial was removed and replaced with 1.0 ml of acetylene (6). After the addition of acetylene each vial was subsequently incubated for an additional 3 h at 32°C then assayed for ethylene.

Acetylene Reduction (Ethylene) Assay—All assays for acetylene reduction were done on 0.5 ml samples taken from the reaction vessels with mininert valves (13). The ethylene produced was determined by using a varian 2700 gas chromatograph with a one-eighth inch, 80/100 mesh Porapak-R column, 2.8 m in length and a flame ionization detector, as outlined by Smibert and Krieg (11) and Haahtela et al. (4). All data are expressed as nanomoles of ethylene produced/mg protein/h.

Protein Assays—Cells were washed from the reaction vials with 0.5 ml of 1N NaOH. After digestion at 23°C for 24 h with NaOH, culture extracts were assayed for protein, using bovine serum albumin as a standard (7).

Table 1. Comparative Rates of Ethylene Formation by Two Cultures of *Azospirillum lipoferum* isolated from a strip-mined Site in Martin County Kentucky

Hours of Incubation Prior to Acetylene Addition[1]	Martiki-S	Martik-R[2]
0	592 ± 82	284 ± 44
3	438 ± 33	439 ± 60
9	360 ± 22	505 ± 49
15	449 ± 19	502 ± 70
18	11,703 ± 756	436 ± 30
21	38,204 ± 2,338	303 ± 13
24	29,172 ± 4,652	391 ± 34
27	51,108 ± 4,128	287 ± 25

[1] At each time indicated acetylene was added to 6 replicate vials of each culture. (The cultures were incubated for 3 additional hours at 32°C then assayed for ethylene).

[2]Values represent nanomoles of ethylene formed/mg protein/h. Each value is the mean ± standard deviation of 6 replicate vials.

Results and Discussion

As shown in Table 1, after 15 h and continuing throughout the incubation period, the rate of acetylene production was markedly higher for Martiki-S than for Martiki-R. Although low in comparison with Martiki-S, in this study, the rate of acetylene reduction by Martiki-R was nevertheless comparable to that previously reported for *Azospirillum lipoferum* (1, 5). David and Fay (2) have reported the preincubation or constant incubation of nitrogen-fixing microorganisms with acetylene for longer than 3.0 h may deplete cellular nitrogen and subsequently depress the nitrogenase system, resulting in artificially high estimates for acetylene reduction. To determine if such derepression might be the cause of high rates of nitrogen fixation in our Martiki-S cultures the acetylene pulse was reduced to 1.0 h (9). The subsequent rates of acetylene reduction under these conditions were still comparable to those shown in Table 1, indicating that for the Martiki-S culture the high values for acetylene reduction were not due to excessive incubation periods with acetylene.

Comparison of maximum rates for acetylene reduction by all bacterial species tested (Table 2) indicate that nitrogen fixation by Martiki-S was approximately 37-fold greater than *Azotobacter paspali* and about 100 times greater than *A. brasilense, A. lipoferum* ATCC 29707, and *A. lipoferum* Martiki-R. With the exception of *A. lipoferum* Martiki-S the maximum rates of acetylene reduction obtained for the cultures used in this study (Table 2) are all comparable to values reported in the literature for *Azotobacter* and *Azospirillum* isolates (2, 3, 9). Some investigators have observed high rates of nitrogen fixation with *Enterobacter agglomerans* and *Klebsiella penumoniae* (8); however, these values are 5-10 fold lower than those observed for Martiki-S.

Table 2. Comparison of Ethylene Formation by Martiki and Stock Cultures[1]

Culture	Ethylene Formation[2]
Azospirillum lipoferum Martiki-R	505 ± 49
Azospirillum lipoferum Martiki-S	51,108 ± 4,128
Azospirillum lipoferum ATCC 29707	527 ± 43
Azospirillum brasilense ATCC 29145	460 ± 13
Azotobacter paspali ATCC 23833	1,384 ± 271

[1]After incubation at 32°C acetylene was added to 6 vials of each microorganism at selected intervals over the 36 h incubation period. Three hours after the addition of acetylene the vials were assayed for ethylene.

[2]Values represent nanomoles of ethylene formed/mg protein/h during the period of maximum ethylene formation. Each value is the mean ± standard deviation of 6 replicate vials.

When the microorganisms used in this study were incubated beyond 27 h and then pulsed with acetylene, ethylene formation decreased with increasing incubation times. After 96 h the Martiki-S culture still retained a substantially greater capacity for acetylene reduction.

Perennial grasses are commonly a part of the grass legume mixture used to stabilize the surfaces of recently graded minesoils. Although symbiotic nitrogen-fixers undoubtedly represent the major factors in maintenance of the nitrogen economy on minesoils, the rapid availability of the fixed-nitrogen from asymbiotic bacteria may be of considerable importance in the early growth and development of grasses on these sites. It would be premature to speculate upon a biochemical basis for the high rate of acetylene reduction we observed with the Martiki-S culture. However, the efficiency of the isolate as demonstrated in this study underscores the need for continued investigations into the factors affecting the nitrogen-fixing capability of *Azospirillum* found in association with reclamation plants.

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The Spread Effects of Nonmetropolitan Industrialization

Robert G. Cromley
Department of Geography, University of Connecticut
Storrs, Connecticut 06268

Thomas A. Arcury
Center for Developmental Change, University of Kentucky
Lexington, Kentucky 40506-0027

Abstract

This paper examines the impact of rural manufacturing decentralization on the occupational structure of rural areas that are not hosting nonmetropolitan industries but are within the labor shed of these factories. Focusing on the manufacturing workers of one such county, changes in occupation structure are related to the development of manufacturing industries in adjacent nonmetropolitan counties. The relationship between manufacturing employment and agriculture, the traditional dominant employer, is tested and the availability of agricultural work is not found to have an impact on the occupational structure of manufacturing workers.

Introduction

A major problem accompanying the industrial development of capitalist economies has been unbalanced regional economic growth (1, 2). While regional disparities in the United States have different forms at various geographical scales, most have their roots in the fundamental transformation from a predominantly rural agricultural society to an industrialized urban one and the separation of worker from the land. Between 1920 and 1970, the rural population of the United States remained constant at 54 million while the urban population increased almost threefold to 149 million in 1970 (3). Improvements in farming technology and the mechanization of agriculture had reduced the need for farm laborers. Nonmetropolitan nonfarm industries were not able to absorb the excess population, thus creating a surplus farm population. The result was a large rural to urban migration stream for most of this century. Metropolitan centers became the vanguard of population and economic growth while rural areas became pockets of poverty, high unemployment, and heavy out-migration.

The major policy measures for improving this imbalance have tried to integrate the lagging rural periphery with the economic opportunities of the cities (4, 5). Growth-center strategists maintained that the best hope for rural areas lay in the 'trickling-down' of economic growth impulses from metropolitan centers (6, 7). This view was supported by the fact that nonmetropolitan regions adjacent to a Standard Metropolitan Statistical Area (SMSA) or part of its daily system were growing at rates higher than the rest of the nonmetropolitan periphery (8, 9).

Recently it has been noted that nonadjacent counties in the rural periphery grew during the 1970's at a rate that exceeded most large metropolitan centers and the national average (10). A major impetus for the population and economic reversal of many nonmetropolitan places has been the decentralization of industry from the urban core to these regions (11, 12, 13). The filter-down of branch plants has been the primary force behind the industrial growth of many nonmetropolitan communities (14, 15). Many manufacturers are establishing factories in rural areas seeking lower labor costs as wages have become a more important component of total costs. Rural residents are still being transformed from agricultural to industrial workers but in many instances no longer need to migrate to an SMSA and can remain closer to their farms.

The level of this industrial movement is not uniform throughout nonmetropolitan America. There exists a place hierarchy within the intermetropolitan periphery whose settlements range from non-urban hamlets to large towns almost equal in size to small metropolitan centers. Branch plants tend to locate in the larger rural towns, while indigenous firms predominate in smaller hamlets (14, 16). Because firm stability is greater among branch plants than indigenous firms, employment is usually more stable in the larger rural towns. Intermetropolitan centers are thus emerging as foci for employment opportunities (17, 18). However, the relocation of industry and retail activity in the periphery does enable places lower in the settlement hierarchy to participate more fully in the industrial economy as the need for commuting long distances to large metropolitan centers is reduced (19, 20). There is also evidence that the labor sheds for branch plants are larger than their indigenous counterpart. Regardless of plant size or industrial type, a larger proportion of Kentucky branch plant employees commute from outside the county in which the plant is located (21). This indicates that branch plants, located in larger rural towns, have a strong impact on the surrounding hinterland.

It also implies that the hinterland residents are an important labor source for the movement of manufacturing to nonmetropolitan urban centers. It has been suggested that rural areas have a wage advantage due to the presence of a class of workers, part-time farmers, who derive income from a supplementary source, farming (22). Alternatively, it has also been suggested that the presence of manufacturing has made it possible for individuals involved in small scale and part-time agriculture to maintain two complementary sources of income (20).

Most research has examined the economic and social impact of manufacturing on these larger urban communities, but few have studied the spread effect of this industrialization on more "rural" counties, and especially the labor relationship between farming in these areas and urban industrial jobs. This paper examines the hypothesis that rural communities that do not have any manufacturing plants, but are located in the vicinity of nonmetropolitan places that are hosting industrial growth, are experiencing an economic metamorphosis of their own. The transformation of the occupational structure of these areas is occurring without being strongly allied with the daily commuting system of an SMSA. Additionally, it examines the linkages that exist within the labor force between the transitional employer, agriculture, and the new industrial factories to determine whether by supplementing their income as part-time farmers, manufacturing workers in these areas are able to work for lower wages, reinforcing the wage disparities between urban and rural regions.

Study Area and Data

Robertson County, Kentucky has been selected as a suitable study area for examining these hypotheses. The nonmetropolitan counties of Kentucky have been part of the nationwide growth of rural industry (14, 16). In 1980, Robertson County was one of only 3 counties in the state that did not host any manufacturing activity, branch or indigenous. The other 2 counties are located in the heart of the Eastern Kentucky coal field, whereas Robertson County is located in the northeast part of the Kentucky Bluegrass Region (Figure 1). Although the Appalachian Kentucky region has experienced recent growth in manufacturing, its overall manufacturing employment still lags behind the central and western portion of the state. Manufacturing is especially weak in the coal producing counties of Eastern Kentucky where there is strong competition with the higher mining wages, and poor access to the highway system.

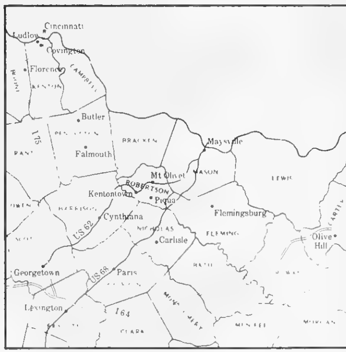

Figure 1: Location of Robertson County, Kentucky.

Robertson County is also removed in proximity from major metropolitan centers. The county is approximately 50 miles northeast of Lexington, Kentucky, and the same distance southeast of Cincinnati, Ohio, the 2 closest SMSAs. The county does not have direct access to the Interstate Highway System, (the closest, I-64, and I-75, are 50 miles distant), railway lines, or commercial bus lines. The major transportation routes are US 62 and US 68 which give the population direct access to the county seats of surrounding counties and to Lexington.

Finally, Robertson is one of the most nonurban counties within the state. It is Kentucky's second smallest county with an area of 101 square miles, and has the smallest county population with 2,265 persons in 1980. Mt. Olivet, the county seat, has a populaton of about 400 persons and is the only incorporated town in the county. The size of the county's population has declined steadily over the past century. From a high of 6,131 persons in 1880 (23) it fell to 2,149 persons in 1970 with an increase to 2,265 persons in 1980. The population decline is due to high-level out-migration.

The primary data for this study were obtained from a general purpose survey of Robertson County that was conducted between June 1 and August 30, 1980. This door-to-door survey attempted to enumerate the residents of every household in the community. Data on earlier occupational and employment patterns have been abstracted from U.S. Census reports. Information on the presence and types of manufacturing industries in Robertson and surrounding counties are derived from the Kentucky Directory of Manufacturing.

Occupational Change

Historically farming has been the predominant occupation in Robertson County. The 1870, 1880, and 1900 Censuses show that over 90% of the county's work force was employed as farmers. Those who were not farmers were employed in agricultural support occupations such as plowmaker and blacksmith. Other documentary sources and ethnographic data indicate that until the mid-1920s subsistence farming was the major pursuit. Farm produce included a wide variety of items needed for home consumption such as vegetables, wheat, sorghum, and honey. Since the 1920s, farming has changed to cash cropping with tobacco and corn being the major crops while some farmers maintain large beef and dairy operations.

The portion of the work force associated with farming occupations has greatly decreased since 1930. In 1930, 70% of the work force was employed as farmers or farm managers while 13% held other agricultural jobs (24, p. 947). During the next 30-year period, these figures slowly declined until only 56.7% were employed as farmers or farm managers and 7% as agricultural workers in 1960 (25, pp. 19-234). The total number of farms decreased from 826 in 1930 to 515 in 1959. Since 1960, the decline in farming has been more rapid. By 1970, only 40.8% of the work force was employed in any type of farming occupation, and this figure had decreased even further, to only 23.7% in 1980 (26, pp. 19-432). Only 356 farms were still in operation in Robertson County in 1978 (27.).[1]

The total size of the work force also decreased from 1094 in 1930 to 728 workers in 1960. This decline is associated with the absolute losses occurring in the agricultural sector without other sectors expanding their job offerings. A Kolmogorov-Smirnov test showed a significant shift in the occupational structure of the labor force during each decade since 1960 (Table 1). The size of the work force also increased even though agriculture was still experiencing a decline. During this latter period other sectors of the economy were expanding faster than agriculture was declining. Every occupational group increased except those that are farm-related. Operatives and kindred workers experienced the greatest absolute increase — from 38 workers in 1960 to 184 in 1980. Clerical and kindred workers, salesworkers, service workers, and laborers also had a substantial increase in numbers. In general, the occupational change that has occurred since 1960 suggests that other activities, such as manufacturing and retailing, are replacing agriculture as the dominant employment for Robertson County residents.

Table 1. Number and Percent of Persons by Major Occupational Groups: 1960, 1970, and 1980.

Major Occupational Groups	1960[a] n	1960[a] %	1970[b] n	1970[b] %	1980[c] n	1980[c] %
Professional, Technical, and Kindred Workers	43	5.9	38	4.8	58	6.8
Farmers & Farm Managers	413	56.7	273	34.6	189	22.1
Managers, Officials & Proprietors, except Farm	25	3.4	40	5.1	32	3.7
Clerical & Kindred Workers	27	3.7	40	5.1	73	8.5
Salesworkers	0	0.0	9	1.1	47	5.5
Craftsmen, Foremen and Kindred Workers	60	8.2	92	11.7	60	7.0
Operatives & Kindred Workers	38	5.2	139	17.6	184	21.5
Private Household Workers	10	1.4	5	0.6	13	1.5
Service Workers	30	4.1	68	8.8	76	8.9
Farm Laborers	51	7.0	44	5.6	77	9.0
Laborers, except Farm	14	1.9	41	5.2	46	5.4
Occupation not Specified	17	2.3	0	0.0	0	0.0
Total Employed	728	99.8	789	100.2	855	99.9

[a] U.S. Bureau of the Census 1970, pp. 19-244; Kolmogorov-Smirnov Test for 1960-1970 significant at .05 level.

[b] U.S. Bureau of the Census 1973, pp. 19-432; Kolmogorov-Smirnov Test for 1970-1980 significant at .05 level.

[c] Compiled by authors.

[1] The decrease in the number of farms between 1930 and 1978 may actually be less than the figures stated. The U.S. Bureau of the Census raised the farm income levels needed to be defined as a farm in 1959 and in 1978.

THE DISTRIBUTION OF MANUFACTURING EMPLOYMENT

The most striking facet of occupational change in Robertson County has been the emergence of manufacturing as an important source of employment although no manufacturing firm has actually established a plant there. In 1960, there were fewer secondary sector employees (only 1.1% of the work force) in the county than there were before 1900. At that earlier time some manufacturing shops existed to produce tools, wagons, and other goods for local consumption. These cottage industries soon lost their market due to increasing external competition. In 1980, the 21.5% of the Robertson County work force employed by manufacturing firms commuted to places outside the county for their jobs.

The spatial distribution of these commuters exhibit a strong distance decay function and directional bias (Table 2). Seventy five % of the manufacturing work force commute to another nonmetropolitan county directly adjacent to Robertson, while only 7.5% commuted to a tier of counties once removed. The remaining commuters are scattered over a wide range of destinations. The distance decay effect is similar for both male and female workers. Females were more selective in their destination outside the adjacent ring of counties. Sixteen of the 20 female workers commuted to either Falmouth in Pendleton County or Cinncinnati, Ohio, while male workers were evenly distributed over the longer trips. This reflects the greater job opportunities for male workers.

The highway system around Robertson County is responsible for a strong direction bias toward those settlements that are directly connected to Robertson by either US 62 or US 68 (see Figure 1). Located on these 2 routes, Maysville, Carlisle, and Cynthiana receive the overwhelming majority of Robertson workers. Bracken and Fleming Counties have relatively poor connector routes, and only 2 workers commute to either of these counties although both are adjacent to Robertson.

The spatial distribution of commuting is also strongly influenced by the arrangement of employment opportunities in neighboring nonmetropolitan counties. Robertson County is not dependent on major metropolitan centers for industrial jobs but rather on other nonmetropolitan areas. Only 14% commuted to a county that is part of a Standard Metropolitan Statistical Area (SMSA) while 82% commuted to another nonmetropolitan county. Robertson is at the bottom layer of the regional settlement hierarchy. Its rapid increase in manufacturing employees is a result of the nationwide movement to nonmetropolitan areas since 1960. Of the 16 firms located in the nometropolitan centers to which Robertson residents commute, only 4 were established before 1960. The majority were estabished in the boom period of nometropolitan industrialization during the late 1960s and early 1970s. Nine of these firms are branch operations of an external parent company, while 7 are indigenous or locally controlled. The indigenous firms account for only 39% of those Robertson County manufacturing employees who commute to nonmetropolitan industry.

This new industry has resulted in a heavy concentration of employment opportunities within relatively few Standard Industrial Classification (S.I.C.) groups among the 6 immediate neighhboring counties. Almost 91% of the total manufacturing work force employed in these counties are distributed among 8 S.I.C. groups and are low technology (Table 3). With respect to individual counties, only Harrison and Mason Counties, the two largest employing counties, have a reasonably uniform distribution of employment over these eight groups, while the majority of jobs in the other counties are centered in a single S.I.C. group.

Table 2. Place of Manufacturing Employment by Sex

	Male		Female		Total	
	N	%	N	%	N	%
In Adjacent Counties						
Maysville, Mason Co.	20	18.9	14	17.5	34	18.3
Flemingsburg, Fleming Co.	1	0.9	1	1.3	2	1.1
Carlisle, Nicholas Co.	6	5.7	34	42.5	40	21.5
Cynthiana, Harrison Co.	53	50.0	11	13.8	64	34.4
In Counties One Tier Removed						
Paris, Bourbon Co.	1	0.9	2	2.5	3	1.6
Butler, Pendleton Co.	1	0.9	0		1	0.5
Falmouth, Pendleton Co.	2	1.9	8	10.0	10	5.4
In Other Counties						
Olive Hill, Carter Co.	1	0.9	0		1	0.5
Lexington, Fayette Co.	6	5.7	0		6	3.2
Georgetown, Scott Co.	3	2.8	1	1.3	4	2.2
Covington, Kenton Co.	1	0.9	0		1	0.5
Ludlow, Kenton Co.	2	1.9	0		2	1.1
Florence, Boone Co.	1	0.9	0		1	0.5
Cincinnati, Ohio	1	0.9	8	10.0	9	4.8
Unknown	7	6.6	1	1.3	8	4.3
Total	106	99.8	80	100.2	186	99.9

Table 3: Major Standard Industrial Classification Group Employment Distribution in Robertson County's Neighboring Counties

S.I.C. Group	Bracken		Fleming		Harrison		Mason		Nicholas		Pendleton		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
21[b] Tobacco Products	0	0.0	0	0.0	0	0.0	570	21.2	0	0.0	0	0.0	570	8.0
22[b] Textile Mill Products	0	0.0	0	0.0	120	6.0	569	21.1	664	97.6	0	0.0	1353	19.0
26[b] Paper and Allied Products	216	76.6	0	0.0	11	0.6	9	0.3	0	0.0	180	21.9	416	5.8
31[b] Leather and Leather Products	0	0.0	476	71.0	0	0.0	252	9.3	0	0.0	430	52.4	1158	16.2
32[b] Stone, Clay, Glass Products	0	0.0	0	0.0	552	27.8	0	0.0	0	0.0	0	0.0	552	7.7
34[b] Fabricated Metal Products	52	18.4	160	23.9	547	27.6	0	0.0	13	1.9	46	5.6	818	11.5
35[b] Machinery, Except Electrical	0	0.0	2	0.3	1	0.1	920	34.1	0	0.0	142	17.3	1065	14.9
38 Instruments, Related Products	0	0.0	0	0.0	531	26.8	0	0.0	0	0.0	0	0.0	531	7.4
Total	282		669		1985		2694		680		820		7130	

a Compiled from 1980 Kentucky Directory of Manufacturers

b Low Technology SIC groups

The S.I.C. distribution of Robertson County residents mirrors this employment pattern (Table 4). Most residents work in a plant that produces either textile mill products, the largest regional employer, or fabricated metals, the third largest employer. The lack of reasonable connector links to Fleming and Pendleton Counties is probably responsible for few residents being employed in S.I.C. 31, leather and leather products, the second largest regional employer. This distribution is also sharply divided by sex. Typical of many rural areas of the South, the majority of the female workers commute to a textile mill, the lowest paying S.I.C. industrial group in Kentucky. Among males, fabricated metals is clearly the dominant employer while non-electrical machinery is a distant second.

Besides the predominance of low technology firms, a concern is whether industries will contribute to the development of local entrepreneurial skills. Branch operations in general contribute relatively few management opportunities for host communities (28). Rural counties that are only part of the labor shed should receive even fewer white collar jobs. For Robertson County, only 3 individuals were employed in a professional or managerial oc-

Table 4. Standard Industrial Classification Group of Those Employed by Manufacturing Firms by Sex, 1980

SIC Group	Males		Females		Total	
	n	%	n	%	n	%
20 Food & Kindred Products	2	1.8	0	0.0	2	1.1
21 Tobacco Products	1	0.9	0	0.0	1	0.5
22 Textile Mill Products	10	9.4	45	56.2	55	29.5
23 Apparel, Other Textile Products	1	0.9	3	3.7	4	2.1
26 Paper & Allied Products	2	1.8	0	0.0	2	1.1
28 Chemical & Allied Products	1	0.9	0	0.0	1	0.5
30 Rubber, Misc. Plastic Products	1	0.9	0	0.0	1	1.1
31 Leather and Leather Products	2	1.8	8	10.0	10	5.4
32 Stone, Clay, Glass Products	5	4.7	0	0.0	5	2.7
33 Primary Metal Industries	4	3.7	5	6.2	9	4.8
34 Fabricated Metal Products	51	48.1	2	2.5	53	28.5
35 Machinery, Except Electrical	16	15.0	5	6.2	21	11.3
36 Electrical, Electronic Equipment	2	1.8	0	0.0	2	1.1
38 Instruments, Related Products	1	0.9	3	3.7	4	2.1
Unknown	7	6.6	9	11.2	16	8.6
Total	106	99.2	80	99.7	186	100.4

cupation (see Table 5). In general, Robertson County residents are blue-collar workers.

Manufacturing and Agricultural Employment Linkages

Although manufacturing has attained an importance as an employer in Robertson County almost equal to agriculture, this change has not created 2 separate classes of workers. Given the dominance of agriculture as the primary employer in the recent past, many currently employed in manufacturing once farmed or were reared in farming households. Some manufacturing employees who do not farm do own land and a tobacco base which they lease to others. Most importantly, many individuals and households obtain portions of their incomes from both manufacturing and agricultural occupations. Of the 186 manufacturing employees, 44 stated that they also farmed as a secondary occupation. Only one of these 44 was female. Most part-time farmers have primary occupations as operatives. However, when a Chi-Square test was performed to see if a greater proportion of manufacturing operative supplemented their incomes with part-time farming than did other manufacturing employees, no significant correlation was found (Table 5).

Table 5. Occupational Group of Manufacturing Workers by Status as Part-Time Farmers

Occupational Group of Manufacturing Workers	Part-Time Farmers N	%	Non-Farmers N	%
Professional, Technical, and Kindred Workers; Managers and Administrators	1	2.3	2	1.4
Sales and Clerical Workers	5	11.3	17	12.3
Craftsmen and Foremen	7	15.9	6	4.3
Operatives and Laborers	30	68.2	108	77.7
All Service Workers	1	2.3	6	4.3
Total	44	100.0	139	100.0

Missing = 3

Chi Square = 7.251 df = 4 not significant at .05 level

Examining the types of employment within a household is another perspective for analyzing the relationship between agricultural and manufacturing employment. A total of 152 households have at least one member employed in manufacturing, and 64 of these contain manufacturing workers who themselves are part-time farmers or have members who are employed full-time in an agricultural occupation (Table 6). The occupations of the majority of the manufacturing workers in these manufacturing-agriculture households is that of operative. Again, a Chi-Square test performed to see if a greater proportion of manufacturing operative households supplemented their income with farming than did other manufacturing employee households showed no significant correlation.

Table 6. Occupational Group of Manufacturing Workers for Families with Manufacturing and Agricultural Workers, and for Families with Manufacturing but No Agricultural Workers

Occupational Group of Manufacturing Workers	Manufacturing and Agricultural Families N	%	Manufacturing with No Agricultural Workers N	%
Professional, Technical, and Kindred Workers; Managers and Administrators	1	1.6	2	2.3
Sales and Clerical Workers	7	10.9	8	9.1
Craftsmen and Foremen	3	4.7	9	10.2
Operatives and Laborers	52	81.2	67	76.1
All Service Workers	1	1.6	2	2.3
Total	64	100.0	88	100.0

Chi Square = 1.873 df = 4 not significant at .05 level

Discussion

One of the predominant industrial trends during the last 2 decades has been the movement of manufacturing from metropolitan to nonmetropolitan regions. The labor mobility of rural areas in former times is now being replaced by capital mobility from metropolitan regions as the mechanism for resolving regional imbalances of labor supply and demand (29). This phenomenon has changed the rural landscape by directly stimulating the growth of nonmetropolitan urban places; some places have even been elevated to metropolitan status.

Just as important, rural communities which do not have manufacturing plants, but which are located near nonmetropolitan places that are hosting industrial growth, are also experiencing economic change and this ecomomic change is occurring without strong alliance wth the daily commuting system of an SMSA. This is supported by the Robertson County situation. The industrial transformation of its occupational structure has occurred without being strongly allied with the daily urban system of an SMSA or having any manufacturing firms of its own. Past studies have noted that job leakage from host communities have regionalized the impacts of these nonmetropolitan manufacturing firms. Due to the perspective of these studies, examining the commuter sheds of specific firms, the full impact of the rural manufacturing phenomenon on participating communities has not been presented. The Robertson County situation is an example of the pervasiveness of rural industrialization. While it has not attracted any manufacturing firms, it is within the commuting sheds of several nonmetropolitan firms in the surrounding counties. Commuting has become the adaptive mechanism by which this formerly agricultural area has added a new mode of economic activity.

Different analysts have suggested that the mix of agricultural and manufacturing employment is both the cause and effect of the nonmetropolian industrial phenomenon. In Robertson County a high percentage of manufacturing workers do farm on a part-time basis, or live in households in which agricultural wages are part of the family income. The availability of agricultural income may allow some rural manufacturing workers to earn a better livelihood given the relatively low wages paid by nonmetropolitan manufacturers. This study does not support the hypotheses that such supplemental agricultural income is necessary for the economic survival of the nonmetropolitan manufacturing worker. The majority of these workers do not reside in households with agricultural income, nor are there significant differences among the manufacturing workers by occupational group in the proportion with agricultural income. Agricultural income may offset the cost of extended commuting for some, but it probably has no relationship to the wage-rates of these workers.

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Demography of the Raccoon *(Procyon lotor)* at Land Between The Lakes

Richard A. Smith and Michael L. Kennedy
Memphis State University, Memphis, Tennessee 38152

Abstract

Sex ratio, age structure, and litter size of a population of raccoons (Procyon lotor) were studied from December 1980 through November 1981. The study area was land Between The Lakes in Stewart County, Tennessee, and Lyon and Trigg counties, Kentucky; 145 specimens were examined. The population was 49.7% male and 50.3% female. Twenty per cent of the animals were juvenile, 13.3% subadult, 25.0% adult, and 41.7% old adult. Average litter size was determined to be 2.9.

Introduction

The raccoon *(Procyon lotor)* has been the subject of many biologic investigations. Since the animal is an important game species, many previous studies have been directed toward questions related to its management. Investigations directed toward collection of data concerning sex ratio, age structure, litter size, parasites, and other features have been numerous. Lotze and Anderson (1) summarized much of the available literature. However, demographic information tends to vary between geographic areas for raccoons; therefore, management information obtained for one region may not be applicable to management programs in others.

With the exception of Dew (2), little information is available concerning population characteristics of *P. lotor* in western Tennessee and western Kentucky. The purpose of this study was to examine the demographic features of sex ratio, age structure, and litter size associated with a raccoon population in western Tennessee and western Kentucky. This study provides additional baseline data for raccoon management in Kentucky and Tennessee.

Materials and Methods

The study was conducted at Land Between The Lakes (LBL) in Stewart County, Tennessee, and Lyon and Trigg counties, Kentucky. LBL is a 170,000—acre peninsula with approximately 482 km of shoreline between Kentucky Lake on the west and Lake Barkley to the east. The habitat was predominantly upland hardwood forest. Some old fields and agricultural lands were within the study area.

Collections from December 1980 through November 1981 yielded 145 animals (72 males; 73 females). Seasonal samples were as follows (male sample size is given first): winter—8,13; spring—20,15; summer—27,25; fall—17,18. Seasonal data were incomplete for 2 females. Most animals were collected by gun, with the use of dogs or spotlighting from a boat or truck. Animals were transferred to the Department of Biology, Memphis State University, where they were stored and later examined. Gross examination was conducted for age and sex determination. Specimens were aged as juvenile (class I, N = 12), subadult (class II, N = 8), adult (class III, N = 15), or old adult (class IV, N = 26) following Junge and Hoffmeister (3). Reproductive tracts were removed and examined. Average litter size was based on counts of embryos and sites of placental attachment (placental scars) from 26 females. Reproductive tracts were stored in 10% formalin. Raccoon skeletons, skins, and preserved material were deposited in the Memphis State University Museum of Zoology. Individual data for specimens and a map of localities are presented in Smith (4).

Results and Discussion

Of the raccoons examined, 49.7% were male and 50.3% female. This sex ratio coincides with those reported for Tennessee specimens by Dew (2) and Woods (5). Studies conducted in other geographic areas (6, 7) also reported, in general, a 100:100 sex ratio. Cummingham (8) and Johnson (9) noted that sex ratios of raccoons collected with dogs and guns may be less biased than those of animals caught in traps. Since specimens in the present study were collected primarily with dogs and guns during all seasons, the sex ratio determined should reflect an accurate estimate of population structure in relation to sex. Schwartz and Schwartz (10) indicated that the sex ratio of raccoons tends to vary with the population level. When the population is increasing, there are more females than males; when it is decreasing, there are more males. Thus, based on sex-ratio results, the LBL population was approximately stable during the study period. However, hunter-success data (raccoons/hunter/night) indicated the population to be decreasing at this time (unpubl. rep., TVA, Golden Pond, KY, 1982). The stability of the LBL raccoon population during the study is uncertain and such population characteristics are in need of additional study.

The age structure of the raccoons taken was 20.0% age class I, 13.3% age class II, 25.0% age class III, and 41.7% age class IV. These results differ from previously reported age structures for raccoons. Whitney and Underwood (11), Sharp and Sharp (12), Johnson (9), and Schwartz and Schwartz (10) reported highest percentages of young animals; percentages decline with age. Age structure seen in the present study probably reflects methods and times of sampling. Since juveniles make up the majority of harvest during the hunting season, this would leave fewer juveniles on the study area during the winter and spring. If summer and fall mortality is high in the first year animals and low in older animals as suggested by Smith (4), one would expect to find greater numbers of older animals in the population during the winter and spring.

From 26 raccoons which contained placental scars, litter size results were as follows: 2, N = 8; 3, N = 14; 4, N = 3; 5, N = 1. Sanderson (13) showed that raccoon placental scars are reliable indicators of the number of young produced. Average litter size for the LBL population was determined to be 2.9. This is greater than the 2.3 reported by Dew (2) for western Tennessee but equal to the 2.9 he reported for eastern Tennessee. The 2.9 value has also been reported in Illinois by Sanderson (13). Johnson (9) indicated a 2.2 litter size for Alabama raccoons. Litter size in raccoons apparently varies geographically, increasing with northern latitudes.

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A Checklist of Phytoplankton (Exclusive of Diatoms) in Kentucky Reservoir[1]

Lisa E. Barnese and Joe M. King[2]

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

Abstract

A survey of the phytoplankton (exclusive of diatoms) in the lower portion of Kentucky Reservoir was conducted from September, 1982 to September, 1983. One hundred and fifty-six species, varieties, and forms representing 59 genera were identified. The green algae dominated the algal flora in all seasons but were most numerous in the summer. Blue-green algae were most abundant in summer and fall, while euglenoids reached their peak numbers in summer. The number of dinoflagellates remained relatively low throughout the year.

Introduction

The algal flora of Kentucky Reservoir has been the subject of relatively few investigations. The only published records of Kentucky Reservoir phytoplankton are those resulting from limnological studies of Anderson Creek and Vickers Creek embayments (1, 2). The dominant phytoplankton at other locations in Kentucky Reservoir are presented in unpublished reports (3-5) from water quality surveillance programs which included this aquatic system. However, these publications and reports focused primarily on identifications of taxa to the generic level; thus, we have little information on the species composition of the algal flora in Kentucky Reservoir.

In this study we attempted to identify the phytoplankton species which occur in the lower portion of Kentucky Reservoir. It is part of an overall effort to gain more insight into the composition of the primary producers of this surface water resource. Diatom identifications are still in progress; thus, these algae are not included.

Collection Sites

Fourteen collection sites were established between Tennessee River miles 43.3 and 49.0 on Kentucky Reservoir (Fig. 1). Two sites were located in each of 2 embayments on the western (Anderson Creek Embayment, Snipe Creek Embayment) and eastern (blockhouse Creek Embayment, Turkey Creek Embayment) sides of the reservoir. Six collection sites were established in the main portion of the reservoir and were situated upriver, between and downriver from the embayments.

Water samples were collected from each site 10 times from September, 1982, to September, 1983. The samples were taken with a plastic bucket at the surface and with a Kemmerer bottle at the mid-water column and 0.5 m from the bottom. Equal volumes of the samples were mixed, transferred to one-liter plastic bottles, and placed on ice for transport to the laboratory. Species identifications were made through microscopic observations of raw samples and from subsamples concentrated by centrifugation at 5,000 x g for 5 minutes.

Checklist

The nomenclature in this report follows that of Bold and Wynne (6). One hundred and fifty six species, varieties' and forms, representing 59 genera were identified (Table 1). Of these, 37 species and three genera had not been previously reported as occurring in Kentucky (7-17).

Species of green algae dominated the phytoplankton assemblages in all seasons but were most numerous in the summer (Table 2). The greatest number of species were in the Chlorellales, due primarily to those in the genus *Scenedesmus*. Species of blue-green algae were most abundant in summer and fall while euglenoid species, especially trachelomonads, reached their peak numbers during the summer. The number of dinoflagellates remained relatively low throughout the year.

This paper provides preliminary information on the species composition of phytoplankton in a segment of Kentucky Reser-

[1] Partial funding provided by Committee on Institutional Studies and Research, Murray State University

[2] Address for correspondence

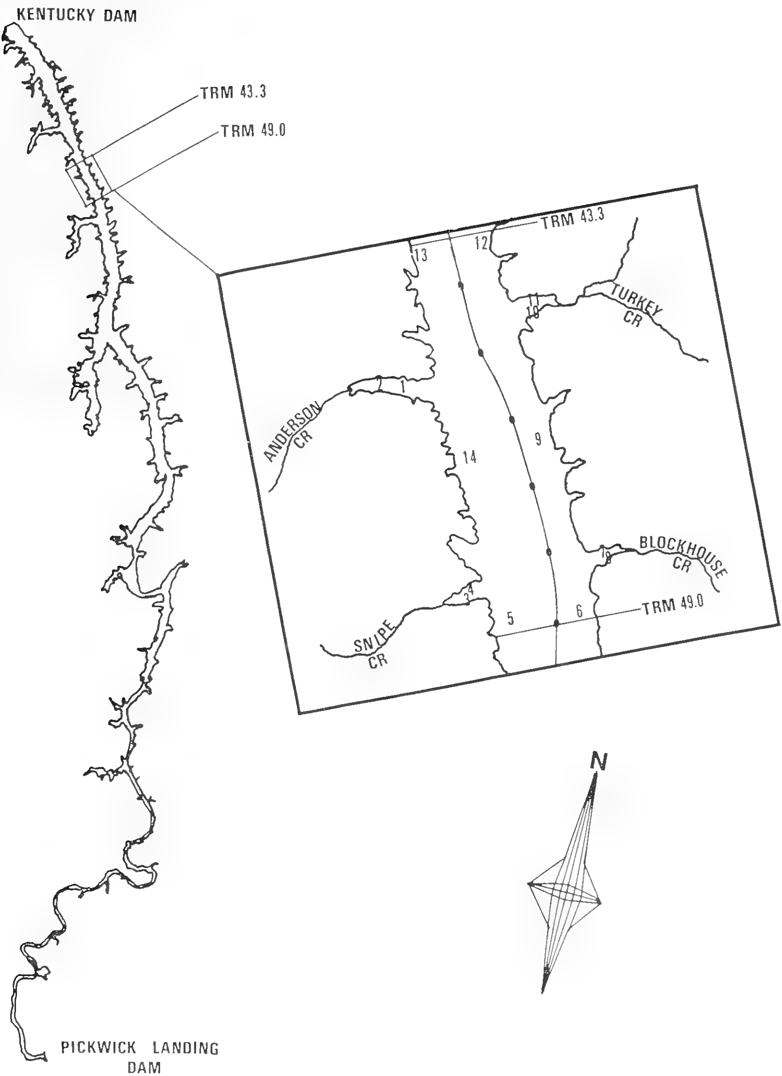

Fig. 1. Collection sites on Kentucky Lake.

voir. The checklist provided is certainly not complete and undoubtedly will be expanded and modified as more information becomes available on these organisms. However, future studies need to be expanded to include other areas of Kentucky Reservoir in order to develop a more comprehensive understanding of the algal flora of this aquatic system.

Table 1. Algal species, varieties, and forms identified in water samples collected between Tennessee River miles 43.3 and 49.0 on Kentucky Reservoir September, 1982, to September, 1983

CYANOCHLORONTA

Chroococcales

Anacystis sp.
Aphanocapsa pulchra (Kütz.) Rabh.
• *Chroococcus dispersus* (Keissl.) Lemm.
C. limneticus var. *subsalsus* Lemm.
C. minutus (Kütz.) Näg.
• *Dactylococcus acicularis* Lemm.
• *D. rhaphidioides* Hansg.
• *D. smithii* Chod. & Chod.
Gloeocapsa punctata Näg.
• *Marssoniella elegans* Lemm.
Merismopedia punctata Meyen
M. tenuissima Lemm.
Microcystis aeruginosa Kütz.
• *M. incerta* Lemm.
•• *Rhabdoderma lineare* Schmid. & Lautb.
• *R. sigmoidea* fa. *minor* Moore. & Car.

Oscillatoriales

Anabaena sp.
A. sp.
•• *Anabaenopsis circularis* (W & W) Miller
A. elekinii Miller
Lyngbya contorta Lemm.
• *L. limnetica* Lemm.
Oscillatoria amphibia Ag.
• *O. limnetica* Lemm.
O. sp.
Phormidium minnesotense (Tilden) Dr.
P. tenue (Menegh) Gom.
Raphidiopsis curvata Fritsch & Rich

CHLOROPHYCOPHYTA

Volvocales

Carteria sp.
Chlamydomonas sp.
Eudorina elegans Ehr.
Pandorina morum (Müll.) Bory
Platydorina caudata Kofoid
•• *Sherffelia* sp.

Chlorococcales

Pediastrum biradiatum Meyen
P. duplex Meyen
P. duplex var. *clathraturm* (A. Br.) Lag.
P. simplex (Meyen) Lemm.
P. simplex var. *duodenarium* (Bail.) Rabh.
P. tetras (Ehr.) Ralfs
Schroederia setigera (Schroed.) Lemm.

continued

Table 1 continued

Chlorellales

Actinastrum Hantzschii var. *fluviatile* Schroed.
Ankistrodesmus falcatus (Corda) Ralfs
A. falcatus var. *marabilis* (W & S) G. M. Sm.
Chlorella sp.
• *Chodatella quadriseta* (Lemm.) G. M. Sm.
C. subsala Lemm.
• *c. wratislaviensis* (Schroed.) Ley
Closteriopsis longissima Lemm.
Coelastrum cambricum Arch.
C. microporum Näg.
Crucigenia crucifera (Wille) Col.
C. fenestrata Schmid.
C. irregularis Wille
C. quadrata Mor.
C. rectangularis (A. Br.) Gay
C. tetrapedia (Kirch.) W & W
Dictyosphaerium Ehrenbergianum Näg.
D. pulchellum Wood
Gloeoactinium limneticum G. M. Sm.
Golenkinia radiata (Chod.) Wille
Kirchneriella contorta (Schmid.) Bohlin
K. lunaris (Kirch.) Moeb.
K. lunaris var. *irregularis* G. M. Sm.
K. obesa (W. West) Schmid.
• *K. subsolitaria* G. S. West
Micractinium pusillum Fres.
Oocystis Borgei Snow
• *O. crassa* Witt.
O. parva W & W
• *Polyedriopsis spinulosa* Schmid.
Scenedesmus abundans (Kirch.) Chod.
S. abundans var. *asymmetrica* (Schroed.) G. M. Sm.
S. abundans var. *longicauda* G. M. Sm.
S. acuminatus(Lag.) Chod.
S. acutiformis Schroed.
S. armatus (Chod.) G. M. Sm.
S. bijuga (Turp.) Lag.
S. bijuga var. *alternans* (Reinsch.) Hansg.
S. brasiliensis Bohlin
S. denticulatus Lag.
S. dimorphus (Turp.) Kütz
• *S. incrassatulus* Bohlin
S. longus Meyen
S. opoliensis Richter
S. quadricauda (Turp.) Bréb.
• *S. serratus* (Corda) Bohlin
Selenastrum bibraianum Reinsch.
S. gracile Reinsch.
S. minutum (Näg.) Col.
Tetradesmus smithii Pres.
Tetraedron gracile (Reinsch.) Hansg.
T. minimum (A. Br.) Hansg.
T. muticum (A. Br.) Hansg.
• *T. pentaedricum* W & W
T. regulare Kütz.
T. trigonum (Näg.) Hansg.
• *T. tumidulum* (Reinsch.) Hansg.
Tetrallantos lagerheimii Teil
• *Tetrastrum heterocanthum* (Nordst.) Chod.
• *T. staurogeniaeforme* (Schroed.) Lemm.
Treubaria setigera (Arch.) G. M. Sm.

Tetrasporales

Elaktothrix gelatinosa Wille
Sphaerocystis Schroeteri Chod.

Ulotrichales

Ulothrix sp.

continued

Table 1 continued

Zygnematales

Closterium acutum (Lyngb.) Bréb.
C. parvulum Näg.
C. venus Kütz.
Cosmarium bioculatum Bréb.
C. circulare Reinsch.
* *C. constrictum* Delp.
Euastrum denticulatum (Kirch.) Gay
E. binale Ehr.
Sphaerozosma sp.
Spondylosium sp.
* *Staurastrum americanum* (W & W) G. M. Sm.
S. chaetoceros (Schroed.) G. M. Sm.
S. cuspidatum Bréb.
* *S. grallatorium* Nordst.
S. grallatorium var. *forcipigerum* Lag.
S. paradoxum Meyen

EUGLENOPHYCOPHYTA

Euglenales

Euglena acus Ehr.
E. gracilis Klebs
E. proxima Dang.
* *Lepocinclis fusiformis* (Cart.) Lemm.
Phacus acuminatus Stokes
P. acuminatus var. *drezepolskii* Skv.
P. helikoides Poch.
P. longicauda (Ehr.) Duj.
P. orbicularis Hueb.
P. pyrum (Ehr.) Stein
Trachelomonas abrupta (Swir.) Defl.
* *T. acanthostoma* (Stokes) Defl.
T. armata (Ehr.) Stein
* *T. bulla* (Stein) Defl.
* T. eurystoma var. *Klebsii* Playf.
T. hispida (Pert.) Stein
T. hispida var. *coronata* Lemm.
T. hispida var. *crenulatocollis* Defl.
G. intermedia Dang.
T. lacustris Drezcp.
T. playfairii Defl.
T. robusta Swir.
* *T. rotunda* Swir.
* *T. spectabilis* Defl.
T. superba (Swir.) Defl.
T. superba var. *duplex* Defl.
* *T. tambowika* Swir.
T. urceolata Stokes
T. volvocina Ehr.
T. volvocina var. *punctata* Playf.

PYRRHOPHYCOPHYTA

Peridiniales

* *Glenodinium gymnodinium* Pen.
* *G. palustre* (Lemm.) Schil.
* *G. pulvisculus* (Ehr.) Stein
G. quadridens (Stein) Schil.
* *Peridinium inconspicuum* Lemm.

*Species not previously reported as occurring in Kentucky

**Genera not previously reported as occurring in Kentucky

Table 2. Summary of the Number of Genera and Species Identified in Each Algal Division.

ALGAL DIVISION	NO. GENERA	NO. SPECIES	NO. SPECIES IDENTIFIED PER SEASON			
			Fall	Winter	Spring	Summer
Cyanochloronta	15	28	22	12	5	20
Chlorophycophyta	38	93	55	39	27	82
Euglenophycophyta	4	30	3	3	8	28
Pyrrhophycophyta	2	5	4	0	1	5
TOTAL	59	156	84	54	41	135

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Excretion of phenolic compounds from the roots of *Festuca arundinacea*, *Eragrostis curvula*, and *Lespedeza striata*.

Robert Creek
Department of Biological Sciences
Eastern Kentucky University
Richmond, Kentucky 40475

and

Gary L. Wade
Northeastern Forest Experiment Station
U.S. Forest Service
Berea, Kentucky 40403

Abstract

Festuca arundinacea, *Eragrostic curvula*, and *Lespedeza striata* were grown hydroponically using a continuous circulating system in which root exudates were collected in columns containing XAD-4 resin. The exudates were separated into neutral, acidic, and basic fractions. Lettuce radicle bioassay showed only the neutral fractions to be inhibitory. Analysis of the neutral fractions by paper chromatography, TLC, and gas chromatography indicated the presence of 5 inhibitory compounds, which were tentatively identified as the phenolic compounds cinnamic acid, ferulic acid, gallic acid, gentisic acid, and syringic acid.

Introduction

Allelopathy, chemical interference by one plant species with another, is a widespread phenomenon. It has been documented in forest, grassland, freshwater, marine, and agricultural ecosystems. Allelochemics, chemical compounds produced by a plant species, may operate directly on another plant species, indirectly on its symbiotic organisms, or through modification of the ecosystem (1). Reforestation of surface-mined lands now requires planting trees in an herbaceous ground cover. Frequent problems with tree survival and growth under these conditions suggest that allelopathy may be a factor in herb-tree competition in some situations. Allelopathy has not been demonstrated on surface-mine spoil, but this is due more to a lack of research than to negative research results. A necessary first step is to determine if species commonly used in land reclamation are allelopaths. Identification of the allelochemics produced together with their known effects on different organisms allows potential problems to be identified and studied. Accordingly, this study investigated allelochemic production by three herbaceous species commonly used as ground cover on surface-mined lands, tall fescue *(Festuca arundinacea* Schreb.), weeping lovegrass *(Eragrostic curvula* Nees.), and Kobe lespedeza *(Lespedeza striata* (Thunb.) H. & A.).

Water extracts of tall fescue, weeping lovegrass, and Kobe lespedeza cause a delay in germination of crown vetch *(Coronilla varia* L) and crimson clover *(Trifolium incarnatum* L.), but later radicle growth is not significantly inhibited (2). Litter of tall fescue inhibits growth and nitrogen fixation in black locust *(Robinia pseudo-acacia* L.), red clover *(Trifolium pratense* L.), and black alder *(Alnus glutinosa* (L.) Gaertn.) (3), and germination, hypocotyl growth and root growth of birdsfoot trefoil *(Lotus cortniculatus* L.) (4). Tall fescue genotypes differ in inhibition of birdsfoot trefoil and red clover (5). Leachates of red fescue *(F. rubra* L.) roots are inhibitory to root and shoot growth of forsythia *(Forsythia intermedia* Spaeth.) (6). Sericea lespedeza *(L. cuneata* L.) residues in the soil give rise to a number of phenolic compounds (7). None of the above studies attempted to identify toxins released into the soil by living plants.

Materials and Methods

Plant Growth And Extraction.—A continuous root exudate collecting system developed by Tang and Young (8) was used to grow donor plants and to collect root exudates. The containers were 3.79 L bottles with bottoms removed. The bottles were placed neck down, stoppered, and filled with a 2 cm layer of pebbles over which was added a mixture of washed silica sand and pebbles. The bottles were then wrapped in aluminum foil and autoclaved.

Seeds of tall fescue, weeping lovegrass, and Kobe lespedeza obtained from commercial sources were sown on the surface of the sand and covered with a layer of sterile sand. They were watered every other day with 0.1 strength Hoagland solution and with additional distilled water as necessary. When the plants were 2 cm tall, the circulating attachments and columns containing XAD-4 resin, which absorbs organic compounds, were connected to the bottoms of the containers. The water level in the sand culture was adjusted to within 1 cm of the surface with distilled water and replenished daily as needed to maintain this level. One hundred ml of 0.1 strength Hoagland solution was added once a week. The solution was circulated at an approximate rate of 500 ml/hr. All plants were grown under greenhouse conditions during the spring and summer without extension of the photo period. Temperatures ranged from 20° to 30°C. Because greenhouse glass does not pass most of the ultraviolet portion of sunlight (9), supplementary ultraviolet light was added four hours per day using Westinghouse FS-40 lamps with 15 mil mylar filters to remove wavelengths less than 320 nm. Lamp to pot distance was 1 m. Pot controls did not contain plants, but they were treated identically otherwise.

The plants were grown for 4 weeks. Then the columns were removed, washed with 2 L of distilled water and eluted with 100 ml of diethyl ether. The eluates from the columns of 5 replicates of each species were pooled, and the ether was evaporated to dryness under reduced pressure. The dried residue was taken up in 50 ml of water, pH was adjusted to 6.0, and the solution was extracted 3 times with 100 ml methylene chloride. The extracts were combined, dried over anhydrous magnesium sulfate and concentrated to 25 ml in vacuo. Final concentration to 3 ml was carried out under a stream of nitrogen. This final concentrated material represented the neutral fraction. The remaining aqueous fraction was acidified to pH 2.0 with 1 N HCl and again extracted with methylene chloride to give the acidic fraction. The acidified aqueous fraction was then adjusted to pH 11.0 with 1 N NaOH and extracted with methylene chloride to give the basic fraction. The acidic and basic fractions were concentrated to a final volume of 3 ml.

Chromatography—Two hundred μl aliquots from the neutral fractions were streaked on Whatman No. 3 MM filter paper and developed in the descending mode using a 2 per cent (v/v) glacial acetic acid solvent system. The chromatograms were dried and cut into 10 equal segments (Rf/10). Each segment was eluted with 5 ml of methanol, then reduced to a final volume of 1 ml and bioassayed as described below. We used thin layer chromatography (TLC) on microcrystalline cellulose plates with phosphor (Alltech Associates) with 2 per cent glacial acetic acid as the solvent system. Spots were visualized under ultraviolet light (253.7 and 375.0 nm) and after spraying with diazotized p-nitroanaline (10). Standards were run with all chromatograms.

Biossay.—Aliquots (100 and 50 μl) of the neutral, acidic, and basic fractions were added separately to Whatman No. 3 MM filter paper contained in 5.5 cm diameter petri dishes. The solvent was evaporated and 0.2 ml of distilled water added to the filter paper. Five 48-hr old lettuce seedings *(Lactuca sativa* L.) were added to each petri dish. After the seedlings were grown in darkness for 48 hours at room temperature, about 21° C, the lengths of their radicles were measured. All bioassays were carried out in triplicate, and results were expressed as per cent of inhibition relative to the pot controls. Student's t-test was used to determine significance of treatment differences. Because only the neutral fraction showed significant effects on lettuce radicle growth, the acidic and basic fractions were not tested further.

Gas-Liquid Chromatography.—The GLC analysis was made with a Varian Model 2840 chromatograph equipped with a flame ionization detector. Nitrogen was used as the carrier gas at a flow rate of 40 ml/min. A 20 mm (I.D.) x 2 m glass column was packed with 3 per cent SP-2250 on 100/120 mesh Sueplcoport and programmed from 150° to 220°C at a rate of 8° C/min. The injector and detector were maintained at 250° C.

Trimethylsilyl derivatives were prepared by evaporating 1 ml of the neutral extract to dryness under nitrogen. One-half ml of Tri-Sil/BSA formula D (Pierce Chemical Co.) was added to the vials and solution allowed to sit for one hour before GLC analysis. The phenolic standards were prepared in a similar manner.

Results

Only the neutral fractions of the root exudates from the 3 donor species were toxic to lettuce (Table 1). The 100 μl dose of each of the 3 donor species significantly inhibited growth of lettuce radicles. Tall fescue was the only donor whose exudates were significantly inhibitory at a 50 μl dose.

The Rf/10 bioassays of the 200 μl aliquots from the neutral fractions of tall fescue significantly inhibited growth of lettuce radicles in segments 0.2-0.3 and 0.5-0.6 (Table 2). The 0.3-0.4 segment from weeping lovegrass and the 0.3-0.4 and 0.5-0.6 segments from Kobe lespedeza also significantly inhibited lettuce radicle growth. No significant stimulations of lettuce radicle growth were found in any of the Rf/10 segments.

Table 1. Results of bioassay using lettuce radicle elongation for effects of acidic, neutral, and basic fractions of donor plant root exudates expressed as percent of controls.

		Donor Species		
Fraction	Dose	Tall Fescue	Weeping Lovegrass	Kobe Lespedeza
Acidic	50 µl	101	99	101
	100 µl	102	102	103
Neutral	50 µl	95*	99	98
	100 µl	89***	92**	94*
Basic	50 µl	99	98	99
	100 µl	100	99	100

* Significantly different from control, α = .05
** Significantly different from control, α = .01
*** Significantly different from control, α = .001

Table 2. Results of bioassay using lettuce radicle elongation for effects of Rf/10 segments from paper chromatography of neutral fraction of donor plant root exudates expressed as percent of controls.

	Donor Species		
Rf/10	Tall Fescue Segments	Weeping Lovegrass	Kobe Lespedeza
0.0-0.1	105	100	105
0.1-0.2	99	102	100
0.2-0.3	95*	96	96
0.3-0.4	96	93**	94*
0.4-0.5	102	99	97
0.5-0.6	95*	101	96*
0.6-0.7	104	98	103
0.7-0.8	97	99	100
0.8-0.9	100	99	102
0.9-1.0	101	101	98

* Significantly different from control, α = .05
** Significantly different from control, α = .01

Comparisons of GLC retention times and TLC and paper chromatograph Rf values and colors with those of standards (Table 3) indicated that tall fescue exuded the three phenolic compounds, cinnamic acid (3-phenyl-2-propenoic acid), ferulic acid (3-(4-hydroxy-3-methoxyphenyl)-2-propenic acid), and Kobe lespedeza exuded ferulic acid, gentisic acid, and syringic acid (4-hydroxy-3, 5-dimethoxybenzoic acid). Other unidentified compounds were released by the 3 donor species.

The Rf value of 0.30 for ferulic acid in paper chromatography indicates that the spot produced in the Rf/10 bioassay would have been split between segments 0.2-0.3 and 0.3-0.4. Both of these segments showed inhibition of lettuce radicle growth, but it was only significant in segment 0.2-0.3 from tall fescue and segment 0.3-0.4 from weeping lovegrass and Kobe lespedeza. The Rf value for gallic acid fell in the middle of segment 0.3-0.4 but GLC indicates that only weeping lovegrass produced this compound. Segment 0.4-0.5 containing syringic acid, produced only by Kobe lespedeza, did not show significant inhibition of lettuce in this test.

Gentisic acid, produced by all 3 species, had an Rf value of 0.59 whch could have caused spot splitting in the Rf/10 test, but significant inhibition was only noted in tall fescue and Kobe lespedeza extracts in the 0.5-0.6 segments. No significant effects were noted in segment 0.6-0.7 which would have contained cinnamic acid.

Table 3 Chromatographic characteristics of exuded compounds and matching standards.

Compound	Paper Rf	TLC Values	Colors UV(254 nm)	DPNA	GLC Rt (sec)	Donor Species
Cinnamic Acid	.65	.57	dk. blue	-	252	1
Ferulic Acid	.30	.23	Blue-purp.	blue	702	1, 2, 3
Gallic Acid	.35	.39	dk. purp.	tan	498	2
Gentisic Acid	.59	.73	blue	-	360	1, 2, 3
Syringic Acid	.47	.48	dk. purp.	l. green	516	3

Donor Species: 1 = Tall Fescue
2 = Weeping Lovegrass
3 = Kobe Lespedeza

Discussion

Lack of inhibition of lettuce radicle growth by some of these compounds may be due to nonsusceptibility of lettuce to some phenolic compounds, insufficient amounts produced by donor plants, or small amounts used in the testing.

Ferulic acid is a unit compound in the synthesis of lignin. It is one of the most commonly identified phenolic compounds leached or exuded from living plants, leached from plant litter, or produced in the soil during decomposition of lignin. It has been found in forest, grassland, peat, and cultivated soils by numerous researchers (1). Ferulic acid causes decreased protein synthesis (11, 12) and decreased root growth in lettuce (12), while in Paul's Scarlet rose cells it causes increased synthesis of lipids and decreased synthesis of protein and organic acids (13). In soybean leaves, ferulic acid reduces dry weight (14), chlorophyl a an b content (14, 15), depresses photosynthesis (15), and lowers stomatal conductance (15). Ferulic acid reduces Mg, Ca, K, P, Fe, Mn, and Mo uptake in Paul's Scarlet rose cells (16), reduces K absorption by oak roots (17), and inhibits phosphate uptake in three varieties of soybeans (18). Ferulic acid acts like polyphenols in synergizing IAA-induced growth by counteracting IAA-decarboxylation (19). Ferulic acid increases total lipid content, changes fatty acid composition of and apparently degrades membrane function, and it decreases growth in vitro of *Pisolithus tinctorius* (Pers.) Coker and Couch, an ectomycorrhizal fungus considered very important in the revegetation of mine spoils with pine and oak (Melhuish and Wade, unpublished data).

Cinnamic acid, derived from L-phenylalanine (20), is known to be produced by many plants (1) and has been identified as a root secretion of guayule (21). Cinnamic acid has been found in corn field residues (22). It decreases rice growth (23), changes water relations in beet cells (1), lowers stomatal conductance and chlorophyl content, and decreases photosynthesis in soybean (15), and inhibits protein synthesis and root growth in lettuce (12). Cinnamic acid causes a breakdown in protein synthesis from amino acids (15). Ferulic acid, in contrast, lowers protein synthesis by diversion of resources away from amino acid synthesis.

Gallic acid is produced in plants from dehydroshikimic acid (20) and can be produced by digestion of hydrolyzable oak tannins (24). It is produced by several plant species and has been found in soils (1). Gallic acid inhibits growth of *Amaranthus retroflexus* L. and *Bromus japonicus* Thunberg. (25), and causes lower chlorophyl concentrations, decreased photosynthesis, and decreased stomatal resistance in soybean (15). It may influence the nitrogen cycle in ecosystems by inhibiting the nitrogen-fixing alga *Anabaena* in soils (26), nitrification by *Nitrosomonas* (27), and by reducing nodulization in legumes (28). Gentisic acid is produced by *Celtis laevigata* L. (29), and *Eucalyptus globulus* Labill. (30).

Syringic acid has been found in crop residues and cropped soils (31, 32, 33, 34) and in the rhizosphere of *Zea mays* L. (35). It is produced by yellow nutsedge *(Cyperus esculentus* L.) (36).

The phenolic compounds produced by donor species in this study have a wide range of potential effects on other organisms and ecosystem functions. The actual importance of production of these phenolic compounds by the species we have examined will be determined by further study. Even if the amounts produced are low, they still may have significant synergistic effects. Additional phenolic compounds can result from decomposition of some of the ones found in this study; for example, vanillic acid is produced during the breakdown of ferulic acid and thus synergistic effects may be enhanced. Local concentrations associated with clays or organic matter in soils may enhance the importance of amounts produced (1).

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NOTES

Runt Egg In The Wood Duck.—Unusually small or runt eggs are extremely rare, with very few reports on the occurrence of such eggs in nature. Among the few species or groups in which runt eggs have been reported are the Canada Goose *(Branta canadensis)*, gulls *(Larus* spp.), House Wren *(Troglodytes aedon)*, Starling *(Sturnus vulgaris)*, Common Grackle *(Quiscalus quiscula)*, and several woodpeckers (Picidae) (Koenig, Wilson Bull. 92:169-176, 1980). In each of these, the incidence of runt eggs is extremely low, ranging from 0.02% in gulls to 0.6% in the Canada Goose. In one exceptional species, the Acorn Woodpecker *(Melanerpes formicivorus)*, the percentage of runt eggs was reported as 4.3% (Koenig 1980). On 4 May 1984 we found a runt egg in a Wood Duck *(Aix sponsa)* nest located in the Clay Wildlife Management Area, 16 Km ENE of Carlisle, Nicholas County, Kentucky. The nest also contained 11 normal eggs. The normal eggs subsequently hatched and the young had apparently all fledged by the time the nest was checked on 2 June. The runt egg measured 35.5 x 27.8 mm. Robinson (Condor 60:256-257, 1958) reported that the average size of 51 Wood Duck eggs was 46.8 x 37.4 mm; Bellrose (Ducks, Geese, and Swans of North America, Stackpole Books, Harrisburg, PA, 1976) noted that the average dimensions of a Wood Duck egg were 51.1 x 38.8 mm; and Palmer (Handbook of North American Birds, Vol. 3, Yale Univ. Press, New Haven, CN, 1975) indicated that the average Wood Duck egg measured 50.7 x 39.0 mm. No mention of runt eggs was made by any of these authors. A review of the literature revealed no other published reports of runt eggs in the Wood Duck.

The runt egg showed no evidence of embryonic development and contained no yolk. The absence of yolk was noted also in the runt eggs of other species (Romanoff and Romanoff, The Avian Egg, Wiley and Sons, New York, 1949). Little is known about runt eggs. Physiologically, the production of such eggs is apparently stimulated by temporary disturbances, accidents, or infections in the oviduct (Romanoff and Romanoff 1949). Very few are thought to be the result of permanent abnormalities (Pearl and Curtis, J. Agricu. Res. 6:977-1042, 1916). The only species with a rather high incidence of runt eggs appears to be the Acorn Woodpecker. Koenig (1980) indicated that this may be due to the fact that these woodpeckers are communal nesters. As females attempt to maneuver within the nest cavities they may come in contact with each other or the walls of the cavity. Such physical contact may subsequently result in the production of runt eggs—GARY RITCHISON and KEITH D. KRANTZ, Department of Biological Sciences, Eastern Kentucky University, Richmond, KY 40475.

The longnose dace, ***Rhinichthys cataractae*** **(Valenciennes), in Kentucky.**—On 4 April 1984, 3 specimens of the longnose dace, *Rhinichthys cataractae*, were collected from the Russell Fork of the Big Sandy River, Pike County, Kentucky at a site 1.21 KM (0.75 mile) downstream from the Kentucky-Virginia state line. These specimens represent the first known record for this species in the state. Other species collected at the same location included *Campostoma anomalum*, *Etheostoma blennioides*, *Etheostoma caeruleum*, *Etheostoma variatum*, and *Percina maculata*.

The habitat from which these specimens were collected is similar to that described by Gilbert and Shute (*in* Lee et al., *Atlas of North American Freshwater Fishes*, p. 353, 1980). Russell Fork at this location is an Order VI mountain stream (elevation 311 m) with clear, fast-flowing, turbulent water and a substrate of boulders and rubble.

The longnose dace is predominantly a northern species (Gilbert and Shute, loc. cit.) which ranges southward through the Appalachian Mountains into North Carolina, Tennessee, and northern Georgia. Burr (Brimleyana 3:53-84, 1980) considered the longnose dace as a problematic species in Kentucky and speculated that it possibly occurs in the Big Sandy or Upper Cumberland River drainages. This report confirms his assumption for the Big Sandy River drainage.

Voucher specimens of *Rhinichthys cataractae* have been deposited at Southern Illinois University, Carbondale (SIUC), Eastern Kentucky University (EKU), and the Kentucky Department of Fish and Wildlife Resources at Frankfort (KDFWR). These specimens have the following measurements: (SIUC 10159) standard length (SL) = 43.0 mm, preorbital head length (PHL) = 5.0 mm, postorbital head length (POHL) = 5.0 mm, and eye diameter (ED) = 2.5 mm; (EKU 1305) SL = 50.0 mm, PHL = 5.5 mm, POHL = 6.0 mm, and ED = 2.9 mm; (KDFWR 1835) SL = 50.5 mm, PHL = 5.2 mm, POHL = 6.0 mm, and ED = 2.9 mm.

The authors appreciated the field assistance of Messrs. Robert Bay and Doug Winford (U.S. Fish and Wildlife Service, Cookeville, Tennessee); the assistance of Mr. Ronald Cicerello (Kentucky Nature Preserves Commission) with the specimens; and Drs. Robert Kuehne (University of Kentucky) and Branley A. Branson (Eastern Kentucky University) for verifying our diagnosis.—DOUGLAS E. STEPHENS and KERRY W. PRATHER, Kentucky Department of Fish and Wildlife Resources, #1 Game Farm Road, Frankfort, KY 40601

Electrofishing vs. Angler Harvest: Differences in Length-Frequency Distributions—In recent years, fishery managers have found it necessary to investigate new, more economical and innovative methods of sampling fish populations. Standard methods of netting and electrofishing are very expensive because of time involvement of personnel and equipment. Use of angler-reported data have been shunned because of biases and inaccuracies. We have found that a combination of techniques can be the most inexpensive and accurate means fo obtaining data on certain fish populations. This method is the use of clerk-collected data from angler harvest.

Several criteria should be met for use of angler-harvest data to be advantageous: (1) the species of interest should be a target species of anglers; (2) the species of interest should have few fishing regulations (i.e., bag or size limits); (3) fishing pressure and harvest need to be high during the collecting period; and (4) areas of fishermen concentration (e.g., fish-cleaning stations) are necessary to optimize data collection.

During nesting and spawning in early May 1982, Kentucky Lake white crappie *(Pomoxis annularis)* data were collected by electrofishing and angler harvest. Fish taken by both methods were most frequently found in shallow water. Weather and water conditions did not change over the sampling period. When fishermen arrived at fish-cleaning stations, creels of cooperative anglers were borrowed for processing. Total length, weight, and sex were recorded for each fish and scale samples were taken. Fish were returned promptly to anglers for cleaning. The white crappie obtained by electrofishing were processed in the same manner.

The length-frequencies of white crappie collected by electrofishing versus angler harvest were compared by a Smirnov Test (Conover, Practical nonparametric statistics, 2nd ed., Wiley and Sons, New York, N.Y., 1980). The dates and sample sizes of the length-frequencies were given for each day (Fig. 1). The differences in the comparison of the length-frequencies of the electrofishing day to each day of angler harvest, and to the 3-day combination angler harvest were significant. The range in size obtained by electrofishing. The angler data is skewed toward smaller fish, while the electrofishing data appeared more normal in distribution. Possibly these differences occurred because of the variability and biases associated with each method.

There was a significant difference in the efficiency of the sampling methods. Fish obtained by angler harvest on 5/2/82 were processed at approximately 31 fish/hr. The rate of collecting and processing of fish taken by electrofishing was approximately 7.6 fish/hr, which was 0.25 as efficient as the angler-harvest method.

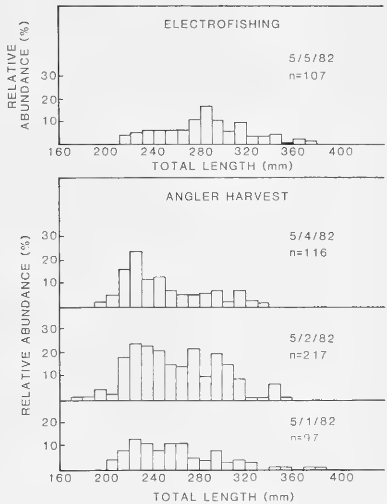

Fig. 1. Length frequency of white crappie collected by two methods.

As an added benefit to the fisheries manager, use of angler-harvest data promotes a cooperative effort involving the public. Anglers generally respond very favorably to helping obtain data concerning "their" fish. Anglers perceive this method as beneficial; whereas, electrofishing removes "their" fish before they have the opportunity to catch them.—DONNA L. PARRISH, Hancock Biological Station, Murray State University, Murray, KY 42071 (Present address: Ohio Cooperative Fishery Research Unit, 1735 Neil Ave., Columbus, Ohio 43210), THOMAS D. FORSYTHE, TVA-Land Between the Lakes, Golden Pond, KY 42231, TOM J. TIMMONS, Hancock Biological Station, Murray State University, Murray, KY 42071.

ACADEMY AFFAIRS

KENTUCKY ACADEMY OF SCIENCE
The Seventieth Annual Meeting
at
Kentucky State University
November 9-10, 1984

Arrangements: Dr. Gerrit Kloek

OFFICERS OF THE ACADEMY

President	Joe Winstead Western Kentucky University
President-Elect	Charles Covell University of Louisville
Vice-President	Larry Giesmann
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 the Transactions	Branley Branson Eastern Kentucky University
Representative to A.S.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
William Hettinger	1987
William Bryant	1988
William Beasley	1988

THE SEVENTIETH ANNUAL BUSINESS MEETING OF THE KENTUCKY ACADEMY OF SCIENCE

KENTUCKY STATE UNIVERSITY FRANKFORT, KENTUCKY

9-10 November 1984

Host: Dr. Gerrit Kloek

Minutes of the Annual Meeting

The meeting was called to order by President Bogess at 0930, 10 November, in the Lobby Auditorium of Bradford Hall with approximately 100 members in attendance.

After a motion by Secretary Creek, and a second from the floor, the minutes of the 1983 annual business meeting at the University of Louisville, as recorded in the *Transactions* Vol. 45(1-2), were approved. Secretary Creek moved that all new members for 1984 be accepted by the Academy. Following a second from the floor, the motion passed. Dr. Creek reported that he had only received 25 forms for the Speaker's Bureau that is being developed. He felt that there should be at least 50 participants in order to have a quality program and anyone wishing to participate should send a form into the Secretary as soon as possible.

The Treasurer's report was made by Dr. Taylor.

TREASURER'S REPORT
KENTUCKY ACADEMY OF SCIENCE
NOVEMBER 3, 1983-NOVEMBER 1, 1984

Cash in Madison National Bank (Nov. 3, 1983)		$ 1059.00
RECEIPTS:		
Registration (total deposits)		$ 5580.00
Membership dues		$ 7200.00
Library subscriptions		$ 1400.00
Institutional Affiliations		$ 2000.000
Page Charges		$ 2593.54
	Total	$18773.54
Total Cash and Receipts		$19832.54
DISBURSEMENTS:		
Junior Academy of Science (83, 84)		$ 1000.00
Operating expenses		$ 2040.38
Transactions (vol 45, + 1-2)		$ 5854.45
Miscellaneous (Banquet, etc)		$ 3035.71
	Total	$11930.54
BALANCE:		
Total Cash and Receipts for 1984		$19832.54
Total Disbursements		$11930.54
Cash on hand (Nov 1, 1984)		$ 7902.00

KENTUCKY ACADEMY OF SCIENCE FOUNDATION

Botany Foundation ($10000 CD) Interest		$ 940.04
Grants 1984		$ 800.00
	Subtotal	$ 1565.51
Floristic Fund (Refund of grant)		$ 300.00
Marcia Athey Fund ($55645-CD's)		
Interest 1983		$ 4638.88
Interest 1984		$ 4449.52
	Subtotal	$ 9088.40
Grants 1984		$ 6250.00
	Total	$ 2838.40

Dr. Taylor indicated that the cash on hand was about $2000.00 more, due to interest from C.D.'s received after November 1.

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

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

Vol. 45 (3-4) of the Transactions has not been received, but have been assured by the printers that the journal will be delivered within the next week.

Vol. 45 (1-2) consisted of 100 pages that included 9 full-length papers, 10 notes, Academy Affairs, Program of the Annual Meeting, abstracts of papers presented at the annual meeting of Academy, and News and Comments. Vol. 45 (3-4), September 1984, 102 pages, included 9 papers, 6 notes, News and Comments, Academy Business, and the annual index to the *Transactions*. The cost for printing 45 (1-2) was $5,854.45, less approximately $360.00 for reprints recovered from authors. He said he had not received a bill for Vol. 45(3-4).

The subjects of the 18 papers and 16 notes in Vol. 45 were: Zoology and Entomology, 21; Geology, 8; Microbiology, 1; Geography, 1; Botany, 1; Anthropology, 1; and Chemistry, 1. Thus, the diversity of papers continues to increase, although the preponderance of them still comes from zoologists.

2. MEMBERSHIP COMMITTEE. Dr. Larry Elliott made the report.

The contact people that have served this year are as follows: Drs. Coltharp and Freytag, University of Kentucky; Dr. Joe Winstead, Western Kentucky University; Dr. Al Smith, Eastern Kentucky University; Dr. Charles Kupchella, Murray State; Dr. Manuel Swartz, University of Louisville; Dr. Susan Studlar, Centre College; Dr. Thomas Strickler, Berea College; Dr. Bill Beasley, Jr., Paducah Community College; Dr. Tom Seay, Georgetown College; Dr. Gertrude Ridgel, Kentucky State College; Dr. Jerry Carpenter, Northern Kentucky University an Dr. John Philley, Morehead 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. To the other inactive members in the KAS I sent a letter reminding them they were inactive. This was beneficial as errors were found on our membership lists and new members have joined.

The secretary of KAS sent me an updated computer list of members in February and the same procedure was followed. The contact people were particularly urged to determine if the people they contacted had followed through on their commitment to renew their membership or join the KAS. This same process was repeated in September of 1984. There were 62 new members for 1984 giving a total of 491 members paid for 1984.

A report from the membership committee appeared in the March Newsletter of KAS. 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 organizations need contact people for recruitment: Ashland Petroleum Co., Elizabethtown Community College, Thomas More College, Hazard Community College, Henderson Community College, Madisonville Community College, Brescia College and Prestonburg Community College. He indicated that members from Ashland Petroleum Co. and Elizabethtown Community College had said they would serve as contact people. He said that if anyone else is interested in being a contact person, to see him or a member of the committee.

3. STATE GOVERNMENT/SCIENCE ADVISORY COMMITTEE. Dr. Charles Kupchella made the report.

He stated that the efforts of the committee to bring science closer to government has resulted in a merger with the "Kentucky Tomorrow: the Commission of Kentucky's Future". This is an effort by Lt. Governor Beshear to focus the importance of science and technology on the future of Kentucky. Dr. Boggess was appointed to the Commission and it is expected that a majority of the members of a Science and Technology panel to serve with the Commission will be members of KAS. A KAS membership list has been submitted to the Lt. Governor's office. An inaugural luncheon was held on July 25 for the Commission. The purpose of the meeting was to brainstorm the approach and the nature of the task of what will ultimately become the Science and Technology Panel under the Commission. Dr. Kupchella concluded by sitting that he felt very positive about the approach being taken by Lt. Governor Beshear.

4. DISTRIBUTION OF RESEARCH FUNDS. Dr. William Bryant presented the following report.

During 1984, the Botanical Grants Fund awarded four grants for a total of $800.00. The recipients were:

1. Mr. Harry Woodward, University of Louisville, $200.00 grant, for his work on *Liriodendron*. This award was in addition to a previous grant of $400.00 in 1983.
2. Ms. Donna Godbey, Eastern Kentucky University, $100.00 grant, for additional work on her floristic survey of Maywoods. Ms. Godbey had received a previous award. She will present a paper on her research at the annual meeting.
3. Mr. Paul Grote, University of Indiana, $400.00 grant, to supplement his work on the paleobotany of the Eocene deposits in Western Kentucky.
4. Ms. Jennifer Sharp, Western Kentucky University, $100.00 grant, for her dendrochronology work in south-central Kentucky.

During the year, a number of requests for information on the Botanical Grants was received. The Botanical Grants Committee is open to applications Botany Fund prior to April 1, 1985. Grants are open to undergraduates and graduate students enrolled in a college or university program within the Commonwealth or applicants may be enrolled in institutions outside of Kentucky but doing research in this state. All areas of botanical research will be given consideration for funding.

Applications should describe the proposed research and include appropriate literature citations and an outline of the costs. Three copies are required. Recipients are expected to file a summary report with the Botanical Grants Committee and/or present the results of his/her research before an appropriate sectional meeting of the KAS.

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

For many years, this committee has been concerned with the number of teachers who are teaching out-of-field. This has been a continuing problem with science last spring, Anna Neal and Ted George visited Mrs. Caroline Wasaba who is now head of the Accreditation Section of the State Department of Education and aired our concerns. (The number of teachers teaching out-of-field are governed by accreditation regulations.) Mrs. Wasaba was very receptive to our point of view. We shall continue to monitor this situation.

We received problems this committee should be addressing in addition to the above—extra pay for science teachers, the proposed three tiers of certification and continuation of the Science Advisory Council. It was decided that the best approach would be to re-establish the Science Advisory Council. Therefore, it was recommended to the Executive Committee that the President write a letter to Alice McDonald, Superintendent of Public Instruction to request that the Science Advisory Council be re-instated. To our knowledge, only one Advisory Council has been organized (the Environmental Council). We shall continue efforts along this line.

Presently, Kentucky teachers are certified in two tiers—elementary (K-8) and secondary (7-12). A three tiered certification has been passed by the Kentucky Council on Teacher Certification in May and by the State Board of Education in July. According to this program, effective September 1, 1989, it is proposed that new teachers may be certified as Elementary (K-4), Middle School/Junior High (5-8) and Secondary (9-12). Teachers certified before that date will be certified under the two tiered system. Teachers meeting the requirements for one tier of certification may be endorsed for another tier by meeting the requirements for that tier.

The requirements for certifying teachers in elementary and secondary remain the same. Briefly, the new requirements for middle school require 48 semester hours in the specialty component, which must be divided between two teaching fields of 24 hours each. The fields are: (1) English and Communication (2) Mathematics (3) Science and (4) Social Studies.

For the science field: Preparation shall include 6 semester hours in each of physical sciences, biological sciences and earth sciences; at least one biological science and one physical science course must be accompanied by a laboratory requirement.

Our committee does have some concerns about the new middle school guidelines and again proposed to the Executive Committee that the President of the Academy write to Superintendent McDonald our concerns. So far, we have had no reply but here are our concerns:

(1) The newly certified middle school teacher must satisfy requirements in two fields. Is this teacher then restricted to teaching subjects only within those two fields? For example, if a new teacher satisfied field requirements in English and Social Science; could that teacher then teach natural science in the middle school? The guidelines as we read them do not specifically say that this would not be allowed. If it is indeed the case that such a teacher would be teaching out-of-field and would not be allowed, then the guidelines should explicitly state that. On the other hand, if it is envisioned that once a teacher has satisfied the requirements of two fields, they could teach any subject in middle school, then I think all science groups would be unalterably opposed. We would appreciate a clarification of this issue.

(2) We are concerned that middle school certification may have difficulty in attracting enough applicants to maintain the teaching staffs. Our experience indicates that prospective teachers will not deliberately choose middle school but will opt for elementary or secondary. It is our understanding that Indiana tried three levels of certification several years ago and has been unable to secure enough applicants for middle school. Have the experiences of other states been surveyed?

(3) While requiring 24 hours in each of the four fields may seem an even-handed approach—we feel that it is severly unbalanced. Six hours in each subject of physical, biological and earth science is not comparable to 24 hours in mathematics. There are many science courses in all universities intended to inform the general student which are certainly *not* suitable as a background for teachers. These courses are most often offered in three hour units and we fear these are the courses that will be used for the science field. We compare this to 24 hours in mathematics, which would probably take the new teacher completely through the calculus sequence! Clearly, the preparations in math and science are not comparable.

Dr. George said that Dr. Boggess and he would be meeting in December with Mr. Simandle to discuss the above mentioned concerns.

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

The 1984 membership was 742 paid members from 20 clubs, an average of 41 students per club.

Research grants were awarded to 10 students for a total of $550.00.

As in previous years, our major activity was the annual symposium which was hosted by Western Kentucky University. Forty-one abstracts were submitted and 37 papers read. These were from 11 schools. Other regular activites included the Lab-Skills and Science Bowl competitions.

A party celebrating the 50th anniversary of the K.J.A.S. was substituted for our usual special speaker. This was so successful that the sponsors and board members decided to make some food and good times a regular feature of our annual spring meeting.

As a result of our "Outstanding Science Graduates" programs, two more students have scholarships this year in the Physics Department at Western. These scholarships were provided by the Ogden Foundation.

This year we are scheduled to hold our Symposium at Model Laboratory School, Eastern Kentucky University the last Friday and Saturday of April.

The KJAS Treasurer's report was presented by Mr. Leopold.

*Balance on hand, September 1, 1984		$ 823.20
Disbursements		-0-
Receipts		
Club Dues		65.00
Grant Co. High School	5.00	
Deming High School	12.50	
Russellville High School	13.00	
Russellville High School (83-84)	12.00	
Bowling Green High School	22.50	

KAS Contribution	500.00
Total Receipts	565.00
Balance on Hand, November 1, 1984	$1,388.20

The report was audited by Dr. Taylor and found to be in order.

7. RARE AND ENDANGERED SPECIES COMMITTEE. Dr. Branson made the report.

Dr. Branson said that Mr. John MacGregor would be the new chairperson of the committee. The committee is in the process of developing a standardized form for the addition or changing of species on the endangered list. He pointed out that Kentucky still had one of the longest lists of endangered species. The committee would have the list completed by the next meeting.

8. AAAS—no report

9. NOMINATING COMMITTEE. Dr. John Philley offered the following nominations and moved their acceptance.

VICE PRESIDENT: Larry Giesmann
Northern Kentucky University

SECRETARY: Robert O. Creek
Eastern Kentucky University

TREASURER: Morris D. Taylor
Eastern Kentucky University

REPRESENTATIVE TO AAAS: Joe King
Murray State University

BOARD OF DIRECTORS: William Bryant
Thomas More College

William Beasley
Paducah Community College

William Hettinger, Jr.
Ashland Petroleum Co.

The motion was seconded from the floor and, with no further nominations, was passed.

10. RESOLUTION COMMITTEE. Dr. John Philley submitted the following resolution which were accepted unanimously.

Resolution No. 1

WHEREAS,
Kentucky State University has served in a very outstanding manner as the host institution for Seventieth Annual Meeting of the Kentucky Academy of Science, and

WHEREAS,
President Raymond Burse, Gerrit Kloek and many others at Kentucky State University have worked diligently to provide for the success of this annual meeting, and

WHEREAS,
Kentucky State University has had a notable past and will have a bright future in providing educational opportunities in the sciences in the Commonwealth of Kentucky,

THEREFORE,
be it resolved herewith that the Kentucky Academy of Science express its appreciation to Kentucky State University and the above-named individuals, and

that the Academy's Secretary be instructed to so inform them, and

that the Kentucky Academy of Science congratulate Kentucky State University for its educational successes in the Commonwealth and the Nation and for promoting science through instruction, public service, and research.

Resolution No. 2

WHEREAS,

the Honorable Steven L. Beshear, Lieutenant Governor of the Commonwealth of Kentucky, is providing outstanding leadership in addressing and improving the status of science, technology, and government,

THEREFORE,

be it resolved that the Kentucky Academy of Science commend Lieutenant Governor Beshear for his concerns and efforts to bring about a productive and cooperative atmosphere for science, technology, and government, and

that the Academy offer its support for these endeavors.

NEW BUSINESS

A. Dr. John Philley, on behalf of Morehead State University, extended to the Academy an official invitation to hold its 1985 annual meeting on the campus of Morehead State University. A motion was made and seconded to accept the invitation.

B. Dr. Joe Winstead announced plans to hold a joint meeting in 1986 with the Kentucky Association for Progress in Science, Kentucky Council of Teachers in Math and School Science and Mathematics Association, Inc. (SSMA). The tentative location is the convention center in Lexington, Kentucky. The only change would involve a joint plenary session. Any workshops sponsored by the other Associations would be available to the Academy. The SSMA would underwrite the cost of the meeting. The joint meeting would also attract a larger number of venders. Dr. Winstead stated that he would be meeting in December with representatives of the different organizations to begin planning for the 1986 meeting.

President Boggess concluded his tenure as President by thanking the Academy for their help during the past year. Although progress was made during the past year, he stated that the Academy needs to continue to strive to obtain more research money for Kentucky and to become the focal unit for representing science in Kentucky. President Boggess then presented President-elect Winstead with the gavel and welcomed him as President of the Kentucky Academy of Science for 1985.

President Winstead presented Dr. Boggess with a plaque for his service as President and his contributions to the Academy. Following a brief address by President Winstead, the meeting was adjourned at 1015.

Robert Creek, Secretary
Kentucky Academy of Science

KENTUCKY ACADEMY OF SCIENCE
70th ANNUAL MEETING
PROGRAM

Friday, November 9, 1984

0900-1200 *Community College Faculty Meeting* - Academic Service Bldg Lobby Auditorium

1130-1300 *Executive Committee Luncheon* - Presidential Dining Room Academic Service Bldg

1200-1600 *Registration* - Lobby, Bradford Hall

1200-1700 *Scientific Exhibits* - Lobby, Bradford Hall

1300-1500 *Sectional Meetings* - (See Following Pages)

1500-1530 *Coffee Break* - Lobby, Bradford Hall

1530-1700 *Plenary Session* - Little Theater, Bradford Hall

1730-1900 *Reception* - Lieutenant Governor's Mansion

1930-? *KAS Annual Banquet* - Capital Plaza Hotel, Ball Room

Saturday, November 10, 1984

0800-10009 *Registration* - Lobby, Bradford Hall

0800-1200 *Scientific Exhibits* - Lobby, Bradford Hall

0800-0900 *Sectional Meetings* - (See Following Pages)

0900-0915 *Coffee Break* - Lobby, Bradford Hall

0915-1015 *Annual Business Meeting* - Little Theater, Bradford Hall

1030-1200 *Sectional Meetings* - (See Following Pages)

1300-? *Sectional Meetings* - (As Needed)

PLENARY SESSION

Friday, November 9

1530 *Little Theater, Bradford Hall*

THE INTERFACING OF EDUCATON, SCIENCE, AND GOVERNMENT

Speakers: Dr. Raphael O. Nystrand
Secretary of Education
and the Humanities Cabinet

Dr. Joseph Danek
Director of Special Projects
National Science Foundation

ANNUAL BANQUET

Friday, November 9

1930 Capital Plaza Hotel, Ball Room

Speaker: Steven L. Beshear
Lieutenant Governor
Commonwealth of Kentucky

"SCIENCE AND GOVERNMENT: PROGRESS THROUGH COOPERATION"

BOTANY AND MICROBIOLOGY SECTION

Max E. Medley, Chairperson, Presiding
Ronald L. Jones, Secretary
Room 107 - Hathaway Hall

Friday, November 9, 1984

1300 The ecological life cycle of *Campanula americana*. *Jerry Baskin* and Carol Baskin, University of Kentucky.

1315 The influences of some environmental factors on the germination of some of the desert annual plants of the Negev Desert of Israel. Y. Gutterman, University of Kentucky, sponsored by J. Baskin.

1330 Preservation of leaves and flowers by microwave in the plant biology laboratory. Charles D. Howes, Ashland Community College.

1345 Nitrogen-fixing capabilities of *Azospirillum lipoferum* from a coal surface-mined site. *D. N. Mardon and F. M. Rothwell, Eastern Kentucky University and USDA-Forest Service.*

1400 *Vegetative growth of Phytophthora* inhibited by ectomychorrhizal fungi. Frederick M. Rothwell, USDA-Forest Service.

1415 Allelopathic inhibition of the bacteria *Thiobaccillus ferrooxidans* Temple and Colmer by woody species on abandoned strip mines. Valina Kay Hurt. Hazard Community College.

1430 The aquatic aeromonads. Dennis Lye, Northern Kentucky University, sponsored by L. Giesmann.

1445 Establishment of tissue culture from mature pine trees—the problem of microbial contamination. Karan Kaul, Kentucky State University

1500 Incidence and dissemination of *Epichloe typhina* in tall fescue. Dan Varney, Eastern Kentucky University.

1515 Coffee Break

1530 Plenary Session

Saturday, November 10, 1984

0800 Community composition of a beech-hemlock woods in south-eastern Madison County, *Ronald L. Jones* and Ralph L. Thompson, Eastern Kentucky University and Berea College.

0815 The status of *Polymnia laevigata* in Kentucky. Marc Evans, Kentucky Nature Preserves Commission.

0830 The Eden Shale flora east of Lexington, Kentucky, along Liberty Road. *Patricia Dalton* and Willem Meijer, University of Kentucky.

0845 *Rafflesia:* the largest flower in the world, studied at the University of Kentucky. Willem Meijer, University of Kentucky.

0900 Coffee Break

0915 Annual Business Meeting

1030 The vascular flora of Maywoods Environmental and Educational Laboratory, Garrard and Rockcastle Counties, Kentucky. Donna A. Godbey, Miami University, Ohio.

1045 Immunization of cucumber against *Collelotrichum logenarium*. Polly Johnson, Paducah Tilghman High School, sponsored by H. A. Leopold.

1100 Growth of oral bacteria on various sugars and sugar substitutes. Rose Marie O'Brien, Notre Dame Academy, sponsored by H. A. Leopold.

1115 Inhibition of nitrogen uptake by sulfate ions. David J. Minter, Berea College.

1130 Diatoms as water quality indicators in Kentucky. Part I: Halophilic species. Stephen D. Porter, Kentucky Division of Water.

1145 Bryophytes as a habitat for Myxomycetes (slime molds). Steven L. Stephenson and *Susan Moyle Studlar,* Fairmont State College, West Virginia, and Centre College.

1200 Lunch break

1300 Patterns of recovery of a clear cut forest stand in Laurel County, Kentucky after 19 years. Joe E. Winstead, Western Kentucky University.

1315 Geographic and vegetational influences on sexual reproduction in *Maianthemum canadense* Desf. (liliaceae). Cynthia L. Williams, Centre College.

1330 The natural vegetation of the so-called Bluegrass Region. Julian Campbell, University of Kentucky.

1345 Uncommon communities and quantitative environmental assessment. Hall Bryan, Frankfort.

1400 The use of historical documents, early maps, military land grants, and GLO surveys in the vegetation research in Kentucky. *William S. Bryant* and William H. Martin, Thomas More College and Eastern Kentucky University.

1415 Election of sectional officers

CHEMISTRY SECTION

Carl D. Slater, Chairman
Audrey L. Companion, Secretary

Session I. Joan Reeder, Presiding
Little Theater - Bradford Hall

Friday, November 9, 1984

1300 Solvent-induced Swelling of Coal using Cyclic Hydrocarbons and their Nitrogen Heterocycle Analogs. *Jan Buckmaster* and Joan Reeder. Eastern Kentucky University.

1315 The Nature of Supported Co-Mo and Ni-W Catalysts. *E. J. Dady,* L. J. Boucher and B. H. Davis. Western Kentucky University and I.M.M.R., University of Kentucky.

1330 Raman Spectra of CO Absorbed on Ni (100). *H. A. Marzouk* and E. B. Bradley., University of Kentucky.

1345 Thermal Analysis in the Study of Petroleum Pitch. *William L. Budden.* Ashland Petroleum Company.

1400 A Field Study on the Self-Heating of Illinois Basin Coals During Barging. S. M. Fatemi, P. E. Pfannerstill, K. J. Thrasher, S. M. Williams, G. S. Yates, J. W. Reasoner and *J. T. Riley*. Western Kentucky University.

1415 Establishment of a Data Bank on the Self-Heating of Coal. S. M. Fatemi, P. E. Pfannerstill, K. J. Thrasher, D. D. Watson, S. M. Williams, G. S. Yates, J. T. Riley and *J. W. Reasoner*. Western Kentucky University.

1430 Preparation and NMR Studies of Stereochemically-nonrigid Molybdenum Complexes. *P. N. Nickias*, J. P. Selegue and S. L. Smith. University of Kentucky.

1445 A Shielded Mercury Microelectrode for Use in Voltammetry. *Cheryl L. Hughes* and Jeffrey E. Anderson. Murray State University.

1500 Antibiotic Susceptibility and Plasmid Screening Studies of Three Clinical Isolates of *Acinetobacter Calco-Aceticus*. *Thomas M. Maudru* and V. Vandegrift. Murray State University.

1530 Plenary session

Session II. Carl D. Slater, Presiding
Room 104 - Bradford Hall

1300 The Preparation, Structure and Reactivity of [Fe CH $(PPh_2)_3$ (Cp)] (PF_6). *Fame D. Goodrich* and John P. Selegue. University of Kentucky.

1315 Selective Oxidations of Sucrose. Synthesis of Glucosyltransferase Inhibitors. S. Singh and *K. G. Taylor*. University of Louisville.

1330 Fourier Transform Spectroscopy at the University of Louisville. *Richard A. Porter*. University of Louisville.

1345 The Design of Reaction Mechanisms. *P. L. Corio*. University of Kentucky.

1400 The Synthesis of Tetrabutylammonium Dichloroidodide and Bis [bis(ethylenedithio)tetratiafulvalene]dichoroiodide. *Patricia Jackson* and Jack D. Williams. Cumberland College and Argonne National Laboratory.

1415 Synthesis and Structure of a Novel Molybdenum-Zirconium Complex. *William J. Sartain* and John P. Selegue. University of Kentucky.

1430 Theoretical Studies on N-Bonded Pyrazole Derivatives of Boron. *A. L. Companion*, Frank Liu and K. Niedenzu, University of Kentucky.

1445 Proton-Transfer in the Hydrolysis of 2- and 4-Fluoro-N-Heterocycles. *Denise Rutherford* and Oliver J. Muscio. Murray State University.

1500 Formation of Lactones by the Palladium Catalyzed Carbonylation of Haloalcohols. *Arlene R. Courtney*, Carol Condon and Julie Obermark. Murray State University.

15:30 Plenary Session

Session III. Audrey Companion, Presiding
Little Theater - Bradford Hall

Saturday, November 10, 1984

0800 Magnetic Properties of o-Diphenol Complexes of Copper (II). Model of Tyrosinase Activity. *Robert M. Buchanan* and Cheryl Wilson-Blumenberg. University of Louisville.

0815 Quinone Chemically Modified Electrodes. Electrocatalytic Reduction of Ferricytochrome c. Robert M. Buchanan and *Mark Mashuta*. University of Louisville.

0830 Orientation and Rotation Effects on Crystal Growth. Sodium Chlorate System. Calcium Tartrate System *Jackie Rust*. Notre Dame Academy.

0845 Studies Involving Liquid Membranes. *Terri Dietz*. Notre Dame Academy.

0900 Coffee Break

0915 Annual Business Meeting

Joint Session with Physics Section: Little Theater - Bradford Hall

1030 A Visit into the Past-Some Views of the History of Science. *Norman Hunter*, Western Kentucky University.

1115 PANEL DISCUSSION: Increasing Communication between High School and College Teachers of Chemistry and Physics

1205 Chemistry Section Meeting: Election of Section Officers.

GEOGRAPHY SECTION

John L. Anderson, Chairman, Presiding
Glen Conner, Secretary
Room 224 - Hathaway Hall

Friday, November 9, 1984

1300 A Simple Interactive Computer Model for Calculating the Soil Moisture Balance, *David A. Howarth* and Tammy J. Baker, University of Louisville.

1315 Geomorphic Variations in the Dripping Springs (Chester) Escarpment. Ronald R. Dilamarter, Western Kentucky University.

1330 Space and Place in Early Childhood, Karen Koegler, University of Kentucky.

1345 Local Weather Fluctuations During the Annular Solar Eclipse, 30 May 1984. L. Michael Trapsso, Western Kentucky University.

1400 A Measure of the Subjective Component of Lineament Analysis of Topographic Maps. Chris Groves, Western Kentucky University.

1415 Cross-validation Techniques to Establish Extent of Concurrent Validity for Discriminant Marketing-Research Surveys. Alan D. Smith, Eastern Kentucky University.

1430 On Rivers that Flow the Wrong Way and Similar Matters. Dennis L. Spetz, University of Louisville.

1445 Cultural Regions of Afghanistan. S. Reza Ahsan, Western Kentucky University.

1500 Coffee Break

1530 Plenary session

Saturday, November 10, 1984

0800 Subscribership Patterns, A Clue to Kentucky's Social Geography. John L. Anderson, University of Louisville.

0815 Spatial Variations in Housing Values in Bowling Green, Kentucky: A Neighborhood Analysis. *James M. Bingham* and Wayne L. Hoffman, Western Kentucky University.

0830 Lion Pride Territory Range. John Snaden, Eastern Kentucky University.

0845 Plant Hardiness Zones in Kentucky. Kevin D. Brown, Western Kentucky University.

0900 Elevation of Sectional Officers

0915 Annual Business Meeting

1030 Water-shy Geographers. Edmund E. Hegen, Western Kentucky University.

1045 Geographical Determinants in the Prehistory of North America. John R. Hale, University of Louisville.

1100 Kentucky's Evolving Lake Landscape: A Recent Development. William A. Withington, University of Kentucky.

1115 A Closer Look at a Record Breaking Atmospheric Low Pressure System. Bryan Kinkel, Western Kentucky University.

1130 Reflexions on Philosophy of Geography. Milos Sebor, Eastern Kentucky University.

1145 A University Student Center and Central Place. Jerry L. Johnson, Western Kentucky University.

1200 Polynomial Modeling and Predictive Evaluation of Tariff-derived Transportation Costs in Kentucky. *Alan D. Smith* and Charles L. Hilton, Eastern Kentucky University.

1215 Rural Development Efforts in Portugal. T. J. Kubiak, Eastern Kentucky University.

GEOLOGY SECTION

Peter W. Whaley, Chairman
Gary L. Kuhnhenn, Secretary, Presiding
Room 226 - Hathaway Hall

Friday, November 9, 1984

1300 Applications of Computer Graphics to Undergraduate Education in the Earth Sciences. Alan D. Smith, Coal Mining Administration, Eastern Kentucky University.

1315 Diagenesis of Mineral Matter in Coal: Application of Carbonate Models. Michael J. Andrejko, Eastern Kentucky University. Sponsored by Gary L. Kuhnhenn.

1330 Three-Dimensional Modeling and Trend Surface Analysis of Selected Borehole Information for Geotechnical Applications. *Alan D. Smith,* Eastern Kentucky University, David H. Timmerman, University of Akron.

1345 Syntectonic Influence on Late Devonian Deposition in the Vicinity of the Cincinnati Arch, Kentucky. *James D. Pollock,* Kentucky Center for Energy Research Laboratory, and Roy C. Kepferle, Eastern Kentucky University.

1400 A Statistical Note on Power Analysis as Applied to Hypothesis Testing Among Selected Petrographic Point-Count Data. *Alan D. Smith,* Gary L. Kuhnhenn, Eastern Kentucky University.

1415 First Occurrence of Ordovician Eurypterids in Kentucky. William B. Beasy III, Oldham County School System. Sponsored by Anne V. Noland.

1430 Dimensional Analysis of Coal Pillars: An Application of Coat-Sensitive Mine Planning Principles to a Southeastern Kentucky Mine. Alan D. Smith, Eastern Kentucky University.

1445 Election of Sectional Officers.

1500 Coffee Break.

1530 Plenary Session

Saturday, November 10, 1984

0900 Coffee Break

0915 Annual Business Meeting

PHYSICS SECTION

Joel Gwinn, Chairman, Presiding
Raymond McNeil, Secretary
Room 104 - Bradford Hall

Friday, November 9, 1984

1500 Coffee Break.

1530 Plenary Session.

Saturday, November 10, 1984

0800 Will Our Atmosphere Survive the Industrial Revolution? *James O. Manning* (sponsored by Bernard Kern), University of Kentucky.

0815 Vibrating Reed Measurements in One-Dimensional Conductors. *William Roark* (sponsored by Bernard Kern), University of Kentucky.

0830 Design of an Apparatus for Producing a Multiple-Charged Ion Beam. *Barton Smith* (spnsored by Bernard Kern), University of Kentucky.

0845 Investigations of the Fluidyne Engine. *Debbie Teisl* (sponsored by Herbert Leopold), Notre Dame Academy.

0900 Al(P,P$^1\delta$) Calibration for In-Beam Gamma-Ray Experiments. *C. E. Laird*, Eastern Kentucky University.

0915 Annual Business Meeting.

1030 A Visit into the Past - Some Views of the History of Science. *Norman Hunter*, Western Kentucky University. (Joint Session with Chemistry Section - Little Theater - Bradford Hall)

1115 Increasing Communication between High School and College Teachers of Chemistry and Physics. *Panel Discussion.* (Joint Session with Chemistry Section - Little Theater - Bradford Hall)

1200 Lunch

1300 It's a Wonderfully Disordered World. *Shiyu Wu*, University of Louisville.

1340 Computer-Assisted Solutions of the Krishnan-Lonsdale Equations for Magnetic Anisotropy. *Michael Eismann* (sponsored by Sr. Mary Eleanor Fox), Thomas More College.

1355 Measuring the Lifetime of a Metastable State in an Optical Material. *Don J. Schertler* (sponsored by Jack Wells), Thomas More College.

1410 A Simple Electrostatic Voltage Generator for the Student Laboratory. *Bernard D. Kern*, University of Kentucky.

1425 Computer Programming in College Physics. *Hai Van Nguyen* and Les D. Burton, Jefferson Community College.

1440 Coffee Break.

1445 Data-Analysis and Tutorial Microcomputer Programs for an Undergraduate Nuclear Physics Course. *Russell M. Brengelman*, Morehead State University.

1500 Progress on the Design of a New Introductory High School Physics Course. *Lester Evans*, Tates Creek Senior High School.

1515 The Physics Teacher - Certification Program at Morehead State University in the Summer of 1983. *Russell M. Brengelman*, Charles J. Whidden, and John C. Philley, Morehead State University.

1530 Physics Section Business Meeting.

PHYSIOLOGY, BIOPHYSICS, BIOCHEMISTRY AND PHARMACOLOGY SECTION

Raymond E. Richmond, Chairman
John Calkins, Secretary Presiding

Friday, November 9, 1984

Room 314 - Hathaway Hall

1300-1500 Workshop: Integrative Study in Physiology and Medicine. Joseph Engelberg, University of Kentucky

Session I - Room 318 - Hathaway Hall

Friday, November 9, 1984

1300 Glycuronidation of 4' -chloro-4-biphenylol, a primary polycholorinated biphenyl metabolite. *Robert F. Volp*, Murray State University.

1315 Amino Acid Incorporation in Pentobarbital-Treated Rat Spleen and Leydig Cells. *Russell Crabtree*, Sponsored by Gertrude Ridgel. Kentucky State University.

1330 Electrophoretic Separation of Proteins in Pentobarbital-Treated Rat Spleen and Leydig Cells. *Linda Winkle*, Kentucky State University.

1400 Monoclonal Antibodies to Human Adenosine Deaminase. *Anne Philips*, University of Kentucky.

1415 Altered Oligosacchorides - Lipid Assembly in Insulin - Deprived 3T3 LI Adipocytes. *Palmer Orlandi*, University of Kentucky.

1430 An Evaluation of Control Tissue in Glycosaminoglycan Histochemistry. *Bradley T. Bryan* and Charles E. Kupchella, Murray State University.

1445 Skin Glycosaminoglycan Changes Associated with Diet-Induced Hypothyroidism in the Rat. *Darrell Johnson* and Charles E. Kupchella, Murray State University.

1500 Coffee break.

1530 Plenary Session.

Session II
Room 318 - Hathaway Hall

Saturday, November 10, 1984

0800 Action Spectra and Quantum Yields for Killing of UV Irradiated *Tetrahymena pyriformis*, *John Calkins*, University of Kentucky.

0815 Use of Aldehyde Dehydrogenase Histochemistry in the Detection of Chemically induced Mouse Liver Tumors. *Raymond E. Richmond*, Northern Kentucky University.

0830 Comutagenicity of Complex Mixtures and Non-Ionizing Radiation, *Christopher P. Selby*, John Calkins and Harry G. Enoch, University of Kentucky.

0845 The UV-C and UV-B Action Spectra for Killing the Algae *Chlamydomonas* and Its Implication for Solar UV-B Action. *Cindy I. Keller* and John Calkins, University of Kentucky.

0900 Election of Sectional Officers

0915 Annual Business Meeting.

1030 Dyes and Dye Mixtures Useful for Generation of UV in a Flashlamp Driven Tunable Dye Laser. *John Wheeler* and John Calkins, University of Kentucky.

1045 Comparisons Between Canavanine -Adapted and Canavanine Non-adapted Seed Predators. *John A. Bleiler*, Gerald A. Rosenthal and Daniel H. Janzen, University of Kentucky.

1100 Skeletal Evidence for Aortic Aneurysms in Three Ancient Indian Populations. *Elizabeth Finkenstaedt*, University of Kentucky.

1115 Caffeine, Exercise, Body Weight and Heart Rate in Rats. *Brent C. White*, Ann Sisto and Amy Boulden, Centre College.

1130 Biological Effects of the Nonprotein Amino Acid, L-Canavanine in the Rat. *Deborah A. Thomas* and Gerald A. Rosenthal, University of Kentucky.

1145 Water Content of the Rat Cremaster Muscle - Effect of Bradykinin. *Jamie S. Young* and Frederick N. Miller, University of Louisville.

1200 Control of Kidney Microcirculation. David L. Wiegman, University of Louisville.

1215 Effects of Hormonal Substances on Rats. *Glen Revan* and Edwin A. Hess, Eastern Kentucky University

1230 Effect of Altered Calcium Concentration on the In Vivo Microvascular Response in the Spontaneously and Renovasculr Hypertensive Rat. *Jessica Dowe* and Irving Joshua, University of Louisville.

SESSION III
Raymond E. Richmond, Chairman, Presiding
Room 320 - Hathaway Hall

1030 Metabolism and Transport of Canavanine in Jackbean *Canavalia ensiformis*. *Timothy P. Rudd* and Gerald A. Rosenthal, University of Kentucky.

1045 Localization of Tobacco Vein Mottling Virus Helper Component Gene by Hybrid Arrest Translation. *Gary Hellman*, University of Kentucky.

1100 A Protein is Covalently Linked to the S' -Terminus of Tobacco Vein Mottling Virus RNA. *Muhammed Shababuddin*, University of Kentucky.

1115 Biochemically-based Studies of L-canavanine Toxicity and Detoxification in *Heliothis virescens* F. Lepidoptera. *Milan A. Berge* and Gerald A. Rosenthal, University of Kentucky.

1130 Separation of Dansyl Hydrazine Denaturized Oligosaccharides by Liquid Chromatography. *Steven A. Hull*, University of Kentucky.

1145 The Effect of Toxic Fescue on the Reproductive Potential in Laboratory Rats. D. Varney, S. L. Jones. *M. Ndefru*, Eastern Kentucky University and M. L. Siegel, P. Zaves, J. Jackson, University of Kentucky.

PSYCHOLOGY SECTION

Terry R. Barrett, Chairperson, Presiding
Virginia P. Falkenberg, Secretary
Room 312 - Hathaway Hall

Friday, November 9, 1984

1300 Stress-Related Physiological Disorders Among Families of Patients Afflicted with Alzheimer's Disease. Linda Hutchcraft Smith, Murray State University. Sponsored by Terry R. Barrett.

1315 The Relationship Between Hand and Foot Thermal Biofeedback. *Jack G. Thompson* and Christopher J. Duff, Centre College.

1330 Frequency Effects for Identifying Rule-Governed Stimuli: Evidence for Dual Codes. *Barney Beins* and Pam Auciello, Thomas More College.

1345 Enhanced Memory for Rule-Generated Letter Strings with Delayed Testing. *Barney Beins* and Karen Lenhoff, Thomas More College.

1400 Children's Use of Substitution. Sandra J. Kearns and *Virginia P. Falkenberg*, Eastern Kentucky University.

1415 Recall and Recognition Memory of Supra- and Subliminal Stimuli. *Annette Rogers* and Jack G. Thompson, Centre College.

1430 Saliency of Handedness in Self Concept. Sandra J. Gibson, Murray State University. Sponsored by Terry R. Barnett.

1445 The Effect(s) of Music on Anxiety and Performance. Allen W. Pool, Murray State University. Sponsored by Terry R. Barrett.

1500 Coffee Break.

1530 Plenary Session.

Saturday, November 10, 1984

0800 Educational Effects on Helping Behavior. Denise Tolle, Murray State University. Sponsored by Terry R. Barrett.

0815 Nontraditional Students in the Two-Year College. Alan D. Smith, Eastern Kentucky University.

0830 The Effects of Candidate Image on the 1984 Presidential Debates. Stanley S. Bone, Murray State University. Sponsored by Terry R. Barrett.

0845 Career Choice in Relation to Job Satisfaction. Tami Canter, Murray State University. Spnsored by Terry R. Barrett.

0900 Coffee Break

0915 Annual Business Meeting

1030 Spatially Depicted Student Flow Models for a Regional State University. Alan D. Smith, Eastern Kentucky University.

1045 The Existence and Origin of Personal Name Sterotypes. Deborah R. Stairs, Murray State University. Sponsored by Terry R. Barrett.

1100 Athletes' Perceptions of the Effects of Athletic Involvement on Academic Achievement. *Richard Brooks* and Virginia P. Falkenberg, Eastern Kentucky University.

1115 Women in Politics: Some Historical and Cultural Aspects of Voting Patterns. Peggy A. Smith, The University of Akron, and *Alan D. Smith*, Eastern Kentucky University.

1130 Differences Between 1-Career and 2-Career Families in the Influence of Sex of Child and Parent on Parental Reactions to Hypothetical Parent-Child Situations. Jacqueline S. McMillan, Eastern Kentucky University. Sponsored by Virginia P. Falkenberg.

1145 Attitudes of College Students Toward Marriage. Keena Peek, Murray State University. Sponsored by Terry R. Barrett.

1200 The Adjustment of Males to Divorce. Thomas L. Montgomery, Murray State University. Sponsored by Terry R. Barrett.

1215 Attitudes and Patterns of Interracial Dating Among Blacks and Whites. Damar Rains, Murray State University. Sponsored by Terry R. Barrett.

1230 Election of Sectional Officer.

Science Education Section

Janice Fish, Chair, Presiding
Don Birdd, Secretary
Room 226 - Hathaway Hall

Friday, November 9, 1984

1500 Coffee Break
1530 Plenary Session.

Saturday, November 10, 1984

0800 Hancock Biological Station as a Resource for Science Education. Charles Kupchella, Murray State University.

0815 Intellectual Survival in Science Teaching. Herb Leopold. Wester Kentucky University.

0830 Progress report on the Development of an Introductory Physics Course. Lester Evans. Fayette County Public Schools. (Don Birdd, Sponsor).

0845 Re-trenching Pre- and Inservice Teachers into Various Areas of the Natural Sciences. Randy Falls and John Philley. Morehead State University.

0900 Coffee Break

0915 Annual Business Meeting

1030 Teacher Perceptions of Mainstreaming in Inquiry-Oriented Elementary Science. Ron Atwood. University of Kentucky.

1045 Do Something WILD — An Overview of Project WILD for Science/Environmental Educators. Ann Seppenfield. Kentucky Department of Education. (Don Birdd, Sponsor).

1100 Creative Potential and Science Career Preference of Participating Students in the Kentucky Governor's Scholars Program. Don Birdd. Eastern Kentucky University.

1115 Election of Sectional Officers

1130 Teaching to Improve Middle School Science. Tim Tassie. Kentucky Educational Television. (Don Birdd, Sponsor).

1145 The Design and Construction of an Economical Column Gel Electrophoresis Chamber. David R. Hartman. Western Kentucky University.

1200 Profile of Kentucky Science Teachers. J. Truman Stevens and Frank Howard. University of Kentucky and Kentucky Department of Education.

1215 Marine Service — A Field Experience for Undergraduate Students. Ed Story. Maysville Community College. (Don Birdd, Sponsor).

1230 Dimensions of Wilderness Anxiety of Junior High School Students. Charles T. Crume and Gary D. Ellis. Western Kentucky University.

1245 A Guide to Preparing Research Reports for Science Projects (Grades 4-12). Janice Fish. Jefferson County Public Schools.

Sociology Section

Reid Luhman, Co-Chairman, Presiding
Craig Taylor, Co-Chairman
Room 320 - Hathaway Hall

Friday, November 9, 1984

1300 K.A.S. vs. A.S.K.: Science vs. Humanism? Thomas P. Dunn

1315 Undergraduate Recruitment of Sociology Major. James S. Wittman, Jr. Western Kentucky University

1330 Alleged Mediterranean Writings in Ancient Kentucky, Tennessee, and Georgia: What Do We Do With Them? James Murray Walker, Eastern Kentucky.

1345 Social Research on Poverty: Is the Classification Paradigm Shifting? Phyll Esh, Eastern Kentucky University.

1400 The Socialization Chapter in 1984. Craig H. Taylor, Western Kentucky University.

1415 The Soical Aspects of Hypertension. S. Brent Tuthill

1430 Unraveling Class Interests. Steve Gilham, University of Missouri, Kansas City.

1445 Is It Growing and Who Cares? A Study of the Growth of the Underground Economy and Its Sigificance. Leo Dyehouse, Eastern Kentucky University.

1500 The Professional Thief: In Defense of Edwin Sutherland. John Curra and Steve Savage, Eastern Kentucky University.

1515 Student/Faculty Perceptions of International Students at Eastern Kentucky University. Allen Singleton, Eastern Kentucky University.

1530 Plenary Session

Saturday, November 10, 1984

0900 Coffee Break

0915 Annual Business Meeting

ZOOLOGY AND ENTOMOLOGY

Douglas L. Dahlman, Chairperson, Presiding
Thomas C. Rambo, Secretary
Room 103 - Hathaway Hall

Friday, November 9, 1984

1300 Oviposition and feeding behavior of the maize weevil, *Sitophilus zeamais* Motsch.

as affected by sex ratio and corn variety. *Philip W. Tipping*, J. G. Rodriguez, and C. G. Poneleit, University of Kentucky.

1315 Photographic analysis of flower color: Its use in the study of pollinator behavior. W. Blaine Early, III, Cumberland College.

1330 Singing behavior of female Northern Cardinals. Gary Ritchison, Eastern Kentucky University.

1345 Observations of Turkey Vulture nesting behavior. William L. Lynch, Eastern Kentucky University.

1400 Interpopulational variation in growth responses of small-mouthed salamanders: The role of genotype versus environment. James W. Petranka, University of Kentucky.

1430 Experimental infections of whitefish, *Coregonus clupeaformis* (Mitchill), with plerocercoids of *Triaenophorus crassus* Forel. Ron Rosen, Union College.

1445 Election of Sectional Officers

1500 Coffee Break

1530 Plenary Session

Thomas C. Rambo, Presiding

Saturday, November 10, 1984

0800 The status of heron rookeries in Kentucky. *Sherri A. Evans*, and John R. MacGregor, Kentucky Department of Fish and Wildlife Resources.

0815 Least Tern *(Sterna antillarum)* survey of the Mississippi River adjacent to Kentucky: Results and management considerations. *Brian D. Anderson*, Kentucky Nature Preserves Commission, and Sherri A. Evans, Kentucky Department of Fish and Wildlife Resources.

0830 The gray treefrogs *(Hyla versicolor* complex) and map turtles *(Graptemys)* of Kentucky. *John R. MacGregor* and Douglas E. Stephens, Kentucky Department of Fish and Wildlife Resources.

0900 Coffee Break

0915 Annual Business Meeting

1030 Effect of salinity on oxygen consumption of *Cyprinodon variegatus*. *Michael Barton* and A. Christine Barton, Centre College.

1045 Fish as indicators of ecological integrity. Lewis Giles Miller, Kentucky Division of Water.

1100 Agonistic behavior in the Northern Fence Lizard, *Sceloporus undulatus hyacinthinus*. Jamie Monroe and *Blaine R. Ferrell*. Western Kentucky University.

1115 The freshwater mussels (Bivalvia: Unionidae) of Buck Creek, Upper Cumberland River System, Kentucky. *Robert S. Butler* and Guenter A. Schuster, Eastern Kentucky University.

1130 Population overlap of aquatic isopods *Caecidotea forbesi* and *Lirceus fontinalis* in a woodland seep and run in north Warren County. Rudolph Prins, Western Kentucky University.

1145 Life history and Ecology of *Eccoptura xanthenes* (Newman) (Plecoptera: Perlidae) from a small Kentucky stream. Beverly L. Allen, Sue Bennett College, and *Conald C. Tarter*, Marshall University.

1200 Effects of variation in atmospheric oxygen levels on hatching in *Drosophila melanogaster*. *Julia A. Clark*, Gerrit Kloek, and Diane Mason, Kentucky State University.

1215 Insect feeding deterrents in endophyte-infected tall fescue. Douglas L. Dahlman, University of Kentucky.

1230 Foraging frequencies of various bees (Superfamily Apoidea) to UV reflectant and absorbent patterns in flowers. Rozenna B. Carr, University of Louisville.

1245 The role of feeding regimens on the growth of neonate broad-banded water snakes, *Nerodia fasciata confluens*, and possible effects on reproduction. Roy Scudder, Millersville University.

1300 Energy Consumption and Food Utilization in the Indian Meal Moth. *Paul Hockensmith*, Kentucky State University, Terry Devine and J. G. Rodriguez, University of Kentucky.

Abstracts of Some Papers Presented at the Annual Meeting

BOTANY AND MICROBIOLOGY

Preservation of leaves and flowers by microwave in the plant biology laboratory. CHARLES D. HOWES, Biological Sciences, Ashland Community College, University of Kentucky, Ashland, KY 41101.

Plant materials with moderately thin tissues such as leaves and flowers may be preserved rapidly by utilizing microwave radiation to dehydrate them. In a single laboratory period 20 students can prepare two or three items using a single microwave oven. Settings of low to medium are used in the preservation steps. Specimens are placed in an old book with absorbent pages, weighted, and cooked for 5 minutes. Dampness is removed by arranging the items in a stack of dinner plates and drying for 3-5 minutes. Samples are loosened, given a final drying of 1-3 minutes on open plates, and mounted.

Geographic and vegetational influences on sexual reproduction in *Maianthemum canadense* Desf. (Liliaceae). WILLIAMS, CYNTHIA L. Division of Science and Mathematics, Centre College, Danville, KY 40422.

The existence of a threshold size for flowering in this species leads to a prediction of lowered flowering rates in stressful habitats; this prediction is not borne out by statewide reproductive patterns in Wisconsin. Southern populations, at the edge of the species range, expend greater effort on flowering. Their ramets flower at younger ages. These populations are not more efficient at producing seeds than the northern populations; in fact, more sexual recruitment takes place in northern populations. Geographic and community-type patterns in flowering, fruit production, and seed production give some insight into factors limiting sexual reproduction.

ENGINEERING

Dimensional analysis of coal pillars: An application of cost-sensitive mine planning principles to a southeastern Kentucky mine. ALAN D. SMITH, Coal Mining Administration, College of Business, Eastern Kentucky University, Richmond, KY 40475.

Cost-sensitive mine planning involves spatial projection of geological and economical conditions having the greatest impact on cost and coal quality for a particular site. Through comparison of actual, maximum safety, and recommended pillar dimensions and associated factors of safety, based on a number of theories, of a small coal mine near Leatherwood, Kentucky, the traditional 40-foot pillars appear too large. The alternative system of room-and-pillar mining with 34-foot pillars and conservative 20-foot entries would allow for five entries to be developed in the same area of coal, which would result in an increase of 320 tons of raw coal per advance.

Three-dimensional modeling and trend-surface analysis of selected borehole information for geotechnical applications. ALAN D. SMITH,* Coal Mining Administration, College of Business, Eastern Kentucky University, Richmond, KY 40475, and DAVID H. TIMMERMAN, Department of Civil Engineering, University of Akron, Akron, OH 44325.

Three-dimensional computer-modeling and statistical significance testing were performed on selected borehole data derived from engineering reports and loggings from construction sites on an urban university's campus. The results indicated that the elevation of bedrock surface was best described by the third-order trend-surface, bedrock depth by the second-order, and elevation of water level after completion of the borehole by the third-order surface. Although the models vary in effectiveness, they can provide insights in predicting and eventually extending the placement of exploratory boreholes in the future.

GEOLOGY

Applications of computer graphics to undergraduate education in the earth sciences. ALAN D. SMITH, Coal Mining Administration, College of Business, Eastern Kentucky University, Richmond, KY 40475.

There are large numbers of commercially available computergraphics hardware and software packages in today's market. Many applications can be directed towards classroom activities in the earth sciences. A working database utilizing geotechnical engineering and geological parameters, used in conjunction with undergraduate courses in mining geology and mine systems design, illustrated the potential capabilities of appropriate computer software (SYMAP, PLOTALL, and QUSMO) with existing output facilities (electrostatic plotter, line-printer terminal, and incremental drum plotter) to produce computer graphics. Computer graphics are an essential tool in helping students conceptualize and visualize complex geological interactions and in preparing them for the applied earth-science disciplines.

A statistical note on power analysis as applied to hypothesis testing among selected petrographic point-count data. ALAN D. SMITH,* Coal Mining Ad-

ministration, College of Business, and GARY L. KUHNHENN, Department of Geology, Eastern Kentucky University, Richmond, KY 40475.

In the power-analysis process are four parameters than can be manipulated: alpha, sample size, effect size, and degrees of freedom. Usually the effect and alpha are set, and sample size and degrees of freedom are directly related. Hence, the greatest advantage of power analysis should be to determine the sample size before a statistical test is performed. Power was applied to a recent petrographic study of the Strodes Creek Member of the Lexington Limestone of north-central Kentucky. Powerful statistical tests ($P = 0.95$) were determined to add internal validity to the microfacies delineated.

PHYSICS

Data-analysis and tutorial microcomputer programs for an undergraduate nuclear physics course. RUSSELL M. BRENGELMAN, Department of Physical Sciences, Morehead State University, Morehead, KY 40351.

Four BASIC programs have been developed on the subject of radioactive decay for the ATARI 800. The first program separates mixed half-life laboratory-counting data for Ag-108 and Ag-110. The program makes resolving time and background data corrections. The two component half-lives are then computed using the method of weighted least squares. Semi-log graphs of the separated components are displayed. A second program uses random numbers to simulate silver-counting data. The third and fourth programs are three-component nuclear-decay-chain demonstration programs.

The physics treacher certification program at Morehead State University, Kentucky, during summer 1983. CHARLES J. WHIDDEN,* JOHN C. PHILLEY, and RUSSELL M. BRENGELMAN, Department of Physical Sciences, Morehead State University, Morehead, KY 40351.

A certification program in physics was offered at Morehead State University during summer 1983, primarily for those teachers already certified in some other area of science. Students could earn up to 15 semester hours of credit, which, when added to the 8 or 10 hours earned previously in an introductory 2-semester course, would meet certification requirements. Courses offered were in optics, astronomy, nuclear science, and secondary physics teaching. Four in-service teachers completed the program and received certification, and four other prospective teachers started work on certification during this session.

PHYSIOLOGY, BIOPHYSICS, AND PHARMACOLOGY

Effect of altered calcium concentration on the in vivo microvascular response in the spontaneously hypertensive rat. J.P. DOWE* and I.G. JOSHUA, Department of Physiology, University of Louisville, Louisville, KY 40223.

In vivo responses of third-order arterioles (3A) to elevations in bath calcium $[Ca^{++}]$ were determined in the spontaneously hypertensive rat (SHR; 12 wk) and the age-matched Wistar Kyoto control (WKY). The cremaster muscle with intact circulation and innervation was suspended in a modified Krebs solution (34.5°C; pH 7.4); $CaCl_2$ (0.0 to 10.2 mM) was sequentially added. The re-introduction of calcium to the bath caused a concentration-dependent constriction in small arterioles. The magnitude of constriction in 3A arterioles appears to be greater in the SHR at bath calcium concentrations of 2.55 mM and above. The ED_{50} value for SHR (1.9 ± .3) had a trend to be lower compared to WKY (2.9 ± .9). The slope of the calcium dose response curve for SHR (.25 ± .02) was steeper than that of the WKY (.11 ± .04). These data suggest a greater entry of extracellular calcium into small arterioles of the SHR.

Aortic aneurysms in the Shawnee. ELIZABETH FINKENSTAEDT, Department of Art, University of Kentucky, Lexington, KY 40506.

Sternal perforations arising from non-syphilitic aneurysms of the ascending aorta in individuals from archaeological sites are examined with respect to etiology. The differential diagnosis includes infective disorders and morphological anomalies. Disease entities considered include bacterial endocarditis, coarctation of the aorta, osteomyelitis, and tuberculosis. The small size of the lesions and the absence of signs of infectious disease affecting bone suggest that congenital predisposition to thinning of the aortic wall may be implicated. At two adjacent sites presumed on archaeological grounds to be Shawnee, the statistical prevalence of sternal lesions expresses a phenotypical feature persisting over time.

Glucuronidation of 4'-cholor-4-biphenylol, a primary polychlorinated biphenyl metabolite. R.F. VOLP, Department of Chemistry, Murray State University, Murray, KY 42071.

Experiments were performed to study the glucuronide metabolites of 4,4'-dichloro-biphenyl (DCB), a representative polychlorinated biphenyl metabolite. DCB incubated with monkey liver microsomes, NADPH, and UDPGA produces a mixture of primary and secondary metabolites. The secondary metabolites are largely glucuronides of the primary metabolites. Since several primary metabolites are produced, definitive studies of glucuronidation require incubations with individual primary metabolites. One such metabolite, 4'-chloro-

4-biphenylol (MCBol) was incubated with rat liver microsomes and UDPGA. MCBol concentration decreased with time, MCBol was extracted, and the remaining aqueous phase gave, after beta-glucuronidase treatment, a chromatographic fraction coeluting with MCBol, indicating that the compound in the incubation mixture was the glucuronide of MCBol.

Control of kidney microcirculation. D.L. WIEGMAN, Department of Physiology, University of Louisville, Louisville, KY 40292.

In vivo observations of the kidney microcirculation were made using the hydronephrotic rat kidney preparation. For this preparation, the kidney is split with a cautery along its greater curvature and is spread out as a thin tissue in a bath. The kidney is transilluminated and image of the vasculature is observed via television microscopy. I quantitated the effects of saralasin (angiotensin antagonist) applied locally in the tissue bath on afferent and efferent arteriole diameters and on glomerular blood flow. Saralasin produced a significant increase in efferent arteriole diameter (21 ± 4%) and blood flow (19 ± 4%) and had no effect on afferent arteriole diameter. These data suggest that angiotensin is involved in the control of total kidney blood flow and in the control of filtration fraction.

Water content of the rat cremaster muscle: effect of bradykinin. JAMIE S. YOUNG* and FREDERICK N. MILLER, Department of Physiology and Biophysics, University of Louisville, Louisville, KY 40292.

The rat cremaster muscle was studied to determine if this preparation was artificially edematous and if a mediator of edema, bradykinin, could alter the water content of this tissue. The cremaster with intact innervation and circulation was equilibrated in Kreb's solution with or without bradykinin or was immediately removed from the animal. Another skeletal muscle, the gastrocnemius, was used for comparison to the cremaster. no significant difference in percent water content was found between the groups of cremaster muscles. However this muscle contained a greater percentage of water than the gastrocnemius and this was not due to equilibration in the Krebs solution.

SCIENCE EDUCATION

Creativity and science career preference of students enrolled in the Kentucky Governor's Scholars Program, 1984. DONALD L. BIRDD, Kentucky Governor's Scholars Program and Department of Science Education, Eastern Kentucky University, Richmond, KY 40475.

Students invited to participate in Kentucky's summer program for rising seniors, designed to promote higher level thinking and to expand creative potential, exhibit many of those characteristics displayed by scientists/technologists. This part of the study involved 185 students (35% of the total population and was equally balanced between females and males) who indicated a science/technology career preference. As a pre-posttest design, students completed the *Torrance Test of Creative Thinking—Figural* and showed significant gains beyond the .001 level (Chi square analysis) in the following categories: fluency, originality, elaboration, and resistance to closure. These students represented 75 counties statewide.

Re-trenching pre- and in-service teachers into the various areas of the natural sciences. RANDY FALLS and JOHN C. PHILLEY,* Department of Physical Sciences, Morehead State University, Morehead, KY 40352.

Data from the Kentucky Department of Education for 1971-81 show that few certified teachers for sciences and mathematics were produced by colleges in the state. A national study in 1982 indicated that Kentucky was experiencing teacher shortages in chemistry, physics, earth science, and mathematics. Responding to the science-and-math loan-incentive program initiated by the Kentucky Department of Education, Morehead State University provided summer programs in 1983 and 1984 in physics, chemistry, and mathematics. From August 1983 to August 1984, 23 newly certified teachers were produced: 11 in mathematics, 6 in chemistry, 5 in physics, and 1 in biology. For the 1984-85 academic year, 23 science-and-math students applied for the teacher-education program, and 17 completed or applied for the student-teaching practicum. All numbers, significantly greater than for previous years, reflect the impact of the loan program.

An economical column gel electrophoresis chamber. 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 enclosed column gel electrophoresis chamber to hold six polyacrylamide gel columns. Complex mixtures of proteins or nucleic acids can be separated in the clear plastic chamber which cost less than 20 dollars to construct. A low-cost power supply can be constructed that would put this sophisticated technique in a price range attractive to secondary schools for science fair projects.

ZOOLOGY AND ENTOMOLOGY

Effect of salinity on oxygen consumption of *Cyprinodon variegatus. MICHAEL BARTON* and A. CHRISTINE BARTON, Division of Science and Mathematics, Centre College, Danville, KY 40422.*

The effect of salinity dilution on routine metabolic rate of the sheepshead minnow, Cyprinodon *variegatus*, was studied. Populations of *C. variegatus* were sampled from several inland lakes of San Salvador Island, Bahamas. Individuals from Little Lake, a body of water that ranges from hypo- to hyper-saline throughout the year, were acclimated for 5 days at 35 ppt after which measurements of oxygen consumption were obtained both at acclimation salinity and at 10 ppt. Analysis of the linear regression of weight upon routine oxygen comsumption revealed a significant increase in oxygen consumption when exposed to dilute salinities. This study suggests that short-term metabolic adjustments are necessary for this euryhaline species when exposed to dilute environments.

Effects of variation in atmospheric oxygen levels on hatching in *Drosophila melangaster*. JULIA CLARK,* DIANE MASON, and GERRIT KLOEK, Area of Biology, Kentucky State University, Frankfort, KY 40601.

Atmospheric oxygen levels affect hatching in *Drosphila* eggs. Below 27°C, increased oxygen concentrations accelerate development and above 27°C increased oxygen levels delay it. Low oxygen levels delay development at all temperatures. Other studies have shown that increased oxygen levels delay hatching and lower oxygen levels stimulate hatching. A contributing factor to this response in *Drosophila* could be that this species is opportunistic and development occurs as rapidly as possible. As such, increased oxygen would speed metabolic rates and reduced oxygen would retard these rates and thus affect development time. Above 27°C heat stress may be a complicating factor.

NEWS AND COMMENTS

The 71st annual meeting of the Kentucky of Science will be held at the Morehead State University, Morehead, in November, 1985. Additional information will be forthcoming in the *Newsletter*.

DEATH OF A GOOD FRIEND

Dr. Robert A. Kuehne died of cancer on 18 December 1984 at the University of Kentucky Medical Center. He was 57 years old. I knew Bob Kuehne in good times and in bad, and always as a fine, caring, and intelligent gentleman, as an incisive thinker, and as a lover of good students; I shall miss him sorely. I first met Bob high upon the sun-blasted rocks of the Edwards Plateau, and we later roiled some of the dust on the Llano Estacado. We came full circle, both ending up in Kentucky. Sometimes the coal dust was so thick that we could not find darters in the streams, but we found something. Sometimes, though, we enjoyed beauty together—at Red River Gorge, at the Narrows of the Rockcastle, in the wine shops of Lexington. The bad times were never all that bad, Bob, but the good times, the good times were wonderful.—Branley Allan Branson

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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.

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The sequence of material in feature-length manuscripts should be: title page, abstract, 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 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, Acknowledgements, and Literature Cited. All tables and figures, as well as all literature cited, must be referred to in the text.

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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 in informative of its contents.

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Shell Polymorphism in Kentucky Colonies of the Exotic Snail *Cepaea nemoralis* (Linnaeus) (Mollusca:Gastropoda)

BRANLEY ALLAN BRANSON, Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

Six colonies of *Cepaea nemoralis* from Kentucky localities were investigated for polymorphism in basic shell color and banding. Banded shells predominated at all colonies. Fusion of bands was common, but fully banded shells were rare. Yellow and brown morphs were nearly equally distributed (46% and 49%, respectively).

INTRODUCTION

Blakeslee (1) and Reed (2) both indicated that *Cepaea nemoralis* occurred in Kentucky without presenting exact localities, and Branson and Batch (3) reported a colony of the snail from Lexington, Fayette County. This highly polymorphic, western and northern European snail appears to have been introduced into North America around 1857 (4), being spread principally by horticultural and agricultural products to a number of secondary loci. *Cepaea* has been polymorphic for shell banding patterns since at least Neolithic times (5).

Helicid snails in general (6) express five-banded conditions and modifications thereof, the main variations being completely unbanded shells, middle-banded shells, five-banded ones, or loss of one or more of the bands and fusion of adjacent bands without loss or modification of other bands (6). The same sort of variation is found in the mantle (the organ that secretes the shell), reddish-brown bands being grouped beneath the bands in the shell (6). Some bands may also be reduced in intensity to faint traces (8).

These features are, of course, genetically determined. The genetics of shell color and banding patterns in *C. nemoralis* are relatively well-understood (8, 9, 10, 11, 12, 13, 14). The genes that control shell color (brown, yellow, pink) and banding constitute a very tightly linked supergene; however, the gene for midbanding (00300—see below) is not a part of the supergene but assorts independently as a Mendelian dominant, being expressed only in banded phenotypes (15). Nonbanded is dominant to all banded phenotypes. At the color locus, brown is dominant over the other two, and pink is dominant to yellow.

The question of genetic drift has also been broached in *Cepaea* because of the ease with which new colonies are established. However, the mating system of *Cepaea* tends to counteract erosion by drift and also plays a profound role in determining the effective population size of the snail (16, 17, 18). *Cepaea* is hermaphroditic, individuals mate more than once, and they store sperm for long periods, and each individual may produce offspring from several matings in a given brood (16), causing departures from Mendelian ratios. Founder Effect, of course, must also be considered when investigating the polymorphism and variation in any colonizing species. For example, a colony at Lynchberg, Virginia, consisting of all yellow shells, probably resulted from a single original introduction (19).

In Europe (12), *Cepaea* has a more or less discontinuous distribution in given regions, i.e., occurs as "subpopulations" or colonies, and lives in various habitats, such as woodlots, hedgerows, tall grass, open meadows, and so forth so that there is much colony-to-colony variation in the frequency of shell color and banding patterns. Lamotte (12) and others believe that much of this variation is enhanced by restricted gene flow by way of low vagility of the snails and because of local selection pressure. Supposedly, the yellow snails tend to live in hedgerows and tall grass, the brown ones in woodlots, and banded individuals are more common in contrasting backgrounds, the unbanded ones in uniform habitats. All this was hypothesized to be under the partial control of predator-oriented protective coloration (visual selection) (10, 12), a hypothesis that was later more or less confirmed (20). Richards and Murray (19) demonstrated that the effect of vegetation in the habitat was less important than the amount of sunlight falling on the ground with reference to the occurence of snails having fused bands, the shadier habitats having higher proportions of shells with fused bnads than sunnier locations. Changes in habitats may be responsible for overall changes in the frequency of occurence of both color and banding morphs (21).

There is also considerable evidence supporting climatic selection on the banding polymorphism in *Cepaea* (22). This factor may be of great importance when the species exists on the margins of its range and where small environmental variations may be critical (23, 24), i.e., lying close to the limits of tolerance (25). Arnold (22) suggested that the reduction in banding, either by elimination of bands or by the fusion of them, was of direct adaptive value to severe climates, a contention that was apparently substantiated by Arnason and Grant (25), who found the bandless condition to be most frequent in cold, dark environments, the fused-band morph being most frequent in temperature-stable environments with occasional very cold nights.

A final factor that may affect local polymorphism in *Cepaea nemoralis* is the population architecture of the species. Of particular importance is annual survivorship and length of life. It has been estimated that about one-half of the individuals that make up most colonies of the snail die each year (26, 27, 28), although Greenwood (18) suggested that the figure may lie closed to 60%. The latter author also estimated the mean reproductive life span as about 2.39 years. Of course, fluctuations occasioned by population dynamics could cause variation in polymorphism, particularly in small colonies (however, see 18).

Thus, the purpose of this paper is to present observations on shell polymorphism in Kentucky colonies of *Cepaea nemoralis*, colonies that certainly act like ones on the margin of the species range. These colonies were investigated under the basic assumption that the Founder Effect was fully operative.

Materials And Methods

The scoring techniques of Brussard (15) and Singh (4), with slight modifications, were employed. Thus, a score of Y12345 indicates a yellow five-banded snail (Fig. 1), the bands being numbered from the suture downward; B00000 or Y00000 (Fig. 2) represents brown or yellow unbanded shells, respectively. A mid-banded snail, as shown in Figure 3, is designated according to shell color, i.e., B00300, and so forth. Shells with fused bands (Fig. 4) are designated by brackets, according to which bands are fused; for example, B12(34)5 indicates a brown shell having bands 3 and 4 fused. When bands are of reduced intensity, the bands are indicated by a semicolon, i.e., Y12;;5, and so forth.

Figure 1. A yellow, five-banded *Cepaea nemoralis*. (Photograph by A.E. Spreitzer Photography, Columbus, Ohio 43212). Scale line = 5.0 mm.

Figure 3. A brown, mid-banded *Cepaea nemoralis* (B00300). Scale line = 11.0 mm.

Figure 2. Brown (left) and yellow (right) unbanded *Cepaea nemoralis*, spire views. Scale line = 8.0 mm.

Figure 4. A yellow *Cepaea nemoralis* showing bands 4 and 5 fused. Scale line = 11.0 mm.

COLONY SITES

As will be noted, some of the localities are represented by small samples only. However, rather than "lose" the data, the specimens from these sites were included in the analysis.

Site 1. Trash dump 28.9 km NW Ludlow, Boone Bounty, Kentucky, near the Ohio River, June 1984. Collector, John MacGregor, estimated the colony to include "hundreds of individuals". N = 36.

Site 2. Near junction of Thompson Road and Old Frankfort Pike, behind slaughter house, west of Lexington, Fayette County, Kentucky, 6 July 1970. Collectors, Holly, Andrew and W. B. Barkley, estimated the colony to number in the "thousands". N = 172.

Site 3. Lawn at 407 Broadway, Frankfort, Franklin County, Kentucky, 9 October 1980. A large colony of all yellow snails. N = 7.

Site 4. Lawn on Payne Street, Lexington, Fayette County, Kentucky, 8 March 1979. Collector, R. S. Butler, estimated the colony to be "very large". N = 29.

Site 5. Lawn at 328 Aylesford Place, Lexington, Fayette County, Kentucky, 15 June 1966. Collector, Frank Howard, estimated the colony to number "in the hundreds". N = 12.

Site 6. Water treatment plant, Lexington, Fayette County, Kentucky, 18 October 1980. A very large colony. N = 7.

RESULTS

Table 1 records the banding pattern and shell color of 319 adult snails collected from the 6 Kentucky colonies at the dates indicated. Banded shells (81.19%) predominated in all the colonies, although only 60% of the shells at Station 1 were banded, and 89.3% of those at Station 4 (25/28) were without bands. Fusion of bands was relatively common (Table 1), bands 4 and 5 being those most often involved. Specimens with diluted bands (26/319) were relatively uncommon, mostly associated with brown shells (7.52%), only 2 of 319 yellow shells had diluted bands; none were observed in the few pink shells present. Bands 1 and 2 and 4 and 5 were most apt to be missing, probably because the mid-banded allele, as previously mentioned, segregates independently of the others.

Table 1. comparison of Banding Patterns in Kentucky Colonies of *Cepaea nemoralis* (see text for explanation of symbols)

Pattern	COLONIES						
	I	II	III	IV	V	VI	Σ
Y12345	3	1	0	4	0	0	8
Y123(45)	1	0	0	0	0	0	1
P123(45)	0	0	0	1	0	0	1
B(12)3(45)	0	1	0	0	0	0	1
B;;3(45)	1	0	0	0	0	0	1
B(;;)3(45)	0	1	0	0	0	0	1
B;(;;);;	0	1	0	0	0	0	1
Y02345	1	0	0	1	0	0	2
BO;;;;	0	1	0	0	0	0	1
Y023(45)	0	0	0	0	1	0	1
BO;;(;;)	0	1	0	0	0	0	1
YO(23)(45)	0	0	0	0	0	1	1
Y00345	0	3	0	0	1	2	6
B003;;	0	0	2	1	0	0	3
B00;;;	0	1	0	0	0	0	1
Y003(45)	1	3	0	0	9	2	15
B003(45)	0	9	0	0	0	0	9
B00;(;;)	0	2	0	0	0	0	2
B0;;00	0	2	0	0	0	0	2
P00300	3	5	0	5	0	0	13
Y00300	10	61	7	11	1	0	90
B00300	0	82	0	1	0	0	83
Y00;00	1	0	0	0	0	0	1
B00;00	0	8	0	0	0	0	8
B00340	0	1	0	0	0	0	1
B003;0	0	1	0	0	0	0	1
Y0030;	0	1	0	0	0	0	1
B;;300	0	1	0	0	0	0	1
B000;;	0	1	0	0	0	0	1
B(12)000	0	0	0	d1	0	0	1
P00000	1	0	0	0	0	0	1
B00000	3	34	0	1	0	0	38
Y00000	10	7	0	2	0	2	21
Σ	35	228	9	28	12	7	319

In fact, various forms of mid-banded shells predominated at all sites except for the small series secured at Station 4: P00300 (13/19) = 4.08%; Y00300 (90/319) = 28.21%; B00300 (83/319) = 26.02%; and B00;00 (8/319) = 2.51%. The next two most common banding patterns were Y003(45) (15/319 = 4.72%) and B003 (45) (9/319 = 2.82%). Colony 2 had a high frequency (82/228) of the brown mid-banded morph as well as a relatively high frequency (61/228) of yellow mid-banded.

Shells bearing all 5 of the bands, distinct, diluted, or fused, were rare in the total collection. Shells with 5 distinct bands (Fig. 1) were observed in the yellow morph only (Y12345) (2.5%): 3 at Station 1, 1 at Station 2, and 4 at Station 4. The distribution of other 5-banded shells was: B(12)3(45) (1 at Station 2); B;;3(45) (1 at Station 2); B(;;)3(45) (1 at Station 2); B;(;;);; (1 at Station 2); P123(45) (1 at Station 4).

Of the bandless morphs, Y00000 was the rarest, only 1/319 presenting this phenotype. B00000 was the most common, 11.9% (38/319), the pink bandless (21/319) was represented in 6.58% of the shells.

Within the total collection, yellow and brown morphs were nearly equally distributed (Y = 46.08%; B = 49.22%), whereas pink shells accounted for only 4.07% of the total. However, the yellow morph represented only 33.33% of the population at Station 2; 77.14% at Station 1 and 64.29% at Station 4. Station 2 was dominated by brown shells (64.48%), having only 2.19% pink ones. Pink occurred 11.43% and 21.43% of the time at stations 1 and 4, respectively.

Discussion

These results differ markedly from those reported by Singh (4) from Ontario populations and by Brussard (15) from various populations in North America, where yellow, full-banded shells predominated more often than not. Because bandlessness is dominant over banding, one might expect that morph to quickly swamp colonies once they are established (29). However, the frequency of occurence or rate of spread through populations is more associated with fitness or genotypes than with dominance-recessiveness (30). Furthermore, *Cepaea* practices obligatory panmixis, multiple matings, and sperm storage (16), all of which may strongly predispose newly established colonies to certain variability patterns. Once established, each colony may be affected simultaneously by multiple selection pressures including climatic conditions (22,32), that control morph survival and frequency of occurence (31).

The Kentucky colonies of this snail doubtless represent secondary introductions from previously founded populations in North America rather than de novo introductions from Europe. Each colony probably should be treated as a more or less unique entity as a consequence of Founder Effect and, perhaps, periodic populational cataclysms. It is highly unlikely that there is any appreciable gene flow between colonies, since this species is seldom found far from human habitations.

Brussard (15), based upon electrophoretic studies (Bray-Curtis method and principal-component analyses) is of the opinion that North American populations fall into two clearly recognizable groups, those living in the Piedmont and Valley Province of Virginia—characterized by a preponderance of yellow shells and derivable from Italy—and those found elsewhere, derivable from multiple northern

European centers of origin, often characterized by mid-banded phenotypes. Whether or not some or all of the Kentucky colonies of *Cepaea* are derivable from those in the Virginia Piedmont must be verified or dismissed upon the basis of electrophoresis. The Piedmont populations express highly polymorphic LAP-2 and PGM-2 systems, whereas the colonies derived from northern Europe are characterized by a "fixed" LAP-2^b phenotype; they may or may not be polymorphic at the PGM loci (15).

Thus, the Kentucky colonies of *Cepaea nemoralis* should be investigated by means of electrophoresis. These colonies, to quote Brussard (15), "may provide numerous opportunities for studying genotype-environment interactions without the complications of gene flow, and have the potential for providing a great deal of information about the rate of evolution in novel environments."

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Life History and Ecology of *Eccoptura xanthenes* (Newman) (Plecoptera: Perlidae) from a Small Kentucky Stream

BEVERLY L. ALLEN, Department of Biology,
Sue Bennett College, London, Kentucky 40741

DONALD C. TARTER, Department of Biological Science,
Marshall University, Huntington, West Virginia 25701

ABSTRACT

The life history and ecology of the stonefly *Eccoptura xanthenes* (Newman) was investigated in the Middle Fork of Cane Creek, Laurel County, Kentucky, between May 1983 and May 1984. Nymphs were carnivorous in their feeding habits. Generally, mayflies *(Ephemerella, Ameletus, Paraleptophlebia)* and dipterans (mostly chironomids) comprised the stable components of the diet during all seasons. Caddisflies *(Hydropsyche)*, stoneflies *(Hastaperla, Leuctra)* and beetles supplemented the diet throughout the year. The highest percentage of empty foreguts (71.7%) occurred in summer. Length-frequency histograms indicate that the nymphal development requires 2 years. According to mean head width values, the greatest growth (35%) of the nymphal population occurred from February (2.47 mm) to March (3.33 mm). The chi-square test was applied to 178 nymphs and a significant deviation from the 1:1 sex ratio (0.05 confidence level) was observed. The emergence period was approximately 4½ weeks (11 June-14 July). Direct egg counts ranged from 110 to 233 per female; the mean was 170. The eggs were oval and measured 0.34 by 0.41 mm.

INTRODUCTION

Stoneflies are integral components of lotic food webs and indicators of water quality. Consequently, ecological studies of each species are important to the understanding of the stream ecosystem. Several investigators, including Smith (1), Needham and Claassen (2), Frison (3,4), Minshall and Minshall (5), Tarter and Krumholz (6), Harper (7), Vaught and Stewart (8), and Kondratieff and Despins (9), have reported ecological studies of North American stoneflies. No detailed paper has been published on the life history and ecology of *Eccoptura xanthenes* (Newman). Under laboratory conditions, Doherty and Hummon (10), reported that acid mine water did not consistently alter the respiratory rates of *E. xanthenes*. The objective of this investigation was to describe the life history and ecology of *E. xanthenes* in Middle Fork of Cane Creek, a second order stream in Laurel County, Kentucky.

TAXONOMY AND DISTRIBUTION

Eccoptera xanthenes was originally described by Newman (11) as *Perla xanthenes*. The male and female cotypes are from Georgia. Klapalek (12) described the genus *Eccoptura* and changed *Perla xanthenes* to *E. xanthenes*. Needham and Claassen (13) assigned *Acroneuria xanthenes* to replace the former designation of *E. xanthenes*. Illies (14) elevated the subgenus *Eccoptura* to the generic level.

Eccoptura is a monotypic genus from the Appalachian region of eastern North America. The recorded distribution of *E. xanthenes* is from Alabama, Connecticut, Delaware, Florida, Georgia, Kentucky, Maryland, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia and West Virigina (14, 15, 16, 17, 18, 19, 20). Tarter et al. (21) recorded the stonefly from Breathitt, Whitley and Wolfe counties in Kentucky. *Eccoptura* has succeeded in exploiting small, spring-fed streams (17).

MATERIALS AND METHODS

Middle Fork of Cane Creek, a tributary of the Rockcastle River, lies in the Daniel Boone National Forest in the south-western portion of Laurel County, Kentucky. The tributary is 9.4 km long. It is 19.3 km west of the city of London, off KSR 192, and flows under Forest Service Road 121, 16 km from the 192 turnoff.

The sampling site is a riffle 112 m upstream from the culvert where the water flows under the road. The riffle area averaged 10.2 by 2.1 m; the depth averaged 9.5 cm. The water shed is the Cane Creek management area and is undisturbed except for management practices. There is no domestic or commercial use of the area.

The substrate is mostly limestone rock with silt and plant litter accummulation in the pool areas. The soil association for the area is Whitley-Latham-Lily (22); gently sloping to steep, moderately deep to deep soil with loamy or clay-like subsoils on ridge tops and side slopes. The riparian vegetation was dominated by hemlock, *Tsuga canadensis* (L.) Carr, and rhododendron, *Rhododendron maximum* (L.)

This study was initiated in May 1983 and completed in May 1984. Collections of nymphs were made on a monthly basis during the study period. Due to a lack of specimens in certain months, the data will be presented on a seasonal basis.

Water quality tests were performed at the collection site with a Hach chemical kit, Model AL-36B, and pH was measured colorimetrically. Dissolved oxygen and carbon dioxide were measured and recorded in mg/l. Water temperature was measured with a mercury thermometer.

Nymphs were dislodged by kicking the substrate and collected in a long handled dredge with a mesh net (60 threads/inch). They were preserved in 70% ethanol for measurements, gut analysis and sex determination. Body length (exclusive of antennae and cerci) was measured to the nearest 0.1 mm using a Vernier calipre. Size classes were determined by length-frequency histograms arranged in 3 mm length groups of 183 nymphs. Head width, measured to the nearest 0.1 mm with an ocular micrometer, was used as an index of growth. Percent growth from one month to the next was calculated using the mean head width measurement. Monthly differences in nymphal head widths were used to calculate the mean, range and two standard errors of the mean (23).

One hundred and 22 nymphal foreguts (usually 10 per month) were examined to determine seasonal food preferences. The head was removed with microdissecting scissors and the abdomen split ventrally to remove the foregut. Contents of the foregut were carefully removed for identification with a Bausch and Lomb dissecting microscope. The percentage frequency of occurrence (%FO) was calculated for each item and the average number of specimens with foreguts containing each item [X] was determined.

Sex of nymphs was determined by the posterior setal margin of the 8 abdominal sternite (3). In the female the fringe is interrupted, in the male it is continuous. After determining the sex, the chi-square test was applied to 178 nymphs to determine any significant departure from the 1:1 sex ratio at the 0.05 confidence level.

Fecundity in the adult stonefly was determined by direct counts of ovarian eggs using a Bausch and Lomb dissecting microscope. Both ovaries were excised from eight females and 1356 eggs were counted. The diameters of 136 eggs were measured with an ocular micrometer (0.01 mm) and a Bausch and Lomb dissecting scope.

Nymphs were collected in May and June for rearing in laboratory tanks to study emergence patterns. Adults were collected with a Ward's ultraviolet light trap during June and July. The exuviae were collected from rocks and bridges to help estimate the length of the emergence period.

RESULTS AND DISCUSSION

Stream Environment—the mean annual temperature for the study period was 11.5°C. The monthly extremes were 4 and 21°C, December and July, respectivley. The pH ranged from 6.5 to 7.7; $\bar{X}$ = 7.5. Dissolved oxygen concentration ranged from 8 to 10 mg/l; $\bar{X}$ = 9.4 mg/l. Carbon dioxide concentration values ranged from 10 to 24 mg/l; $\bar{X}$ = 19 mg/l.

Nymphal Food Habits—The following food categories were identified in the foreguts of *E. xanthenes* nymphs: Coleoptera, Diptera, Ephemeroptera, Plecoptera, and Trichoptera (Table 1). Of the 122 foreguts examined, 62 (50.8%) contained food items and 60 (49.2%) were empty. There was a marked increase in the percentage of empty foreguts during the year. In winter and spring, approximately 33% of the foreguts were empty. The highest percentage of empty foreguts (71.7%) occurred in summer, a possible correlation with warmer water temperatures ($\bar{X}$ = 18.5°C) and emergence of mature nymphs.

The nymphs of *E. xanthenes* were carnivorous in their feeding habits (Table 1). Generally, mayflies *(Ephemerella, Ameletus, Paraleptophlebia)* and dipterans (mostly chironomids) comprised the stable components of the diet during all seasons. Caddisflies *(Hydropsyche)*, stoneflies *(Hastaperla, Leuctra)*, and beetles supplemented the diet throughout the year. In fall, the nymphal diet consisted mainly of chironomids [$\bar{X}$ = 1.8 per foregut, 50.0 %FO) and caddisfly larvae [$\bar{X}$ = 1.0 per foregut, 25.0 %FO). In winter, the mayfly *Paraleptophlebia* ranked first in percentage frequency of occurrence (30.0) in the nymphal diet. A few benthic populations, including other mayflies, dipterans and stoneflies, supplemented the diet. In spring, the nymphal diet consisted primarily of the mayfly *Ephemerella* [$\bar{X}$ = 1.0 per foregut, 28.5 %FO) and chironomid larvae [$\bar{X}$ = 1.5 per foregut, 28.5 %FO). The mayfly *Ameletus* ranked second in percentage frequency (23.8) during spring. In summer, the nymphal diet consisted mainly of *Paraleptophlebia* and chironomids [$\bar{X}$ = 1.5 and 1.3 per foregut, respectively, 44.4 %FO for each).

Table 1. Seasonal foregut analysis of *Eccoptura xanthenes* nymphs from Middle Fork of Cane Creek, Laurel County, Kentucky. $\overline{X}$ = mean, %FO = percent frequency of occurrence. Summer = June, July, Aug.; Fall = Sept., Oct., Nov.; Winter = Dec., Jan., Feb.; and Spring = March, April, May. N = number of foreguts with food. Total number of foreguts = 122.

	Category	Taxa	$\overline{X}$	%FO
	Mayflies	*Paraleptophlebia*	1.5	44.4
Summer	Dipterans	Chironomids	1.3	44.4
(N = 9/32)	Beetles	*Psephenus*	1.5	11.1
	Mayflies	*Ephemerella*	1.0	16.6
Fall	Caddisflies	*Hydropsyche*	1.0	25.0
(N = 12/28)	Dipterans	Chironomids	1.8	50.0
	Mayflies	*Ameletus*	1.0	10.0
Winter		*Ephemerella*	1.0	20.0
(N = 20/30)		*Paraleptophlebia*	1.0	30.0
	Dipterans	Chironomids	1.0	15.0
		Simulium	2.0	15.0
	Stoneflies	*Leuctra*	1.0	10.0
	Mayflies	*Ameletus*	1.0	23.8
Spring		*Ephemerella*	1.0	28.5
(N = 21/32)		Unidentified	1.0	4.7
	Caddisflies	*Hydropsyche*	1.3	19.0
	Dipterans	Chironomids	1.5	28.5
	Stoneflies	*Hastaperla*	1.0	4.7

Nymphal Development—Length-frequency histograms showed that 2 size classes were represented in the nymphal population (Fig. 1). Recruitment of young nymphs began in July. The earliest and smallest nymph was collected 12 July 1983, and measured 6.2 mm in body length (head width = 1.61 mm). Smaller nymphs could have escaped due to the colleciton method. Nymphs at the end of one year of development had a mean body length of 14-15 mm. Mature nymphs at the end of the second year of development showed a mean body length of 20-21 mm. The largest male and female nymphs were 20.0 (16 December 1983) and 21.9 mm (8 May 1983) body length, respectively. For the study period, the mean total length (males and females) was 12.4 mm.

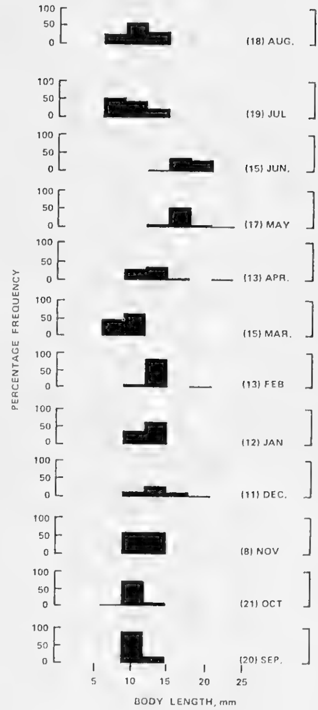

Figure 1. Length-frequency histograms at monthly intervals of Eccoptura xanthenes nymphs from the Middle Fork of Cane Creek, Laurel Co., Ky. The number of nymphs collected each month is given in parenthesis.

Head width was used to show the monthly variation in growth (Fig. 2). Based on the mean head width values, there were not significant changes in growth from August to February. During this time period the mean head width was 2.62 mm (range = 2.32-2.93). According to the mean head width values, the greatest growth (35%) of the nymphal population occurred from February (2.47 mm) to March (3.33 mm). Another increase in nymphal growth (8%) occurred from March to April. The mean head widths were 3.33 and 3.59 mm, March and April, respectively. Following the emergence period in June-July, there was an abrupt decrease in mean head width in July. The second greatest growth (21%) occurred from July (head width = 2.43 mm) to August (head width = 2.93 mm). For the study period, the mean head width (males and females) was 2.9 mm. The mean head width values were 3.26 and 2.65 mm, females and males, respectively.

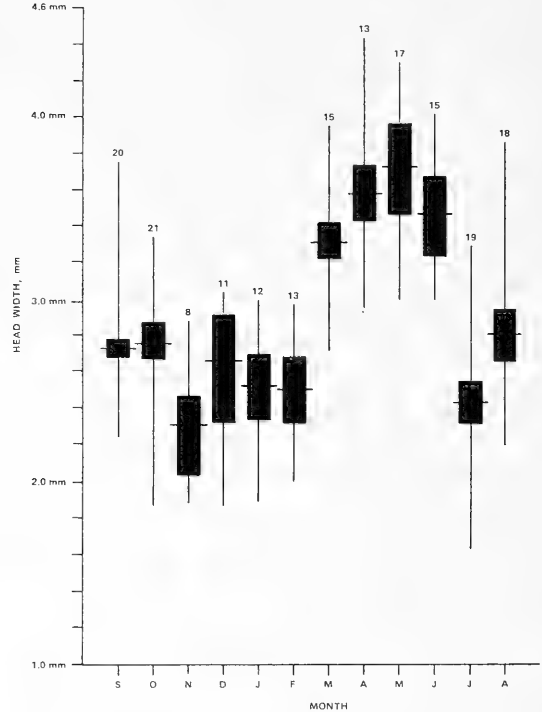

Figure 2. Monthly variation of the head capsule width in nymphs of *Eccoptura xanthenes* from Middle Fork of Cane Creek, Laurel Co., Ky. Vertical lines = ranges, horizontal lines = means, dark rectangles = two times the standard error of the mean, and numbers = sample sizes.

There was a high correlation (r = 0.68) (p◄0.01) between head width (Y) and body length (X) of nymphs (males and females). The following equation was calculated to express this relationship: $Y = 0.133 + 1.269X$.

Nymphal Sex Ratio—The sex ratio was based on 104 male and 74 female nymphs, a ratio of about 142 males per 100 females. The chi-square test showed a significant deviation from the 1:1 sex ratio at the 0.05 level.

Adult Stage—The emergence period of *E. xanthenes* was approximately 4½ weeks. The first exuviae were found on 11 June and marked the beginning of the flight period. No exuviae or adults were collected after 14 July. The adults (8 females) collected in July corresponded with the highest water temperature (21°C) recorded in the Middle Fork of Cane Creek during the study period. Kondratieff and Despins (9) reported an emergence period of about 7 weeks (approximately May 29-July 17) for *E. xanthenes* from North Otter Creek in Virginia. Peckarsky (24) recorded the emergence period of *E. xanthenes* throughout its range as mid-April to August.

Direct egg counts of 8 females showed a range from 110 to 233 eggs per female; the mean was 170. The eggs were oval and measured 0.34 by 0.41 mm. Needham and Claassen (2) illustrated the eggs and Stark and Gaufin (17) provided a detailed description of the eggs.

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Resistance of Selected Soybean Genotypes to the Twospotted Spider Mite *Tetranychus urticae* Koch (Arcarina: Tetranychidae)[1]

Abdul Aziz Atta Mohammad and J. G. Rodriguez
Department of Entomology, University of Kentucky, Lexington, Kentucky 40546-0091

ABSTRACT

Nine soybean genotypes, 'Bonus', 'Williams', 'Hill', PI 227687, PI 229358, S-100, D54-2437, 'Tracy', and 'Bragg', were evaluated for resistance to *Tetranychus urticae* Koch by using various detached and intact leaf tests. Mite fecundity was not significantly different on the upper or lower leaf surface of detached leaves of all genotypes, but on intact leaves, the lower surface was strongly preferred for oviposition. There was no evidence of any mortality or repellency factor in any of the genotypes. Leaf pubescence did not appear to be a factor in resistance to mites. Egg production was significantly higher on Bonus, compared to Tracy, Williams and Bragg. Genotypes PI 227687, PI 229358, Hill, S-100 and D54-2437 were intermediate in their resistance to mites. Egg production and quiescent deutonymph weight were not significantly affected when mites were fed on Bonus, Williams and Bragg for 3 consecutive generations. Averaged over 3 generations, the total number of eggs produced in 20 days post-emergence was significantly higher on Bonus (173.9) compared to Williams (125.9) and Bragg (104.7). Resistance was primarily associated with a reduction in fecundity of the mites. Ranking for resistance was similar in seedlings (V1-V2) or in V3 trifoliates taken from V4 plants. The detached leaf bioassay for resistance proved to be an acceptable technique.

INTRODUCTION

Soybeans are of much importance worldwide. In a relatively short period of time, soybeans have arisen from a minor crop to a major source of oil and protein. Among the arthropod pests of soybeans generally is the twospotted spider mite, *Tetranychus urticae* Koch. The mite is especially severe in dry seaons when the soybean plant comes under water stress. At such times, egg production in this soft-bodied mite is accelerated because in the process of maintaining a water balance, nutrient uptake from the leaf cells is relatively higher with each unit of water imbibed (1). Under these conditions, management of mites becomes a problem, both from an economic viewpoint and the negative impact that pesticides may have on the environment. In Kentucky, for example, the severe drought of 1983 caused an estimated 50% decrease in soybean yield compared to the 1982 yield (Ky. Agric. Statistics, 1983-84, ed.). A large percentage of the drought-affected agreage was heavily infested with *T. urticae* and received rescue treatment. Host plant resistance then becomes a significant management alternative as it can be very cost effective to the grower if it prevents mite populations from reaching the economic injury level.

Research in soybean resistance to mites appears to have developed slowly, probably because of the complexity of soybean plant

[1]The investigation reported in this paper (No. 85-7-10) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director, and is part of research presented to The Graduate School, University of Kentucky, as a Master's Thesis by A.A.A. Mohammad.

growth physiology (2). Nevertheless, progress is becoming evident. Parameswarappa et al. (3) obtained genetic data on reaction to spider mite damage on parental, F_1 and F_2 generation plants of 2 soybean crosses. In one cross, mite damage was apparently monogenically determined with susceptibility recessive; in the other, susceptibility was apparently due to the complemention of two nonallelic genes, one from each parent. For example, 12 soybean cultivars were tested for possible 'tolerance' to *T. urticae* (4). Two cultivars, "Dare" amd "Hill", showed low 'tolerance' whereas the other 10 cultivars showed moderate to high 'tolerance'. Differential susceptibilities of soybean cultivars to mite damage have also been found (5). Rodriguez et al. (6) found different effects of mite infestations on dry matter production of the soybean cultivars "Bonus", "Fiskeby V", "McCall", and "Williams". All cultivars showed greater reductions in growth with early infestation (V2) as opposed to late infestation (R5). The cultivar Williams showed a lower reduction in dry matter production due to mite infestation than the other cultivars, but especially Bonus which was more susceptible to mite injury.

The general objectives of the present study were to assess the resistance of 9 selected soybean genotypes to *T. urticae* and to assess the relative merit/validity of several bioassay techniques in determination or characterization of resistance. The genotypes selected were chosen from those studied by the workers cited above (3, 4, 5, 6).

MATERIALS AND METHODS

General Procedures—Nine soybean genotypes, 'Bragg', 'Bonus', 'Hill', 'Tracy', 'Williams', 'S-100', 'D54-2437', PI 229358 and PI 227687 were grown in the greenhouse in this study. The descriptions of soybean growth stages are those of Fehr and Caviness (2). *Tetranychus utricae* used in the experiments were mites of uniform age, and infestation procedure involved a double transfer of female mites, thusly: detached soybean leaf discs, kept on wet paper towels, were heavily infested with mites from the colony maintained on beans. The females were allowed to oviposit on the leaf discs for several hours, after which the mites were removed with a stream of air. The remaining eggs then hatched evenly and were transferred as teneral adult females with a fine artist's brush. The first transfer was to the soybean genotype that corresponded to the genotype being tested. Two time-tested feeding techniques were used: detached leaf disc and intact leaf (7). Experiments were conducted under standard conditions of 27°C, 80% R.H., and 14-hour photoperiod.

Detached Leaf Technique—In this technique, leaves at the required growth stages were detached from the genotypes being tested. These were placed on wet paper towels in a plastic tray and the perimeter of the leaf was then ringed with Tanglefoot® . The test mites were then carefully transferred onto the leaves, using a fine artist's brush. The following tests were done using this technique.

(1) Detached V2 leaf—comparison of mite response on upper and lower leaf surface. The middle leaflet from the V2 trifoliate of plants at the V3 stage of growth was used. A leaflet was placed with the lower surface down on the wet towel and a similar leaflet was placed with the upper surface down. After ringing with Tanglefoot® , 5 teneral females were placed on each leaflet of all 9 genotypes, and replicated 4 times. The experiment was maintained at 27°C and data were collected on fecundity, mortality and number of mites trapped in the Tanglefoot® .

(2) Detached V3 leaf—comparison of mite response on the upper leaf surface. The procedure was similar to the above except the V3 leaflet from the plants at the V4 stage was used and placement was with lower surface down on the wet paper towel. Data were collected on egg production, mortality, and the number of mites caught in the Tanglefoot® barrier.

(3) *Overlapping leaf test*—Bonus and Williams, susceptible and resistant cultivars, were selected for this test (6). These 2 genotypes were compared against each other, and against the 7 other genotypes for feeding and oviposition preference. Two leaflets, 1 from each pair being compared, were overlapped by ca 1-2 cm. The pair were joined thusly by a paper clip and Tanglefoot® was applied around the edge. This confined mites to the pair, but allowed free movement of mites from one leaflet to another, as they preferred. Ten teneral females were placed on each leaflet pair and the experiment was replicated 5 times. Data were recorded on egg production.

(4) Egg production, daily oviposition, mortality and longevity of T. urticae on Bonus, Williams, and Bragg—The middle V3 leaflet from V4 stage plants was used. Two teneral female mites and 2 mature males were placed on each detached leaflet. Thirty female mites per genotype were observed daily. Dead mites and mites trapped in Tanglefoot® were replaced with mites from the same culture, maintained on leaf discs of the corresponding genotype, under similar conditions. Leaf discs were replaced at weekly intervals. Daily oviposition was recorded up to 20 days.

(5) Effects on T. urticae reared for 3 consecutive generations on Bonus, Williams, and Bragg—Mites were reared from 3 consecutive generations on detached V3 middle leaflets of the above mentioned genotypes. Thirty mites were observed from each generation. Two teneral females were introduced to the upper surface of each detached leaflet. Mites that died or were caught in Tanglefoot® were replaced from a culture of the same generation and age, maintained under similar conditions. Leaves were replaced weekly with fresh leaves of the same growth stage. Oviposition was recorded daily for 20 days and quiescent female deutonymphs from each generation were weighed using a Cahn electrobalance.

Intact Leaf Technique—(1) Isolated leaf test. The middle V2 leaflet from V3 stage plants was isolated by removing the 2 lateral leaflets from the trifoliate and by banding the petiole with a strip of 'Scotch® ' tape to which a streak of Tanglefoot® was applied. Five teneral females, placed on the upper surface of the leaflet, were free to oviposit on either surface. This procedure was conducted for all genotypes, replicated 5 times, and egg production was recorded after 5 days.

(2) Confinement cage test—The V1 (unifoliolate) leaf of plants at the V2 growth stage was used. Five teneral females were caged (2 cm at the base by 1.6 cm high with a ventilated top) on the paper surface of the leaflet. The cage was clamped to the leaf with an aluminum hair clip. This was done for all 9 genotypes, and replicated 4 times. After 5 days, the cages were removed and eggs laid on the leaf were counted.

RESULTS AND DISCUSSION

Detached Leaf Test—Three parameters were used to evaluate resistance to *Tetranychus urticae* among the 9 genotypes: fecundity (as measured by egg production), mortality of the mites on the leaves, and the number of mites trapped in the Tanglefoot® . Mortality of the mites was a measure of direct antibiosis, and the number of mites trapped in Tanglefoot® was used as an index of the degree of repellency of the different genotypes to the mites.

The differences in egg-production response when mites were confined to the upper or lower leaf surface of the V2 leaf are shown in Table 1. Mites laid more eggs on the upper surface of genotypes Bonus, Williams, Hill, PI 229358, PI 227687, and Bragg, while more eggs were laid on the lower surface of S-100, D54-2437 and Tracy. However, the difference in the number of eggs laid on either surface for all genotypes was not significant. There was no significant difference also in mite mortality and the number of mites trapped in Tanglefoot® on both leaf surfaces. Generally, very few mites died or were repelled into the Tanglefoot® on either leaf surface for any genotype. There were differences in the number of eggs laid on the different genotypes, the most marked being between Bonus and Williams (Table 1).

Table 1. Average fecundity and mortality of *T. urticae* on upper and lower surfaces of detached soybean V2 leaves (5 teneral females/leaf; 4 replicates).

Genotype	Leaf Surface[1]	Avg. no. of mites/leaf[2] Dead	In Tf[3]	Avg. no. eggs/leaf[2] (5th day)	t-statistic for paired comparison
Bonus	a	0.50	0.50	218	0.80
	b	0.25	0.25	206	
Williams	a	0.75	1.00	147	0.83
	b	0.75	0.75	138	
S-100	a	0.00	0.25	195	0.68
	b	0.25	0.50	206	
D54-2437	a	0.25	0.50	170	1.14
	b	0.50	0.25	184	
Hill	a	0.50	0.50	183	0.90
	b	0.25	0.50	170	
PI 229358	a	0.75	0.50	201	1.92
	b	1.00	0.50	182	
PI 227687	a	0.50	0.25	198	0.62
	b	0.25	1.00	160	
Tracy	a	0.25	0.75	150	1.27
	b	0.25	1.00	160	
Bragg	a	0.25	0.50	154	1.19
	b	0.75	0.75	142	

[1]a = upper leaf surface, b = lower leaf surface.
[2]Means in pair are not significantly different from each other at the 5% level (paired t-test).
[3]Tanglefoot® .

Because there were no significant differences in mite responses to upper or lower leaf surfaces, it appeared reasonable and convenient to restrict the bioassay to the upper leaf surfaces. The test on slightly older leaves, i.e., on the upper V3 leaf surface, showed that the lowest number of eggs (153.8) was produced on Bragg, followed in increasing order by Tracy, Williams, Hill, D54-2437, PI 227687, S-100, PI 229358 and Bonus (214.8) (Table 2). The numbers of eggs on Bragg, Tracy and Williams were significantly lower than on all the other genotypes. Mite fecundity on Bonus, however, was not significantly different from PI 229358, S-100, PI 227687 and D54-2437. There was no significant difference among the genotypes with respect to their number of dead mites and the number caught in the Tanglefoot® , attesting to lack of acute toxicity/antibiosis and repellency.

Table 2. Average fecundity and mortality of *T. urticae* on upper surface of detached soybean V3 leaf (5 teneral females/leaf; 5 replicates).

	Avg. no. of mites[1]		Avg. no. eggs/leaf[2]
Genotype	Dead	In TF[3]	5th Day
Bonus	0.2	0.6	214.8 ± 14.84a
PI 229358	0.6	0.6	204.6 ± 8.84ab
S-100	0.2	1.0	203.6 ± 12.71ab
PI 227687	0.2	0.4	198.2 ± 11.44ab
D54-2437	0.2	0.2	195.4 ± 12.81ab
Hill	0.2	1.0	185.3 ± 6.76b
Williams	0.4	1.2	162.0 ± 6.89c
Tracy	0.2	0.8	157.2 ± 11.63c
Bragg	0.6	0.8	153.8 ± 15.11c

[1]Means in column were analyzed after transformation and are not significantly different at the 5% level (Duncan's Multiple Range Test).
[2]Means in column followed by a common letter are not significantly different at the 5% level (Duncan's Multiple Range Test).
[3]Tanglefoot® .

Bonus and Williams were compared in overlapping leaf tests against each other and against the other 7 genotypes for ovipositional preference. Egg production was signficantly higher on Bonus than on Williams, Tracy, Bragg or S-100 (Table 3). Although more eggs were produced on Bonus than on Hill, PI 227687 and PI 229358, the differences were not significant. Also involved in this test was the presumed preference that the mite exercised in choosing to feed on Bonus over Williams, Tracy and Bragg.

In the overlapping leaf tests with Williams, significantly more eggs were laid on Hill and PI 229358 than on Williams (Table 4). Mites also produced more eggs on Bragg, S-100, Tracy, D54-2437 and PI 227687 although statistically there was no difference between these genotypes and Williams. This strengthens the evidence that Williams has resistance characteristics.

Often reproduction effects are not acute but rather subtle changes noted over several generations. To assess this possibility, egg production was recorded (for 20 days post-emergence) for each of 3 generations of *T. urticae* maintained on Bonus, Williams and Bragg. On all 3 genotypes, fecundity was not significantly changed over the 3 consecutive generations, although on Bonus the third generation appeared to show a substantial increase in the number of eggs laid (Table 5). However, when the fecundity of mites averaged over 3 generations was compared among the 3 genotypes, there were significant differences among the means. The number of eggs produced on Williams and Bragg was significantly lower than on Bonus.

Table 3. Preference for oviposition by *T. urticae* on one of a pair of overlapping leaves of 2 soybean genotypes (10 teneral females/pair; 4 replicates).

Genotype	Avg. no. of eggs (5th day)	t-statistic for paired comparison[a]
Bonus	151.0	3.21
Williams	108.5	
Bonus	175.0	1.27
Hill	154.8	
Bonus	195.8	1.23
PI 227687	178.5	
Bonus	164.0	0.31
D54-2437	168.0	
Bonus	211.8	12.36**
Tracy	101.0	
Bonus	177.5	12.03**
Bragg	110.5	
Bonus	205.8	4.48*
S-100	164.3	
Bonus	191.0	2.31
PI 229358	161.3	

[a]Means in pair significantly different from each other at the 5% (*) level, or 1% (**) level.

Table 4. Preference for oviposition by *T. urticae* on one of a pair of overlapping soybean leaves of 2 genotypes (10 teneral females/pair; 4 replicates).

Leaflet pair	Avg. No. of Eggs (5th Day)	t-statistic for paired comparison[a]
Williams	142.3	1.15
Bragg	153.0	
Williams	131.8	3.75*
Hill	181.3	
Williams	142.0	2.67
S-100	189.3	
Williams	120.0	6.44**
PI 229358	160.3	
Williams	138.8	1.38
Tracy	154.5	
Williams	149.3	1.24
D54-2437	175.3	
Williams	136.5	1.96
PI 227687	159.3	

[a]Means in pair significantly different from each other at the 5% (*) or 1% (**) level.

Table 5. Fecundity of *T. urticae* maintained for 3 consecutive generations in soybean genotypes Bonus, Williams and Bragg. Values are means of the number of eggs laid per female for 20 days following emergency.

	Avg. No. of Eggs/Mite			
	Generation			
Genotype	1	2	3	Mean[1]
Bonus	163.7	164.1	193.9	173.9a
Williams	115.5	134.6	127.8	125.9b
Bragg	91.5	116.3	106.2	104.7b
Mean[2]	123.6	138.3	142.6	

[1]Means in the column followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).
[2]No signficant difference among generations, at the 5% level.

In order to study possible allelochemic chronic effects detrimental to mite physiology, quiescent female deutonymphs were weighed from each of the 3 generations. The results showed there were no significant changes in the fresh weight of the mites among the 3 generations for the 3 genotypes (Table 6). The highest average weight obtained was 11.37 μg, for the third generation raised on Williams.

Daily egg production was followed for 20 days following emergence on female mites feeding on Bonus, Williams and Bragg. Oviposition was recorded on day 1 for all 3 genotypes. Peak daily oviposition on Bonus was reached on day 5, with a mean of 12.7 eggs per female. On Bragg, maximum oviposition was 8.8 eggs, also on day 5. On Williams, maximum oviposition occurred on day 3, with 10.8 eggs. From the 4th day after emergence up to 20 days, daily oviposition was substantially higher on Bonus than on Williams and Bragg. By day 20, daily oviposition had fallen to a mean of 3.8, 2.8 and 2.4 eggs on Bonus, Williams and Bragg, respectively (Fig. 1).

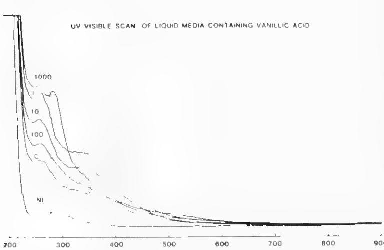

Figure 1. mean daily oviposition per female of *Tetranychus urticae* Koch on soybean genotypes 'Bonus', 'Williams', and 'Bragg' at 27°C.

Table 6. Weight of quiescent female deutonymphs of *T. urticae* maintained for 2 consecutive generations on Bonus, Williams and Bragg soybeans.

Genotype		Generation	(n)	Mean Weight[a] (μg)
Bonus		1	35	11.12 ± 0.28
		2	33	11.37 ± 0.30
		3	38	11.09 + 0.44
	Mean			11.19
Williams		1	39	10.98 ± 0.13
		2	30	11.20 ± 0.14
		3	33	10.53 ± 0.37
	Mean			10.90
Bragg		1	35	10.89 ± 0.32
		2	36	10.96 ± 0.25
		3	31	11.00 ± 0.15
	Mean			10.95

[a]Means not significantly different at the 5% level (Duncan's Multiple Range Test).

Table 7. Fecundity and oviposition preference of *T. urticae* on upper or lower surface of isolated soybean V2 leaves (5 teneral females/leaf; 5 replicates. Count made 5 days after infestation).

	Avg. No. of Eggs[1]		
Genotype	Upper	Lower	Total[2]
Bonus	34.8	145.6	180.4 ± 9.37a
PI 227687	29.4	140.4	169.8 ± 5.99ab
S-100	36.6	133.0	169.6 ± 5.67ab
Hill	38.0	120.6	158.6 ± 8.57abc
PI 229358	31.4	126.6	158.0 ± 10.02abc
D54-2437	17.8	127.4	145.2 ± 14.78bc
Tracy	27.8	115.0	142.8 ± 9.52c
Williams	19.4	119.0	138.4 ± 5.79c
Bragg	33.2	101.4	134.6 ± 12.05c

[1]Highly significant difference (1% level) in the number of eggs laid on upper and lower leaf surface for all genotypes.

[2]Means in column followed by a common letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

Longevity and natural mortality of mites on Bonus, Williams and Bragg was recorded on day 1 on all 3 genotypes (Fig. 2). One hundred per cent mortality was reached on days 26, 28, and 33, on Williams, Bonus and Bragg, respectively. Fifty percent of the mites feeding on Bonus had died by day 16, compared to days 17 and 19 for Bragg and Williams, respectively. It is quite possible that food resources become limiting earlier on Bonus, causing an earlier death of the female.

Tests Using Intact Leaves—This study was conducted to ascertain the validity of using detached leaves in the bioassays. Two tests were carried out using intact leaves, one utilizing an isolated leaf and the other a confinement cage.

Mite preference for oviposition on the upper or lower leaf surface in the isolated leaf test is shown in Table 7. The difference in the number of eggs laid on the surfaces was highly significant, with the lower surface being strongly preferred. This is in contrast to comparable oviposition found when the mites were isolated on either surface (Table 1), demonstrating that the females are capable of feeding equally well from either surface, but preferring to feed from the lower side. Also, the lowest number of eggs laid was on Bragg (134.6), and the highest was on Bonus (180.4), on V2 leaves. The numbers of eggs on Bragg, Williams and Tracy were significantly lower than on Bonus, PI 227687, and S-100, but not significantly different when compared to Hill, PI 229358 and D54-2437.

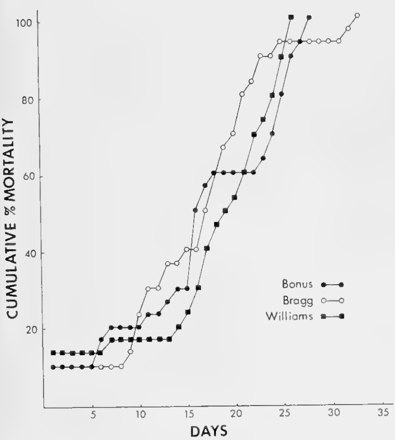

Figure 2. Cumulative % natural mortality of female *Tetranychus urticae* Koch on soybean genotypes 'bonus', 'Williams', and 'Bragg' at 27°C.

The fecundity of mites confined in cages on the upper surface of the V1 leaf is shown in Table 8. Once again, the highest number of eggs were produced on Bonus and the lowest numbers on Bragg and Williams. The number of eggs laid on Bonus was significantly higher than on Tracy, Williams and Bragg. The results of this study attest to the validity of utilizing seedlings in the very early stages of plant growth (V1) for bioassays on soybean plant resistance to the twospotted spider mite, at least compared to V2/V3 stages.

Bonus consistently produced the highest oviposition, while Tracy, Williams and Bragg, in decreasing order, had the lowest. Hill, PI's 227687 annd 229358, S-100 and D54-2437 were genotypes ranked intermediate in resistance.

Table 8. fecundity of *T. urticae* caged on upper surface of soybean V1 leaf (5 teneral females/leaf; 4 replicates. Count made 5 days after infestation).

Genotype	Mean No. of Eggs[1]
Bonus	206.8 ± 10.60a
PI 227687	201.8 ± 8.61ab
Hill	195.5 ± 7.60ab
PI 229358	193.5 ± 10.47abc
S-100	191.8 ± 914 abc
D54-2437	184.5 ± 13.43abc
Tracy	173.3 ± 6.14 bc
williams	167.5 ± 10.15c
Bragg	159.5 ± 8.72c

[1]Means followed by a comon letter are not signficiantly different at the 5% level (Duncan's Multiple Range Test).

Moreover, the ranking of Tracy, Williams and Bragg as the most resistant, and Bonus as the least, was consistent in both detached and intact leaf tests, confirming results of Patterson et al. (8), irrespective of leaf/plant age ranging from V1 to V3, the limits of our assays. The work also showed that feeding preference is directly related to egg production but that longevity may be limited by food resources. The genotypes studied did not exhibit acute toxicity effects (antibiosis) nor did they demonstrate repellency, confirming our previous findings (6) relative to the interaction of Bonus and Williams with *T. urticae*. The lack of allelochemic or acute effect was further demonstrated by the similarity of body weight of quiescent deutonymphs reared on Bonus, Williams and Bragg. The reduced weight and fecundity of arthropods feeding on resistant gentoypes can be partly attributed to the unsuitability of the plants as a food source (9, 10). The nutritional value of plants and the absence of toxic compounds determine the adequacy of the plant as a food source to sustain the various physiological processes related to growth and development. When arthropods feed on resistant plants, they manifest antibiotic symptoms that range from lethal or acute to very mild or subchronic (11).

The genotype, PI 229358, was found to be a source of resistance to the soybean looper *Pseudoplusia includens* (Walker) (E. E. Hartwig, pers. com.), and also a source of pinitol which inhibited larval growth in *Heliothis zea* (Boddie) in bioassay (12). This genotype showed intermediate resistance to *T. urticae* in our bioassay but the role of pinitol in this case is uncertain because this compound attains its higher levels as the plant matures, and our bioassay utilized young leaves. Also, Rodriguez et al. (6) showed that *T. urticae* populations increase as the plant reaches the reproductive stage.

Although obvious differences in resistance to mites were shown in the 9 genotypes, it must be borne in mind that Painter (13) pointed out, that resistance is relative, and is definable only in terms of other and usually more susceptible genotypes. This situation is demonstrated in the case of D54-2437, and S-100, where these genotypes were classified as 'resistant' and Hill was evaluated as 'susceptible' to mites (3). In our study, these genotypes were 'intermediate' in their resistance. However, it is possible that mite populations in the Parameswarappa study (3) were distributed over more foliage in S-100 and D54-2437 at maturity since these genotypes have an indeterminate type of growth, as contrasted with Hill that has a determinate growth type. In our study the bioassays were on young leaves and this has the advantage of not being influenced by growth type or plant growth stage.

It is therefore important that in categorizing genotypes for resistance, ambiguity be minimized. This can be achieved to a certain extent by the use of standard techniques to evaluate resistance, and including a standard to known resistance as a reference genotype. We have demonstrated that resistance of soybeans to mites can be measured at an early stage of plant growth and the results are apparently compatible with whole plant-mite interaction.

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Resistance of Pepper, *Capsicum annum* L. to European Corn Borer, *Ostrinia nubilalis* (Hubner)[1]

Abdul-Aziz Ajlan, D.E. Knavel, and J.G. Rodriguez
Department of Entomology and Department of Horticulture and Landscape Architecture,
University of Kentucky, Lexington, Kentucky 40546-0091

ABSTRACT

Field tests consisted of (1) screening 2 commercial cultivars and 6 breeding lines of pepper for European corn borer (ECB) fruit damage in 1981, and (2) inoculating plants with 0, 2, and 4 egg masses of ECB and (3) 0, 1, and 2 applications of acephate after inoculating plants with egg masses in 1981 and 1982. All breeding lines had less fruit infestation than the cultivar, California Wonder, and 5 of the breeding lines had less fruit infestation than both commercial cultivars. Increasing egg masses of ECB per plant on California Wonder and UK 76-G increased fruit infestation in both years, but the damage was less severe in UK 76-G. Fruit infestation decreased with one application of acephate in both California Wonder and UK 76-G, but the damage was less severe in UK 76-G. Laboratory tests consisted of using capsaicin and ground pepper fruits in larvae diets. Larval survival decreased with increasing concentration of capsaicin. Using ground fruits of a sweet pepper selection, UK 76-G, as 20% of the diet, and fruits of a pungent (hot)-pepper selection, UK 14-B, as 10 and 20% of the diet, decreased the percentage of larval pupation. These concentrations of ground fruits of the pungent-pepper selection also decreased the percentage of larvae surviving to the adult stage.

INTRODUCTION

The European corn borer (ECB), *Ostrinia nubilalis* (Hubner), is a serious pest on peppers, *Capsicum annuum* L. in Kentucky. Kentucky growers produce around 30,000 tons of pepper fruits annually on approximately 1200 ha for a net return of 2.5 million dollars. Dupree, et al. (5) estimated the yield loss to ECB damage in 1978 to commercial growers of pimiento peppers in Spalding County, Georgia to be about 3.5 million dollars. The damage to peppers is done primarily to the fruit, where the larvae feed internally, but occasionally larvae also bore into the stems, causing stem breakage.

The pest is widely distributed in the cornbelt area of the United States. Burkhardt (3), Little (11), and Ritcher (15) stated that ECB attacks over 200 kinds of plants besides corn and peppers. The pest overwinters as a full-grown larva in corn stalks or in other protective host plants. Pupation occurs in late winter or early spring and lasts about 10 to 15 days. The adults are active at night and live from 6 to 24 days. The fertilized females lay their eggs on the underside of plant leaves, and the eggs hatch within 3 to 7 days. In Kentucky, the first generation feed primarily on corn and become full-grown larvae in 25 to 35 days. The first-generation adults appear about mid-July and lay their eggs on many kinds of plants, including pepper. The eggs hatch into the second-generation brood and within 24 to 36 hours the larvae enter pepper fruits. Entry is mainly in the cap (calyx) area or under the cap, but may also be made from the shoulder or the end of the fruits. No foliage feeding has been observed. These larvae feed inside the fruit and the cap. This kind of damage to the fruit allows microorganisms to enter the fruit, often resulting in fruit rot which causes dropping of the fruit and, therefore, reduced yield. When rotting begins, the larvae often leave and move to infest new fruit. In this way, one larva can damage several peppers and with heavy infestations more than one larva can be found in one fruit. Sometimes full-grown larvae feed in the stem or the branch and pupation takes place there, as well as in the fruit. In Kentucky, there are 2 generations and a small third brood. Weather conditions during egg laying can affect the severity of ECB problems. Calm, warm nights are most favorable for moth activity.

Many studies have been made on the control of the ECB on corn, including chemical, biological, and cultural controls. On pepper, the most effective chemical control has been with application of Sevin® (carbaryl) (2, 7, 12, 13), Furadan® (carbofuran) (1, 14), and Orthene ® (acephate) (2, 10). Presently, the recommendations in Kentucky (4) are the use of acephate, carbaryl, or granular carbofuran. The use of the

[1]The investigation reported in this paper (No. 85-10-7-14) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director, and is part of research presented to the Graduate School, University of Kentucky, as a Master's Thesis by Abdul-Aziz Ajlan.

oophagid chalcid wasp, *Trichogramma nubilale* Erthe and Davis, has been studied by Burbutis and Koepke (1) for parasitizing ECB egg masses. They obtained as much as 88% parasitism, depending upon the number of female released per day.

Jarvis and Guthrie (8) reported that sweet peppers had a higher percentage of damage fruits than pungent peppers. They also found that oblate-shaped fruits had the lowest level of damage and surviving larvae, whereas the round, elongate and conical shaped fruits had moderate levels of damage. The bell-shaped peppers (sweet) had the highest infestation level. Further, they found that the smaller peppers, which were also the most pungent, had a smaller number of surviving larvae and less damage thatn the larger fruits.

The objectives of these studies were: (1) to evaluate commercial pepper cultivars and breeding selections for fruit damage by ECB; (2) to determine the degree of resistance in pepper selections pressured with egg masses; (3) to determine the effectiveness of chemical control on ECB when combined with host plant resistance as a component of pest management, and (4) to evaluate the effect of capsaicin, the naturally occurring chemical for pungency, and ground pepper fruits in diets for larval survival and growth.

MATERIALS AND METHODS

The pepper cultivars used in these studies were obtained from commercial sources while the breeding selections were part of an on-going pepper breeding program in the Department of Horticulture and Landscape Architecture, University of Kentucky. The field experiments were conducted at the University of Kentucky's south Farm near Lexington in 1981 and 1982. The plot designs were randomized complete blocks with 8 plants of each cultivar or selection per treatment. Each treatment was replicated 3 times. The seeds were started in trays and transplanted to peat pots and grown in a greenhouse. The transplants were set in the field on June 3, 1981, and May 20, 1982. The 1982 field experiments were a repeat of Experiments 2 and 3 conducted in 1981.

The pepper plants were infested artificially in the field by pinning ECB egg mases (approx. 30 eggs/mass) on the stems and near fruits. ECB damage was determined about 4 weeks after the first application of egg masses by dissecting the fruits and examining them for evidence of damage by the presence (or absence) of either larvae, larval frass webbing, or exit holes.

Field Studies

Experiment 1.—The test consisted of 2 commercial cultivars, Yolo Wonder and California Wonder, and breeding selections, UK 45, UK 66, UK 66-CBR4, UK 76-E, UK-76-G, and UK 14-B (pungent fruit). The plants were infested with 2 egg masses per plant on July 16 in 1981 and on July 21 in 1982.

Experiment 2.—This test was designed to determine the influence of placing 0, 2, and 4 egg masses per plant on fruit damage in the cultivar California Wonder and the breeding selection UK 76-G. The first application of 2 egg masses per plant was made on July 16 in 1981 and July 21 in 1982. The second application of 2 egg masses (4 egg mass treatment) was made on July 28 in 1981 and July 29 in 1982.

Experiment 3.—This test was designed to determine the influence of chemical control on ECB when combined with host plant resistance as a component of insect pest management. The sources of infestation were 2 egg masses per plant on July 16 in 1981. In 1983, one egg mass per plant was applied on July 21 and again on July 29. Acephate was applied in 0, 1, and 2 spray applications at the rate of 0.75 1b ai/A. The first and second spray applications in 1981 were on July 19 and July 29. In 1982, spray applications were made on July 24 and August 3.

Laboratory Studies

Experiment 1.—This experiment was to determine the effect of capsaicin on the development and survival of ECB larvae. Synthetic capsaicin (dissolved in 95% alcohol) was added to a meridic diet described by Lewis and Lynch (9) in concentrations of 0.001, 0.01, 0.05, 0.1, and 0.2%. Newly hatched larvae were transferred individually to a 4-dram vial containing a plug of diet weighing approximately 3 g. The vials were plugged with cotton, placed on trays and incubated at 27°C, 80% R.H., and 24-hr photoperiod. A total of 25 vials (25 larvae) were evaluated at each level of capsaicin for (1) percentage survival to pupation, (2) percentage survival to adults, (3) days to pupation, and (4) weight of female and male pupae.

Experiment 2.—Fruits of California Wonder, and UK 76-G and UK 14-B were freeze-dried, ground, and added to the meridic diet to determine the effect of natural capsaicin in pepper fruits on larval survival and development. The concentrations of dried fruits in diets were 0, 1, 5, 10, and 20%.

All percentage data were arcsin-transferred prior to subjecting to ANOVA. Means were statistically separated by either Duncan's multiple range test or L.S.D.

RESULTS AND DISCUSSION

Field Studies

Experiment 1.—In the 1981 screening for ECB damage, commercial sweet peppers had the highest level of fruit damage. California Wonder had 46.7% and Yolo Wonder had 43.9% of their fruits showing damage (Table 1). Fruits of the pungent selection, UK 14-B, had the lowest level of damage with 6.9%.

Experiment 2.—Recorded data were similar for both years (Table 2). The breeding selection UK 76-G had significantly less fruit damage. Placing 2 egg masses/plant on California Wonder plants resulted in 50.3 and 63.3% damaged fruits while only 14.4 and 32.9% of fruits were damaged for UK 76-G in 1981 and 1982, respectively. Placing 4 egg masses/plant on California Wonder resulted in 65.0 and 60.3% fruit damage, while only 19.3 and 30.9% of UK 76-G fruits were damaged in 1981 and 1982, respectively.

Experiment 3.—Unsprayed plants had more fruit damage than sprayed plants for both plant types in both years, but damage from natural infestation seemed to be more severe in 1982 than in 1981. The second spray application appeared to have no effect on reducing fruit damage in either plant type (Table 3).

It should be noted that plants of the commercial cultivars have morphological features that differ from those of the breeding selections. Plants of commercial cultivars have larger leaves and bell-shaped fruits, while leaves of the breeding selections are somewhat smaller and fruits are either conical or elongate. The difference in plant and fruit types and their relationship to resistance to ECB have been previously noted (6, 8).

Laboratory Studies

Experiment 1.—Adding capsaicin to the diets at 0.1 and 0.2% concentration reduced larval survival and the percentage of larvae reaching adulthood (Table 4). Pupal (male) weight was highest at 0.1% concentration of capsaicin in the diet. Jarvis and Guthrie (8) found adult survival to be highly correlated with pupal survival and the higher concentrations of capsaicin also reduced the number of days required to reach pupation. They found that their higher concentrations also reduced pupal weight.

Experiment 2.—Larval survival decreased as the percentage of ground fruits of UK 76-G (sweet) and UK 14-B (pungent) selections was increased (Table 5). The 10 and 20% concentrations of the pungent selection gave the greatest reduction of larval survival and the percentage of larvae reaching adulthood. Low concentrations (1%) of California Wonder and both UK selections resulted in similar survival data. The percentage of larvae surviving to adulthood appeared to be similar to that reaching pupation. Diets containing 20% of UK 76-G and UK 14-B fruits resulted in heavier male weights. Only the high concentrated diet of UK 76-G increased female weight over all other diets. However, high concentrations of both California Wonder and UK 76-G, and the 10% diet of UK 14-B increased female pupa weight over other diets.

The use of ground fruits in larval diets gave results similar to the use of synthetic capsaicin (8-methyl-non (6)en-(1) oic acid-(1)-14oxy, 3-methoxy-benzyl-amide) in diets. We concluded, as did Jarvis and Guthrie (8), that the presence of capsaicin in the pungent genotype

Table 4. Influence of capsaicin in a meridic diet on survival and development of the European corn borer.

Capsaicin (%) in diet	Survival (%) to pupation	Survival (%) to adult	Length of larval period (days)	Length of pupation (days)	Number days to adult	Pupal weight (mg) male	Pupal weight (mg) female
0.2	29.4 a*	23.5 a	17.5 a	7.5 a	25.0 a	71.0 ab	92.0 a
0.1	58.2 b	39.3 a	18.7 a	7.1 a	25.8 a	70.6 ab	78.6 b
0.05	78.5 c	67.3 b	14.5 b	7.3 a	21.8 b	74.1 c	88.3 c
0.01	90.0 c	81.9 b	13.3 b	7.9 a	21.2 b	74.1 c	93.6 ad
0.001	90.0 c	81.9 b	13.8 b	7.6 a	21.4 b	69.1 b	93.9 ad
Control	90.0 c	81.9 b	13.9 b	8.3 a	22.2 b	71.9 a	96.2 d

*Means followed by the same letter within column are not significantly different by Duncan's multiple range test (P = 0.05).

Table 5. Influence of pepper types in a meridic diet on survival and development of the European corn borer.

Cultivar/ Selection	Ground pepper fruit (%) in standard diet	Survival (%) to pupation	Survival (%) to adult	Length of Larval Period (days)	Length of pupation (days)	Number days to adult	Pupal weight (mg) male	Pupal weight (mg) female
California Wonder	1	89.9 ab*	81.9 ab	14.9 b	6.9 a	21.9 a	75.3 bcde	96.7 ef
	5	81.9 ab	78.5 ab	14.6 b	6.9 a	21.5 a	73.6 de	95.2 eg
	10	81.9 ab	78.5 ab	14.6 b	7.3 a	21.9 a	76.6 abc	105.2 b
	20	75.6 b	73.2 bc	15.1 b	7.9 a	23.0 a	74.6 cde	105.0 bc
UK-767-G	1	81.9 ab	81.9 ab	15.3 b	7.1 a	22.4 a	73.3 e	93.6 gh
	5	73.2 bc	73.2 bc	15.1 b	7.3 a	22.4 a	69.0 f	89.1 i
	10	73.2 bc	73.2 bc	15.2 b	7.4 a	22.6 a	76.6 ab	103.2 c
	20	66.4 cd	61.9 c	17.5 a	7.8 a	25.3 b	77.7 a	109.9 a
UK-14-B	1	81.9 ab	78.5 ab	15.0 b	7.0 a	22.0 a	76.2 abc	98.0 de
	5	64.2 cd	56.6 c	16.2 ab	6.9 a	23.1 a	75.4 bcd	98.1 de
	10	53.1 d	36.6 d	15.3 b	7.5 a	22.8 a	74.7 bcde	104.0 bc
	20	53.1 d	36.6 d	15.2 b	7.5 a	22.7 a	77.6 a	98.8 d
Control	0	90.0 a	90.0 a	14.5 b	7.1 a	21.9 a	67.8 f	92.5 h

* Means followed by the same letter within column are not significantly different by Duncan's multiple range test (P = 0.05).

was mostly responsible for its resistance to ECB. Since survival of larvae is acutely affected by capsaicin, the type of resistance in UK 14-B appears to be antibiosis. However the type of resistance demonstrated in UK 76-G is probably associated with the morphological differences between its plants and those of other sweet commercial cultivars used in this study. The large bell-shaped fruits of the commercial cultivars, borne close to each other and in the crotch or between branches, are more susceptible to damage. Larvae can move easily from fruit to fruit and cause more fruits to rot. Whereas, fruits in genotypes such as UK 76-G are borne further apart, are smaller, and are generally more numerous which makes it less likely for the larvae to infect all fruits. It was observed that there were greater numbers of ECB egg masses laid on plants of commercial cultivars than on the breeding selections, which indicates that plant compactness and large leaves provide hiding areas that make these plants more attractive for oviposition.

Thus it is conceivable that selecting for small leaf size on compact plants with fruit setting on outer branches would reduce ECB damage. However, no data are availabe on the relationship of leaf size or leaf area with size and numbers of fruits for pepper plants with ECB damage. It should also be noted that the more open plant configuration and small leaves would allow for better chemical penetration and spray coverage than in present cultivars that have large leaves and compact fruit setting characteristics.

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Table 1. The effect of European corn borer infestation (two egg masses/plant) in peppers in 1981.

Cultivars/selections of peppers	Fruit infested (%)*
California Wonder	46.7 a
Yolo Wonder	43.9 ab
UK-66	31.9 bc
UK-66 CBR 4	22.1 cd
UK-76-E 16	24.6 cd
UK-76-G	16.0 de
UK-45	11.4 de
UK-14-B	6.9 e

*Percentages followed by the same letter are not significantly different by Duncan's multiple range test (P = 0.05).

Table 2. Effect of egg mass inoculation on European corn borer infestation in peppers in 1981 and 1982.

	Fruit infested (%)					
	number egg masses/plant					
	0		2		4	
Cultivar/selection	1981	1982	1981	1982	1981	1982
California Wonder	39.2	55.4	50.3	63.3	65.0	60.3
UK-76-G	6.2**	22.1**	14.4**	32.9**	19.3**	30.9**

**Means significantly different at 1% probability.

Table 3. Effect of acephate application on European corn borer infestation in 1981 and 1982.

	Fruit infested (%)					
	number of sprays					
	0		1		2	
Cultivar/selection	1981	1982	1981	1982	1981	1982
California Wonder	44.3	65.6	31.1	21.8	19.9	23.3
UK-76-G	17.0**	21.9**	8.0**	10.1*	6.5**	10.4*

*,**Means within column significantly different at 5 and 1%, respectively

The Aquifoliaceae of Kentucky

Ronald L. Jones
Department of Biological Sciences, Eastern Kentucky University, Richmond, Kentucky 40475

ABSTRACT

Documented county distributions are presented for the 4 species of Aquifoliaceae known to occur in Kentucky. These species are *Ilex opaca* (28 counties), *I. decidua* (24 counties), *I. verticillata* (15 counties), and *I. montana* (8 counties). A key to the species is given, and their distributions and habitats are discussed.

INTRODUCTION

The Aquifoliaceae is a cosmopolitan woody family of 4 genera and about 400 species, with most of the species in *Ilex* (hollies). Following Cronquist (1), the family is placed in the subclass Rosidae, order Celastrales. The diagnostic features of the family are as follows: trees or shrubs; leaves alternate, simple, stipulate; inflorescence axillary, with flowers solitary, cymose, or fascicled; flowers 4-9-merous, hypogynous, usually unisexual; fruit a drupe, with 4-9 pyrenes.

In the United States there are 2 genera of Aquifoliaceae—*Ilex*, with 14 species, and *Nemopanthus*, with 2 species (2). Brizicky (3) prepared an account of *Ilex* in the southeastern United States, including information on species relationships, reproductive biology, and economic importance. Statewide treatments of the Aquifoliaceae in Kentucky have been published by Garman (4), McInteer (5), Braun (6), Meijer (7), and Wharton and Barbour (8). The objective of this paper is to provide updated herbarium-documented county maps for each species of Aquifoliaceae in Kentucky. This study will provide a contribution toward the preparation of a flora of Kentucky, a project under the direction of Dr. John Thieret, Northern Kentucky University.

MATERIALS AND METHODS

A total of 216 specimens from 19 herbaria was involved in this study. Each specimen was checked for identity, and locality and collector data were recorded. Cultivated specimen records and undocumented literature reports are excluded. The species taxonomy and distributions are based on Little (2, 9, 10).

RESULTS

This study resulted in the documentation of 4 species of Aquifoliaceae in Kentucky. As shown in Figure 1, I have found records of *Ilex opaca* in 28 counties, *I. decidua* in 24, *I. verticillata* in 15, and *I. montana* in 8. The Kentucky Nature Preserves Commission has collections, which are presently unavailable for study, that include *Ilex* records from the following additional counties (R. Hannan, pers. comm.): *I. opaca*—Leslie, *I. decidua*—Butler, Hardin, Logan; *I. verticillata*—Casey, Lewis, Nelson; *I. montana*—Letcher.

I was unable to confirm the occurrence of any other member of the Aquifoliaceae in Kentucky. The mountain holly, *menopanthus mucronatus* (L.) Trel., is a wetland species of the northeastern United States, but is not known to be native to Kentucky. There is a C.W. Short specimen (NY!) of the species that might be from Kentucky. Unfortunately, the locality of the collection is not indicated on the label.

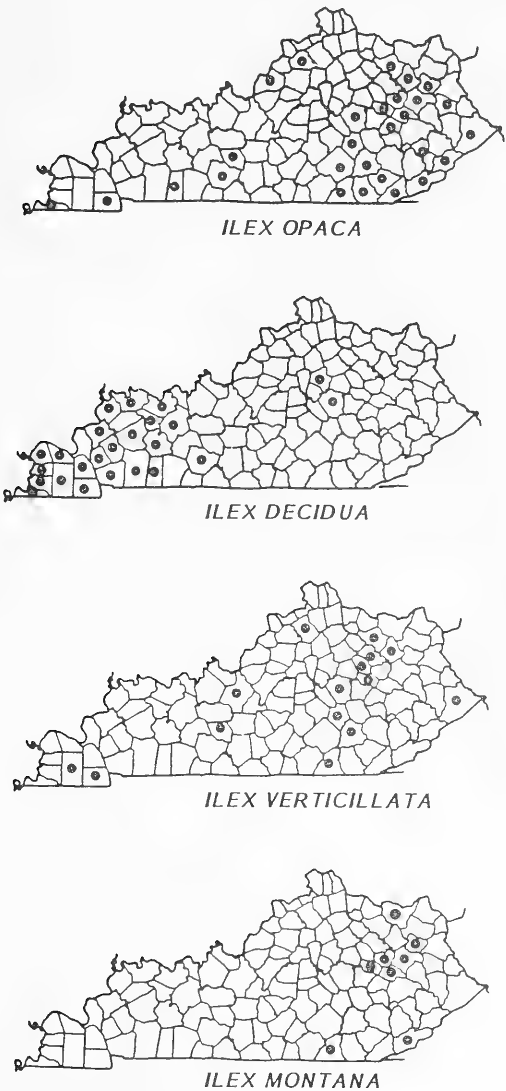
Key to *Ilex* species in Kentucky

A. Leaves evergreen, margins spiny (or entire . . . . *I. opaca*

A. Leaves dedicuous, margins crenate to serrate

- B. Leaves obtuse, margins crenate, sepals entire, pyrenes with striate surfaces . . . . 2.*I decidua*
- *B. Leaves acute to acuminate, margins serrate, sepals ciliate*
  - *C. Flowers in axillary clusters, staminate in puduncled cymes, pistillate 6-8-merous, sepals obtuse, petals inture pyrenes with smooth surfaces . . . . 3. I verticillata*
  - C. Flowers on spur branches, staminate in sessile blusters, pistillate 4-5-merous, sepals acute, petals ciliate, pyrenes with striate surfaces . . . . 4. *I montana*

Figure 1. Documented county distributions of the Aquifoliaceae of Kentucky.



DISCUSSION

1. *Ilex opaca* Ait. American holly.

The American holly is widely distributed through the southern states, ranging northward into southern New England, and is usually associated with rich bottomlands and mesophytic slopes, Garman (4) considered this species as common in eastern Kentucky, but rare in the western half of the state, and listed it for 47 counties. McInteer (5) also listed the plant as common in the eastern coal fields, and later (11) provided a 10-county dot map for the species. Braun (6) gave 22 counties, and described the habitat of *I. opaca* as "mesophytic woods and gorges." According to Wharton (12), the species is rare in black shale regions, and grows in oak-pine woods. In Little (9), the species is mapped through the eastern coal fields and in 3 counties of western Kentucky.

For the 28 counties reported here, all but 7 are in the eastern coal fields (Fig. 1). The species is often used as an ornamental, so there is a possibility that some collections, such as those from Jefferson and Henry counties, are from cultivated plants. *Ilex opaca* thus appears to be a species of wide distribution and variable habitat in Kentucky. It occurs in mixed mesophytic communities, in oak-pine woods, and even in swamps in the western part of the state. The American holly often grows in the understory, but it is our tallest native holly, reaching heights of 15 m or more. The Appalachian associates of *Ilex opaca* include *Tsuga canadensis, Fagus gradifolia, Rhododendron maximum, Betula lenta,* and *Magnolia macrophylla* (13).

2. *Ilex decidua* Walt. Swamp holly. Possumhaw.

The swamp holly is a coastal plain species ranging from Maryland to Texas and Illinois. Garman (4) listed only 4 Kentucky counties, and it was treated as a rare species of the Jackson Purchase region by McInteer (5). Braun (6) cited only Hopkins County, and described the habitat as "alluvial flats." Little (10) mapped the swamp holly through about 20 western Kentucky counties, and the species is now considered to be widespread in this region.

The present study produced a total of 24 counties for *Ilex decidua* in Kentucky, all but 2 in the western half of the state (Fig. 1). The collections from Fayette and Madison counties may be from planted specimens, for the localities were given only as "Lexington" and "Richmond." *Ilex decidua* is an understory species, reaching 10 m, and is most frequently found in bottomland hardwood communities in western Kentucky. Associates include *Itea virginica, Forestiera acuminata, Styrax americana, Quercus michauxii,* and *Liquidambar styraciflua* (14).

3. *Ilex verticillata* (L.) Gray. Common winterberry.

The common winterberry occurs in wetlands through the eastern United States, becoming less common in its southern distribution. Only 3 counties are listed by Garman (4), and McInteer (5) classified the plant as rare on black shale and very rare on limestone. Braun (6) reported 9 counties, and gave the habitat as "alluvial bottoms, river banks, and swampy woods." According to Wharton (12) the species is infrequent in black shale areas, in "swampy thickets and borders of swampy forests." In Little (10) the plant is mapped across the eastern three-fourths of the state, with an additional record from Hickman County.

I documented 15 counties for Ilex verticillata, with all but 6 in the east-central part of the state (Fig. 1). A number of geographic varieties of this species have been described—Kentucky plants are var. *padifolia* (Willd.) Torr. and Gray. This is a shrubby species, rarely over 8 m, of floodplain communities, and evidently occurs infrequently across Kentucky. It commonly grows with Cornus amomum, Cephalanthus occidentalis, Salix nigra, Platanus occidentalis, and *Betula nigra (12).*

4. *Ilex montana* Torr. and Gray. Mountain holly. Mountain winterberry.

The mountain holly, also called *Ilex monticola* Gray in some manuals, is a native of high-elevation regions of the Appalachians from New York to Georgia, but may also be found in widely scattered localities from Florida to Louisiana to western Tennessee. Garman (4) provided no county or regional data for Kentucky, while McInteer (5) called the plant a very rare species of the eastern coal fields. Braun (6) listed 4 counties and described the habitat as "oak-chestnut summit forests and in dense forests with hemlock in sandstone gorges." Seven Kentucky counties, including Bell County, are mapped by Little (10).

I could confirm only 8 counties for *Ilex montana* in Kentucky (Fig. 1). The collections indicate that the plant has been most frequently found in McCreary, Harlan, and Powell counties. Some specimens have large, glabrous leaves, while others have smaller, more pubescent leaves. The hairy-leaved forms have been treated by some authors as distinct taxa *(I. mollis* A. Gray; *I. beadlei* Ashe). The mountian holly was classified by Radford et al. (15) as a variety of the Carolina holly, *I. ambigua* (Michx.) Torr. These taxonomic differences have yet to be fully clarified.

The mountain holly is a small tree, reaching a height of 12 m, and occurs very infrequently through the eastern coal fields of Kentucky. The Appalachian associates of *Ilex montana* include *Kalmia latifolia, Amelanchier arborea, Viburnum cassinoides, Chionanthus virginicus, Rhododendron nudiflorum,* and *Ilex opaca* (16).

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Fishes of the Rolling Fork of the Salt River, Kentucky

William L. Fisher
Water Resources Laboratory, University of Louisville, Louisville, Kentucky 40292

Ronald R. Cicerello
Kentucky Nature Preserves Commission, Frankfort, Kentucky 40601

ABSTRACT

Sixty eight species of fishes were collected at 42 sites in the Rolling Fork of the Salt River, exclusive of the Beech Fork, from 1981 to 1984. Six of the species (*Notropis ariommus, N. emiliae, Rhinichthys atratulus, Noturus stigmosus, Ammocrypta pellucida,* and *Percina phoxocephala)* verify historic distributional findings, establish new drainage records, or provide information regarding conservation status assignments in Kentucky. Nine additional species reported from previous collections yield a total of 77 species known from the drainage. Faunal resemblance indices revealed that 82% of the Beech Fork fauna and 80% of the Salt River fauna is shared with that of the Rolling Fork. The Rolling Fork appears to support the most diverse ichthyofauna within the Salt River drainage.

INTRODUCTION

During the past 35 years the fishes of Kentucky have been extensively surveyed; however, collections from the Rolling Fork, a tributary of the Salt River, are conspicuously absent (1). The aquatic resources of the Rolling Fork are of particular concern because the drainage lies within Kentucky's oil shale region (2).

The earliest ichthyofaunal survey of the Rolling Fork was reported by Woolman (3). Recent studies have been limited to single species accounts (4, 5), sport fishery surveys (6), and sampling at potential oil-shale development sites (2).

The present survey was undertaken to provide new and updated distributional information for the fishes of the Rolling Fork. In addition, the relative similarity between the Rolling Fork ichthyofauna and that of the other major stream systems within the Salt River drainage is assessed.

STUDY AREA

The Rolling Fork, exclusive of Beech Fork, drains 1,804 sq km of north-central Kentucky (7) (Fig. 1). The drainage basin lies within the Knobstone Escarpment and Knobs subsection and the Outer Blue Grass subsection of the Interior Low Plateaus Physiographic Province (8), and drains primarily Ohio-Waverly shales and Silurian-Mid-Devonian limestones (9). Rolling hills generally occur in the east-central portion of the drainage. Rugged, well-dissected uplands known as the Knobstone Escarpment, or Muldraugh Hill, form the southern and western divide. Outlying hills are scattered throughout the remainder of the drainage. The watershed is predominantly forested, with agriculture occurring on floodplains, and small communities scattered throughout the drainage.

A recent investigation found the Rolling Fork water quality to be generally good (2). Based upon the range of mean values for parameters measured quarterly during 1983 to 1984 at seven sites within the drainage, the river has moderately alkaline (70-165 mg/$CaCO^3$), medium hard to hard water (130-210 mg/l), and circumneutral pH (7.2-8.3).

MATERIALS AND METHODS

Fish were collected using seines, gill nets, and an ichthyocide. An effort was made to intensively sample all habitats during each collection. All collections were made and identifications determined by one or both of the authors. Representative specimens of all species collected during the current survey were fixed in 10% formalin, stored in 40% isopropanol or 70% ethanol, and deposited in the University of Louisville (UL) or Southern Illinois University at Carbondale (SIUC) fish collections.

Comparisons of faunal similarity were made using Long's (10) average resemblance formula as follows:

$$\text{average faunal resemblance} = C(N_1 + N_2)(100)/2N_1N_2$$

where C is the number of species shared by both faunas, N_1 is the number of species in the smaller fauna, and N_2 is the number of species in the larger fauna. Resemblance values range from 0 to 100, where 0 indicates that the two faunas share no species, and 100 indicates that the two faunas are identical.

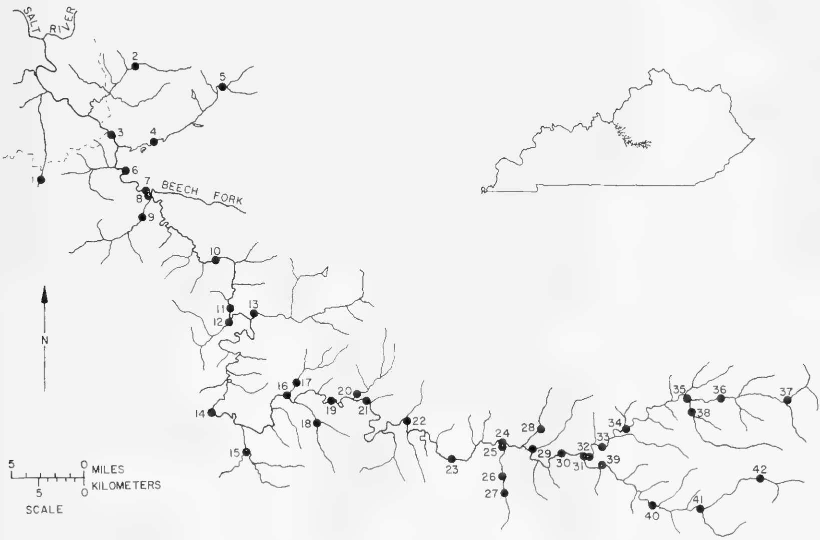

Figure 1. Map of Rolling Fork drainage, Kentucky, showing location of collection sites (dashed line indicates boundary of Fort Knox Military Reservation).

COLLECTION SITES

Eighty three collections were made at 42 sites in the Rolling Fork drainage (Fig. 1). The lower part of the drainage that lies within the Fort Knox Military Reservation, and the Beech Fork drainage were excluded from this study. Each site description given below includes the site number, stream name, locality, county, latitude, longitude, and collection date(s).

1. Cedar Creek, approximately 0.4 km N of Hwy 434 crossing, Hardin Co., 37°46'52"N, 85°50'10"W, 13 July 1984.
2. Crooked Creek, at L & N railroad crossing downstream from Collings Hill Rd., 2.0 km SW of Hwy 251-61 jct., Bullitt Co., 37°53'22"N, 85°43'20"W, 3 Aug 1983, 31 Oct 1983.
3. Rolling Fork, at Hwy 434 crossing, Bullitt-Hardin Cos., 37°49'21"N, 85°*43'51"W, 29 Sep 1983, 30 Aug 1984.*
4. Wilson Creek, at Hwy 61 crossing, Bullitt-Nelson Cos., 37°48'51"N, 85°41'40"W, 28 Jul 1983, 31 Oct 1983.
5. Wilson Creek, at confluence with Overalls Cr., Bullitt Co., 37°52'13"N, 85°36'11"W, 3 Jun 1981.
6. Rolling Fork, Petersburg Rd., 4.8 km W of Hwy 61, Hardin-Nelson Cos., 37°47'18"N, 85°43'37"W, 31 Aug 1984.
7. Rolling Fork, at Hwy 61/62 crossing, Hardin-Nelson Cos., 37°46'01"N, 85°42'14"W, 31 Aug 1984.
8. Rolling Fork, immediately downstream from Beech Fork confluence, Nelson-Hardin Cos., 37°45'45"N, 85°42'00"W, 10 Jun 1984.
9. Younger Creek, at Hwy 583 crossing, Hardin Co., 37°44'24"N, 85°42'29"W, 9 Jun 1984.
10. Rolling Fork, at Hwy 52 crossing S of Patton Rd. intersection, Nelson-Larue Cos., 37°41'51"N, 85°36'57"W, 10 Jun 1984.
11. Rolling Fork, at L & N railroad crossing (37°39'33"N, 85°35'45"W) and Hwy 31E crossing (37°38'57"N, 85°35'50"W) at New Haven, Ky., Larue-Nelson Cos., 18 Mar 1981, 21 Sep 1982, 27-28 Jul 1983, 29 Sep 1983.

12. Thompson Creek, at Blanton Rd. crossing, Larue Co., 37°38'10"N, 38°35'57"W, 9 Jun 1984.
13. Pottinger Creek, 1.3 stream km upstream from confluence with Rolling Fork, Nelson Co., 37°38'47"N, 85°34'18"W, 1 Aug 1983, 1 Nov 1983.
14. Rolling Fork, at Gaddy's Ford Rd., 4.1 km SW of Hwy 84-247 jct. at Howardstown, Ky., Larue-Nelson Cos., 37°32'33"N, 85°37'32"W, 18 Mar 1981, 1 Aug 1983, 1 Nov 1983, 9 Jun 1984.
15. Otter Creek, at Genseng, Ky., Larue Co., 37°30'10"N, 85°34'40"W, 9 Jun 1984.
16. Rolling Fork, at Hwy 462 crossing, Larue-Nelson cos., 37°33'43"N, 85°31'34"W, 21 Sep 1982, 13 Jul 1984.
17. Sulphur Lick Creek, ford W of Hwy 457 and 0.6 km N of Hwy 84 jct., Nelson Co., 37°34'15"N, 85°31'08"W, 9 Jun 1984.
18. Salt Lick Creek, at Dry Fork confluence, Larue-Marion Cos., 37°32'09"N, 85°29'38"W, 13 Jul 1984.
19. Rolling Fork, at Highview Pike crossing, Marion Co., 37°33'19"N, 85°28'27"W, 14 Jul 1984.
20. Prather Creek, at Hwy 84 crossing, Marion Co., 37°33'43"N, 85°26'40"W, 13 Jul 1984.
21. Rolling Fork, at Hwy 527 crossing. Marion Co., 37°33'20"N, 85°25'54"W, 13 Jul 1984, 30 Aug 1984.
22. Rolling Fork, at Hwy 412 crossing, Marion Co., 37°32'06"N, 85°22'48"W, 20 Oct 1983.
23. Rolling Fork, at Hwy 289 and new Hwy 55/68 crossings, Marion Co., 37°29'37"N, 85°18'36"W, 21 Sep 1982, 4 Aug 1983, 29 Sep 1983, 20 Oct 1983, 1 Nov 1983.
24. Rolling Fork, at Hwy 208 crossing, Marion Co., 37°30'45"N, 85°15'40"W, 18 Mar 1981.
25. Cloyd Creek, Hwy 208, 0.8 km S of Calvary, Ky., Marion Co., 37°30'30"N, 85°15'41"W, 2 Apr 1981.
26. Cloyd Creek, Hwy 208, 4.3 km S of Calvary, Ky., Marion Co., 37°28'23"N, 85°15'34"W, 2 Apr 1981.
27. Cloyd Creek, Hwy 208, 1.3 km S of Philipsburg, Ky., Marion Co., 37°26'38"N, 85°15'21"W, 2 Apr 1981.
28. Caney Creek, 1.4 km SW of Arbuckle Rd.-Hwy 49 jct., Marion Co., 37°30'50"N, 85°13'39"W, 3 Aug 1983, 12 Oct 1983.
29. Pope Creek, at Arbuckle Rd. crossing, Marion Co., 37°30'18"N, 85°13'32"W, 13 Jul 1984.
30. Rolling Fork, at Hwy 49 crossing, 3.2 km W of Bradfordsville, Ky., Marion Co., 37°30'08"N, 85°11'11"W, 2 Sep 1983.
31. Rolling Fork, at confluence of North Rolling Fork and Big South Fork, Marion Co., 37°29'32"N, 85°09'35"W, 17 Mar 1981, 2 Sep 1983.
32. North Rolling Fork, 0.45 km upstream from Big South Fork confluence, Marion Co., 37°29'39"N, 85°09'20"W, 3 Aug 1983, 12 Oct 1983.
33. North Rolling Fork, 1.6 km E of Bradfordsville, Ky., at Mullins Lane crossing, Marion Co., 37°30'18"N, 85°07'54"W, 14 May 1982, 25 Jun 1982, 17 Jul 1982, 18-19 Aug 1982, 10 Sep 1982, 14 Oct 1982, 13-14 Nov 1982, 10 Dec 1982, 11 Jan 1982, 25-26 Feb 1983, 23 Mar 1983, 2-3 Jun 1983, 26 Jun 1983, 21 Jul 1983, 2 Sep 1983, 22 Aug 1984.
34. North Rolling Fork, at Siloam Rd. ford, Marion Co., 37°31'18"N, 85°06'21"W, 2 Sep 1983.
35. North Rolling Fork, Hwy 243 crossing downstream from Little South Fork confluence, Casey Co., 37°33'00"N, 85°01'27"W, 17 Mar 1981, 2 Sep 1983.
36. North Rolling Fork, Hwy 37 near Forkland, Ky., Boyle Co., 37°33'04"N, 84°58'57"W, 17 Mar 1981.
37. North Rolling Fork, Hwy 37 at Carpenter Fork confluence, Boyle Co., 37°32'46"N, *84°54'23"W, 17 Mar 1981.*
38. Little South Fork, Hwy 243, 1.6 km S of Hwy 37 jct., Casey Co., 37°32'10"N, 85°04'48"W, 2 Sep 1983, 13 Jul 1984.
39. Big South Fork, Hwy 49, 1.6 km S of Bradfordsville, Ky., Marion Co., 37°29'23"N, 85°08'12"W, 29 Sep 1983.
40. Big South Fork, Hwy 49, 8.8 km E of Bradfordsville, Ky., Marion Co., 37°27'13"N, 85°04'48"W, 2 Sep 1983, 13 Jul 1984.
41. Big South Fork, Hwy 49 crossing near Jacktown, Ky., Casey Co., 37°26'23"N, 85°00'55"W, 17 Mar 1981.
42. Big South Fork, Hwy 78, 0.6 km E of Hwy 243 jct., Casey Co., 37°28'13"N, 85°57'06"W, 2 Sep 1983, 13 Jul 1984.

RESULTS AND DISCUSSION

Sixty eight species of fishes, representing 9 orders and 14 families, were collected in the current survey of the Rolling Fork and its tributaries (Tables 1, 2). The collections from the 15 mainstem sites yielded 58 species, 16 of which were not found at the tributary sites. The 10 most common fishes in the mainstem were: *Campostoma anomalum, Notropis chrysocephalus, N. rubellus, Pimephales notatus, Moxostoma erythrurum, Fundulus catenatus, Lepomis megalotis, Etheostoma caeruleum, E. flabellare,* and *E. zonale.* Fifty three species occurred in the collections made at the 27 tributary sites. Ten of these were not taken in the mainstem collections. The 10 most frequently occurring fishes in the tributaries included: *C. anomalum, N. ardens, N. chrysocephalus, P. notatus, Semotilus atromaculatus, F. catenatus, L. megalotis, E. caeruleum, E. flabellare,* and *E. spectabile.* Forty two species were common to both the mainstem and tributary collections.

Several of our collections verify historic distributional findings, establish new drainage records, or provide additional information regarding conservation status assignments. *Notropis ariommus* is of Undetermined status in Kentucky (11) and is seldom common throughout its rather wide but discontinuous range (12, 13, 14). A single specimen collected by Woolman (3) is the only historic record for the drainage. Subsequently, Rice et al. (4) reported an additional specimen, and 17 were collected from 4 sites during this study. Our collections were from pools of moderate depth (0.5-1.5 m) with substrates ranging from silt to pebble-cobble to bedrock. *Notropis ariommus* is apparently limited to the upper mainstem of the drainage between sites 23-33, where it is uncommon.

The collection of *Notropis emiliae* and *Rhinichthyes atratulus* constitute new records for the drainage. The pugnose minnow record was previously reported by Cicerello and Warren (5) and is known from only one population in the Rolling Fork which constitutes the eastern range limit of the species in the Ohio River drainage. The blacknose dace was collected from a single, spring-fed tributary (site 1), but probably occurs in similar habitats elsewhere in the drainage.

Taylor (15) described *Noturus stigmosus* based in part upon specimens from the Rolling Fork at Boothe and New Market that Woolman (3) had identified as *N. miurus.* The 12 specimens collected from 3 mainstem sites during our study are the only subsequent records for the Rolling Fork and Salt River drainages (16). Habitat at these sites consisted of shallow, moderately swift riffles underlain with gravel, cobble, boulders, and mussel shells. Branson et al. (11) consider *N. stigmosus* Threatened in Kentucky, and although this species is not common in the Rolling Fork, we believe additional specimens can be secured from the rather limited mainstem habitat between sites 11-21 in the central part of the drainage.

Ammocrypta pellucida is listed as Threatened in Kentucky (11) and is undergoing status review for possible addition to the U.S. Endangered and Threatened species list (17). Cicerello and Warren (5) reported the first record of the eastern sand darter from the drainage since the 1890 collection by Woolman (3). We have collected 3 more specimens from the site given by Cicerello and Warren (5) and believe appropriate, though limited, mainstem habitat in the middle part of the drainage will yield additional specimens.

Percina phoxocephala is regarded as of Special Concern in Kentucky by Branson et al. (11). Twenty two specimens of the slenderhead darter were collected from clean to silted riffle and/or flowing pool habitat at 4 sites along the Rolling Fork mainstem. The prevalence of such habitat along the lower mainstem suggests that *P. phoxocephala* is probably rather common in the drainage, and lends further support to the recommendation that it should be removed from the Kentucky Threatened and Endangered list (14).

Our findings verify all but a few of the species reported by Wollman (3) from the Rolling Fork and the results of a recent sport fishing survey by Henley (6). All of the species collected and identified by Woolman except *Hybopsis storeriana, Notropis umbratilis,* and *Carpiodes carpio* were taken during our study. However, 9 specimens of *Notropis umbratilis* were recently collected from Cain Run, Bullitt Co. (UL 4626), and the other species are likely to occur in the Rolling Fork. Woolman's record for *Hybopsis dissimilis (= H. x-punctata)* is not extant and is unverifiable (J. Harris, pers. comm.).

Henley (6) reported 53 species from 14 Rolling Fork collection sites excluding Beech Fork. Acceptable additions to the fauna include: *Anguilla rostrata, Pimephales promelas, Erimyzon oblongus, Minytrema melanops,* and *Stizostedion vitreum.* Museum records verify the presence of *E. oblongus* (UL 4837) and *M. melanops* (SIUC 1564), and walleye have been introduced into the drainage (18). A recent attempt to collect *P. promelas* from the site reported by Henley was unsuccessful. *Lepomis humilis* was recovered from a Hardin County pond (UL 6301). The addition of these accepted records to our findings yields a total of 77 species known from the Rolling Fork drainage.

Table 1. Occurrence of fish species at Rolling Fork collection sites 1 through 21.

Species	Collection Sites 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Lepisosteus osseus										X										X	
Dorosoma cepedianum			X				X	X	X							X				X	
Hiodon alosoides							X	X													
H. tergisus								X													
Esox americanus		X											X								
Campostoma anomalum	X	X	X					X	X		X	X	X	X	X	X	X	X		X	X
Cyprinus carpio								X											X		
Ericymba buccata											X	X	X	X			X			X	
Hybopsis amblops														X	X					X	
H. dissimilis																					
Notropis ardens		X			X			X	X		X	X	X	X	X		X	X			
N. ariommus																					
N. atherinoides			X					X			X			X							
N. boops												X				X	X			X	
N. buchanani			X																		
N. chrysocephalus		X	X	X	X				X		X	X	X	X	X	X	X	X		X	X
N. emiliae													X								
N. photogenis			X																		
N. rubellus											X			X	X	X				X	X
N. spilopterus								X			X			X						X	
N. stramineus			X						X									X			
N. volucellus											X		X	X		X					X
N. whipplei			X					X			X	X	X	X		X				X	X
Phenacobius mirabilis			X								X		X	X							
Phoxinus erythrogaster	X																X				
Pimephales notatus		X	X	X	X			X	X		X	X	X	X	X	X	X	X		X	X
P. vigilax			X					X			X		X	X							
Rhinichthys atratulus	X																				
Semotilus atromaculatus	X	X									X		X		X		X	X		X	
Catostomus commersoni																				X	
Hypentelium nigricans					X			X	X					X		X					X
Ictiobus bubalus							X														
Moxostoma duquesnei									X			X			X					X	X
M. erythrurum			X			X	X	X		X	X	X	X	X							X
M. macrolepidotum			X			X	X			X				X							
Ictalururs melas																				X	
I natalis													X							X	
I. punctatus			X			X		X		X	X			X							X
Noturus flavus			X								X										X
N. miurus											X			X							X
N. stigmosus											X			X							X
Pylodictis olivaris											X										X
Fundulus catenatus								x	X		X	X		X	X	X		X			
F. notatus		X		X																	
Gambusia affinis		X	X	X				X			X		X	X						X	
Labidesthes sicculus				X							X		X	X		X	X			X	
Ambloplites rupestris					X							X		X		X	X		X	X	X
Lepomis cyanellus		X	X																	X	
L. gulosus												X									
L. macrochirus		X	X	X				X	X		X		X		X		X		X	X	
L. megalotis		X	X	X	X			X	X		X	X	X	X	X	X	X	X		X	X
L. microlophus													X								
Micropterus dolomieui														X	X						X
M. punctulaus		X	X	X							X	X	X	X						X	X
M. salmoides								X								X					
Pomoxis annularis				X		X		X				X									
Ammocrypta pellucida														X							
Etheostoma blennioides									X		X			X	X						X
E. caeruleum		X	X	X	X				X		X	X	X	X	X	X		X		X	X
E. flabellare	X		X	X					X		X	X	X	X	X	X	X	X		X	X
E. nigrum									X			X	X							X	X
E. spectabile	X	X											X				X	X			
E. zonale								X			X			X		X					X
Percina caprodes			X		X						X			X		X				X	X
P. maculata		X	X																		
P. phoxocephala			X					X			X			X							
Aplodinotus grunniens			X				X														
Cottus carolinae				X														X			
Total Species	6	15	26	12	8	4	6	21	14	5	31	17	24	34	15	18	13	12	3	27	24

Table 2. Occurrence of fish species at Rolling Fork collection sites 22 through 42.

Species	Collection Sites																				
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Lepisosteus osseus																					
Dorosoma cepedianum			X				X	X													
Hiodon alosoides							X	X													
H. tergisus								X													
Esox americanus		X																			
Campostoma anomalum	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X
Cyprinu carpio																					
Ericymba buccata			X					X													
Hybopsis amblops																					
H. dissimilis	X	X										X									
Notropis ardens	X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X
N. ariommus		X							X		X	X									
N. atherinoides																					
N. boops	X	X	X				X		X	X	X	X	X	X				X			
N. buchanani																					
N. chrysocephalus	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
N. emiliae																					
N. photogenis			X							X											
N. rubellus	X	X	X	X	X				X	X	X	X	X	X				X	X		
N. spilopterus	X	X	X		X		X		X	X	X	X	X	X			X	X	X		
N. stramineus				X						X	X	X	X	X			X	X	X	X	X
N. volucellus	X	X																			
N. whipplei	X	X																			
Phenacobius mirabilis																					
Phoxinus erythrogaster				X		X														X	X
Pimephales nottus	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
P. vigilax																					
Rhinichthys atratulus																					
Semotilus atromaculatus			X	X	X	X		X		X		X				X	X		X	X	X
Catostomus commersoni																					
Hypentelium nigricans		X			X					X				X	X	X		X			
Ictiobus bubalus																					
Moxostoma duquesnei		X		X			X			X				X							
M. erythrurum		X	X	X	X		X														
M. macrolepidotum		X																			
Ictalurus melas		X																			
I natalis								X									X				X
I. punctatus		X																			
Noturus flavus																					
N. miurus		X									X	X									
N. stigmosus																					
Pylodictis olivaris																					
Fundulus catenatus		X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X
F. notatus																					
Gambusia affinis	X	X																			
Labidesthes sicculu	X	X	X						X	X			X					X			
Ambloplites rupestris	X	X			X						X	X	X					X			
Lepomis cyanellus		X					X														
L. gulosus																					
L. macrochirus		X			X		X				X							X			
L. megalotis	X	X	X		X		X	X	X	X	X	X	X	X				X		X	X
L. microlophus																					
Micropterus dolomieui		X					X	X	X	X		X	X					X	X		
M. punctulatus		X							X	X	X	X									
M. salmoides							X														
Pomoxis annularis																					
Ammocrypta pellucida																					
Etheostoma blennioides	X	X	X		X					X	X	X		X	X				X	X	
E. caeruleum	X	X	X	X	X			X	X	X	X	X	X		X	X	X		X	X	
E. flabellare	X	X	X	X	X	X		X		X	X	X		X	X	X			X	X	X
E. nigrum		X	X				X			X		X		X	X					X	
E. spectabile			X		X	X	X					X		X	X	X				X	X
E. zonale	X	X	X							X	X	X		X	X						
Percina caprodes	X	X			X							X									
P. maculata		X	X																		
P. phoxocephala																					
Aplodinotus grunniens		X																			
Cottus carolinae																					
Total Species	19	35	21	13	18	6	16	12	14	21	20	24	10	18	10	10	10	14	13	14	12

Extensive fish collection data from the Beech Fork and Salt River by Hoyt et al. (19, 20) and Henley (6) were used to compare the relative similarity of the Rolling Fork ichthyofauna with that found in those drainages. Three species reported by those researchers were excluded from the analysis. Our reexamination of the specimens of *Noturus eleutherus* reported by Hoyt et al. (20) revealed them to be *N. miurus*. Voucher specimens for *Fundulus olivaceus* and *Percina copelandi* collected by Henley (6) are unavailable and we believe those species were misidentified. Thus, the total number of species for the Beech Fork and Salt River were considered to be 65 and 70, respectively.

Eighty two per cent of the Beech Fork fauna and 80% of the Salt River fauna are shared with that of the Rolling Fork. The close affinity of the faunas was not surprising considering their proximity to one another. Faunal differences were mainly a result of the absence of several large-river catostomids from our collections and the absence of the hiodontids, several cyprinids, an ictalurid, and a percid (e.g., *Hiodon alosoides, H. tergisus, Hybopsis dissimilis, Notropis emiliae, Rhinichthys atratulus, Noturus stigmosus, Ammocrypta pellucida*) from known the ichthyofauna of the Beech Fork and Salt River.

The Rolling Fork appears to support the most diverse ichthyofauna within the Salt River drainage. The central part of the Rolling Fork drainage is of particular importance as it possesses habitat that supports 2 of Kentucky's threatened fishes as well as several flourishing mussel beds. In view of recent efforts to develop the oil shale resources in the Rolling Fork drainage, special attention should be given to protecting and maintaining the integrity of these habitats and the diverse fauna they support.

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An Analysis of the Lloyd Wildlife Preserve Forest, Grant County, Kentucky

William S. Bryant
Department of Biology, Thomas More College, Crestview Hills, Kentucky 41017

ABSTRACT

The forest of the Lloyd Wildlife Preserve, Grant County, Kentucky was sampled and analyzed in 1978 and these results were compared to those Braun reported on this same forest in 1950. The same 16 tree species were reported in both samples, but the percentage composition of the canopy dominants varied considerably between the 2 sampling dates. This latter difference may be real or an artifact of difference in sampling techniques and size-class determinations. Resamplings of old-growth forests in the Midwest have shown that compositional changes do occur as a result of growth, death, and reproduction and can occur over time periods as short as 10 years.

INTRODUCTON

The canopy composition of the Lloyd Wildlife Preserve Forest (LWPF) in northern Grant County, Kentucky was reported by Braun (1). Because of the topography, and the forest's location and species composition, she had difficulty in deciding whether it was more representative of the Outer Bluegrass or the Eden Shale Belt subregion of the Bluegrass Region. Her general conclusion was that it illustrates the type of mixed forest on the less steep slopes of the region along the boundary of the Outer Bluegrass and Eden Shale Belt. Braun's description of the LWPF is as follows: "Here oaks (mostly white and black) form about 30 per cent of the canopy, beech 22 per cent, and sugar maple 15 per cent, in a mixed forest of 16 canopy species".

This forest was briefly described in "Naturalist's Guide to the Americas" (2). Their description is as follows: "This [forest] consists of two tracts of about 20 acres each that have never been touched with the ax. It represents the natural woods as it existed originally in the Blue Grass region of Kentucky. The trees are mostly beech, maple, walnut, oak, tulip and other trees. Lying on the crest of the ridge they are not subject to wash and the soil is the accumulation of the humus of ages. Trees that blow over or fall down are not removed and the rotting logs are characteristic of a primeval forest".

At one time the 2 tracts that make up the LWPF were contiguous, but they are now separated by a field. Each old-growth tract is ≈ 8 hectares in size. They are nearly identical in topography and soils. The most widely distributed soil in the preserve is the Lowell silt loam, a deep, well-drained soil formed in residuum from limestone and siltstone interbedded with thin layers of calcerous shale (3). Other soils present but of limited distribution in the forest are the Nicholson silt loam, a loessal soil with a slowly permeable fragipan, and the Eden flaggy silty clay, a well-drained, but somewhat droughty soil (3).

The average annual temperature for Grant County is 12.2°C, with an average January minimum of 6°C and a July maximum of 30°C (3). The average annual precipitation is 108.5 cm with approximately 55% of the total falling during April-September (3).

This paper presents the results of a vegetational study of LWPF and attempts to compare the results with Braun's. It is recognized that exact comparisons are impossible due in part to Braun's failure to give her canopy size class diameter determination.

METHODS OF ANALYSIS

The point-quarter method was used to sample the forest (4). A total of 50 points was sampled at 30-m intervals along line transects through the two forest tracts. No points were taken within 10 m of the forest edge. Only trees ≥ 10 cm diameter-breast-height (dbh) were measured. Relative frequency (RF), relative density (RD), and relative dominance (RDo) were calculated, and these values were summed to give an importance value (IV) for each tree species. Tree seedlings and shrubs were sampled in 20 0.004 ha circular plots and saplings in 20 0.01 ha circular plots. Seedling-sapling size classes follow Bryant (6) and are placed in 5 classes based on height and diameter. Following Abrell and Jackson (5), trees ► 30 cm dbh were considered to be canopy trees and those smaller subcanopy trees. At Natural Bridge, Kentucky Braun (1) used ► 30 cm dbh and at Ault Park, Ohio she used ► 46 cm dbh as her canopy size. These were the only 2 forests based on her studies for which she gave canopy size determinations (1). Much of Dr. Braun's correspondence and papers are held by the Cincinnati Museum of Natural History, but these have not been catalogued. No field notes are known to be in these papers so exact size for canopy members at the LWPF is not known, however, based on the 2 studies cited it is known that ► 30 cm was a value that she used for canopy inclusion.

Species diversity patterns were calculated from Braun's (1) canopy data and for each stratum recognized in the present study using the Shannon-Wiener (7) index (H^1): $(H^1) = -\Sigma p_1 \log^2 pi$, where S is the number of species and p_i is the proportion of each species in the forest. The similarity coefficient of Bray and Curtis (8) was used to calculate vegetational similarity between Braun's sample and my sample for LWPF. It is $C = (2w)/(a + b)$, where a = the sum of the canopy percentages for all tree species in Braun's (1) sample, b = the sum for my sample, and w = the sum of the lower percentages for those species which are common to the two samples. The $\overline{z}$ test was used to determine significance of difference between the two samples.

Counts of fallen trees and standing dead trees were made at LWPF. Nomenclature follows Fernald (9) for all trees in the study.

Table 1. Canopy composition of the Lloyd Wildlife Preserve Forest, Grant County, Kentucky as presented by Braun in 1950 and in 1978 (this study). Data on subcanopy composition in 1978 also is given.

	CANOPY			SUBCANOPY	
	1950 %	1978 %	t/ha	1978 %	t/ha
Acer saccharum	15.00	25.81*	(31.2)	81.31	(113.0)
Tilia americana	5.40	5.38	(6.5)	3.74	(5.2)
Fagus grandifolia	22.20	10.75*	(13.0)	4.67	(6.5)
Juglans nigra	9.60	7.53	(9.1)	---	---
Quercus alba	16.20	4.30*	(5.2)	---	---
Quercus velutina	9.00	7.53	(9.1)	---	---
Quercus muehlenbergii	2.40	2.15	(2.6)	---	---
Quercus rubra	1.80	2.15	(2.6)	---	---
Fraxinus americana	6.60	15.05*	(18.2)	1.87	(2.6)
Fraxinus quadrangulata	0.60	1.08	(1.3)	---	---
Carya ovata	4.20	9.68**	(11.7)	2.80	(3.9)
Carya cordiformis	0.60	3.23*	(3.9)	0.93	(1.3)
Carya glabra	1.20	2.15	(2.6)	0.93	(1.3)
Ulmus rubra	3.00	1.08	(1.3)	1.87	(2.6)
Nyssa sylvatica	1.80	1.08	(1.3)	---	---
Celtis occidentalis	0.60	1.08	(1.3)	1.87	(2.6)

*These values are significantly different at the 0.05 level
**These values are significantly different at the 0.01 level

RESULTS

If it is assumed that *Carya cordiformis, Tilia americana,* and *Quercus rubra* are the same as *Carya* sp., *Tilia neglecta,* and *Quercus shumardii,* respectively, of Braun's (1) list, then the same 16 species were recorded in both samplings. Braun (1) counted canopy trees only. Thus, she gave no information on tree-size classes or on other strata.

In my study there were 260 trees/hectare (t/ha), of which 46.5% (121 t/ha) were in the canopy and 53.5% (139 t/ha) in the subcanopy. A comparison of the present canopy to the one sampled by Braun (1) is presented in Table 1. Sugar maple is now the canopy dominant followed by white ash and then beech. It should be remembered that Braun (1) did not state her canopy class dbh so care was exercised in judging the 2 samples. Of the 8 most prominent canopy trees in Braun's study, *Acer saccharum* (sugar maple), *Fraxinus americana* (white ash) and *Carya ovata* (shagbark hickory) have higher percentage canopy composition in my sample; *Fagus grandifolia* (beech), *Quercus alba* (white oak), *Q. velutina* (black oak) and *Juglans nigra* (black walnut) now have lower percentages and *Tilia americana* (basswood) is about the same. The other 8 tree species were of minor importance in both samples and it is their consistency which suggests that the canopy size class used in both samplings is approximately the same.

Sugar maple in now the dominant subcanopy tree, accounting for over 81% (113 t/ha) of the individuals in this stratum (Table 1). No other tree species accounted for as much as 5% of the subcanopy, and the oaks and black walnut are not represented at all.

Sugar maple ranks first in IV at 118.83 (Table 2) when all trees are included. The IVs for all other tree species generally follow the present canopy rankings. The total basal area for the forest is 35.5 m^2/ha, with 86% of that contributed by the canopy component. Based on seedling-sapling data, only sugar maple reached tree replacement size and was represented in all 5 size classes (Table 3). Basswood is reproducing from sprouts and seed, but percentage seedling establishment of the oaks and hickories is low. Beech is not represented in the seedling-sapling stratum. The shrub layer is primarily composed of *Asimina triloba* and *Lindera benzoin,* and they are rather localized in the forest.

Canopy diversity (H') based on Braun's data was 3.33; it is now 3.37. Subcanopy diversity, 1.22, is the lowest of any stratum. Total tree diversity is 2.53, seedling-sapling when grouped 2.32 and shrub 1.93.

A total of 44 dead canopy trees was counted. Of these, 36 were windthrown, and 8 were standing dead. Most of them are oaks, beech, hickory, and basswood; however, some identifications were difficult due to many of the trees being in late stages of decomposition.

Table 2. Relative frequency (RF) relative density (RD), relative dominance (RDo) and importance value (IV) of tree species at the Lloyd Wildlife Preserve Forest in 1978.

Tree Species	RF	RD	RDo	IV
Acer saccharum	37.70	55.50	25.63	118.83
Fraxinus americana	11.48	8.00	18.66	38.14
Fagus grandifolia	9.02	7.50	8.52	25.04
Carya ovata	8.20	6.00	5.45	19.65
Quercus velutina	5.74	3.50	10.30	19.54
Tilia americana	4.92	4.50	5.34	14.76
Juglans nigra	4.92	3.50	4.86	13.28
Quercus alba	3.28	2.00	7.44	12.72
Carya cordiformis	3.28	2.00	1.87	7.15
Quercus rubra	1.64	1.00	4.50	7.14
Quercus muhlenbergii	1.64	1.00	2.70	5.34
Carya glabra	2.46	1.50	1.00	4.96
Celtis occidentalis	2.46	1.50	0.70	4.66
Ulmus rubra	1.64	1.50	1.19	4.33
Fraxinus quadrangulata	0.82	0.50	1.21	2.53
Nyssa sylvatica	0.82	0.50	0.62	1.94

Table 3. Seedlings and saplings per hectare of tree and shrub species at the Lloyd Wildlife Preserve Forest, Grant County, Kentucky. Relative density (RD), based on all size classes for each species, is presented also.

	Seedlings		Saplings			
Trees / Size Class	1	2	3	4	5	RD
Acer saccharum	1025.05	24.70	34.58	29.64	39.54	36.03
Ulmus rubra	975.65	24.70	19.76			31.87
Fraxinus americana	419.19		4.94			13.27
Celtis occidentalis	209.95					6.56
Tilia americana	160.55	12.35	4.94	29.64		6.48
Carya sp.	86.45					2.70
Morus rubra	37.05					1.16
Prunus serotina	24.70					0.77
Quercus muhlenbergii	12.35					0.39
Quercus alba	12.35					0.39
Juglans nigra	12.35					0.39
Shrubs & Understory Trees						
Asimina triloba	1222.65	49.40	34.58			51.41
Lindera benzoin	382.85	234.65	19.76			25.07
Sambucus canadensis	271.70					10.69
Staphylea trifolia	111.15	12.35				4.86
Euonymus atropurpureus	111.15					4.37
Cornus florida	61.75	24.70				3.40
Cercis canadensis			4.94			0.19

DISCUSSION

Braun's (1) data show that the beech-maple and oak-hickory components of the LWPF were nearly equal, i.e. 37.2% and 35.4%, respectively. In southern Indiana *Fagus-Quercus-Acer-Carya* forests were termed "western mesophytic" (10) but, they were later renamed "mixedwoods" (11) which is similar to Braun's (1) designation of the LWPF as "mixed forest". The present canopy composition of 36.56% beech-maple and 31.19% oak-hickory may appear at first to be little different from Braun (1). However, this is not the case, since individual tree species showed differences in canopy percentages. Similarity (C) between Braun's (1) canopy and the present canopy is 70.4%. Bray and Curtis (8) reported that replicate samples in the same forests that they sampled probably would have C values of ≈ 80-85%. Again, it is assumed that Braun and I were sampling approximately the same canopy-size class for these differences to be meaningful.

Recent studies of forests suggest that there may be shifts in the dominant tree species at long (12) or short term intervals (5, 13, 14). Lindsey and Schmelz (13) and Schmelz et al. (14) recorded composition changes at Donaldson's Woods, Indiana for 10 and 20 year periods, respectively. In their study of Hoot Woods, Indiana, Abrell and Jackson (5) noted composition changes due to growth, mortality, and reproduction over a 10-year period. These works and others (15, 16, 17, 18) point to an increasing importance of sugar maple and a decreasing importance of certain associated hardwoods in the Midwest. Buell et al. (19) stated that the upland oak forests of New Jersey were changing to maple.

The abundance of sugar maple in the LWPF subcanopy shows its shade tolerance and thus its competitive advantage over associated species. Sugar maple benefits from release (20) and because of its dominance in the subcanopy is in position to take advantage of any canopy openings created by death or windthrow. White ash ranked second in IV to sugar maple largely because of its basal area. Schmelz et al. (14) found that white ash is increasing in importance in the canopy of Donaldson's Woods, Indiana. Although white ash was quite abundant in the seedling classes at the LWFP its density was much lower in the sapling classes. This is in agreement with Fowells (21) who stated that white ash is shade tolerant when young, but with age it becomes intolerant.

The lesser importance of beech and white oak in the LWPF canopy in 1978 than in 1950 (1) seems to be consistent with data reported in the literature. Abrell and Jackson (5) and Schmelz et al. (14) reported that beech is declining in the old-growth forests of Indiana. Their conclusions are based on resampling studies of greater precision than used in this study. In Indiana, Schmelz et al. (14) found little growth or increase in density of oak in the seedling-sapling layers. Anderson and Adams (17) stated that in the forests of central Illinois, white oak was being replaced by shade tolerant trees on mesic sites. Peet and Loucks (22) considered the oaks to be shade-intolerant species, and in their studies they found oak species to be of greatest importance in the larger size classes. This also is true for the oaks at the LWPF.

Although sugar maple presently is the dominant tree species at LWPF, it seems premature to conclude that the forest is now a different type than at the time of Braun's (1) sampling. Canopy diversity remains high, and no species have been eliminated from the LWPF between the 2 sampling periods. For the longer-lived species, i.e. oaks and beech, the potential seed source is still there to maintain diversity. The shifting and sorting of the dominants demontrates the dynamics of the forest system and seems consistent with the results of other resampling studies. The low diversity in the sub-canopy follows the trend hypothesized by Loucks (12). More work on the subcanopy is needed to determine its relationship to the canopy.

The earlier reports on the LWPF (1, 2) considered it to be climax. Its species composition (23) and basal area (24) are regarded as characteristics of the regional climax. According to Horn (25), "The stability of the climax forest, if it exists, is not a stability of age structure but a stability of species composition." Thus, it would seem that the periodic resampling of old-growth forests is one way to determine if they are stable.

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Statistical Modeling and Mapping Selected Physical Characteristics Associated with Roof Falls in an Eastern Kentucky Coal Mine

Alan D. Smith

Department of Quantitative and Natural Science,
Robert Morris College, Coraopolis, PA 15108

Abstract

Cost-sensitive mine planning systems assume that the physical and economic conditions that will have the greatest impact on cost and coal quality can be predicted accurately enough to assist mine planners in making decisions. Although roof falls are discrete in their occurrence, mapping applied to mining design assumes that the causes of failure are based primarily on geological and rock mechanical properties which may be continuous in nature and, hence, be subject to detectable patterns. Two such factors, namely thickness of first immediate rock bed in mine roof and estimated volume of fallen material, both extremely important parameters in entry span calculations and design layout, were measured and mapped for 72 roof falls in an eastern Kentucky coal mine. The major statistical and analysis tools used in the present study were polynomial trend surface analyses, hypothesis testing and model comparisons of trend surfaces, and three-dimensional displays generated from commercially available computer software, via the incremental plotter.

The mean thickness of the first immediate roof bed was determined to be 36 cm and the average volume of roof fall was found to be 294m^3. Traditional AVOVA techniques and hypothesis testing and model comparisons of trend surfaces delineated the fifth order surface (R^2 = 46%) as the statistically best fit (p = 0.01) over the lower-order, polynomial trends. However, no trend surface accounted for enough explained variance in predicting the estimated volume of fallen debris as a function of location in the mine site. In addition, three-dimensional graphical displays of structure contour, trend, and residual surfaces were generated to allow the potential user to portray selected distributions in order to plan preventative measures in the future.

INTRODUCTION

Since the first records were kept in 1838 on coal mine health and safety, more than 130,000 miners have lost their lives in mine accidents in the United States. Death rates in mines of this country have been found to be higher than in any other Western industrial nation engaged in coal mining (1). A major cause of this death and physical injury to underground coal mines is roof failure. As suggested by Moebs and Stateham (2), instability in coal mine roofs is considered to be either the result of defect-related/geological features or non-defect-related, such as the strength-stress state existing in the rock mass (3). Support of underground entries are based on recommendations of the physical characteristics of geologic structures and the overall effect the structures have on mine roof stability.

The stability of coal mining tunnels, entries, rooms, and associated openings plays a major role in the success of any major underground project. Hence, if the main access openings to a new coal mine become deformed and damaged by strata movement to the extent of requiring serious repairs, special problems may arise which will have an influence on ventilation, impairment to speed and reliability of transport systems as well as the direct and indirect costs involved with the repair program (4-7).

The mechanical design of a roof support system is basically a matter of a working knowledge of statics and dynamics, assuming that the imposed loads and mining conditions are known. However, in the Appalachian coal fields the general conditions are known well enough to allow for the majority of mining operations, including traditional room-and-pillar as well as longwall mining techniques, to be furnished with standard and commercially available supports. Of course, these support systems and roof control procedures are equipped with suitable variants and options (8). The overall design of a mining system, which design incorporates not only size and capacity of the equipment to be used; but includes: equipment adaptability to the mining scheme; equipment versus human constraint, operation at the designed levels; and coordination of operation, maintenance and support design (8).

Hence, a multitude of factors must be considered in the successful underground operation (9). Cost-sensitive mine planning systems have been developed to help coal companies design underground mines that will recover coal reserves in the most profitable method. Information obtained from borehole logs, local mines, mining equipment manufacturers, and previous mining experience should be used in the mine planning process. According to Ellison and Scovazzo (10), cost-sensitive mine planning assumes that the physical and economic conditions that will have the greatest impact on cost and coal quality can be predicted accurately enough to assist mine planners in making decisions. In the planning process, many maps, such as coal seam thickness, expected roof caving conditions, geologic lineaments, roof shale thickness, distance to the first sandstone, overburden thickness, underclay thickness, as well as a host of other factors, can be generated as overlays on each other to assist planners in selecting appropriate locations and orientations for the portal, mains, submains, and longwall panels (3, 11-13). As compiled and summarized by Moebs and Stateham (11), a recent study to investigate in a graphic manner, all rock fall hazards related to geologic conditions in the Pittsburgh Coalbed for a 9-county area, located in northern West Virginia and Southwestern Pennsylvania, resulted in the systemic collection and analysis of field data. A total of 7 geologic and 5 mining-engineering related variables were found to be causally related to roof failure. However, only 3 of the significant geological parameters, namely overburden thickness, roof lithology, and vertical distance to the rider coal seam, were found to be useful in the final map preparation.

The thrust of the present study is to examine the spatial distributions of thickness of the first immediate roof bed and estimated volume of fallen debris from a historical record of previous mine roof falls in a particular site and determine if spatially predictive relationships exist and plot them for future design work. Although mine roof falls are not random events and their occurrence is usually contibuted to an interaction of a host of geological and stress-strength parameters, frequently some of the conditions that cause failure may be continuous in nature. Example of this continuous nature in mine roof failure includes, as previously stated, overburden thickness, roof lithology, and vertical distances to selected bedding-plane features. Thickness of the first immediate roof bed may be continuous and a factor in ground control. In fact, this factor serves as a standard input variable in the calculation of safe entry spans in underground mine design. However, volume of fallen material in a roof failure is the result of a complex interaction of tensile and compression forces occurring in a rapidly changing geologic environment and conditions. The factors related to the amount of volume swell and material released from a fall are based on both continuous and discrete distributions. If these relationships exist, they may prove useful in a cost-sensitive mine plan to avoid selected interactions of ranges of thickness of immediate roof beds and possibly high volumes of fallen material for room or main entry development

METHODS

The major analysis and statistical tools used in the present study are polynomial-trend surface analyses (14), hypothesis testing and model comparisons of trend surfaces (15-18), and three-dimensional displays generated from commercially available computer software via the incremental plotter (19-21).

One mine was selected for the study of the Eastern Kentucky coal fields to apply cost-sensitive mapping procedures with the combined use of trend surface analyses and three-dimensional modeling techniques. However, due to proprietary purposes, the mine site will remain unidentified. A total of 72 actual mine roof falls were measured and the thickness of the first immediate roof bed (in cm) and estimated volume of fallen rock (in m^3) were recorded. The mean thickness was determined to be 36 cm and the average volume of roof fall was found to be 293 m^3. Each roof fall location was recorded and trend surface analyses, via SYMAP (22) and a computer program suggested by Smith (15) were performed. In addition, three-dimensional graphical displays were created.

RESULTS

Tables 1 through 2 illustrate the results of the model comparisons and hypothesis testing of polynomial trend surfaces in predicting thickness of immediate roof bed and volume of fall. Contained in Table 1 is the hypothesis testing results, in standard analysis (ANOVA) format, to determine if the fifth degree polynomial trend surface for thickness of immediate roof bed is significant. The variance accounted for by the fifth order surface was 46 percent, and this was found to be statistically significant ($p = 0.01$). Table 1 also contains a similar ANOVA table presenting the model comparison of the fifth order versus the fourth order trend surface for the thickness parameter. Table 2 presents a summary of the actual, predicted, and residual or error values of the immediate mine bed. The fifth-degree regression equation, as shown at the bottom of the table, was employed to derive the predicted values for immediate roof bed. In Table 1 is a summary of the F-ratios, probability levels, R^2 for both the full and restricted models, degrees of freedom-numerator, degrees of freedom-denominator, and significance for each trend surface for the associated roof fall parameters. As evident from the table, the fifth degree polynomial trend surface was the statistically best fit; however, no trend surface accounted for enough explained variance in predicting the estimated volume of fallen debris as a function of location in the mine site.

TABLE 1. -Summary of F-Ratios, Probability Levels, R^2 for Both the Full and Restricted Models, Degrees of Freedom-Numerator, Degrees of Freedom-Denominator, and Significance for Each Trend Surface for Associated Roof Fall Parameters.

Order of Trend Surface	R^2_f	R^2_r	dfn / dfd	F-Ratio	Prob.	Significance
THICKNESS OF THINNEST IMMEDIATE LAYER (N = 72)						
1	0.0466	0.0	2/69	1.6872	0.1926	NS
2	0.1063	0.0	5/66	1.5704	0.1807	NS
3	0.2093	0.0	9/62	1.8238	0.0816	NS
4	0.2733	0.0	14/57	1.5309	0.1296	NS
5	0.4595	0.0	20/51	2.1680	0.0136	S*
6	0.4945	0.0	27/44	1.5942	0.0828	NS
1 vs 2	0.1063	0.0466	3/66	1.4694	0.2309	NS
2 vs 3	0.2093	0.1063	4/62	2.0192	0.1027	NS
3 vs 4	0.2733	0.2093	5/57	1.0029	0.4244	NS
4 vs 5	o.4595	0.2733	6/51	2.9294	0.0156	S**
5 vs 6	0.4945	0.4595	7/44	0.4349	0.8749	NS
VOLUME OF FALLEN MATERIAL (N = 72)						
1	0.0118	0.0	2/69	0.4124	0.6637	NS
2	0.0217	0.0	5/66	0.2931	0.9151	NS
3	0.0710	0.0	9/62	0.5265	0.8498	NS
4	0.1204	0.0	14/57	0.5576	0.8861	NS
5	0.2451	0.0	20/51	0.8279	0.6703	NS
6	0.3230	0.0	27/44	0.7774	0.7541	NS
1 vs 2	0.0217	0.0118	3/66	0.2228	0.8802	NS
2 vs 3	0.0710	0.0217	4/62	0.8222	0.5160	NS
3 vs 4	0.1204	0.0710	5/57	0.6409	0.6694	NS
4 vs 5	0.2451	0.1204	6/61	1.4035	0.2315	NS
5 vs 6	0.3230	0.2451	7/44	0.7230	0.6532	NS

NOTE: The symbols* denote statistical significance at 0.01 level, ** denote statistical significance at 0.05 level, both for a two-tailed, nondirectional test. The term R^2_f refers to the variance explained by the higher order surface compared to total variation. In addition, this "full model" may contain the equation that is being tested for its contribution of additional variance in explaining the spatial distribution of these parameters. The term R^2_r refers to the restricted model concept in multiple linear regression terminology. The term is a measure of the relationship of random variation (R^2_r = 0.0) or the contribution to explained variation associated with the lower order coefficients or the equation that is being held constant or covaried with respect to the other models.

TABLE 2 - Location Coordinates, Actual and Predicted Values, and Error Values for Thickness of First Immediate Mine Roof Bed Using the Fifth-Order Polynomial Trend Surface (Partial Listing Only).

Coordinates[a]		Thickness Values, Inches (cm)		
X	Y	Actual	Predicated[b]	Residual
65.9	8.5	14.0(35.6)	40.735	−26.735
65.5	15.0	5.0(12.7)	1.842	3.158
65.0	15.8	8.0(20.3)	14.632	−6.632
17.1	16.1	8.0(20.3)	11.929	−3.929
16.0	17.4	8.0(20.3)	12.730	−4.730
16.7	19.4	72.0(182.9)	25.046	46.954
11.1	8.2	12.0(30.5)	47.698	−35.698
7.0	9.0	22.0(55.9)	42.917	−20.917
49.4	21.2	22.0(55.9)	29.628	−7.628
5.5	7.8	30.0(76.2)	14.546	15.454
29.9	17.5	60.0(152.4)	26.141	33.859
66.2	17.0	60.0(152.4)	54.416	5.584
66.7	17.0	60.0(152.4)	56.539	5.461
15.4	21.5	3.0(7.6)	−0.027	3.027
11.7	7.7	68.0(172.7)	45.785	22.215
50.0	7.9	13.0(33.0)	6.296	6.704
47.3	20.5	2.5(6.4)	0.283	2.217
46.0	20.5	2.5(6.4)	−6.780	9.280
47.4	18.7	3.0(7.6)	−1.351	4.351

[a]Coordinates are in the SYMAP-axis system

[b]Fifth-order polynomial equation (where X and Y are geographic coordinates):

$$\begin{aligned}\text{thickness} &= 2768.7116427 + 21321686128X + 782.77753213Y - 5.602514505X^2 \\ &- 45.814074202XY - 81.42855572Y^2 + 0.070304671515x^3 + 0.85569130249x^2y + \\ &.3485095666XY^2 + 3.9214765325Y^3 - 0.00051850363X^4 - .00463995993X^3Y - \\ &0.05181088811X^2Y^2 - 0.937890466930001\,XY^3 - 0.96351327910001\,Y^4 + \\ &0.227491497260005X^5 - 0.000000380589X^4Y + 0.00023142890X^3Y^2 + \\ &0.000068338864046X^2Y^3 + 0.00093184394XY^4 + 0.00094858352Y^5\end{aligned}$$

The graphic displays of the three-dimensional plots for each mine-roof fall parameter can be found in figures 1 through 11. Figures 1 and 2 illustrate the basic isopach contour for thickness of first immediate roof bed, Figure 3 displays the fifth degree polynomial surface, and figures 4 and 5 present the three-dimensional distribution of residuals (the difference between the actual and predicted values). Figures 6 through 11 display similar information for estimated volume of fall debris from the mine roof, using fourth-order surface as an example. Since, several statistical techniques were applied to the response surfaces found in the figures, a common orientation was not shared among all the graphical displays. The perspective were changed from NE to SE in order to view high and low areas on the structure, trend, and residual maps to aid in their overall interpretation and illustrate the plotting software's versatility in graphically presenting the distributions.

DISCUSSION

As evident from Figures 1 through 11, and Tables 1 and 2, a significant and predictive trend exists for thickness of the thinnest immediate layer in the mine roof, but not for estimated volume of fallen debris, for the roof falls studied. A fourth-degree polynomial surface accounted for a significant amount of explained variance ($R^2 = 0.46$) in predicting thickness of immediate roof beds. However, as shown in figures 4 and 5, residuals or the errors between the actual and predicted values occur and are centrally located.

Although coal-mine failure areas are discrete in their actual occurrence, mapping procedures applied to mine-layout design assumes that the causes of failure are primarily based on geological and rock mechanical properties, which may be continuous in nature and, hence, be subject to detectable patterns. As evident from the statistical analyses of response

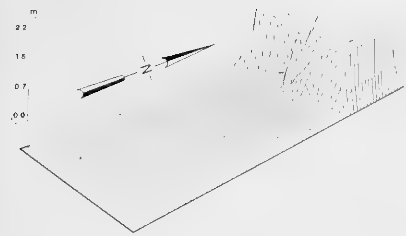

Figure 1. Structure Contour of Thickness of First Immediate Roof Layer in Mine Roof as Viewed from the Southeast Direction.

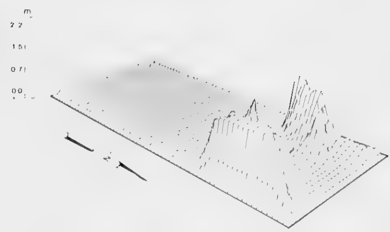

Figure 2. Structure Contour of Thickness of First Immediate Roof Layer in Mine Roof as Viewed from the Northeast Direction.

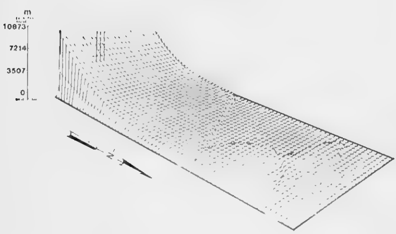

Figure 3. Three-dimensional Model of the Fifth-Order, Polynomial Trend Surface for Thickness of First Immediate Roof Layer in Mine Roof as Viewed from the Northeast Direction.

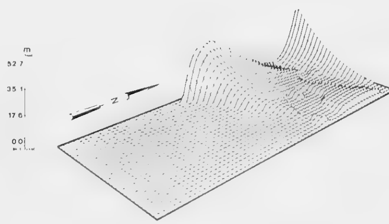

Figure 4. Three-dimensional Model of the Fifth-Order, Polynomial Residual Surface (Positive Values) for Thickness of First Immediate Roof Layer in Mine Roof as Viewed from the Southeast Direction.

surfaces, detectable patterns of the thickness of the first immediate roof bed, associated with the recorded roof falls, were found. This pattern is probably due to continuous geologic conditions found in the mine site. However, no detectable pattern was discovered for determining the regional trend of estimated volume of fallen rock in these failure areas throughout the mine site. Although the size of roof falls are related to mine span, bedding and geological features that may be continuous, a host of other factors and their sequential interactions were evidently too complex to effective map and predict, without controlling for these other important parameters. In addition, since volumes of roof falls are generally not continuous in space, it may not be apparent that polynomial modeling is appropriate in this circumstance. However, the search in the literature of coal-mine roof failure presented no other acceptable alternative for mapping and predictive evaluation of size and volume characteristics of fallen debris as a function of spatial coordinates.

The figures show the magnitude and distribution of error in prediction of the various roof-fall parameters. However, as demonstrated in Table 2, the spatial coordinates of the measured values are somewhat clustered and irregularly-spaced throughout the mine layout. When fitting a continuous polynomial surface over this type of data, the few control points along the periphery of the mine site allows the surface to be distorted and highly exaggerated. The magnitudes of the parameters, as evident from the legends on each figure that is derived from the curve-fitting of the regression equation were quite large and unrealistic. For example, in Figures 1 and 2, the actual data range, starting from the base plane, was 0.0 to 2.16 meters. The magnitudes for immediate roof-bed thickness reached an unrealistic value of over 10,871 meters. These extreme values, of course, are the extrapolations of the polynomial surface beyond the constraints of the data, where spatial control is not achieved. Hence, most of the graphical displays are merely artifacts or abstracts of the polynomial surface that has no real meaning. Although, the equations used to predict immediate roof-bed thickness are restricted to about two-thirds of the mine layout, the methodology is essentially correct. However, a greater attempt must be made to have representative control points through the study area. One useful function of generating these plots are to isolate these areas that are unconstrained in terms of modeling. With this knowledge, the mining engineer/geologist can quickly isolate those mine sections that do not meet the conditions of the polynomial model. In this way, the model can be correctly applied to those areas that are feasible for predictive purposes.

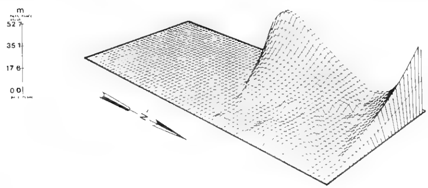

Figure 5. Three-dimensional Model of the Fifth-Order, Polynomial Residual Surface (Positive Values) for Thickness of First Immediate Roof Layer in Mine Roof as Viewed from the Northeast Direction.

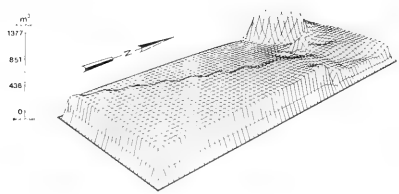

Figure 6. Structure Contour of Estimated Volume of Fallen Material from Mine Roof as Viewed from the Southeast Direction.

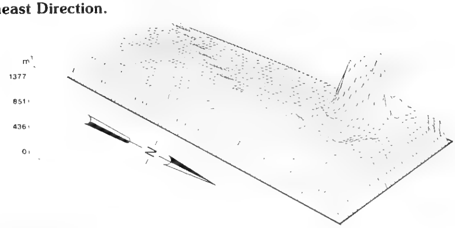

Figure 7. Structure Contour of Estimated Volume of Fallen Material from Mine Roof as Viewed from the Northeast Direction.

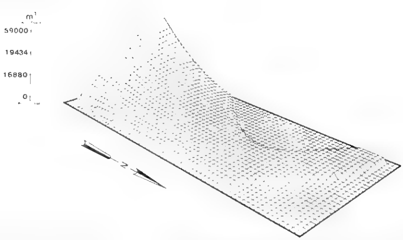

Figure 8. Three-dimensional Model of the Fourth-Order, Polynomial Trend Surface for Estimated Volume of Fallen Material from Mine Roof as Viewed from the Northeast Direction.

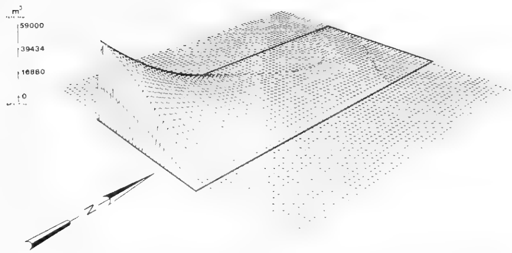

Figure 9. Three-dimensional Model of the Fourth-Order, Polynomial Trend Surface for Estimated Volume of Fallen Material from Mine Roof as Viewed from the Southeast Direction.

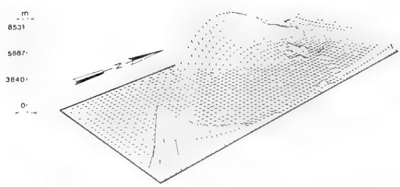

Figure 10. Three-dimensional Model of the Fourth-Order, Polynomial Residual Surface (Positive Values) for Estimated Volume of Fallen Material from Mine Roof as Viewed from the Southeast Direction.

Figure 11. Three-dimensional Model of the Fourth-Order, Polynomial Residual Surface (Positive Values) for Estimated Volume of Fallen Material from Mine Roof as Viewed from the Northeast Direction.

CONCLUSIONS

The major benefit of modeling research is to be able to visualize the actual distributions of important parameters associated with roof falls. Examples illustrated in this research allow the user to portray selected distributions of parameters in order to access the potential of these techniques as an aid to avoid potentially problematic areas. The use of plotting statistical as well as actual contour surfaces, allows the investigator a chance to actually visualize what the surface looks like and the residuals or errors in prediction and their magnitudes. This process can bring in the administrator and engineer's "common sense" as well as geological and engineering judgement into play to determine the best fit or model, if one exists. With the increasing use and availability of appropriate software and hardware, computer modeling should be used in conjunction with statistical models in estimating the usefulness and limitations of trend-surface analyses for predictive purposes in the mining industry.

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Effect of Soil Phenolic Compounds on Growth and Fatty Acid Composition of *Pisolithus tinctorius*

J. H. Melhuish, Jr. and G.L. Wade
United States Department of Agriculture, Forest Service
Northeastern Forest Experiment Station, Berea, KY, USA 40403

ABSTRACT

One to 1000 μ mol/L of ferulic, p-coumaric, and vanillic acids in liquid growth media decreased growth (dry-weight production), increased total lipids as percent of dry weight and lowered the 18:1 to 18:2 fatty acid ratio in the ectomycorrhizal fungus *Pisolithus tinctorius*. Vanillic acid affected the fatty acid ratios only at the higher concentrations tested. Two-and three-times normal nutrient concentrations decreased growth but partly offset some of the effects of ferulic acid. These results suggest that phenolic compounds produced by some higher plants may cause alteration of growth and liquid synthesis in *P. tinctorius*.

INTRODUCTION

Reclamation of surface-mined lands for forestry and wildlife uses is an established and desirable practice, but it has declined in the United States in recent years due to frequent failure of reforestation efforts. The Surface Mining Control and Reclamation Act (Public Law 95-87) and regulations promulgated under it now require regrading of spoils and establishment of a nearly complete herbaceous ground cover. Competition between this herbaceous vegetation and tree seedlings often results in death of trees. One of the mechanisms of this competition may be allelopathy, the chemical interferences of plant species with each other (1). Allelochemics may be acting directly to inhibit the survival and growth of planted trees, retard the development of fungi that form mycorrhizae, and/or interfere with the process of mycorrhizal formation.

Water extracts from prairie soils inhibited oxygen uptake of Monterey pine (*Pinus radiata* D. Don) mycorrhizae to a greater extent than did water extracts of forest soils (2). Grass-root decomposition products also reduced mycorrhizal infection of Monterey pine (3). Many workers have found that mycorrhizare are essential for establishment of trees in adverse environments such as mine spoils (4). Plant-produced compounds are known to inhibit mycorrhizal associations (5, 6, 7, 8). Phenolic compounds limit ion uptake through alteration of membrane properties, and it has been suggested that phenolic acids can depolarize membranes (9, 10). Little work has been done on the influences of specific allelochemics on mycorrhizae (11).

Ferulic, p-coumaric, and vanillic acids are phenolic acids that have been identified in other allelopathic situations (12, 13, 14, 15), and all 3 of these compounds have been found in soils (8, 15, 16, 17). Ferulic acid is known to be exuded by root systems of *Festuca arundinacea* Schreb., *Eragrostis curvula* (Schrad.) Nees, and *Lespedeza striata* Thunb., which are commonly used as ground cover in surface mine reclamation (18). Vanillic acid is a product of fungal degradation of ferulic acid (19).

This study investigated the effect of ferulic acid (3-(4-hydroxy-3-methoxyphenyl)-2-propenoic acid), p-coumaric acid (3-(4-hydroxyphenyl)-2-propenoic acid), and vanillic acid (4-hydroxy-3-methoxybenzoic acid) on the growth and lipid content of the ectomycorrhizal fungus *Pisolithus tinctorius* (Pers.) Coker and Couch, a pioneering ectomycorrhizal fungus associated with pine on sparsely-vegetated dark-colored acid surface mine spoils (20).

MATERIALS AND METHODS

Mycelia of *P. tinctorius* were transferred to petri dishes containing approximately 25 ml of glucose-ammonium tartrate agar medium (5). When the diameter of the colonies was approximately 50 mm., 25 mm^2 sections were cut on the perimeter of mycelial mats and transferred to petri dishes containing fresh agar medium. After 3 days, individual sections that had developed aerial hyphae were transferred into forty, 125-ml Erlenmeyer flasks containing 50 ml of glucose-ammonium tartrate medium without agar (21). The phenolic compounds were sterilized by filtration and added to the sterile nutrient solution.

Flasks were incubated at 25°C in the dark for 21 days. The mycelia from each treatment group of 40 flasks were recovered by filtration using a Buchner funnel, pooled, freeze-dried, macerated in a Waring blender, and funneled into an extraction thimble. The remaining liquid media were pooled by treatment. After acidification, phenols were extracted from about 80 ml of each medium and separated by thin-layer chromatography (TLC) (22). Ultraviolet-visible scans of the liquid media (reduced 1:10) were performed on a Varian SuperScan 3 spectrophotometer for the purpose of determining absorbance peaks and thus relative amount of metobolites released into the media.

Macerated mycelia were weighed and lipids were extracted in chloroform-methanol according to Melhuish and Hacskaylo (23), and dried at 40°C under nitrogen. The lipid extract, redissolved in chloroform, dried, and weighed, was considered to be the total lipid fraction. Fatty acids were separated from the total lipid fraction after saponification with alcoholic KOH, methylation, and fractionation on an alumina column. They were stored under nitrogen in a freezer for later use. The fatty acid methyl esters were separated by gas-liquid chromatography (GLC). The separated methyl esters were characterized by comparing their retention times to those of standards. A methyl stearate standard was used for quantitative analysis.

An experiment was conducted using 1, 2, or 3 times (1X, 2X, 3X) the normal concentration of nutrients in media with and without 100 μmol/L ferulic acid to determine whether the phenolic compounds complexed nutrients in the media. The flasks were inoculated, incubated, pooled, and processed in the same manner as described in the preceding experiments.

RESULTS

Dry weight production and final pH of the media have a significant (α = .001) negative correlation (−0.84) (Table 1). Initial pH of the media was 5.40, and the pH dropped proportionally to growth of the fungus. Additionally, the mycelial mats were lighter in color, and the sizes of the fungal mats were smaller at the higher concentrations of phenolics. At 1000 μmol/L, and occasionally at 100 μmol/L, dark-colored droplets appeared on the tops of the mycelial mats. The media also became darker with each increase in concentration of the phenolic compounds. UV-visible scans (Fig. 1) of the autoclaved media before inoculation with the fungus showed no absorption in the visible range, but there was a low peak (optical density = 0.064) at about 260 nm. A peak at the same frequency was present in all subsequent scans of the treated media. The optical density of the vanillic acid treatment increased from .301 in the control to .622 at 1 mol/L, but optical density was lower at 10 and 100 μmol/L (.503 and .383, respectively). Optical density was 0.650, and a second peak appeared at 285 nm in the 1000 μmol/L treatment.

Table 1. Influence of common phenolic compounds on dry weight production in *Pisolithus tinctorius*.

	P-Coumaric Acid		Ferulic Acid		Vanillic Acid	
	dry wt.[a]	pH[b]	dry wt.[a]	pH[b]	dry wt.[a]	pH[b]
Control	100	3.11	100	3.53	100	3.19
1μ mol/L	35	3.99	72	3.86	48	4.07
10μ mol/L	33	4.00	30	4.37	60	3.79
100μ mol/L	31	4.04	37	4.27	54	3.88
1000μ mol/L	16	4.52	36	4.45	33	4.12
r^2		.95		.95		.97

[a]Dry weight as percent of control
[b]End pH of growth medium. pH at start of experiment was 5.40.

Table 2. Influence of common phenolic compounds on total lipid production in *Pisolithus tinctorius*. Values are percent of control

	P-Coumaric Acid	Ferulic Acid	Vanillic Acid
Control	100	100	100
1μ mol/L	111	80[a]	116
10μ mol/L	134	122	138
100μ mol/l	95[a]	100[a]	110
1000μ mol/L	122	66	120

[a]Small portion of sample lost during quantification

Table 3. Influence of common phenolic compounds on fatty acid chain length and saturation in *Pisolithus tinctorius*. Values are percent of total fatty acids.

	P-Coumaric Acid			Ferulic Acid			Vanillic Acid		
	16:0	18:1	18:2	16:0	18:1	18:2	16:0	18:1	18:2
Control	12	20	52	13	28	57	13	10	76
1μmol/L	13	9	76	14	10	76	16	13	70
10μmol/L	12	10	75	16	18	64	13	9	78
100μmol/L	13	9	75	13	12	73	14	6	78
1000μmol/L	19	9	69	13	14	70	14	5	79

Table 4. Influence of nutrients and 100μ mol/L ferulic acid on growth of *Pisolithus tinctorius*.

	Dry Wt./Flask		*pH at End*		*Final Media OD 260*	
	− FA	+ FA	− FA	+ FA	− FA	+ FA
1X Nutrients	.388	.148	3.22	3.94	.333	.480
2X Nutrients	.214	.158	4.36	4.35	.647	.620
3X Nutrients	.173	.165	4.53	4.55	.848	.873

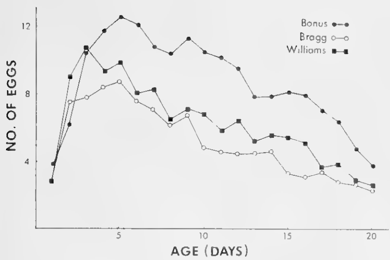

Figure 1. UV-visible scan of liquid media containing different concentrations of vanillic acid at end of experiment. NI = No inoculated; C = control; 1, 10, 100, 1000 are in μmol/L.

Extraction of the vanillic acid treatment media and separation by TLC indicated that compounds secreted by the fungus included phenolic compounds. The TLC chromatrogram at 1000 μmol/l vanillic acid showed numerous, intense, overlapping bands not seen at lower concentrations.

Percent total lipid in *P. tinctorius* increased when p-coumaric and vanillic acids were added to the media, but ferulic acid did not consistently show this response (Table 2). With the smallest additions of ferulic and p-coumaric acids, there was a change in the ratio of 18:1 to 18:2 fatty acids; the proportion of 18:1 decreased to about half of the control value (Table 3).

Increasing nutrient content of the media to 2X or 3X the normal concentration resulted in decreased dry-weight production of the fungus and a corresponding higher final pH of the media (Table 4). Adding 100 μmol/l ferulic acid to the 1X media reduced dry-weight production by 62%, but the proportional reduction in dry weight and final media pH were less at 2X and 3X the normal nutrient concentration. Optical density of the media increased with increased nutrient concentrations, with and without ferulic acid. Ferulic acid also caused optical density to increase at normal nutrient concentrations.

DISCUSSION

The negative correlation of dry weights of *P. tinctorius* and concentrations of phenolic acids in the media indicate that the phenolic acids are detrimental to *P. tinctorius* growth. Concentration of phenolics and the appearance of dark droplets on the mycelial mat surface at the highest concentrations of phenolics suggest (1) production of compounds in response to the phenolics or (2) phenolic-caused leakage of fungal metabolites into the media.

The apparent higher potency of ferulic and p-coumaric acids (cinnamic acid derivatives) over vanillic acid (benzoic acid derivative) parallels Glass' (9) observation that cinnamic acid derivatives are more potent inhibitors of phosphate uptake than the corresponding benzoic acid derivatives. In the vanillic acid experiment, the control 18:1 to 18:2 fatty acid ratio was lower than the control of the p-coumaric and ferulic acid treatments. This may be attributable to temperature fluctuation problems in the growth chamber used in the vanillic acid and nutrient concentration experiments. Lower temperatures themselves also result in a lower ratio of 18:1 to 18:2 fatty acid (Melhuish, unpublished data).

UV-visible scans of the liquid media at the end of the vanillic acid experiment suggest that even the smallest amount of vanillic acid caused significant release of additional metabolites into the media (260 nm peak). Lesser amounts of released compounds at 10 and 100 μmol/L may be due to reduced or altered physiological functions reponsible for production or release of the media metabolites. At 1000 μmol/l the fungus metabolism may have changed radically, resulting in more materials contributing to the 260 nm peak and causing the additional 290 nm peak. Alternatively, membrane integrity may have broken down, allowing more metabolites to be released — including some that were retained by membranes at lower toxin concentrations.

Increasing nutrient concentraton decreased dry-weight production in the absence of ferulic acid, indicating that oversupply of nutrients was toxic. Addition of 100 μmol/L of ferulic acid to the normal media level of nutrients reduced dry-weight production by 62%, but addition of 2 or 3X normal nutrients to 100 μmol/L ferulic acid in media did not result in additional growth suppression. Optical densities (which we believe to be a measure of excretion or "leakage") increased more due to the addition of nutrients than to addition of ferulic acid. The influence of ferulic acid was appreciable only at 1X untrient concentration. Decoloration of the mycelium accompanied by the appearance of dark-colored droplets at the highest toxin concentrations in the other experiments was observed only in the 1X nutrient concentration with ferulic acid. This supports the idea that additional nutrients, though in themselves toxic, somewhat ameliorate the effects of the toxin.

Many have observed *P. tinctorius* sporocarps in the harsh envionments of surface mines which were bare of vegetation except for scattered host trees (Beckjord, personal communication). We have not found *P. tinctorius* sporocarps on surface-mined sites that have progressed beyond the initial stages of succession or on mined lands reclaimed with extensive grass-forb covers. We suspect that plant-produced compounds might be inhibiting *P. tinctorius* in such situations. In a field with woody ground cover, growth of *Quercus rubra* L. seedlings infected with *P. tinctorius* was significantly inferior to that of seedlings with *Scleroderma auranteum* Pers. (24). Molina (25) noted that some phenolics secreted by one higher plant might inhibit mycorrhizae formation between another higher plant and a compatible fungus by inhibiting cellulose production.

Changes in *P. tinctorius* 18:1 to 18:2 fatty acid ratios, which may be a reaction to stress, can also be induced by decreasing C:N ratios (23), changing the nitrogen source for ammonia to nitrate (26), and lowering environmental temperature (Melhuish, unpublished). *P. tinctorius* is, in general, more susceptable to toxic effects of cadmium, lead, and nickel than are other mycorrhizal fungi (27). Since mycorrhizae are necessary for tree growth in severe environments, other mycorrhizal fungal genera such as *Russula, Suillus, Lactarius, Amanita,* and *Boletus* that have been found in forests next to surface mines might be more suitable symbionts for plantings on vegetated surface-mined lands.

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The Buxaceae, Clethraceae, Myricaceae, Sapotaceae, and Theaceae of Kentucky

Ronald L. Jones

Department of Biological Sciences, Eastern Kentucky University, Richmond, KY 40475

ABSTRACT

Documented county distributions are given for 5 species, each the sole representative of its family in Kentucky. The number of county records based on a herbarium survey, are as follows: 19 for *Pachysandra procumbens* (Buxaceae); 13 for *Clethra acuminata* (Clethraceae); 2 for *Comptonia peregrina* (Myricaceae); 12 for *Bumelia lycioides* (Sapotaceae); and 5 for *Stewartia ovata* (Theaceae). An account is given of the distribution, habitat, and associates of each species.

INTRODUCTION

This paper reports the Kentucky county distributions of the Buxaceae, Clethraceae, Myricaceae, Sapotaceae, and Theaceae, each represented in the state by a single species. This study was initiated as part of an organized effort by Kentucky botanists to document the distributions of vascular plants in the state, to eventually lead to the production of a flora of Kentucky.

METHODS AND MATERIALS

The county maps presented here are based on herbarium specimens examined during this study only, a total of 170 specimens from 19 herbaria. Literature reports that I could not document and records for cultivated plants are excluded. Identifications were carefully checked and the pertinent label data were recorded. The family classifications follow those of Cronquist (1), while the species treatments are based on Little (2, 3), except where noted.

RESULTS

County distributions of 5 species in Kentucky are presented in Figure 1. *Pachysandra procumbens* is reported from 19 counties, *Clethra acuminata* from 13, *Comptonia peregrina* from 2, *Bumelia lycioides* from 12, and *Stewartia ovata* from 5. According to Richard Hannan (pers. comm.), the Kentucky Nature Preserves Commission has recent collections from the following additional counties: Pachysandra procumbens—Lincoln; *Clethra acuminata*—Rowan; *Bumelia lycioides*—Butler, Grayson and McLean. These collections are not yet accessioned and available for study.

For the 5 familes under consideration, I found no evidence of any other species occurring natively in Kentucky. *Pachysandra terminalis* Sieb. and Zucc., the Japanese pachyandra, may sometimes persist around old homesites. *Clethra alnifolia* L. was reported for the state by Defriese (4), and listed without comment by Garman (5), but I was unable to locate any specimens. *Bumelia lanuginosa* (Michx.) Pres. occurs in Illinois and Missouri counties adjacent to Kentucky, and could eventually be discovered in western Kentucky. Garman (5) noted an old report of *Stewartia malachodendron* L. in Kentucky, but he was "disposed to question the accuracy of the reference."

DISCUSSION

1. Buxaceae—*Pachysandra procumbens* Michx. Allegheny spurge.

The Buxaceae is a mostly evergreen, woody family of worldwide distribution, and is classified in the subclass Rosidae, order Euphorbiales. There are 5 genera with about 60 species. The genus *Pachysandra* contains 4 species, with *P. procumbens* being the only native American species (6).

Pachysandra procumbens occurs in the southeastern United States only, from central Kentucky to Georgia and Louisiana. Braun (7) mapped the southeastern distribution of the species, and later (8) listed 8 conties in south-central Kentucky. In 1950 Braun called the Allegheny spurge one of the abundant and characteristic species of the Western Mesophytic Forest Region (9). Robbins (6) gave 8 Kentucky counties for the species, and described the habitat as "calcareous, clayey soils, on ravine slopes, in deciduous woods..."

All of the 28 counties reported here (Fig. 1) are in south-central Kentucky, from Fayette to McCreary and Simpson Counties. The Fayette County record is from Raven Run, evidently the most northerly known site for the species.

Pachysandra procumbens is a low-growing, rhizomatous, slightly woody plant of the herbaceous layer in mesic woods. It has crowded, evergreen coarsely-toothed leaves, and small spikes with apical male and basal female flowers. The Allegheny spurge flowers in early spring, but the brownish spikes are often obscured by leaf litter and are easily overlooked. I have observed this species in McCreary County growing in rich woods with *Hydrastis canadensis, Anemone quinquefolia, Panax trifolium, Trillium luteum,* and *Trillium sulcatum.*

2. Clethraceae—*Clethra acuminata* Michx. Sweet pepperbush.

The Clethraceae is a woody family with a single genus, *Clethra,* and about 65 species distributed in the Americas and in Asia. The family is classified in the subclass Dilleniidae, order Ericales. *Clethra* has long been considered as closely allied with the Ericaceae, and in some older treatments it is listed under this related family. A study of the family in the southeastern United States has been published by Thomas (10).

Clethra acuminata is an Appalachian species occurring from West Virginia through Kentucky to Georgia. Garman (5) cited only Wolfe County for the species, and McInteer (11) considered the sweet pepperbush as very rare in black shale regions and scarce in the eastern coal fields. Braun provided a distribution map of the species (7) and in 1943 she listed 11 counties, giving the habitat as "steep mesophytic sandy banks, shaded sandstone cliffs and gorges" (8). Wharton (12), in her study of the black shale areas, also called the plant rare, and reported it from Powell County only. In Little (3), the species is mapped through about 8 counties in northeastern Kentucky and 7 counties in southeastern Kentucky, with an outlying record from Bullitt County.

The 13 counties reported here (Fig. 1) range from Pike to McCreary and Pulaski counties. The sweet pepperbush is probably much more

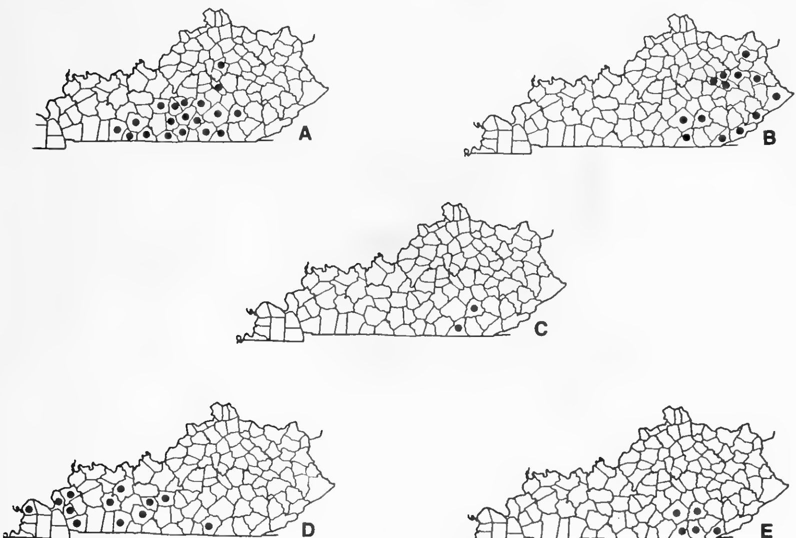

Figure 1. Kentucky county distribtuions of *Pachysandra procumbens* (A), *Clethra acuminata* (B), *Comptonia peregrina* (C), *Bumelia lycioides* (D), and *Stewartia ovata* (E).

widespread, but many of the eastern Kentucky counties have been very poorly collected. The species can be easily identified by the reddish, shreddy bark, silvery buds, and the terminal racemes of white, 5-merous flowers, which develop into small globose capsules. It is less than 6 m tall, and occurs in the understory of mixed mesophytic communities typically dominated by *Liriodendron tulipifera, Betula lenta, Tsuga canadensis,* and *Fagus grandifolia,* with understory associates such as *Magnolia macrophylla, Cornus florida,* and *Stewartia ovata* (13).

3. Myricacae—*Comptonia peregrina* (L.) Coult. Sweet fern.

The Myricaceae, of the subclass Hamamelidaceae, order Myricales, is a woody family of 3 genera and about 50 species, distributed in both the Old and New World. Most of the species are in the genus *Myrica*, which is represented in the southeastern United States by 4 species (14). *Comptonia* is a monotypic genus native to eastern North America.

Comptonia peregrina, also called *Myrica asplenifolia* L. in some manuals, occurs from Canada to Georgia and is one of Kentucky's rarest woody plants. It was first reported for Kentucky by Braun (8), who collected a specimen (McCreary Co.; *Braun 1010,* GH!) at the "S. fork of Cumberland River river bank," on June 18, 1935. Braun noted on the label that the locality was the "southernmost interior record." The species was relocated in 1978 (15) on gravel bars in Big South Fork of Cumberland River, McCreary County (*Wofford 78-96,* EKY!, NY!). In 1980 a single plant was found on the east bank of the Rockcastle River, Laurel County *(Jacobs 0616791,* EKY!).

The sweet fern is thus known from only 2 counties in Kentucky (Fig. 1). I searched the Laurel County site in April, 1984, without success. According to Max Medley (pers. comm.), a good number of individuals have now been located at the McCreary County site. This plant is a many-branched, aromatic shrub, about 1.5 m tall, with pinnately-lobed leaves, flowers in aments, and nutlets in a bur-like cluster. It grows on rocky gravel bars and stream banks that are subjected to frequent scouring. These are unique Kentucky communities, containing many other unusual species, such as *Orontium aquaticum, Calycanthus floridus,* and *Conradina verticillata* (16). *Comptonia peregrina* is a rare plant study element of the Kentucky Nature Preserves Commission (16), and is listed as a threatened species by Branson et al. (17).

4. Sapotaceae—*Bumelia lycioides* (L.) Pers. Southern buckthorn.

The Sapotaceae are members of the subclass Dilleniidae, order Ebenales. The family includes about 70 genera and 800 species, mostly of tropical regions. In the genus *Bumelia* there are about 25 species, with 6 occurring in the southeastern United States (18).

The southern buckthorn is distributed through the southern states from Kentucky to Virginia, Florida, and Texas. Garman (5) noted only 2 counties, and McInteer (11) stated that the species is very rare in the sandy, acidic soils around the western coal fields. McInteer mapped the species in Kentucky, finding it fairly common in Edmonson and Monroe counties (19). Braun (8) gave the habitat of the species as "shaded limestone cliffs," and cited 5 counties. Little (3) mapped the species through 9 counties of west-central Kentucky.

The present study documents 12 counties for the species (Fig. 1), ranging from Ballard to Wayne County. The southern buckthorn is nondescript and is probably often overlooked. It is a small thorny tree with alternate, entire leaves, small flowers in axillary clusters, and the fruit is a berry. It may occur in both upland limestone areas and in bottomlands, often in open habitats. In the uplands, *Bumelia lycioides* is associated with *Rhamnus caroliniana, Rhus aromatica,* and *Juniperus virginiana,* while in wetter soils it grows with *Asimina triloba, Lindera benzoin,* and *Sambucus canadensis* (20).

5. Theaceae—*Stewartia ovata* (Ca.) Weatherby. Mountain Stewartia.

The Theaceae are classified in the subclass Dilleniidae, order Theales, and includes about 40 genera and 600 species. According to Wood (21) there are 6 species in the genus *Stewartia,* with 2 native to the southeastern United States. The family also includes *Gordonia lasianthus* (L.) Ellis, a coastal plain species, and *Franklinia alatamaha* Marshall, discovered by John and William Bartram in 1765 in McIntosh County, Georgia. The famed "Lost Franklinia" has not been seen in the wild since 1790, but persists through cultivation.

Stewartia ovata, the mountain stewartia, ranges through the southern Appalachians from southeastern Kentucky to central Alabama. Garman (5) named four counties—Bell, Letcher, Powell, and Rowan for the species. McInteer (11) treated the plant as a rather common species of the eastern coal fields, and later (19) gave a four-county dot map of the species in Kentucky. Braun (8) listed Bell, McCreary, and Whitley Counties, and described the habitat as "meophytic ravines and gorges, and occasionally on ridges." The mountain stewartia is mapped by Little (3) in 4 counties of southeastern Kentucky, with an additional site from Menifee County.

I found records of *Stewartia ovata* from Bell, Laurel, McCreary, Pulaski, and Whitley Counties (Fig. 1). Most of the collections were from the Yahoo Falls and Cumberland Falls regions. Except when flowering, the mountain stewartia can be easily overlooked. It has simple, alternate leaves, with distinctive spinulose margins, single bundle traces, and pubescent buds. The flowers, however, are remarkable; they are up to ten cm across, with large, white imbricate petals, numerous stamens with purplish filaments, and a 5-styled ovary. The fruit is a loculicidal capsule, about 1.5 cm in diameter. *Stewartia ovata* often grows with *Clethra acuminata*, and has similar associates.

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An Examination of the Predatory Behavior of Captive American Kestrels

Christopher J. Kellner[1] and Gary Ritchison

Department of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475

ABSTRACT

The predatory behavior of captive American Kestrels (*Falco sparverius*) was examined to determine if kestrels attacked or handled vertebrate and invertebrate prey in different ways. A total of 157 attacks on 92 vertebrate and 65 invertebrate prey items was observed. A comparison of the attacks on vertebrates versus invertebrates revealed several significant differences. (1) Powered (flapping) flights generally were used in attacks on vertebrates while attacks on invertebrates were evenly divided between powered flights and gliding flights. (2) Kestrels made direct contact with invertebrate prey more frequently than with vertebrate prey. However, when only live, adult vertebrates were considered, kestrels made direct contact with vertebrate prey more frequently than with invertebrate prey. (3) Whereas all vertebrate prey were taken to a perch before being consumed, most invertebrate prey were consumed on the floor of the aviary. (4) Kestrels cached significantly more vertebrates than invertebrates. Thus, kestrels utilized different types of attacks on vertebrates and invertebrates and handled these two types of prey differently after successful attacks. Such differences probably relate to differences in the abilities of vertebrates and invertebrates to detect and elude a predator and differences in the average size of vertebrate and invertebrate prey. The behavioral differences exhibited by American Kestrels appear to (1) increase the chances of successful attacks, (2) increase the chances of further successful attacks within an area, (3) reduce the chances that prey will escape once captured, and (4) both increase the time available for hunting and reduce the energy expended while hunting.

INTRODUCTION

The American Kestrel (*Falco sparverius*) is an opportunistic predator that feeds on a wide variety of both vertebrates and invertebrates (1, 2, 3). Certain aspects of the predatory behavior of kestrels have been examined. For example, attempts have been made to determine the importance of such factors as shape, color, and movement in the selection of prey by kestrels (4, 5, 6, 7). Other investigators have reported field observations suggesting that kestrels may use different types of attacks for different types of prey (8, 9). The objective of this study was to examine the predatory behavior of captive American Kestrels. Specifically, the objectives were to determine if kestrels (1) utilize different types of attacks on vertebrate and invertebrate prey and (2) handle vertebrate and invertebrate prey differently after a successful attack.

METHODS

Feeding trials were conducted with 3 American Kestrels (2 females, 1 male) in a 6 x 6 x 3 m outdoor aviary. These kestrels were captured near Richmond, Madison Co., Kentucky, using a bal-chatri trap (10). Trials were conducted from 5 May to 21 September in 1983 and from 24 May to 28 May in 1984. Observations were made through a one-way mirror from an observation booth located adjacent to the aviary. The side of the aviary next to the observation booth was covered so observers could enter and exit the booth without being observed by the kestrels. A tube 70 cm long with a diameter of 10 cm allowed observers to place prey items into the aviary while seated in the observation booth. Both vertebrate and invertebrate prey were offered in this manner. Vertebrate prey included both adult and young (less than a week old) laboratory mice (*Mus musculus*) and adult House Sparrows (*Passer domesticus*). Invertebrate prey included a crayfish (*Cambarus sp.*), cicadas (*Tibican sp.*), grasshoppers (Acrididae), crickets (Gryllidae), and cockroaches (*Periplanta americana*). Several dead mice (adults) and 2 dead rats (*Rattus norvegicus*) were also offered as prey to the kestrels. Prey items were classified as either large (average weight = 25 gms or more) or small (average weight = 10 gms or less). Large

[1] Department of Zoology, University of Arkansas, Fayetteville, AR 72701

items included adult mice, young rats, and House Sparrows. Small items included young mice and all invertebrates. The average weights are listed in Table 1.

Table 1. Average weights of prey items offered to kestrels.

Item	No. Offered	Avg. wgt. (gms)
Adult lab mice	32	35
Juvenile lab mice	37	1.4
Juvenile lab rats	2	25
House Sparrows	5	25
Cray fish	1	9.5
Cicadas	3	3
Grasshoppers	51	1.5
Crickets	8	0.4
American Cockroach	3	1

Attacks were classified as either powered or gliding, depending on whether or not a descent to a prey item involved flapping flight. The time interval between presentation of prey and the initiation of an attack by a kestrel was measured with a digital stopwatch. Other information noted with each attack included: (1) whether a prey item was contacted immediately or if the kestrel landed next to the item prior to contact, (2) whether a prey item was cached or was consumed immediately, and (3) if an item was carried to a perch, whether it was carried in the talons or the bill.

RESULTS

A total of 176 prey items was offered to kestrels. Nine of these potential prey items escaped and 10 were ignored; thus, a total of 157 attacks were observed (Table 2). Both vertebrate and invertebrate prey were attacked almost immediately. The time interval between presentation of a prey item and the initiation of an attack was so short that it was difficult to measure accurately. Most attacks on vertebrates were classified as powered attacks (Table 2). Overall, 71 of 92 attacks on vertebrates (77%) were powered. If young mice were not included in the analysis this percentage increased to 91% (50/55). Attacks on invertebrates were evenly divided between powered and gliding flights (Table 2). This difference in the type of flight used to attack vertebrates and invertebrates was found to be signficant (X^2 = 11.92, d.f. = 1, P ◄ 0.001). The difference between vertebrates other than young mice and dead mice and invertebrates was also significant (X^2 = 8.66, d.f. = P ◄ 0.01).

Kestrels killed small invertebrates (grasshoppers, crickets, cicadas, and cockroaches) by removing their heads. The single crayfish presented as a prey item was killed when the kestrel removed parts of the head. Young mice were either ingested whole or killed when parts of their heads were removed. Adult mice were killed by removal of parts of the skull and brain (generally the frontal or occipital regions). House Sparrows were handled in the same way. Dead mice and rats were handled in the same manner as live prey, i.e., parts of the head were removed before other portions were consumed. Thus, both living and dead vertebrates and invertebrates were handled in the same manner.

All vertebrate prey items were taken to a perch before being consumed (Table 2). Adult mice, young rats, and House Sparrows were carried in the talons (39/39). Dead mice were carried both in the talons (6/16) and the bill (10/16). All young mice were carried in the bill (37/37). Most invertebrates were consumed on the floor of the aviary (45/65). Of the 20 invertebrates taken to a perch, 45% (9/20) were carried in the bill and 5% (11/20) were carried in the talons. Thus vertebrates and invertebrates were handled differently by kestrels, with significantly more vertebrates being taken to a perch before being consumed. (X^2 = 86.16, d.f. = 1, P◄0.001). Finally, whereas all large prey (55/55) were taken to a perch before being consumed, only 56% (57/102) of the small prey were taken to a perch (Table 2). This difference was also significant (X^2 = 32.03, d.f. = 1, P◄0.001).

Table 2, Summary of attacks by kestrels on various prey items.

	Large Prey[1]				Small Prey[2]		
	Mice and Rats	Dead Mice	House Sparrows	Total Large prey	Younr Mice	Invert.	Total Small prey
Powered attack	30/34	15/16	5/5	50/55	21/37	32/65	53/102

(continued)

(Table 2 continued)

Gliding attack	4/34	1/16	0/5	5/55	16/37	33/65	49/102
Attack w/ direct contact	34/34	2/16	5/5	41/55	0/37	50/65	50/102
Attack w/o direct contact	0/34	14/16	0/5	14/55	37/37	15/65	52/102
Carried to perch:							
w/talons	34/34	6/16	5/5	45/55	0/37	11/65	11/102
w/bill	0/34	10/16	0/5	10/55	37/37	9/65	46/102
Consumed on floor	0/34	0/16	0/5	0/55	0/37	45/65	45/102
Cached	7/34	1/16	0/5	8/55	2/37	0/65	2/102

[1]Average weight $>$ 25 gms

[2]Average weight $<$ 10 gms

Few prey items were cached by kestrels. Approximately 11% (10/92) of all vertebrates were cached while no invertebrates were cached (Table 2). This difference between number of vertebrates and invertebrates cached was significant ($X^2 = 5.71$, d.f. = 1, $P < 0.05$). Further, although 14.5% (8/55) of all large prey items were cached, only about 2% (2/102) of the small prey items were cached. This difference between the number of large and small prey items cached was also found to be significant (X^2 = *7.51, d.f.* = 1, $P < 0.01$).

DISCUSSION

American Kestrels were found to attack both vertebrate and invertebrate prey almost immediately upon presentation. Such results may be due to the relatively small size of the aviary used in these experiments. That is, prey were presented within 5 m of kestrels and, at that distance, there probably was little chance that the prey would be able to escape. Sparrowe (11) speculated that kestrels assessed their chances of success before launching an attack. He suggested that it would not be adaptive for kestrels to attack prey immediately or even to attack all prey sighted because in some cases the chances for success would be slight and launching an unsuccessful attack would waste energy.

Kestrels were found to attack vertebrates and invertebrates in a significantly different manner. Whereas powered flights were used in attacks on most vertebrates, powered and gliding flights were used equally in attacking invertebrates. This difference may be due to differences in the abilities of vertebrate and invertebrate prey to elude a predator. That is, a vertebrate probably is more likely to detect and elude a predator than is an invertebrate. Therefore, a kestrel would increase its chances of success by getting to the prey as soon as possible, i.e., using a powered flight. Similar observations have been reported by other investigators (8, 9). These authors noted that attacks on vertebrates may be characterized as rapid, head-first dives while attacks on invertebrates tend to be slow, braking attacks. Differences in the ability to elude a predator may also explain why some prey were attacked directly (with contact). Kestrels made direct contact with adult mice, young rats, and House Sparrows. When attacking young mice and dead mice, kestrels generally landed next to the prey before attacking. Young mice and dead mice obviously could not escape, therefore, immediate contact would not be required for a successful attack. On the other hand, adult mice and House Sparrows could potentially escape and, therefore, immediate contact would be desirable. When considering only adult mice and House Sparrows, kestrels made direct contact significantly more often with vertebrates than with invertebrates. Again, this may relate to the relative abilities of vertebrates and invertebrates to elude a predator. However, it should be noted that most invertebrates were also attacked directly (77%). Although invertebrates probably cannot detect predators at a distance as well as vertebrates (hence the use of gliding attack by kestrels), once aware of a predator (i.e., a kestrel landing nearby) an invertebrate may be able to escape. Thus direct attacks on invertebrates, as well as vertebrates, might increase the chances of a successful attack.

Once captured, both vertebrates and invertebrates were killed by removal of all or parts of the head. This may be related to the importance of the head (i.e., brain) in coordinating escape movements. By removing or damaging the brain, a kestrel greatly reduces the chances that the prey will escape. Severing the spinal cord would have the same effect and some investigators have suggested that the tomial tooth might be used to sever the cord (12, 13). Although this may occur in free-living kestrels, such use of the tomial tooth was not observed in this study.

Whereas all vertebrate prey were taken to a perch before being consumed, most invertebrate prey were consumed on the floor of the aviary. Further, whereas all large prey were taken to a perch, many of the small prey items were consumed on the floor of the aviary. Small prey (e.g. invertebrates) can be consumed quickly. In contrast, eating a large prey item (e.g., an adult vertebrate) takes much longer, not only because of the size difference but also because kestrels frequently remove some of the fur or feathers before consuming mammalian and avian prey, respectively. Reduced time on the ground may reduce the likelihood that other potential prey in the area will detect the kestrel and, thus, increase the chances of success in subsequent attacks. If true, the tendency for kestrels to carry young mice to a perch is difficult to explain. Such mice could.be consumed quickly (6 were ingested whole) so the advantage of carrying them to a perch is not clear. All adult mice, young rats, and House Sparrows were carried with the talons while young mice and most dead mice were carried in the bill. Those prey carried in the talons would appear to be those most likely to escape or, possibly, to harm a kestrel. Prey carried in the talons (as opposed to the bill) probably are less likely to escape or harm a kestrel as they struggle.

Only vertebrate prey were cached by kestrels and most of these were "large" prey. Of the 10 items cached, 8 were adult mice and 2 were young mice. Rijnsdorp et al. (14) suggested 2 possible reasons for caching: (1) if prey availability varies temporally, caching would allow a kestrel to continue hunting rather than spending time to feed, and (2) by caching large prey items, kestrels can maintain a lower body weight during periods when they are actively hunting (thereby conserving energy). The results of the present study seem to support these hypotheses since, as just noted, most prey cached by kestrels were "large " prey (adult mice).

In conclusion, the results of this study suggest that American Kestrels do utilize different types of attacks for vertebrate and invertebrate prey and also handle these two types of prey items differently after a successful attack. Such differences apparently relate to (1) differences in the abilities of vertebrates and invertebrates to detect and elude a predator, and (2) differences in the average size of vertebrate and invertebrate prey. These behavioral differences exhibited by kestrels appear to (1) increase the chances of further successful attacks, (2) increase the chances of successful attacks within an area, (3) reduce the chances that prey will escape once captured, and (4) both increase the time available for hunting and reduce the energy expended while hunting.

ACKNOWLEDGEMENTS

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NOTES

Dr. Robert Andrew Kuehne: Obituary. Born 22 June 1927 in Austin, Texas, Robert Andrew Kuehne was graduated from Southern Methodist University in 1949, and in 1950 earned an M.S. Degree at the same institution. Prior to enrollment in graduate school at the University of Michigan in 1954, he worked as an aquatic biologist for the Texas Department of Parks and Wildlife.

He earned the PhD degree in the spring of 1958, taught a summer session at Michigan State in 1958, and joined the faculty of the University of Kentucky in the fall of 1958 as an Instructor.

I first met Bob in the fall of 1959 when I returned from a two-year sojourn in Indonesia. I found him to be an extremely congenial individual, with a tremendous store of knowledge of fishes and their way of life. Bob was always willing, sometimes to his own detriment, to go the last mile out of his way to assist someone in need, be it student, faculty member, friend, or some stranger in need of help. Rarely does one encounter such a compassionate individual.

To my knowledge, Bob served as chairman for three doctoral and nine master's candidates, and played a substantial role in three additional doctoral and six master's degrees.

Bob is senior author of *The American Darters.* He did essentially all the writing and research, and played a major role in finding darters to photograph. My role was minor; I helped catch most of the fishes, phototgraphed them, and helped in organizing, map making, editing, and proof-reading. Obviously, Bob was the prime mover, I the assistant.

The labors to bring the book to fruition were enormous, and covered a span of about fifteen years and many thousands of miles of travel. We were often cold, wet, hungry, and dog-tired, but I never once saw Bob Kuehne angry, upset, or even particularly disturbed.

Aside from *The American Darters* Bob had some twenty five papers published in various journals; the number would have been substantially larger had he allowed his student's papers to bear his name. He refused to do so, although he guided the research and worked side by side with the student.

Bob was always willing to help a student, a colleague, or a group thereof, and these activities took an inordinate amount of his time.

He received the prestigious "Distinguished Teacher Award" from the Kentucky Student Government in 1978. Bob was an outstanding teacher, loved by both students and colleagues, and he will be sorely missed.

During a visit to his bedside just a few days before he passed away, he asked for my hand, gripped it firmly, and told me that for several years he had often thought of me as an older brother. Neither of us knew that the other felt the same closeness. Bob died 18 December 1984, after a brief illness.

All of us who knew him are the better for his having crossed our paths, and his passing left a void that can never be filled.—**Roger W. Barbour, Prof., Emeritus,** 4880 Tates Creek Pike, Lexington, KY 40515.

Distribution of the European Hornet in Kentucky—The number of inquiries received by University of Kentucky insect diagnostic laboratories concerning the European hornet, *Vespa crabro germana* Christ, increased sharply in 1984. This insect introduced into the United States ca. 1840-1860 (Shaw and Weidhaas, J. Econ. Entolmol. 49:275, 1956) is known to have occurred in Kentucky as early as 1958 (USDA, CEIR 8:466, 1958). The distribution of *V. crabro germana* according to published reports is limited to 14 counties in south central Kentucky. This report combines information from the two published reports with records of the University of Kentucky survey entomologists and insect diagnostic laboratories to provide the most current known distribution of *V. crabro* in Kentucky.

The earliest record of *V. crabro germana* in Kentucky is a 1958 distribution map, illustrating the wasp present in Rockcastle Co. (USDA, CEIR 8:466, 1958). In 1967, 13 additional counties, Bell, Boyle, Butler, Casey, Estill, Knox, Laurel, Lincoln, Madison, Pulaski, Taylor, Whitley and Wolfe were added to the distribution (IBID 23:172, 1973). An additional map was developed for 1973 but no new Kentucky records were added.

Six counties were added to the known distribution of *V. crabro germana* during 1975-80. Specimens from these counties (county-year of report) Barren-1977, Green-1979, Hopkins-1979, Muhlenberg-1979, Trigg-1980, and Washington-1978 were diagnosed by U.K. survey entomologists.

During 1984, *V. crabro* samples were diagnosed from 19 additional counties: Bourbon, Bullitt, Fayette, Caldwell, Calloway, Christian, Crittenden, Daviess, Grant, Grayson, Hart, Lee, Lewis, Logan, Lyon, Owen, Rowan, Russell, and Wayne.

In addition to these confirmed collections, an informal survey of County Extension Agents for Agriculture (U.K.-C.E.S.) indicates the distribution of *V. crabro* may be even more widespread. Our knowledge of the distribution of this insect is probably more closely related to *V. crabro germana* coming into contact with humans than to its true distribution. Although the wasp will nest in attics, barn lofts, etc., it more naturally occupies hollow trees that may be far removed from human habitations— **Douglas W. Johnson** and **Rudy A. Scheibner**, Department of Entomology, University of Kentucky, Lexington, KY 40546.

Clarks River Revisited: Additions to the Ichthyofauna.—In 1965, Morgan E. Sisk surveyed the ichthyofauna of Clarks River in western Kentucky and reported a total of 61 species of fishes (Trans. Ky. Acad. Sci. 30:54-59, 1969). Prior to and subsequent to his survey, 13 additional species were reported from the drainage by various authors (Hubbs, Occas. Pap. Mus. Zool. Univ. Mich. 530:1-30, 1951; Page and Smith, Copeia 1976:532-541, 1976; Bauer and Branson, Trans. Ky. Acad. Sci. 40:53-55, 1979, Burr and Mayden, Trans. Ky. Acad. Sci. 40:58-67, 1979; Burr, Brimleyana 3:53-84, 1980; Burr et al., Trans. Ky. Acad. Sci. 41:48-54, 1980; Rice et al., Trans. Ky. Acad. Sci. 44:125-128, 1983; and Warren and Cicerello, Brimleyana 9:97-109, 1983[1984]).

A compilation of distributional records taken from our own survey efforts and the unpublished collections of various other workers (*fide* Brooks M. Burr) in the drainage yielded a total of 57 collections from the main channels of both East and West Forks, as well as from various tributaries, wetlands, and springs. These collections resulted in the addition of 13 species previously unknown from Clarks River and extended the known distributions of 20 other species to one and/or both forks of the system (Table 1). Presently 87 fish species are documented from the drainage.

Table 1. New Records for the Ichthyofauna of Clarks River*

Species	East Fork	West Fork
Esox americanus		x
Hybognathus nuchalis **	x	x
Hybopsis storeriana **	x	
Notropis emiliae		x
Notropis lutrensis **		x
Notropis whipplei	x	
Phenacobius mirabilis	x	
Pimephales promelas **	x	
Catostomus commersoni **		x
Minytrema melanops		x
Ictiobus cyprinellus	x	
Ictalurus melas	x	x
Ictalurus natalis		x
Ictalurus punctatus	x	x
Noturus gyrinus **	x	x
Noturus miurus **	x	x
Noturus nocturnus **	x	x
Pylodictis olivaris	x	
Morone chrysops	x	
Centrarchus macropterus		x
Elassoma zonatum	x	
Lepomis gulosus		x
Lepomis humilis		x
Lepomis marginatus	x	
Lepomis microlophus **	x	
Pomoxis nigromaculatus		x
Etheostoma asprigene **	x	x
Etheostoma chlorosomum		x
Etheostoma histrio **	x	x
Percina ouachitae **	x	x
Percina sciera **	x	x
Stizostedion canadense	x	
Aplodinotus grunniens	x	x

* Complete locality data is available upon request from the authors.
** Denotes new drainage record

Several of the fishes missed or reported by Sisk (1969) and other workers are of particular interest because of their possible indication of environmental pertubation in the system, their purported rarity in the state of Kentucky, or the problem of documenting their presence in the drainage. The discovery of *Notropis lutrensis* in the West Fork in the summer of 1984 may be indicative of habitat modification and degradation in this recently re-channelized arm of Clarks River. This aggressive, ecologically tolerant

[1]The investigation reported in this paper (No. 85-7-44) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with approval of the Director.

shiner has recently expanded its range eastward in both Illinois and Indiana (Smith, The Fishes of Illinois, Univ. Illinois Press, Urbana, 1979), and may ultimately replace less tolerant members of the native ichthyofauna and displace close relatives (e.g., *Notropis whipplei*) through hybridization and competition (Page and Smith, Ill. St. Acad. Sci. Trans. 63:264-272, 1970). To our knowledge, this is the first record of the red shiner in the Tennessee River drainage. The eastward spread in Kentucky of the red shiner may be expected (see Burr et al., 1980) as habitat in other rivers and streams are degraded by man's activities.

The discovery in Clarks River of *Percina ouachitae* and *Etheostoma histrio* is of interest because these species are listed as of undetermined status and threatened, respectively, within the state (Branson et al., Trans. Ky. Acad. Sci. 42:77-89, 1981). Based on our observations of the large populations of these species in both West and lower East Forks of Clarks River, and their widespread occurrence in the lower Green River (Warren, Trans. Ky. Acad. Sci. 43:21-26, 1982) and much of extreme western Kentucky (Burr 1980), we feel their retention on the state list of endangered and threatened species is unwarranted. Other species for which we cite records (Table 1), and which are recognized by Branson et al. (1981), are *Elassoma zonatum* and *Lepomis marginatus*. Extensive clearing and drainage of wetlands in Clarks River suggests the continued existence of these wetland-inhabiting species is uncertain.

In compilation of the records comprising this note, 2 enigmatic records came to light. Sisk (1969) reported *Notropis spilopterus* from the West Fork; however, voucher specimens have not been located. Subsequent workers (Bauer and Branson 1979), including the authors, have collected only the closely related *Notropis whipplei* from Clarks River. We regard Sisk's record as unsubstantiated. Clay's (The Fishes of Kentucky, Ky. Dept. Fish Wildl. Res., Frankfort, 1975) report of *Etheostoma asprigene* in Clarks River was based on a misidentification of *E. neopterum* (*fide* Brooks M. Burr). Our report of *E. asprigene* in Clarks River is the first substantiated record.

We wish to thank Dr. Brooks M. Burr, Southern Illinois University at Carbondale, for providing records and editorial comments, and Mr. Richard R. Hannan, Director, Kentucky Nature Preserves Commission, for providing field assistance—**Bernard R. Kuhajda** and **Melvin L. Warren, Jr.**, Department of Zoology, Southern Illinois University, Carbondale, Illinois, 62901.

***Thlaspi alliaceum* (Cruciferae) in Kentucky and Indiana**—Two introduced species of *Thlaspi* are widespread in the U.S. A third species, *T. alliaceum* L., has recently been found by us in Kentucky and Indiana as "new" for these states and for the standard northeastern U.S. floristic manuals (Fernald, *Gray's Manual of Botany*, 8th ed., American Book Co., New York, 1950; Gleason, *The New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada*, New York Botanical Garden, New York, 1952; Gleason and Cronquist, *Manual of Vascular Plants of Northeastern United States and Adjacent Canada*, Van Nostrand, Princeton, N.J., 1963). The only U.S. manual we have noted to account for the species is that for the Carolinas (Radford et al., *Manual of the Vascular Flora of the Carolinas*, Univ. N.C. Press, Chapel Hill, 1968), which ascribes the species to one county in North Carolina; the earlier Carolina guide (Radford et al., *Guide to the Vascular Flora of the Carolinas*, Book Exchange, Univ. N.C., 1964) and atlas (Radford et al., *Atlas of the Vascular Flora of the Carolinas*, N.C. Agr. Exp. Sta. Tech. Bull. 165, 1965) do not include the species. Rollins (J. Arnold Arbor. 62:517-540, 1980), in his article on cruciferous weeds in North America does not mention *T. alliaceum*, nor does the FNA checklist (Shetler and Skog, Eds., *A Provisional Checklist of Species for Flora North America*, Missouri Bot. Gard. Monog. Syst. Bot. 1, 1978). The species *is* in the Pennsylvania atlas — 1 county (Wherry et al., *Atlas of the Pennsylvania Flora*, Morris Arboretum, Philadelphia, 1979), the Kartesz and Kartesz checklist (*A Synonymized Checklist of the Vascular Flora of the United States, Canada, and Greenland*, Univ. N.C. Press, Chapel Hill, 1980), and the *National List of Scientific Plant Names* (Soil Conservation Service, U.S.D.A., Washington D.C., 1982).

We have collected *T. alliaceum* in 4 counties (Campbell, Harrison, Kenton, and Pendleton) in northern Kentucky, 1 county (Pike) in eastern Kentucky, and 1 county (Dearborn) in southeastern Indiana; the vouchers are in the NKU Herbarium (KNK). Some of our northern Kentucky collections were made within about 3 km from the Ohio border; the species almost certainly grows in Ohio, but our searches for it there have so far been unsuccessful. That we have the species from Pike County, Kentucky—the state's easternmost county—at a site about 30 km from Virginia and West Virginia suggests that it is probably in those states too.

Thlaspi alliaceum grows in fallow fields and pastures and along roadsides, often with the other 2 naturalized *Thlaspi* species. In northern Kentucky the plant is quite infrequent although it may be common locally. Part of the vernal flora, the plants are dead and brown by mid-May. When crushed, *T. alliaceum* has a strong garlic odor—thus its specific epithet. Such an odor is present, but to a lesser degree, in *T. arvense*.

Our first collections of *T. alliaceum* (1982 and 1984) were identified as *T. perfoliatum*. We relied on Fernald (loc. cit.), Gleason (loc. cit.), and Gleason and Cronquist (loc. cit.) for identification, being unaware that our plant is missing from these works. In spring 1985, as we became more uncertain as to the plant's identity, we made additional collections. Finally we determined it to our satisfaction through the European flora (*Flora Europaea* 1, 1964) and the British flora (Clapham et al., *Flora of the British Isles*, Univ. Press, Cambridge, 1962).

Features useful to distinguish among the three *Thlaspi* species introduced into the U.S. are: stem vestiture, fruit size, and seed characteristics (at 15X).

Thlaspi alliaceum
Stem base with long hairs (Fig. 2) (sometimes nearly glabrous on older plants).
Fruits 5-8 mm long, 3-4 mm wide, 3 mm thick, the wing to 1 mm wide (Fig. 4, 7).
Seeds reticulate, brown (Fig. 10).

Thlaspi arvense
Stem base glabrous.
Fruits 9-15 mm long, 7-12 mm wide, 2 mm thick, the wing to 4 mm wide (Fig. 5, 8).
Seeds concentrically ridged, brown (Fig. 11).

Thlaspi perfoliatum
Stem base glabrous.
Fruits 4-6 mm long, 2-4 mm wide, 2 mm thick, the wing to 1 mm wide (Fig. 3, 6).
Seeds essentially smooth, yellow (Fig. 9).—**John W. Thieret** and **John R. Baird,**

Department of Biological Sciences,
Northern Kentucky University,
Highland Heights, KY 41076.

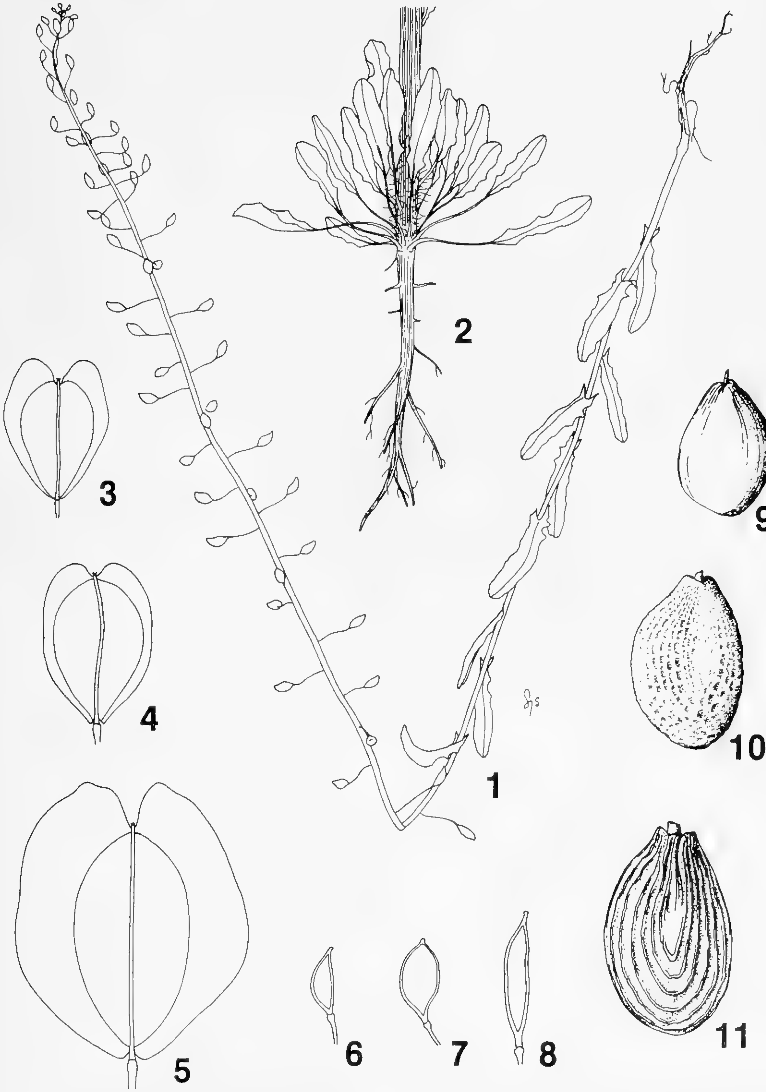

Fig. 1-11. *Thlaspi*. Fig. 1. *T. alliaceum:* plant in mature-fruit stage, basal leaves gone, X 1/2. Fig. 2. *T. alliaceum:* base of plant in early flowering stage, X 1. Fig. 3. *T. perfoliatum:* fruit, X 5. Fig. 4. *T. alliaceum:* fruit, X 5. Fig. 5. *T. arvense:* fruit, X 5. Fig. 6. *T. perfoliatum:* septum from fruit, to show fruit thickness, X 2. Fig. 7. *T. alliaceum:* septum from fruit, X 2. Fig. 8. *T. arvense:* septum from fruit, X 2. Fig. 9. *T. perfoliatum:* seed, X 20. Fig. 10. *T. alliaceum:* seed, X 20. Fig. 11. *T. arvense:* seed, X 20.

President's Message to the Kentucky Academy of Science
The Academy and the Spirit of Inquiry

Upon assuming an office like the Presidency of the Academy one gains the responsibility and privilege to address immediate goals, plans and hopes of the organization. Seeking help and comfort in beginning this task I turned to the records of the Academy as preserved in the *Transactions*. A planned hour or two examining early volumes turned into several afternoons of enjoyable and stimulating reading and an appreciation of our organizations history and heritage. An impressive thread of sound achievement in research is documented, as one would expect, but what caught my attention was a significant pattern of the membership and officers making suggestions, taking stands and supporting issues that were either contemporary or well ahead of the time and that thrust has continued to the present.

At the Fourth Annual Meeting, Academy President A.M. Miller (1) discussed the origin and antiquity of man and the membership subsequently supported the teaching of organic evolution and freedom of scientific inquiry, teaching and research by resolution (2) at a time in the south-central states when such a stand was not the mode of the day (re the Scope's trial in Tennessee). At the Thirteenth Annual Meeting, the President of KAS, A.R. Middleton (3), strongly rebuked suggestions that evolutionary teachings were detrimental to religious convictions of students. The Academy has not retreated from the conflict in this regard as is attested by the work of Wallace Dixon's (4) Ad Hoc Committee report and the KAS resolution concerning Scientific Creationism.

Early in the history of KAS attempts were made to influence the State Legislature to support science and the Legislative Committee headed by C. H. Shull (5) developed a proposal that included requests that the legislature pass a bill providing $1000 for publication of the Tranactions, enact a law to increase the teaching of science in high schools and to compel school boards to appropriate more for equipment and materials for science. The state government was also asked to establish an annual prize for research work. Those efforts, far from being successful, have remained a priority of the membership. Through the development of research endowments the Academy has lead the way in attempting to stimulate and recognize research. The initiation in 1978 of joint efforts between the Academy, Legislative Research Commission and the Council on Higher Education to assess the status of research support has been a significant effort and documents the long and arduous task ahead of the Commonwealth concerning science development and support (6,7,8).

Paper presentations, published abstracts and research articles compiled in our journal continually have shown great foresight in research areas of the future that could impact the economic development of the state. The potential of oil shale development was alluded to by Gardner (9) and more recently the 1981 annual meeting's plenary session and banquet address featured the topic of genetic engineering that we now see as a potential strategy developing an alternative to this state's dependency upon smoking tobacco as a significant part of the farm economy. Much of what is known concerning the diversity of Kentucky's flora and fauna is preserved within the bound volumes of the *Transactions* providing immense base-line data for contemporary analysis of the problems facing man and nature. While we may question the magnitude and depth of research efforts within the state, there is no dispute that the KAS through its paper sessons, symposia, plenary sessions and publications has provided a treasure trove of material for future scientists to improve upon.

As I contemplated the past record of achievements there are admittedly indications of efforts which were not successful. I also perceived a condition that, at first, seemed to show a glaring weakness of the Academy. That particular item is the independent and separate makeup of the Academy via its diverse membership which represents numerous separate disciples of science. Since the early 1930's the organization has not been dominated by any one institution in terms of the composition of elected officers (in fact since 1934 the 51 presidents have represented 14 different institutions). I would propose, however, that this seemingly lack of unified institutional clout so important in dealing with budgetary considerations via the Legislature, Council of Higher Education, Federal granting agencies and private foundations is now one of the Academy's best assets. This rebuttal of my initial statement on this topic comes from a new perception that since the KAS is so free of institutional bias we have important credibility when commenting, suggesting or implementing changes that effect the science status of Kentucky. It is in this vein that I would like to address a view from the Presidency of The Academy concerning both immediate and long-term goals of our organization.

All of the current membership are well aware of the efforts of the Academy to develop better and closer ties between science, industry and government. Your support and the tremendous hard work by various committees as well as the officers have built a foundation that will continue to improve such relationships. Financially, the Academy is slowly building toward a stability that will ensure both successful administrative and publication functions and support of basic research. Your elected officers are committed to continue in the direction of fiscal stability. The above goals are consistent with our charge, but now it is also evident that a need exists which, while trying our patience and stamina, is indeed a worthwhile and logical extension of the Academy's heritage. That need is to help provide a rebirth of the spirit of inquiry at the secondary and elementary school levels as well as among the lay citizens of the Commonwealth of Kentucky.

I am indebted to Bill Hettinger of Ashland Oil for the initial stimulus to address this issue of the spirit (or lack thereof) of inquiry as a basic component of both education and direction for society. While among scientists it is not required that I remind you of the scientific method, I would perhaps be remiss by not summarizing an explanation of the scientific method by Mueller (10) who wrote "Fundamentally requisite as a basis for wise decisions is the scientific method. This consists, in simplest terms, in examining every question in a spirit of *searching, creative objectivity.* For this purpose there should be freedom from all authoritarianism, dogma, and (what is worst of all) conscious deception; and ample scope for honest criticism and counter-criticism. It is carried out by the activity of wide-roving imagination, harnessed speculation, ruthless analysis, coordination with other relevant knowledge from no matter how remote-seeming a sphere, discerning calculation, enlightened observation, versatile probing, and well-designed testing". One can not question that such a procedure is demanded for every endeavor of human understanding. The obvious question is how shall the Kentucky Academy of Science be a force in promoting the spirit of inquiry?

It is my impression that a great opportunity now exists for meaningful changes in both the training of teachers of science and in the expectations of student performance in all subjects. By emphasis on the independent credibility and objectivity of our membership the Academy can have a leading role in the decision making processes at the state level. Two of the Academy's more active components; the Junior Academy and the Science Education Committee have proven records of accomplishment and are bound to play still a greater role in the future. A key word today in education and other facets of state government is citizen's participation. Although we the Academy have a vested interest in science, our interest is slanted toward a science not geared toward any particular institution funded by the public. Utilizing our experience from operating the scientific method we should prove to be very credible in being active participants in drafting the needed changes for the state's educational endeavors. No single legislated institution alone can develop that spirit of inquiry. Therefore I propose that the membership actively participate by supporting local advisory groups as well as the programs that are being planned by the Academy in the near future.

It seems logical that our synthesis of science, industry and government that has been the major theme of KAS annual meetings over the part 3 years now aim toward addressing the issue of science and education. This will be the thrust of symposia and plenary sessions over the next two years.

I feel most fortunate to have the opportunity to associate with so many fine people who are active members of the Kentucky Academy of Science. The dedication and commitment to bring forth excellence via the science community shown by the membership is both inspirational and humbling. The membership role shows dedicated stewardship that has enabled our organization to persist for over 70 years. I found comfort in reading C. J. Robinson's (11) minutes of the organizational meeting of the Academy where he recorded comments made by Stanley Coulter of Purdue University, the principal speaker at that meeting in 1914. In speaking of "Science and State" Coulter said "The relation involves a mutual duty, offers opportunities and opens splendid possibilities". I will be so bold to add that as part of our mutual duty we can provide the spark and catalyst to generate a new spirit of inquiry for future generations in Kentucky.

Respectfully submitted,
Joe E. Winstead
14 January 1985

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ANNUAL MEETING

The next annual meeting of the Kentucky Academy of Science is scheduled for 8-9 November 1985 at Morehead State University.

ACADEMY BUSINESS

COMMITTEES OF THE KENTUCKY ACADEMY OF SCIENCE: 1984-85

On behalf of the membership of the Academy, President Winstead expresses the sincerest appreciation for the committment and dedication shown by the individuals serving in the many important leadership roles of the Academy.

EXECUTIVE COMMITTEE

Joe E. Winstead (President)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6004

Charles V. Covell, Jr. (President-Elect)
Dept. of Biological Sciences
University of Louisville
Louisville, KY 40292
(502) 588-6771

Larry Giesmann (Vice-President)
Dept. of Biology
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5110

Gary Boggess (Past-President)
College of Science
Murray State University
Murray, KY 42071
(502) 762-2886

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Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1539

Morris D. Taylor (Treasurer)
Dept. 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

Herbert Leopold (Director-KJAS)
Smiths Grove, KY 42171
(502) 563-5731

Manuel Schwartz (Chairman, Board of Directors)
Department of Physics
University of Louisville
Louisville, KY 40292
(502) 588-6787 or 588-5235

BOARD OF DIRECTORS

Manuel Schwartz (1986) (Chairman)
Department of Physics
University of Louisville
Louisville, KY 40292
(502) 588-6787 or 588-5235

Paul Freytag (1985)
Department of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-7452

William A. Baker (1986)
The General Electric Company
Appliance Park A 35-1301
Louisville, KY 40225
(5052) 452-4642

Gerrit Kloek (1986)
Department of Biology
Kentucky State University
Frankfort, KY 40601
(502) 227-6931

Laurence Boucher (1987)
Department of Chemistry
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6244

Bill Hettinger (1987)
Director of Research
Ashland Petroleum Company
P.O. Box 391
Ashland, KY 41101
(606) 329-333

William Bryant (1988)
Department of Biology
Thomas More College
Box 85
Ft. Mitchell, KY 41017
(606) 341-5800

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Department of Biology
Paducah Community College
Paducah, KY 42002-7380
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Department of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
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Lexington, KY 40506-0055
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Richmond, KY 40475
(606) 622-1818

Gerrit Kloek (1987)
Department of Biology
Kentucky State University
Frankfort, KY 40601
(502) 227-6931

Joe E. Winstead (KAS President)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6004

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

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Dept. of Biological Sciences
Eastern Kentucky University
Richmond, KY 40475
(606) 622-1539

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University of Kentucky
Lexington, KY 40546-0091
(606)257-7456

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Richmond, KY 40475
(606) 622-1115

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Graduate School
University of Louisville
Louisville, KY 40292
(502) 588-6495

Ex Officio

Joe E. Winstead (President)
Department of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6004

Charles V. Covell, Jr. (President-Elect)
Department of Biological Sciences
University of Louisville
Louisville, KY 40292
(502) 588-6771

Gary Bogess (Past-President)
College of Science
Murray State University
Murray, KY 42071
(502) 762-2886

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Richmond, KY 40475
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(502) 745-6009

Sue K. Ballard (1985)
Celotex Corporation
901 Westpark Drive
Elizabethtown, KY 42701
(502) 769-3391

Donald L. Birdd (1986)
Science Education
Eastern Kentucky University
Richmond, KY 40475
(606) 622-2167

Dan Ochs (1986)
Science Education
University of Louisville
Louisville, KY 40292
(502) 588-6591

Larry Giesmann (Vice-President)
Department of Biology
Northern Kentucky University
Highland Heights, KY 41076
(606) 572-5110

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John MacGregor (Chairman)
KY Fish and Wildlife Resources
Frankfort, KY
(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 Commission
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

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Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-4902

Les D. Burton
College of Natural Science and Math
Jefferson Community College
Louisville, KY 40218
(502) 584-0181

Joe King
Dept. of Biological Sciences
Murray State University
Murray, KY 42071
(502) 762-2786

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Campbellsville, KY 42718
(502) 465-8158

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Dept. of Chemistry
Berea College
Berea, Kentucky
(606) 986-9341

Modesto Del Castillo
Dept. of Science
Elizabethtown Community College
Elizabethtown, KY 42701
(502) 769-2371

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Larry P. Elliott (1985) (Chairman)
Dept. of Biology
Western Kentucky University
Bowling Green, KY 42101
(502) 745-6002

Paul Freytag (1985)
Dept. of Entomology
University of Kentucky
Lexington, KY 40546-0091
(606) 257-745?

Herbert Berry (1986)
Computer and Information Science
Morehead State University
Morehead, KY 40351
(606) 783-2749

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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, abstract, 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 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, 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 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 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.

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