

Volume 61, Numbers 2, 3 and 4

# Proceedings of the West Virginia Academy of Science 1989



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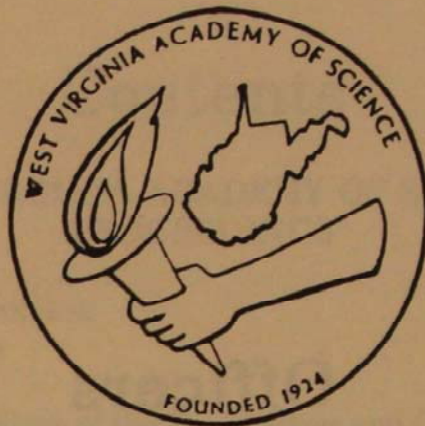
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**Proceedings of the West Virginia  
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**Vol. 61—No. 2, 3, and 4**

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# Proceedings of the West Virginia Academy of Science

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# 1989 WEST VIRGINIA ACADEMY OF SCIENCE AWARDS

## Science Talent Search Awards

**First Place:** Brian O. Porter

**Second Place:** Anne D'Alessandri

**Third Place:** Brian D. Bovard

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# Botany Section

Updates on the Vascular Flora of  
West Virginia

William Rogers  
Department of Biology  
West Virginia University

Presented at the  
Meeting of the  
Botanical Society of America

The following is a list of the vascular plants of West Virginia that have been added since the last publication of the West Virginia Flora. The list is based on the collections of the West Virginia University Herbarium and the collections of the West Virginia University Botanical Garden. The list is arranged alphabetically by the scientific name of the plant.

The first section of the list is:

*Asplenium adnigrum* (L.) Oakes & Smith. This species was first collected in West Virginia in 1912 by Oakes & Smith. It is a small, creeping fern that grows in moist, shaded areas. It is now common in the mountains of West Virginia.

*Asplenium platyneuron* (L.) Oakes & Smith. This species was first collected in West Virginia in 1912 by Oakes & Smith. It is a small, creeping fern that grows in moist, shaded areas. It is now common in the mountains of West Virginia.

*Asplenium septentrionale* (L.) Oakes & Smith. This species was first collected in West Virginia in 1912 by Oakes & Smith. It is a small, creeping fern that grows in moist, shaded areas. It is now common in the mountains of West Virginia.

*Asplenium thelypteris* (L.) Oakes & Smith. This species was first collected in West Virginia in 1912 by Oakes & Smith. It is a small, creeping fern that grows in moist, shaded areas. It is now common in the mountains of West Virginia.

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of  
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# Botany Section

## Updates on the Vascular Flora of West Virginia. V.

William Homer Duppstadt  
Department of Biology  
West Virginia University  
P. O. Box 6057  
Morgantown, West Virginia 26506

### Abstract

The following five species of vascular plants have been recorded during the past year at the West Virginia University Herbarium (WVA) as additions to the flora of West Virginia (based on Strausbaugh and Core, 1978). Unless otherwise noted, the nomenclature and distribution information follows Fernald, 1950.

The new species are as follows:

ARACEAE. *Peltandra virginica* (L.) Schott & Endl. Berkeley County: Rodney Bartgis s. n., August 2, 1982 and Preston County: Rodney Bartgis 1097, May 20, 1985. This species is in all surrounding states and is to be expected in West Virginia.

CYPERACEAE. *Scleria pauciflora* Muhl. Harrison County: Brian McDonald and Roger Stern s. n., August 8, 1986. West Virginia is in the midst of the range of this plant. It is, therefore, to be expected.

CARYOPHYLLACEAE. *Silene cserei* Baumg. Randolph County: Eugene E. Hutton s. n., August 26, 1988. This is a southeastern european species that is becoming naturalized.

CAPRIFOLIACEAE. *Lonicera mackii* Maxim. Monongalia County: William N. Grafton. September 26, 1981 and Mineral County: William N. Grafton, September 22, 1987. This is an asian species that is becoming established.

ASTERACEAE. *Eupatorium godfreyanum* Cronq. Fayette County: T. F. Wieboldt, August 25, 1984, Raleigh County: T. F. Wieboldt, August 25, 1984 and Greenbrier County: L. J. Uttal 14532, October 3, 1986. Our oldest specimen that fits the specifications for this new species is one collected in Fayette County by the West Virginia University Botanical Expedition on August 10, 1926. We also have fourteen other specimens from Barbour, Jackson, Monongalia, Nicholas, Pendleton, Pocahontas, Raleigh, Summers, Upshur, Webster, and Wyoming counties. This new species is described from western Virginia. (Cronquist, 1985).

#### Literature Cited

1. Cronquist, Arthur. 1985. *Eupatorium godfreyanum* (Asteraceae), a "new" species from Eastern United States. *Brittonia* 37(3):237-242.
2. Fernald, M. L. 1950. *Gray's Manual of Botany*, 8th edition. American Book Co., New York.
3. Strausbaugh, P. D. and E. L. Core. 1978. *Flora of West Virginia*, 2nd edition. Seneca Books, Grantsville, WV.

# ECOLOGY SECTION

## Influence of Brine Pollution upon Macroinvertebrates in three streams of the Pocatalico River, West Virginia

Alan Turner and Donald Tarter  
*Department of Biological Sciences*  
*Marshall University*  
*Huntington, West Virginia 25701*

### Abstract

Physico-chemical conditions and benthic macroinvertebrate community structure were compared among three headwater streams influenced by oil field brines within the Pocatalico River Basin, West Virginia. The River Continuum Concept model was applied to distinguish oil field brine influences from the natural influences acting upon the benthic macroinvertebrate community. Community structure was quantitatively related to the physico-chemical conditions by analysis of variance and Ecological Community Analysis.

Salinity was unique for each stream, from highly saline or brackish water at KcKown Creek, to moderately saline water at Johnson Creek, to freshwater at Flat Fork. Flows acted in conjunction with salinity to maintain low density populations within the saline streams. Reduced abundance without a corresponding change in richness created diversities within high and moderate salinities that equaled or exceeded those within freshwater.

Although richness remained fairly constant, the taxonomic composition tended to be highly variable among the streams. Hemimetabolous insects with well developed or protected tracheal gills replaced insects without gills within moderate salinities. Holometabolous insects replaced hemimetabolous insects within high

salinities. Structural and functional characteristics of the stream communities appeared to be conserved through the replacement of brine-intolerant forms with brine-tolerant forms as long as replacement species existed with the streams.

The Ecological Community Analysis identified a predominance of burrowing invertebrates, mainly oligochaetes, existing within the saline streams. Turbidity, total suspended solids and percent burrowing community values recorded for the saline streams did not conform to predictions of the River Continuum Concept model. This is maybe due to greater siltation occurring within the saline streams. Brine influences adversely affect benthic macroinvertebrate community structure within lower salinities than previously identified by toxicity testing and biological indices.

## Introduction

The onshore oil and gas industry within West Virginia is regulated by the Best Practicable Technology Currently Available (BPTCA) Effluent Limitations under the National Pollutant Discharge Elimination System (NPDES). Under this system, waste streams generated from onshore oil field development and oil recovery operations are not permitted to discharge directly to a stream (EPA, 1985). Between 1982 and 1985 a general permit was developed by the West Virginia Department of Natural Resources to establish a water quality control technology over drilling pit discharges that previously were not practical to regulate under the federal guidelines of zero discharge (WVDNR, 1985a, b.). Since this time, regulatory agencies have become concerned over the waste generated during secondary oil and gas recovery operations. Brine disposal during secondary oil and gas recovery may not meet the zero discharge requirement in areas where there is a high density of active oil and gas wells. This has become evident from high chloride concentrations detected during ambient stream monitorings in the oil fields of eastern Kentucky, southern Pennsylvania and west central West Virginia (Birge et al., 1985; Brown and Arkay, 1987; Mitsch et al., 1983; Sidhu and Mitsch, 1985; Wood 1985).

This study was conducted in the Walton Oil Field within the headwaters of the Pocatalico River of Roane County, West Virginia. The area has a history of brine-related problems and intermittently moderate to heavy salinities have been documented within a number of streams (Wood, 1985). A variety of sources may contribute to brine pollution. Brine may enter streams directly from broken carrier lines and

corroded storage tanks. It may enter streams indirectly by percolating into the ground water from unlined dikes, or by seeping into aquifers during underground injection.

Benthic macroinvertebrate communities may respond to oil field brine influences by reductions in their total abundance and overall richness (Harrell and Dorris, 1968; Mathis, 1965; Van Gundy, 1969; Wilhm, 1965; Winget and Mangum, 1979). With low to moderate brine influences, macroinvertebrate species abundance may be equalized through differential reduction of their numbers with little change in the overall richness of the community (Mathis, 1965; Harrell and Dorris, 1968).

The objectives of this investigation were to determine: (1) if brine influence is a significant limiting factor to macroinvertebrate populations of low order streams receiving brine pollution, (2) the general degree of salinity that limits macroinvertebrate richness, abundance and diversity, (3) which of the area's freshwater macroinvertebrate populations are intolerant to salinity, and (4) how this study's findings compare to laboratory experiments that have examined saline toxicity to benthic macroinvertebrate organisms.

### Study Area

Three headwater streams were studied in from the Pocatalico River Basin located within the Walton Oil Field in Roane County, West Virginia, (81°24' W 38°37'30" N (Turner, 1987). This area is within the mixed mesophytic Central Hardwood Forest of the Allegheny Plateau (Strausbaugh and Core, 1977).

McKown Creek, Johnson Creek and Flat Fork were chosen based upon their proximity and their relative differences in chloride concentrations. Watersheds of Johnson and McKown creeks have been extensively developed as oil fields and the creeks had shown intermittent chloride concentrations exceeding 250 mg/L on several occasions (Wood, 1985). Flat Fork, a relatively undeveloped oil field stream where chloride concentrations had been consistently below 40 mg/L, was selected as a control. Flat Fork drains an area of approximately 13.5 km<sup>2</sup> and is 17 km in length. It falls an average of 4.3 m/km. Johnson Creek is similar to Flat Fork with an average fall of 4.7 m/km, but is slightly smaller draining only 10.6 km<sup>2</sup> over its 11.3 km length. McKown Creek drains 5 km<sup>2</sup> over its length of 5.6 km. It falls an average of 10 m/km and has more stone outcrops and stands of

hemlock, as well as fewer hardwoods, along its banks than do the other streams. All these streams have similar bottom morphology. The stream bottoms consist of long stretches of sandy to silty substrate interspersed by exposed bedrock and deep pools.

## Materials and Methods

### Biological Analyses

Macroinvertebrates were collected with a Surber sampler from six locations along a single transect perpendicular to flow each month, except February, from January to December, 1986. Each sample was preserved with Kahle's solution (Pennak, 1978) before being transported to the laboratory.

Within one week of sampling, inorganic sediment, such as rock, sand and silt, was removed from all samples. Benthic macroinvertebrates and organic material were saved and preserved in an 70% ethanol. They were removed from each sample by flotation method using a 25% sucrose solution (Greeson et al., 1977). All invertebrates were identified to the generic level using Merritt and Cummins (1984) as the final authority, although many other keys were used for verification (Hitchcock, 1874; Mason, 1973; Oliver et al., 1978; Pennak, 1978; Simpson and Bode, 1980; Tarter, 1976). After identification the macroinvertebrates were counted.

### Chemical Analyses

Stream water was sampled monthly for chlorides (mg/L), sodium (mg/L), calcium (mg/L), potassium (mg/L), magnesium (mg/L), aluminum ( $\mu\text{g/L}$ ), iron ( $\mu\text{g/L}$ ), and manganese ( $\mu\text{g/L}$ ). Additionally, total acidity (mg/L) alkalinity (mg/L, total Kjeldahl nitrogen (mg/L), ammonia nitrogen (mg/L), sulfate (mg/L), total organic carbon (mg/L), total suspended (mg/L) and dissolved solids (mg/L), and turbidity (JTU) were sampled. All samples were collected from locations along a single transect on each stream.

Field measurements for temperature (C), conductivity ( $\mu\text{S/cm}$ ), pH (SU) and dissolved oxygen (mg/L) were measured on site at each of the locations where water quality samples were collected. These parameters were analyzed by electrometric method using a Hydrolab series 4000 meter. All metals were preserved and analyzed according to standard methods (APHA).

## Physical Analyses

Flow was measured by pygmy Gurley meter from six locations along a single transect on each of the three study streams. The bottom substrate was visually estimated at each Surber sample site by determining the particle size class as boulder, cobble, pebble, granule, or sand by the Wentworth scale (Folk, 1968). Its composition was estimated by using a percentage composition chart (Terry and Chilingar, 1955) to judge the relative area occupied by each particle size class within one square meter.

## Data Analysis

Data were sequenced by the date, stream and site by which samples were collected. Biological data were totaled to obtain richness and abundance values for each month and for the entire year. A Shannon diversity index (Lloyd et al., 1969) was calculated for each month utilizing Oakleaf Systems software (Eckblad, 1984). Spearman rank correlation analysis was performed between the physico-chemical parameters to determine the strength of their interrelationships at the time of sampling. Interactive Microware software (Warme, 1980) was used to plot fluctuations within the physico-chemical and biological variables to examine spatial and temporal variations.

A single factor analysis of variance was chosen to determine which parameters were significantly different among the three streams. A two-factor analysis of variance test was performed to observe seasonal variation. Each parameter was analyzed separately with the streams serving as the effects for the single factor model, and the streams by date serving as the crossed effects for the two-factor model. Both a standard analysis of variance and a Kruskal-Wallis test on the Wilcoxon Scores were performed upon the data (Neter et al., 1985; SAS, 1985).

The Kruskal-Wallis test was chosen to even the variability found between some of the test sites for certain parameters (Allan, 1984; Prepas, 1984). Arcsine transformations were performed upon proportional data, such as the variables for substrate composition and organic matter, before testing by standard analysis of variance. Flow data were analyzed both as a proportion of a stream's maximum flow and as a ranked variable, so those effects due to flow intensity could be isolated from those due to stream size. A pairwise comparison test, the Bonferroni T test, was performed on each dependent variable identified as significantly different by analysis of variance to contrast the order of

differences among the streams. All statistical analyses were performed utilizing SAS software upon an IBM 3081 computer through the West Virginia Network for Educational Telecomputing (SAS, 1985).

### Ecological Community Analysis

Ecological Community Analysis (Rooke and Mackie, 1982 a,b) compares ecological differences identified by analysis of variance to those differences predicted by the conceptual model of the River Continuum Concept (Vannote et al., 1980). It was chosen for this study to augment the biological and physico-chemical measurements by isolating functional differences existing among the three study streams.

The percentage represented by each benthic macroinvertebrate type was calculated from the total abundance of each monthly stream sample. Those representing greater than five percent of the sample were researched and assigned to the ecological classification system devised by Merritt and Cummins (1984). Our study uses four ecological categories: habitat, habit, trophism, and silt tolerance. The macroinvertebrates were identified as being of lotic, lentic or marine habitats; climbing, clinging, sprawling, swimming or burrowing habits; collector-filtering, collector-gathering, scraping, shredding-herbivore, shredding-detritivore or predatory trophic preference; and as being tolerant or intolerant to silt.

Arcsine transformations were performed upon the percentages (Neter et al., 1985) for all the macroinvertebrates comprising greater than five percent of the sample. Each subcategory was then analyzed separately by a single factor analysis of variance model through the General Linear Models (GLM) procedure of SAS System software, due to there being unequal observations between treatment levels (SAS, 1985). Seasonal effects were analyzed by a two-factor analysis of variance model. Pairwise comparisons were performed along with both analyses of variance to contrast the order of differences among the streams.

## Results

### Physico-Chemical Conditions

Water temperature was generally lower at Flat Fork and higher at McKown Creek (Turner, 1987). For the study period, the maximum water temperature was 24.4 C in June and the minimum

was 0.7 C, recorded in January. No significant differences existed for temperature among the three streams.

Stream discharge was extremely variable over the course of the year and did not always change proportionally over the same periods for all streams (Fig. 1). Flow was negatively correlated to salinity and specific conductance at McKown Creek, where extreme salinities occurred.

Turbidity was determined to be a function of flow intensity. Turbidity was negatively correlated with the salinity and specific conductance within McKown Creek, and it is only at McKown Creek that turbidity significantly correlated to flow with  $r = -0.75$  ( $p < 0.001$ ). Turbidity was positively correlated to total Kjeldahl nitrogen, ammonia-nitrogen, total suspended solids, aluminum and iron with an  $r > 0.5$  ( $p < 0.001$ ) at all streams.

Conductivity was determined to be a function of a stream's salinity. It positively correlated to sodium, calcium, chlorides, total dissolved solids and magnesium with  $r > 0.75$  at McKown Creek and  $r > 0.50$  at Johnson Creek. Conductivity was less related to these parameters, except magnesium, at Flat Fork, where salinities were very low. This may reflect the relationship of surface runoff to differing degrees of brine influx. Specific conductance was consistently greater at McKown Creek, with an annual mean value of 2,602  $\mu\text{S}/\text{cm}$ , ranging from 259  $\mu\text{S}/\text{cm}$  in December to 9,790  $\mu\text{S}/\text{cm}$  in October. Flat Fork had an annual mean value of 177  $\mu\text{S}/\text{cm}$ , ranging from 137  $\mu\text{S}/\text{cm}$  in November to 225  $\mu\text{S}/\text{cm}$  in September.

Chlorides exceeded the state water quality limit of 250 mg Cl/L (McCoy, personal communication) for seven months at McKown Creek and for four months at Johnson Creek (Fig. 1). The annual mean chloride concentration for McKown Creek was 687 mg Cl/L, and was 247 mg Cl/L at Johnson Creek, nearly equal to the state water quality limit. Flat Fork never exceeded 50 mg Cl/L throughout the year.

Conductivity correlated highly to stream alkalinity. Correlation coefficients were greatest at Flat Fork,  $r = 0.89$ ; intermediate at Johnson Creek,  $r = 0.78$ ; and least at McKown Creek,  $r = 0.50$  ( $p < 0.001$ ).

Dissolved oxygen and pH were generally well within acceptable water quality limits (Ellis, 1937; WVWRB, 1983).

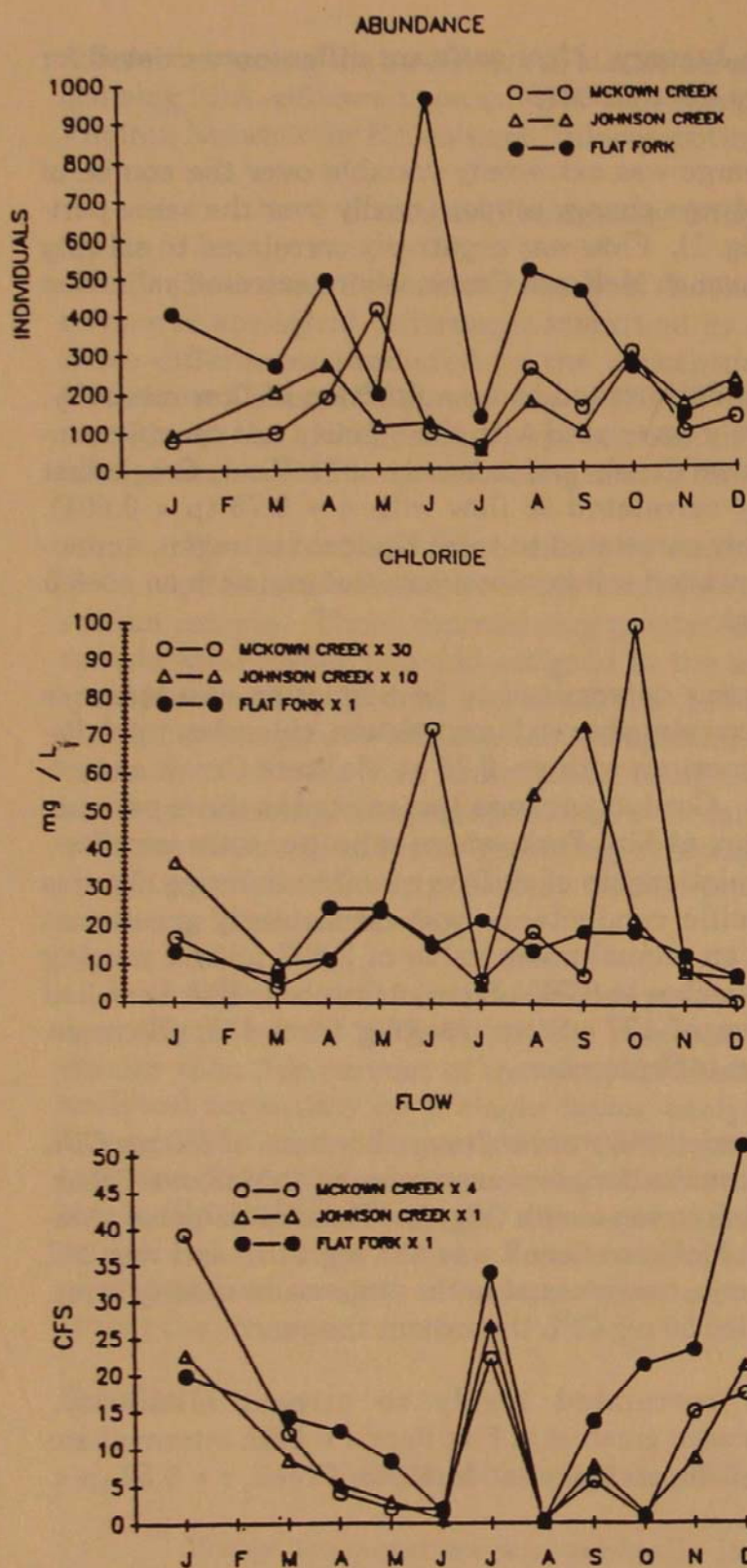
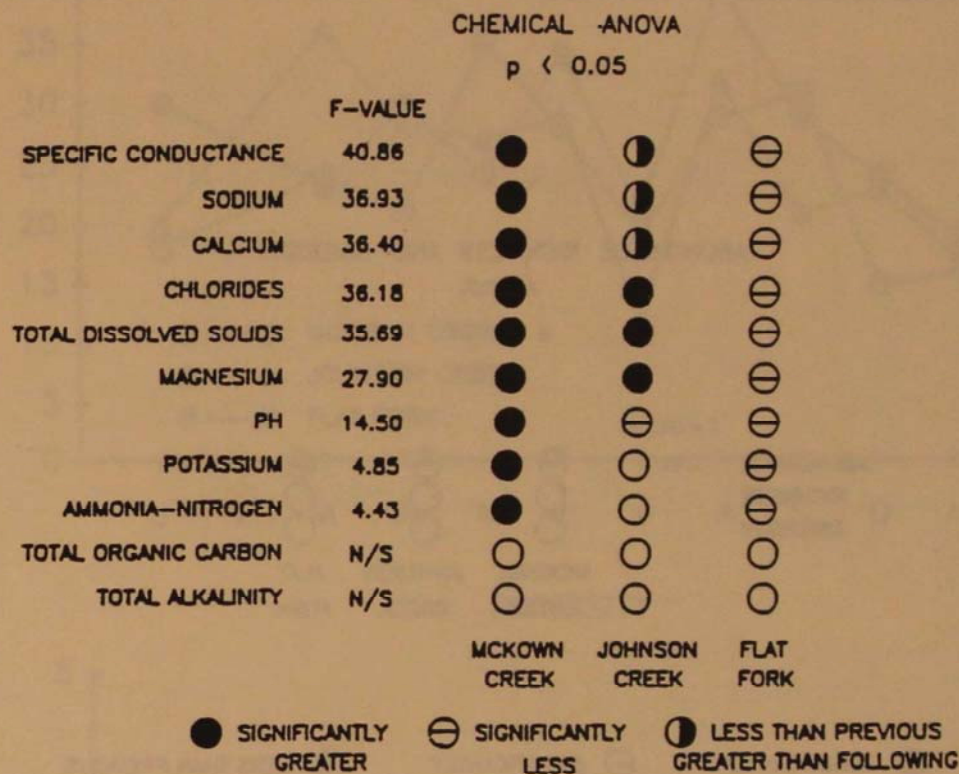


Fig. 1. Time plots summarizing the interrelationships of flow, (cfs) chloride (mg/L) and abundance of macroinvertebrates.



**Fig. 2.** Analysis of variance and pairwise comparison for chemical and physical parameters. Greater F-values indicate greater significant differences among streams. Absence of an F-value indicates no significant difference.

Analysis of variance identified the streams as being significantly different for mean specific conductance, sodium, calcium, chlorides, total dissolved solids, magnesium and pH values ( $p < 0.01$ ) (Fig. 1). Analysis of variance also identified mean ammonia-nitrogen and potassium as significantly different ( $p < 0.05$ ).

Flow and substrate composition were the only significantly different physical measurements among streams. Flat Fork was greater in flow volume, but proportionally, mean flow was equal among streams (Fig. 1). Percent composition of cobble was greater at McKown Creek than at Flat Fork.

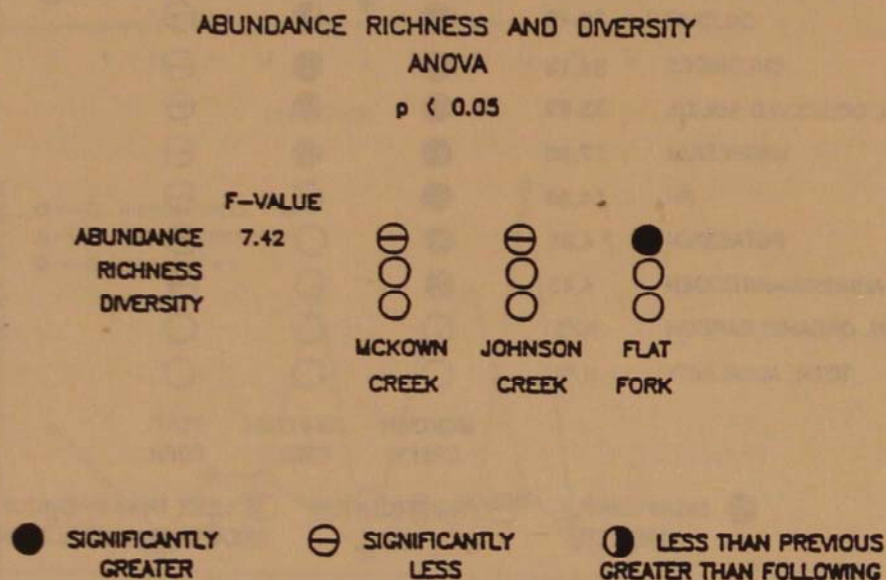


Fig. 3. Analysis of variance of abundance, richness and diversity. Greater F-values indicate greater significant differences among streams. Absence of F-value indicates no significant difference.

#### Biological Conditions

The control stream, Flat Fork, was more abundant than either of the test streams (Figs. 1, 3). A total of 3,734 macroinvertebrates were collected yielding a mean density of 8.2 individuals/m<sup>2</sup>, with the mayfly *Stenonema* most abundant. Eight-hundred and ninety (890) *Stenonema* were collected from Flat Fork, compared to 65 from Johnson Creek and 0 from McKown Creek.

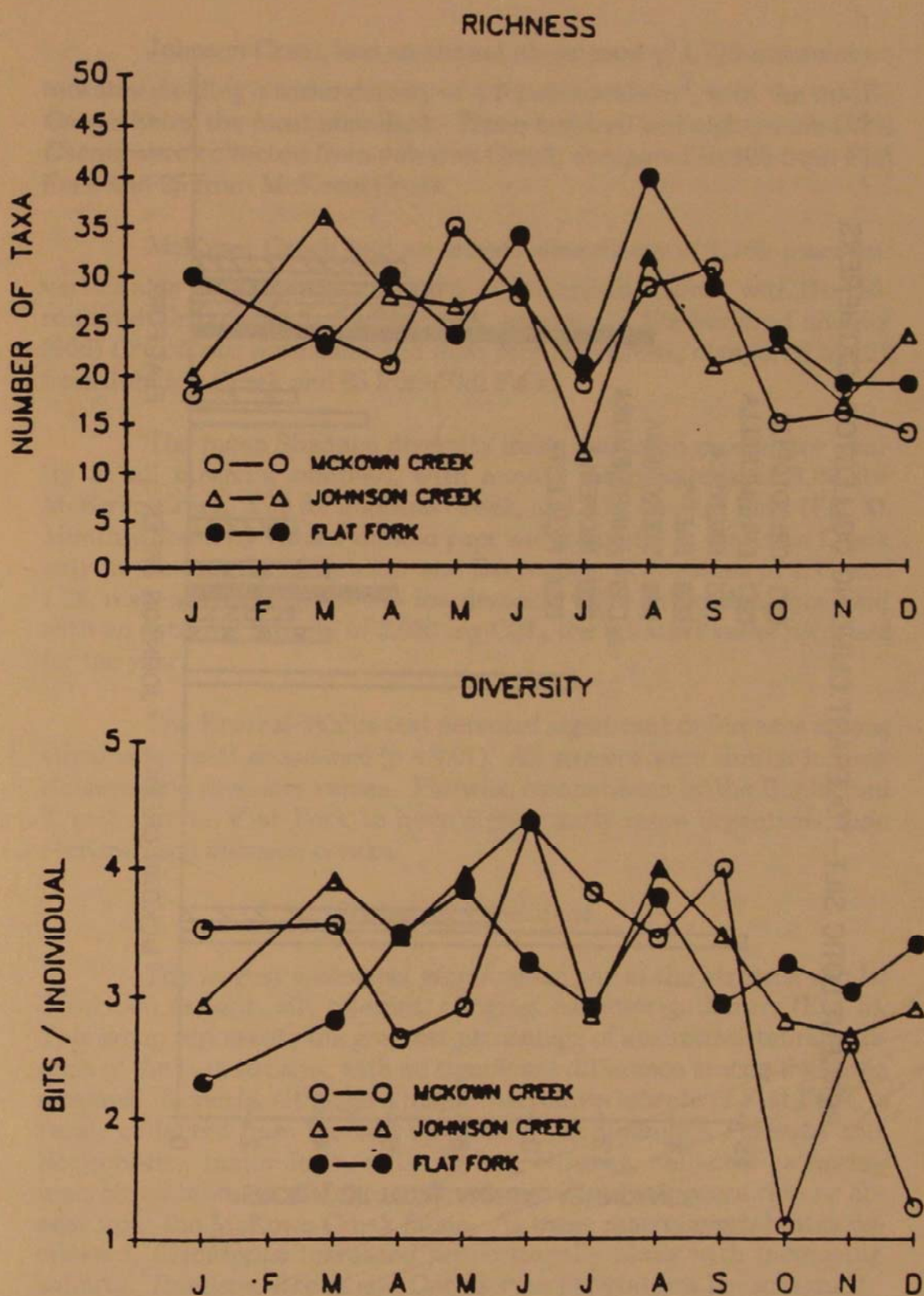


Fig. 4. Comparison of richness (number of taxa) and diversity (bits/individual). See Figure 1 for interrelationships with flow (cfs) and chloride (mg/L).

PERCENT LOTIC SILT-TOLERANT CLINGING COLLECTOR-GATHERERS

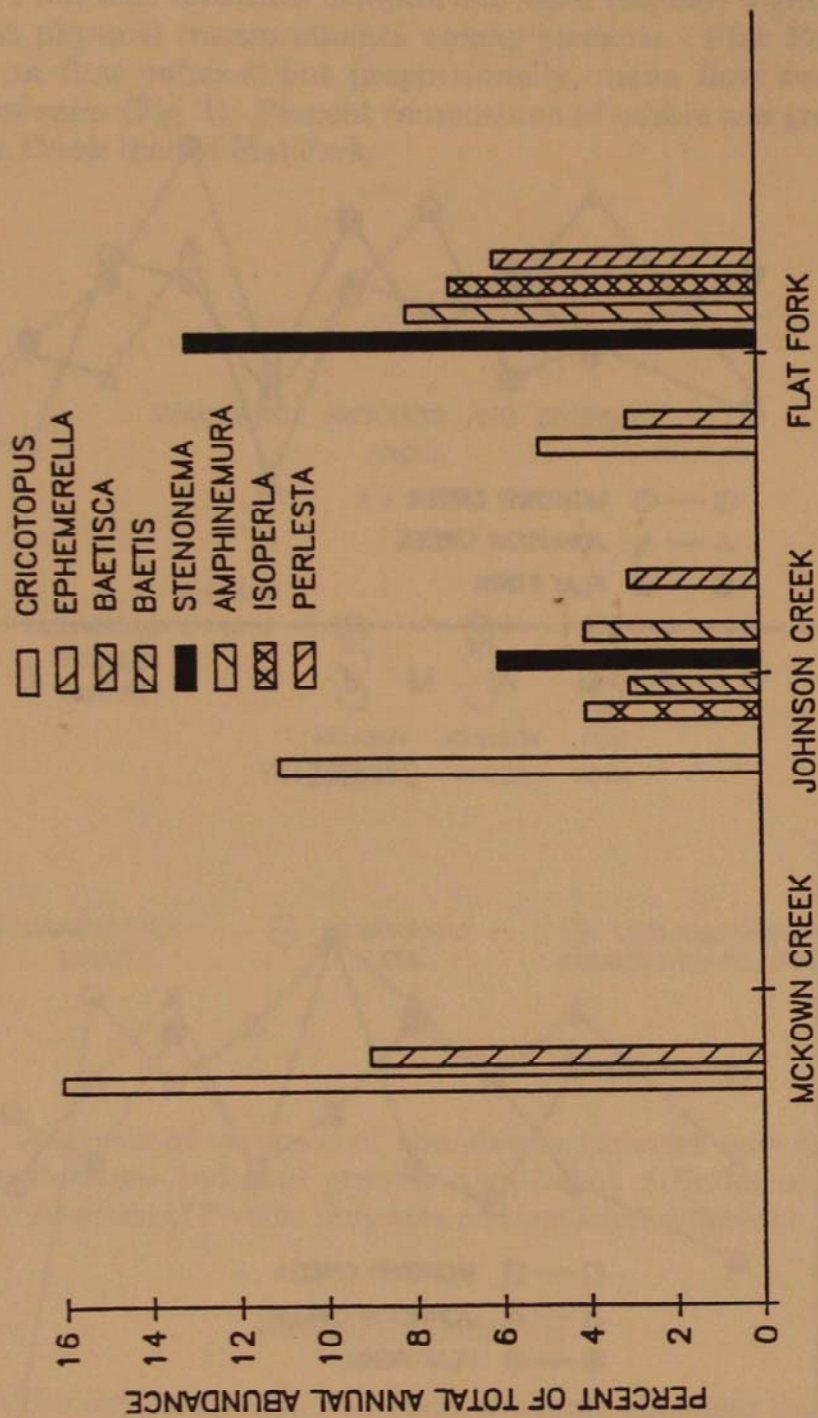


Fig. 5. Taxonomic composition of the lotic, silt-tolerant, clinging, collector-gathering benthic macroinvertebrates.

Johnson Creek had an annual abundance of 1,749 macroinvertebrates yielding a mean density of 4.9 individuals/m<sup>2</sup>, with the mayfly *Caenis* being the most abundant. Three-hundred and eighty-nine (389) *Caenis* were collected from Johnson Creek, compared to 103 from Flat Fork and 25 from McKown Creek.

McKown Creek had an annual abundance of 1,789 macroinvertebrates yielding a mean density of 5.6 individuals/m<sup>2</sup>, with the chironomid *Cricotopus* being the most abundant. Six-hundred and six (606) *Cricotopus* were collected from McKown Creek, compared to 123 from Johnson Creek and 65 from Flat Fork.

The mean Shannon diversity index indicated good water quality at all streams sampled, with annual mean values of 3.00 for McKown Creek, 3.43 for Johnson Creek, and 3.27 for Flat Fork (Fig. 4). Monthly diversity values showed poor water quality in McKown Creek only in the months of October and December, with values of 1.11 and 1.26, respectively (Fig. 4). The low diversity value in October coincided with an extreme salinity of 3,030 mg Cl/L, the greatest value recorded for the year.

The Kruskal-Wallis test detected significant differences among streams for total abundance ( $p < 0.01$ ). All streams were similar in their richness and diversity values. Pairwise comparisons by the Bonferroni T test showed Flat Fork to have significantly more organisms than McKown and Johnson creeks.

### Ecological Conditions

The largest ecological grouping for any of the streams can be described as lotic, silt tolerant, clinging, collector-gatherers (Fig. 5). This group represents the greatest percentage of macroinvertebrates in each of the test streams, with no significant difference among the three streams. *Isoperla*, although a major macroinvertebrate of Flat Fork, is rarely collected from the test streams. *Amphinemura*, *Perlesta*, and *Stenonema*, major lotic, silt-tolerant, clinging, collector-gathering macroinvertebrates of Johnson Creek and Flat Fork, were rare or absent from the McKown Creek fauna. As these macroinvertebrates decreased, *Cricotopus* increased proportionally along with increasing salinity. *Baetisca*, *Baetis* and *Optioservus* populations became major components of the clinging, collector-gathering types of Johnson Creek.

The percentage of silt-tolerant macroinvertebrates ranged from an annual mean of 61% at Johnson Creek to 65% at Flat Fork. Intolerant forms nearly disappear from McKown and Johnson creeks in March, October, November and December, while Flat Fork shows intolerant forms at 7% in March, but increasing dramatically from 20% in October to 52% in November and to 44% in December.

The macroinvertebrate habits were an average 10% swimmers, 25% sprawlers, 4% climbers, 46% clingers and 15% burrowers for the total community from all the streams.

The one-way model for Ecological Community Analysis identified only the ecological subcategory of burrowing invertebrates as being significantly different among the three streams. The pairwise comparison Bonferroni T test ( $p < 0.01$ ) identified the burrowing invertebrates existing in significantly lesser mean percentages at Flat Fork than those found at McKown Creek.

## Discussion

### Physico-Chemical Conditions

Conductivity was the greatest difference found among the three streams. In order of significance, sodium, calcium, chlorides, total dissolved solids and magnesium support the results obtained for conductivity. These parameters are major components of brine (Mathis, 1965, U. S. Geological Survey 1983; Van Gundy, 1969), highly related to conductivity, and also comprise the greatest differences found among the streams. Statistically, the streams represent three distinct ranges of salinity; a highly saline stream represented by McKown Creek, a moderately saline stream represented by Johnson Creek, and a fresh water stream represented by Flat Fork.

The interrelationship of flow to various water quality parameters illustrates how water quality is influenced by stream size. Harrel and Dorris (1968) reported that as stream order increased, physico-chemical fluctuations and mean annual turbidity decreased, while mean annual flow, alkalinity, and conductivity increased. Physico-chemical fluctuations did decrease from McKown Creek to Johnson Creek to Flat Fork, as would be predicted from stream size. However, because of brine influences, conductivity, turbidity and alkalinity decreased as stream size increased.

Turbidity, a function of stream size, is highly associated with total Kjeldahl nitrogen, ammonia-nitrogen, total suspended solids, aluminum, iron and, at Johnson Creek, total organic carbon. Mathis (1965) reported that high salinities by brine influences inhibit repulsive forces, counteracting the van der Waals forces between clay particles, so clay particles tend to clump and settle more rapidly in saline water. The greater turbidity experienced at Johnson Creek does not conform to expected results as indicated by the findings of Mathis (1965) and Harrel and Dorris (1968). Negative correlations between brine-associated parameters and turbidity at McKown Creek are likely due to their relationships to flow and not to one another.

### Biological Conditions

Distinct differences in community composition were found between the test streams McKown and Johnson creeks, and the control stream, Flat Fork. Seasonally, abundance was greatest during dry periods and least after heavy rain (Fig. 1). Fauna was particularly depleted in the months of July and November. Heavy rain creates severe fluctuation of flow that can present environmental stress to the benthic fauna (Fisher, 1983).

The greatest changes in abundance after a storm occurred at Flat Fork. Density-dependent factors could explain the proportional loss differences between the control and the test streams. "Catastrophic" drift (Minckley, 1964) could dislodge greater numbers of macroinvertebrates due to increased activity and a reduction in the available attachment sites that occurs when the macroinvertebrates become crowded (Shiozawa, 1983; Waters, 1972).

Shannon diversity indices proved to be rather insensitive to the changes community structure until October, when a peak concentration of 3,030 mg Cl/L occurred at McKown Creek (Figs. 1, 4). Diversity had not recovered two months later at the end of the sampling program. At McKown Creek in June, at a concentration of 2,233 mg Cl/L, diversity had actually increased to 4.34 bits/individual (Figs. 1,4). High diversity within oil field brine-polluted water has been reported before (Birge et al., 1985; Harrel and Dorris, 1968; Mathis, 1965). Mathis (1965) found that since oil field brines did not limit the number of species to the extent organic pollutants do, faunal assemblages more closely resemble natural communities. Mathis (1968) theorized that moderate loads probably cause the replacement of fragile species with tolerant ones, with an equalizing distribution of numbers over the species present, resulting in higher diversity values.

Results from this study support Mathis' (1968) theory. In June, the dominant McKown Creek genera composed only 60% of 40 individuals, while the dominant Flat Fork genera composed 80% of 700 individuals. *Polypedilum*, *Stenonema*, and *Isonychia* could be considered the "fragile" populations that were replaced by *Cricotopus*, *Thienemannimyia*, and *Pericoma*.

Lenat (1983) proposed that average taxa richness can provide the best control information for biological monitoring of polluted streams. He reasoned that the small variability of types over a wide range of unpolluted streams suggests a constant number of niches within stream ecosystems. In this study, richness at the generic level was nearly identical among the study streams over the year (Fig. 4). Analysis of variance showed no difference in richness due to chloride levels, but did show richness to decline with flows exceeding 20 cfs at Johnson Creek and Flat Fork, and with flows exceeding 5 cfs at McKown Creek. These results suggest richness within brine-polluted streams does not vary from the richness within unpolluted streams. Richness and diversity values support the conclusion that fragile species, or intolerant species, are replaced by tolerant ones once the fresh water environment experiences moderate salinity changes.

The taxonomic composition among the streams offers more supportive evidence for Mathis' (1968) theory. Major taxonomic groups shift from a predominance of plecopterans at Flat Fork, to a predominance of ephemeropterans, coleopterans and dipterans at Johnson Creek, to a predominantly dipteran fauna at McKown Creek.

The plecopterans *Leuctra*, *Isoperla*, *Taenionema*, and the ephemeropterans *Isonychia* and *Stenacron*, were eliminated once salinities approached 250 mg Cl/L. They were replaced by the ephemeropterans *Baetis* and *Baetisca*; the coleopterans *Optioservus*, *Oulimnius*, and *Stenelmis*; the odonate *Lanthus*; and the chironomids *Halocladius*, *Paratanytarsus*, and *Rheotanytarsus*; the plecopterans *Amphinemura*, *Ostrocerca*, *Perlesta*, and *Taeniopteryx*; the ephemeropterans *Heptagenia* and *Stenonema*; and the chironomids *Polypedilum* and *Pilaria* continued to exist within salinities above 250 mg Cl/L, but became less dominant as salinity increased. The ephemeropterans *Caenis* and *Pseudocloeon*, and the chironomids *Cricotopus* and *Thienemannimyia*, became more dominant as salinity increased.

The genera *Amphinemura*, *Perlsta*, *Taeniopteryx*, *Baetis*, *Baetisca*, *Caenis*, *Heptagenia*, *Stenonema*, *Halocladius*, *Rheotanytarsus*, *Optioservus*, *Stenelmis*, *Lanthus*, and *Pilaria* were eliminated within salinities above 750 mg Cl/L. They were replaced by the plecopteran *Allocaenia*; the trichopteran *Ochrotrichia*; the chironomids *Pentaneura*, *Natarsia*, *Eukiefferiella*; and the dipterans *Pericoma* and *Tipula*. The genera *Ostrocerca*, *Paratanytarsus*, and *Polypedilum* continued to exist within salinities above 750 mg Cl/L, although becoming less dominant, while *Pseudocloeon*, *Cricotopus*, and *Thienemannimyia* became more dominant as salinity increased.

Generally, hemimetabolous insects with cuticular respiratory systems were replaced by insects with well-developed tracheal gill systems at moderate salinities, and hemimetabolous insects were replaced by holometabolous insects at extreme salinities. The greater surface to volume ratio that tracheal gills provide may serve as an advantage in moderately saline water. Since chloride cells expire as salinity increases, tracheal gills may allow a greater range of tolerance by increasing the number of chloride cells over the body surface. Rectal gills (e.g. odonates) or an operculum (e. g. *Caenis*) may be an advantage by limiting the transport of chloride ions across the gills. Holometabolous insects, like some chironomids, may undergo brief larval stages and avoid extended exposure to extreme salinities. They also may have thickened cuticles to increase water retention at isosmotic levels, as do the coleopterans, and internal gills may be protected from a saline environment.

Acute and chronic toxicity testing of saline water and oil field brines (Birge et al., 1985; Clemens and Jones, 1954; Kapoor, 1978; Van Gundy, 1969; Wichard et al., 1973) showed median toxic salinities to range from 2,480 mg Cl/L, for *Physa gyrina* (Birge et al., 1985), to 12,000 mg Cl/L, for *Paragnetina media* (Kapoor, 1978). Field studies tend to be less specific about what salinities create distress within individual species, simply because data collected for one or two years is insufficient to obtain significant results through quantitative analysis. However, field evaluations have established that community composition does change well before toxic salinities are realized within the natural environment.

Van Gundy (1969) listed the maximum specific conductance at which species were collected from the oil field drainage of Lewis Run in Pennsylvania. Most plecopterans and trichopterans from Lewis Run were collected at maximum conductivities of 280  $\mu\text{S}/\text{cm}$ , which translates to approximately 60 mg Cl/L. Somewhere between 280  $\mu\text{S}/\text{cm}$  and

2,500  $\mu\text{S}/\text{cm}$ , or approximately 750 mg Cl/L, the plecopterans *Leuctra*, *Allocapnia*, *Paracapnia*, *Pteronarcys proteus* Newman, *Peltoperla*, *Isoperla*, *Alloperla*, and the trichopterans *Parapsyche*, *Dolophilodes distinctus* (Walker), *Rhyacophila fenestra* Ross, *Agapetus*, *Polycentropis*, *Goera*, *Ptilostomis*, *Micrasema*, *Lepidistoma* and *Pycnopsyche* were eliminated.

### Ecological Conditions

Ecological Community Analysis results did not conform to predictions of the River Continuum Concept for headwater streams of first to third order. Stream size, flow and the presence of fresh water clams would indicate Flat Fork to be a large third order stream that may function more like a fourth order stream as described by River Continuum Concept. Functioning as a fourth order stream, Flat Fork would be expected to support a larger proportion of collector-gathering, burrowing, and collector-filtering invertebrates than would be supported by a headwater stream. Ecological Community Analysis identified burrowing macroinvertebrates as comprising a significantly greater proportion of the community within McKown Creek than of the community within Flat Fork. Collector-gathering and collector-filtering macroinvertebrates did occur in greater proportions at Flat Fork, but the differences were not significant among the streams.

The greater proportions of burrowing invertebrates were entirely due to the Oligochaeta and *Cricotopus* populations. Their populations alternated throughout the year. More Oligochaeta were collected during intermediate and high flows, while *Cricotopus* populations were abundant during low flows and high salinities.

*Corbicula fluminea* was the only burrowing macroinvertebrate of Flat Fork that was not collected from the other streams. *Cricotopus* was generally not as dominant at Flat Fork as it was at McKown and Johnson creeks. Again, more Oligochaeta were present during high flows, especially if following a month of high salinity as occurred in January, June, and October at McKown creek. *Corbicula fluminea* and *Isonychia* were the only collector-filtering macroinvertebrates of Flat Fork that were not collected from the other streams.

Ecological Community Analysis demonstrated that a change in the communities' taxonomic composition does not necessarily mean a change within the functional groups existing within a stream. It did not prove to be a more sensitive test, but it was a more informative test for identifying changes in community structure than were the measures of

abundance, richness, or the Shannon diversity. The greater proportion of burrowing macroinvertebrates at the saline streams were identified as Oligochaeta. Because the stream bottoms are characteristically long stretches of sandy to silty substrata, increased numbers of Oligochaeta collected from the riffle area during high flow is probably due to disturbance of the substrate upstream from the riffle area. Aquatic oligochaetes thrive within silty substrate, and may be indicative of greater silt deposition within the pools of the saline streams (Pennak, 1978). This conclusion is supported by the greater turbidities and suspended solids recorded for these streams during flow events.

### Summary

Analysis of variance showed that greatest significant differences between the three streams were due to parameters associated with salinity; specific conductance, total sodium, total calcium, total chlorides, total dissolved solids and total magnesium. Pairwise comparisons by the Bonferroni T test identified each stream as significantly distinct in degree of salinity, with McKown Creek as the most saline, and Flat Fork as the least saline of the three streams. Flow intensity was a major influence upon the water quality parameters tested. Due to surface runoff negative correlation coefficients between flow and brine-associated ions indicated a greater dilution effect occurs at McKown Creek than at the larger streams. This implies the source of brine-associated ions is less from surface runoff than it is from point source discharges or ground water infiltration to McKown Creek. Cross correlation analysis and time plots of brine-associated ions illustrate how oil field brines alter the chemical composition of a stream. At the control stream Flat Fork, ions tend to be less related to one another and more related to changes in alkalinity, with some ions increasing in concentration along with increasing flows; At McKown Creek there is a surplus of salts that does not function in an ionic equilibrium with alkalinity, and so are transported to influence alkalinity downstream.

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# Benthic Macroinvertebrate Populations and Community Structure in the Cranberry River, West Virginia

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## Abstract

A one year investigation of the Cranberry River, Nicholas County, West Virginia, a naturally acidic and poorly buffered watershed, was conducted to determine relations between the environmental conditions and the benthic macroinvertebrate abundance and community structure. Compared to those of nearby watersheds, benthos was diverse but more sparsely populated. Newman-Keul's pairwise comparison tests showed significant differences between the station farthest upstream and the remainder of the watershed. In addition, selected tributaries were shown to have significantly poorer water quality than the main stream. However, these tributaries supported a diverse and abundant benthic community. Generally, benthic macroinvertebrate density, relative abundance, diversity, and water quality declined as flow increased in the Cranberry River. We concluded that population numbers in the benthos were limited by the chemical water quality, but that the benthic community was structured by physical habitat conditions related to stream flow.

## Introduction

The Cranberry River is a small trout stream in the Alleghany Plateau of West Virginia. An ecological study was initiated to determine the abundance and distribution of the benthic macroinvertebrates and to examine the physico-chemical factors responsible for these results. This is the first detailed investigation of the composition and structure of the Cranberry River macroinvertebrates. Phares and Oldham (1977) and Tarter (1980) reported benthic macroinvertebrate studies on nearby watersheds.

## Study Area

The Cranberry River, a fourth order stream, originates 11 km west of Marlinton, Pocahontas County, West Virginia, at the union of Cranberry Mountain and Black Mountain of the Yew Range. The river flows westward 52 km through Webster and Nicholas Counties to its confluence with the Gauley River at Cranberry Station (Price and Reger, 1929). The geologic formations in the Cranberry watershed are of the Pennsylvanian Mauch Chunk Series (Darlington, 1943). The watershed upstream from Woodbine encompasses 251 km<sup>2</sup> (Doll et al., 1963).

Cranberry River descends sharply from 1400 m to 1065 m and then has a mean gradient of 9.5 m/km. The Cranberry River flood plain varies from 30 m to 150 m in width. The stream banks average 1.2 m high, ranging from 0.9 m to 2.1 m. The width of the bed of the main-stream averages 30 m and ranges from 21 m to 45 m. The substrate is composed of 55% boulders, 40% cobbles, and 8% pebbles and gravel, and 0.75% sand, as defined on the modified Wentworth grade scale of Cummins (1962). Flow varies considerably and runoff is rapid. The Cranberry River, like other West Virginia streams associated with the same geologic formations, is lightly buffered and mineral nutrient poor.

Seven sampling sites, corresponding to West Virginia Department of Natural Resources water quality monitoring stations were selected for the investigation (Fig. 1). Four sites (Stations 3, 5, 6, and 7) are on the mainstream. The three remaining sites are on major tributaries, South Fork (Station 1), North Fork (Station 2), and Dogway Fork (Station 4). These tributaries, collectively, account for about 35% of the flow of the Cranberry River. Physical characteristics of the sampling sites are summarized in Table 1.

Most tributaries originate in the Pottsville Series, but the South Fork flows entirely over the Mauch Chunk Series (Menendez, 1983). South Fork flows through the Cranberry Glades, a flat, bottom area of northern peat bog that is 4.8 km in length and drops about 0.8 m/km (Miles and Gasper, 1966)

## Methods and Materials

### Site Description Measurements

Stream order, station elevation, and channel gradient were determined for each station. Stream order classification was based on the methods of Strahler (1957). Station elevation was estimated from a topographical map with contour lines at 12.2 m intervals. Channel gradient was measured over a 60 m reach, extending 30 m upstream and 30 m downstream from the site (Platts et al., 1983). Gradient measurements were made with an Abney hand level and distances were estimated by pacing.

### Physico-chemical Analysis

Stream flow estimates and water chemistry analyses were provided by the West Virginia Department of Natural Resources. Flow data were determined from staff gauges and from two United States Geological Survey gauging stations. Gauge readings were recorded at the time water sample was collected.

Water samples were collected and analyzed bimonthly from December 1983 through November 1984. Values of chemical parameters reported are quarterly means calculated from the bimonthly measurements. Chemical water quality analyses of alkalinity, acidity, pH, and conductivity were conducted at stream side at all stations. In addition, two sets of samples were collected and returned for analysis at the Water Resources Division Laboratory, West Virginia Department of Natural Resources in Elkins, West Virginia. One set of samples was analyzed for the same parameters tested at stream side and also included total solids, dissolved solids, and sulfates. The other set was analyzed for iron, aluminum, zinc, and manganese. All laboratory analyses were done in accordance with Standard Methods (APHA, 1978).

The substrate was sampled once at each station to determine the particle size distribution. A standard sieve analysis was not possible due to the coarseness of the materials. Instead, the random pebble count field method of Leopold (1970) was used. Procedure for selecting a sample involves dividing an area into 100 unit areas, and picking up one rock from each unit. Details of the method of substrate sampling are available in Meadows (1986). Substrate heterogeneity, a statistical measure of the degree of sorting, was determined by the method of Friedman and Sanders (1978) which uses a formula for "inclusive graphic standard deviation."

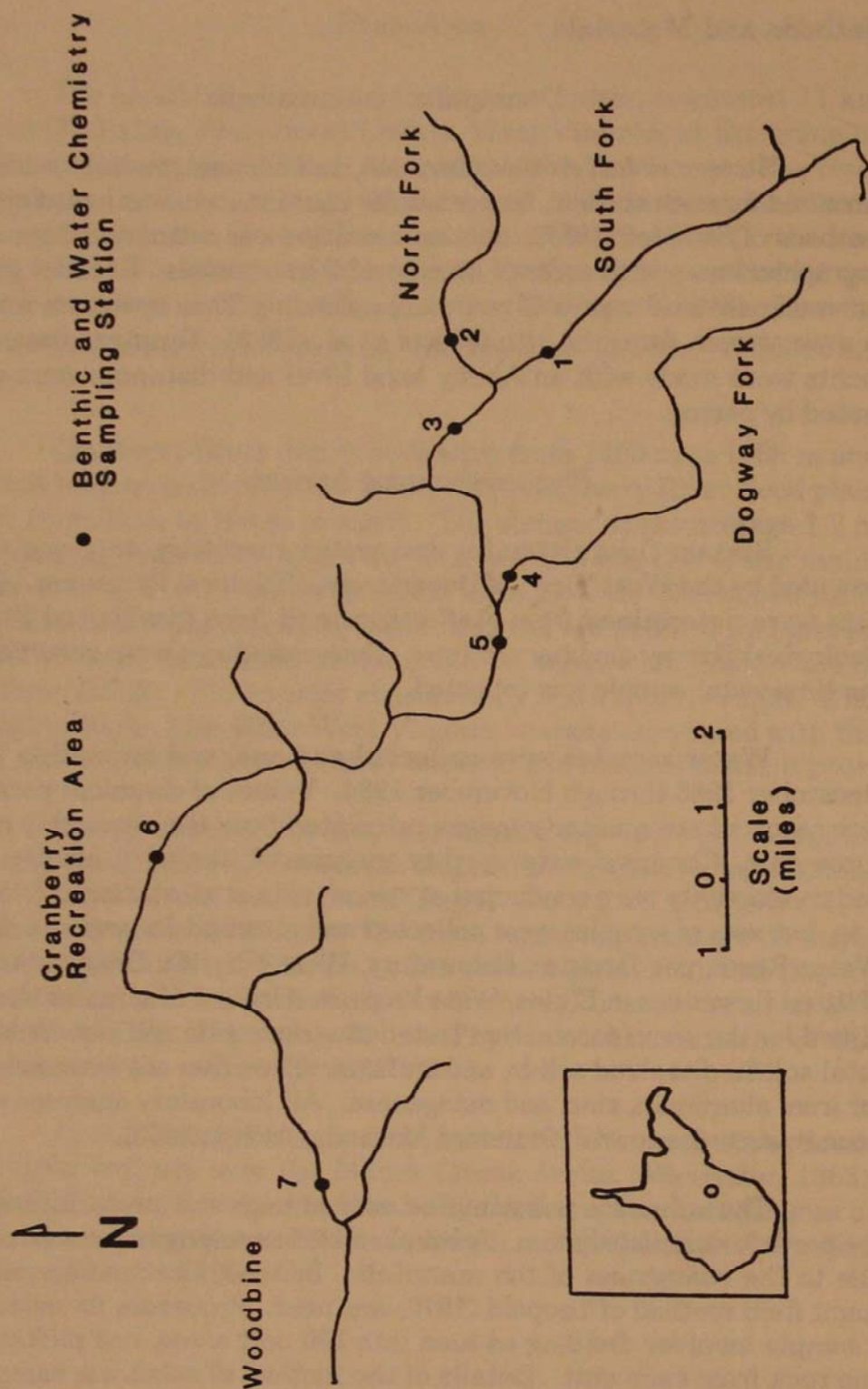


Figure 1. Cranberry River collection sites for benthic and water chemistry samples. Inset shows location of study area in West Virginia.

**Table 1.** Physical characteristics of Cranberry River sampling sites.

Station	Stream order	Stream Watershed		Gradient (m/km)	Width* (m)	Elevation (m)	Substrate type
		length (km)	area (km <sup>2</sup> )				
1	3	13.7	45	9.5	9.0	1013	Boulder-cobble
2	3	8.0	27	20	10.5	965	Cobble
3	4	-	-	9.5	23.0	957	Boulder-cobble
4	2	13.7	25	31	14.0	896	Cobble-pebble
5	4			9.5	30.0	873	Boulder-cobble
6	4	-	-	9.5	33.0	770	Cobble
7	4	52.0	251	9.5	35.0	655	Boulder-cobble

\* bank full

### Biological Analyses

Benthic macroinvertebrates were sampled quarterly at the Cranberry River sites using a Surber square-foot sampler (0.093 m<sup>2</sup>) (mesh size, 1050 microns). A total of 2.325 m<sup>2</sup> of stream per site per quarter was sampled to a depth of 10 cm. At each station, benthic macroinvertebrates were composited (contents of each 0.093 m<sup>2</sup> replicate added to same container) and preserved in 10% formalin. In the laboratory, macroinvertebrates were separated from the detritus and placed in 70% ethanol for identification and enumeration at a later date. Except for chironomids, identification of the benthic macroinvertebrates was made to the generic level based on the taxonomic keys of Burks (1953), Hitchcock (1974), Tarter (1976), Wiggins (1977), Pennak (1978) and Merrith and Cummings (1984). Chironomids were identified to the family level.

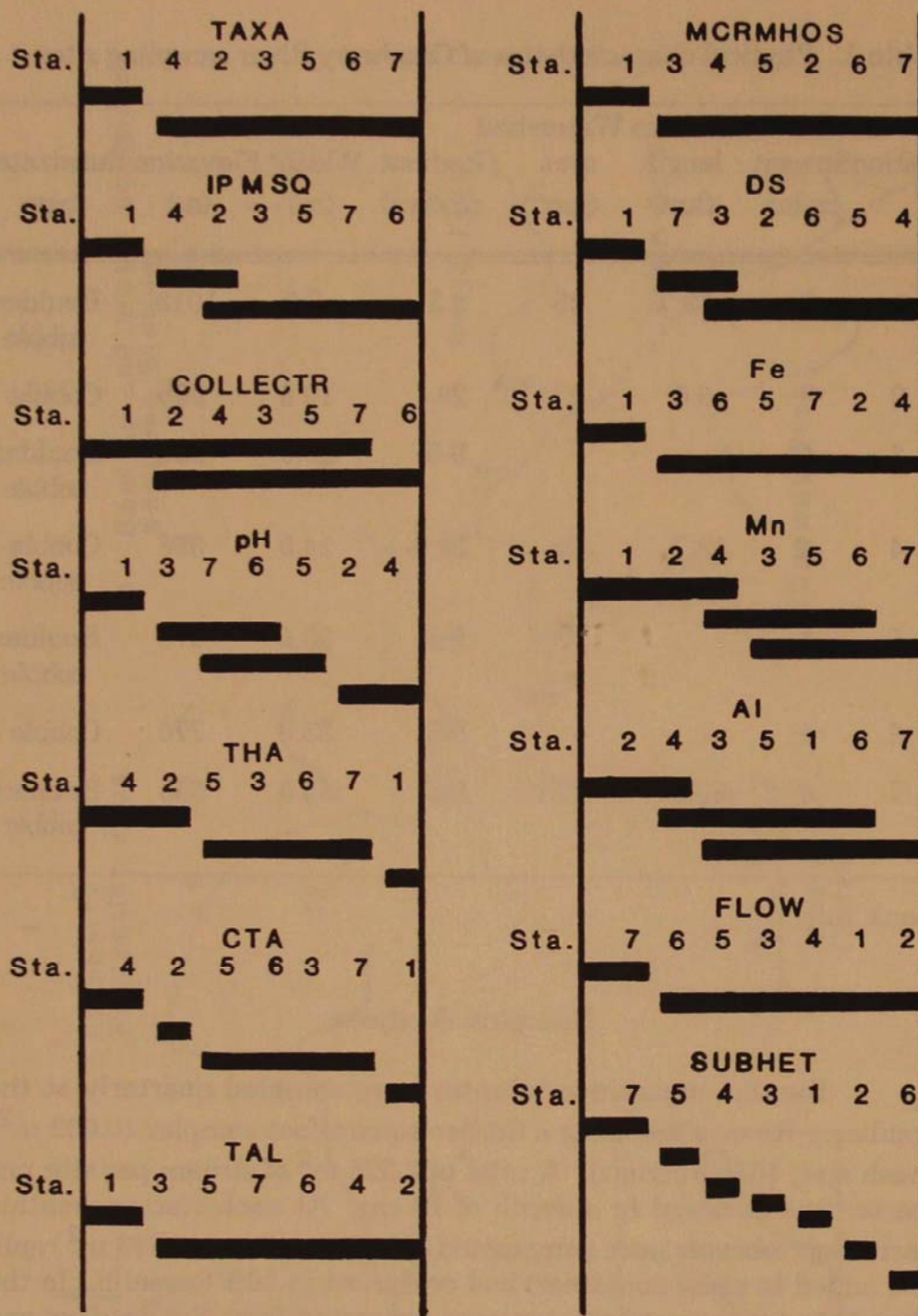


Figure 2. Newman-Keul's test applied to mean annual biological and physico-chemical parameters at seven stations in Cranberry River. Means at any two stations underscored by the same line are not significantly different. Taxa = number of taxa; Ipftsq = number of specimens/m<sup>2</sup>; Collectr = percent of collectors; Tha = total hot acidity; Cta = cold total acidity; Tal = total alkalinity; Mcrmhos = conductivity; Ds = dissolved solids; Fe = iron; Mn = manganese; Al = aluminum; Flow = discharge; Subhet = substrate heterogeneity.

**Table 2.** Physico-chemical parameters of the Cranberry River, West Virginia, study for the entire sampling period of December 1983 through November 1984. S. E. = standard error; THA = total hot acidity; CTA = cold total acidity; TAL = total alkalinity(mg/l CaCO<sub>3</sub>); Fe = total iron; Mn = total manganese; Al = total aluminum; Zn = total zinc; DS = total dissolved solids; Q = discharge in cubic ft/sec; Subhet = substrate heterogeneity; 0 phi = standard deviation of phi units.

Parameter	Mean	Range	S. E.	ANOVA F-value
pH	5.50	4.4 - 6.9	0.12	25.21
THA (mg/l)	9.40	4.4 - 13.8	0.40	13.70
CTA	3.10	1.3 - 6.0	0.23	37.87
TAL	3.80	0.0 - 15.0	0.50	10.26
Conductivity (µmhos/cm)	24.00	4.0 - 38.0	0.96	6.31
Sulfate (mg/l)	5.40	4.2 - 7.0	0.10	1.16*
Fe (mg/l)	0.21	0.05 - 1.30	0.04	7.15
Mn (mg/l)	0.05	0.01 - 0.10	0.004	7.53
Al (mg/l)	0.31	0.12 - 0.65	0.022	5.73
Zn (mg/l)	0.04	0.01 - 0.08	0.004	1.14*
DS (mg/l)	24.50	11.0 - 48.0	1.5	13.13
Q (m <sup>3</sup> )	2.53	0.18 - 14.88	18.5	8.74
Subhet (0 phi)	1.5	1.0 - 1.9	0.05	9999.90

\*not significant at 95% confidence level

Percentage composition, number of taxa, mean number of individuals per sq m and a Shannon-Weaver index of diversity were calculated quarterly for each station. Shannon-Weaver diversity was calculated using Aquatic Ecology Program Plus software package (Eckblad, 1984) on an Apple II Plus computer.

## Statistical Analyses

Differences between stations for a given season of the year (quarter) were tested using analysis of variance (ANOVA). ANOVA was followed by the Newman-Keul's pairwise comparison test procedure to identify which means among the stations differed significantly (Mendenhall et al., 1977). These statistical operations were calculated using the Statistical Analysis System (SAS) computer package (SAS Institute, 1984).

## Results and Discussion

### Physico-chemical Analyses

A summary of the measured values for selected physico-chemical parameters is presented in Table 2. The mean value of pH in the Cranberry River during the study period was 5.5 and ranged from 4.4 to 6.9 (Table 2). ANOVA indicated a significant difference between the mean value of pH measurements among the sampling sites. Newman-Keul's test showed that Station 1 had a significantly higher mean value of pH than any of the other stations (Fig. 2). Stations 2 and 4 had the lowest mean values of pH among the stations.

Total hot acidity (THA) ranged from 4.4 to 13.8 mg/l and the mean was 9.4 mg/l (Table 2). ANOVA indicated a significant difference between mean values of THA among the sampling stations. Newman-Keul's test showed that mean values of THA in Stations 4 and 2 were significantly higher than the other sites (Fig. 2). Station 1 had the lowest mean value of THA and was significantly different from the other sites.

The values of total alkalinity (TAL) ranged from 0.0 to 15.0 mg/l and the mean was 3.8 mg/l (Table 2). ANOVA indicated a significant difference between mean values of TAL among the sampling sites. Newman-Keul's test showed that Station 1 had the highest mean value of TAL and was significantly different from the other stations (Fig. 2).

The mean value of conductivity was 24.0  $\mu$ mhos/cm and ranged from 4.0 to 38.0  $\mu$ mhos/cm (Table 2). ANOVA indicated a significant difference between mean values of conductivity among the sample sites. Newman-Keul's test showed that Station 1 had the highest mean value of conductivity among the sample sites and was significantly different from the remaining stations (Fig. 2).

Flow in the Cranberry River ranged from 0.18 to 14.88 m<sup>3</sup> and the mean was 2.53 m<sup>3</sup> (Table 2). ANOVA indicated a significant difference among the sample means of flow. Newman-Keul's test showed that the mean value of flow at Station 7 was significantly higher than the values at other sites (Fig. 2).

The chemical water quality of the Cranberry River declines gradually from the headwaters towards the mouth. Menendez (1982) reported that water quality in the Cranberry River is significantly correlated to flow levels. Upon first inspection, one would assume that the South Fork (Station 1) that flows through the Cranberry Glades, a peat bog, was responsible for the acid flow problems. However, streams that flow through the Glades, the South Fork and its tributaries, are not underlain by peat (Darlington, 1943). Rather, the South Fork flows entirely over the Mississippian Mauch Chunk shales that are calcareous and provide the stream with some ability to buffer acids. The remainder of the watershed originates in the Pennsylvanian Pottsville sandstones that contribute little to acid-buffering capacity. Two major tributaries, North Fork (Station 2) and Dogway Fork (Station 4) contribute most to the acidic nature of the main stream. Chemical water quality improves slightly in the lower reaches (from Station 5 to 7), but never returns to the quality of the headwaters.

### Biological Analyses

*Percentage composition.* A total of 2119 benthic macroinvertebrates, representing 11 orders, 38 families, and at least 55 genera, were collected from the seven stations in the Cranberry River (Table 3 and Fig. 1). Four orders of insects comprised 90.8% of the benthos (Table 4) as follows: Ephemeroptera (mayflies), 43.2%, N = 916; Plecoptera (stoneflies), 19.6%, N = 416; Diptera (dipterans), 18.0%, N = 381; and Tricoptera (caddisflies), 10.0%, N = 211.

Several authors have reported similar percentage compositions among the major taxa in their studies. In two nearby West Virginia streams, Little Black Fork (Phares, 1974) and Upper Shavers Fork Basin (Tarter, 1980), the same four insect orders, as in our study, in different sequences, comprised 93.0% and 93.2%, respectively, of the benthos collected. Though percentage composition was not included, based on the number of taxa reported in each order collected, Ettinger and Kim (1975) reported that the orders Ephemeroptera, Tricoptera, Diptera, and Plecoptera dominated a naturally acidic stream, Sinking Creek in Centre County, Pennsylvania. Woodall and Wallace (1972)

compared four southern Appalachian watersheds in western North Carolina and found that these same four orders, together with Coleoptera, ranked highest in relative importance among the benthos collected in each of the four streams. In a study comparing unstressed southern Appalachian mountain rivers and streams in North Carolina and Tennessee, Penrose et al. (1982) reported similar percentage composition of major taxa in 16 of 17 streams investigated.

**Table 3.** Numerical distribution of benthic macroinvertebrates in the Cranberry River, West Virginia. Taxa are listed alphabetically.

	Station						
	1	2	3	4	5	6	7
<b>Arthropoda</b>							
Ephemeroptera							
Baetidae							
<i>Baetis</i>	1	33	7	66	-	-	4
<i>Centroptilum</i>	1	-	2	-	-	-	-
<i>Pseudocloeon</i>	2	-	-	-	-	-	7
Baetiscidae							
<i>Baetisca</i>	1	-	-	1	-	-	4
Ephemeridae							
<i>Ephemera</i>	10	-	-	-	-	-	-
Ephemerellidae							
<i>Ephemerella</i>	235	16	13	17	6	1	-
Heptagenidae							
<i>Epeorus</i>	6	47	2	102	-	-	1
<i>Heptagenia</i>	14	1	-	-	-	-	-
<i>Stenacron</i>	9	-	5	4	1	-	1
<i>Stenonema</i>	39	1	2	9	4	2	12

Table 3 cont.

	Station						
	1	2	3	4	5	6	7
<hr/>							
Leptophlebia							
<i>Habrophlebia</i>	1	-	1	-	-	-	-
<i>Paraleptophlebia</i>	161	-	6	-	-	-	-
Siphonuridae							
<i>Ameletus</i>	13	13	16	14	5	-	-
<i>Isonychia</i>	2	-	-	-	-	-	-
Plecoptera							
Capniidae							
<i>Paracapnia</i>	30	7	14	15	11	-	-
Chloroperlidae							
<i>Hastaperla</i>	2	19	-	13	-	-	-
Leuctridae							
<i>Leuctra</i>	27	12	4	11	2	11	1
Nemouridae							
<i>Amphinemoura</i>	-	19	-	11	-	-	1
Peltoperlidae							
<i>Peltoperla</i>	1	-	-	-	-	-	-
Perlidae							
<i>Acroneuria</i>	43	4	8	6	13	5	16
<i>Paragnetina</i>	1	-	-	-	-	-	-
Perlodidae							
<i>Isogenoides</i>	-	-	3	-	-	-	-
<i>Isoperla</i>	3	1	-	1	-	-	-

Table 3 cont.

	Station						
	1	2	3	4	5	6	7
<i>Malirekus</i>	-	6	1	2	-	-	-
Pteronarcidae							
<i>Allonarcys</i>	1	-	-	-	-	-	-
Taeniopterygidae							
<i>Taeniopteryx</i>	19	-	1	-	-	2	-
<i>Brachyptera</i>	-	24	2	37	3	3	-
Trichoptera							
Brachycentridae							
<i>Brachycentrus</i>	1	-	-	-	-	-	-
Hydroptilidae							
<i>Stactobiella</i>	3	-	-	-	-	-	-
Hydropsychidae							
<i>Cheumatopsyche</i>	34	3	1	-	2	-	4
<i>Diplectrona</i>	-	-	-	-	2	-	-
<i>Hydropsyche</i>	19	1	1	-	2	2	1
Limnephilidae							
<i>Neophylax</i>	31	-	3	14	3	-	-
<i>Pycnopsyche</i>	2	-	1	4	4	2	4
Philopotamidae							
<i>Dolophilodes</i>	12	2	-	-	2	-	-
<i>Wormaldia</i>	-	-	-	1	-	-	-
Polycentropodidae							
<i>Neureclipsis</i>	9	-	-	-	3	2	4

Table 3 cont.

	Station						
	1	2	3	4	5	6	7
Rhyacophilidae							
<i>Rhyacophila</i>	13	7	3	5	1	3	-
Diptera							
Chironomidae	105	9	36	27	39	9	24
Heleidae							
<i>Palpomyia</i>	2	16	-	7	1	2	-
Rhagionidae							
<i>Atherix</i>	9	-	2	-	-	1	-
Simulidae							
<i>Simulium</i>	47	9	3	1	3	-	-
Tipulidae							
<i>Tipula</i>	7	-	-	2	1	-	-
Megaloptera							
Corydalidae							
<i>Nigronia</i>	2	-	-	6	-	1	-
Sialidae							
<i>Sialis</i>	1	-	-	-	-	3	-
Odonata							
Aeshnidae							
<i>Boyeria</i>	1	-	-	-	-	1	5
Cordulegastridae							
<i>Cordulegaster</i>	-	-	-	-	-	-	1

Table 3 cont.

	Station						
	1	2	3	4	5	6	7
<hr/> <hr/>							
Coleoptera							
Dryopidae							
<i>Pelonomus</i>	1	-	-	-	-	-	-
Elmidae							
<i>Stenelmis</i>	19	-	-	-	-	2	3
Decapoda							
Cambariidae							
<i>Cambarus</i>	14	5	2	8	4	4	-
Oligochaeta							
Haplotaxida	-	2	-	76	5	1	-
Branchiobdellida	26	-	-	1	-	-	-
Turbellaria							
Tricladia	1	-	-	-	-	-	-
<hr/>							

The order Ephemeroptera comprised nearly half of all benthic macroinvertebrates collected from the Cranberry River. Phares (1974) reported similar percentage composition of mayflies (55.8%) in nearby Little Black Fork. Penrose et al. (1982) reported similar dominance (ca. 50%) of mayflies in 9 of 17 unstressed southern Appalachian mountain rivers and streams. Minshall (1981) suggested that the numerical predominance of mayflies (ca. 50%) is typical of Rocky Mountain trout streams. Culp and Davies (1982) also reported that Ephemeroptera accounted for about 50% of all taxa collected in South Saskatchewan River, Canada.

*Number of Taxa.* The mean number of taxa of benthos for the entire sampling period in the Cranberry River was 15.2, ranging from 1 to 47. ANOVA indicated a significant difference between the number of taxa among the sampling stations. Newman-Keul's test showed the

mean number of taxa (31.8) at Station 1 was significantly higher than the number of each of the other stations (Fig. 2). Stations 4 and 2 ranked second and third highest in mean number of taxa, but there were no significant differences among Station 2 through 7 (mean = 12.5, range 9.2 to 16.4). In the main stream sites, the mean number of taxa collected progressively declined in a downstream direction. Tarter (1980) stated that West Virginia streams with a circumneutral pH will be inhabited by 20 or more benthic taxa. Based on this criterion, Cranberry River is moderately stressed, with variations of degree among the different stations. Menendez (1983) described the Cranberry River as naturally acidic and poorly buffered. Additionally, based on running water and precipitation chemistry studies, he inferred that acid precipitation was compounding the acid-stressed conditions.

Other investigators have reported similar numbers of taxa in mountain streams of West Virginia. In Roaring Creek, Warner (1971) reported that the presence of 25 or more benthic taxa characterized stations not severely polluted by acid mine drainage. Numbers of taxa decreased in a downstream direction due to acid mine drainage. Their number of benthic taxa in Little Black Fork, a nearby undisturbed watershed, ranged from 15 to 19 with a mean of 16.4 (Phares, 1974). In Upper Shavers Fork Basin of West Virginia, a lightly buffered watershed disturbed by both mining and logging activities, Tarter (1980) found that the mean number of taxa was 16.8 and the number of taxa ranged from 5 to 36. Neither Phares (1974) or Tarter (1980) reported downstream declines in the number of taxa collected.

Ettinger and Kim (1975) reported a richer taxonomic composition in Sinking Creek, a naturally acidic stream in Pennsylvania (mean = 34, range 24 to 48). The acidity in Sinking Creek was associated with drainage from a peat bog in the headwaters, and the number of taxa collected progressively increased with increasing distance downstream from the bog. Penrose et al. (1982) also reported a richer taxonomic composition in southern Appalachian mountain rivers and streams. The average taxonomic richness in four southern Appalachian mountain rivers ranged from 29.6 to 73.7; the mean was 47.5. Average taxa richness in 10 southern Appalachian mountain streams ranged from 37.5 to 56.1; the mean was 48.9.

*Mean Number of Specimens/m<sup>2</sup>.* The mean number of benthic macroinvertebrates per m<sup>2</sup> for the entire sampling period in the Cranberry River was 0.34 and ranged from 0.02 to 1.26. ANOVA demonstrated a significant difference between mean number of speci-

mens per m<sup>2</sup> among the sampling stations. Newman-Keul's test showed the mean number of specimens per m<sup>2</sup> (1.08) at Station 1 was significantly higher than all the remaining sites (Fig. 2). Station 4 (mean = 0.49) and Station 2 (mean = 0.34) were second and third highest in mean number of specimens per m<sup>2</sup>. Mean numbers of specimens per m<sup>2</sup> among the main stream sites progressively declined downstream (mean = 0.12, range 0.06 to 0.20).

Phares and Oldham (1977) reported similar declines progressively downstream in benthic densities in the main stream of Cranberry River and in the nearby North Fork of Cherry River for the years 1969-71 (mean = 1.12, range 0.186 to 4.37). They reported a sharp decline in density from headwaters (mean = 5.95, range 1.3 to 13.76) to downstream reaches (mean = 1.95, range 0.19 to 4.37) in the nearby Williams River, Pocahontas County, West Virginia, for the years 1969-73. However, benthic densities remained fairly constant at stations along progressive reaches of the main stream. In the Upper Shavers Fork Basin, tributaries that were more acidic than the main stream contained higher mean numbers of specimens per m<sup>2</sup> (mean = 3.1, range 0.37 to 10.14). Both Phares and Oldham (1977), for the years 1969-77, and Tarter (1980) reported fairly constant numbers along progressive downstream reaches of the main stream Shavers Fork.

*Shannon-Weaver Index of Diversity.* The Shannon-Weaver index of diversity for the entire sampling period ranged from 0.0 to 4.1 and the mean was 2.8. ANOVA indicated no significant differences between diversity values among the sampling stations. The main stream sites were lower than the tributaries but did not exhibit a progressive decline.

Phares (1974) reported a higher Shannon-Weaver index in nearby Little Black Fork, an undisturbed watershed. The range of Shannon-Weaver index in Little Black Fork was 2.8 to 3.3 and the mean was 3.0, indicating an unstressed environment. In the Upper Shavers Fork Basin in West Virginia, the mean value of the Shannon-Weaver index was 2.8 and ranged from 1.8 to 3.5, indicating a watershed of intermediate pollution (Tarter, 1980). In addition, using step-wise discriminant analysis to compare values of Shannon-Weaver index in Little Black Fork, mined tributaries of Shavers Fork, unmined tributaries, and main stream Shavers Fork, no significant differences among these sites were found (Tarter, 1980).

Table 4. Percentage frequency of the major taxa of the benthic macroinvertebrates of the Cranberry River, West Virginia.

Station	1	2	3	4	5	6	7
Taxa	Total %	Total %	Total %	Total %	Total %	Total %	Total %
Trichoptera	124 12.5	13 5.1	9 6.5	24 5.3	19 16.4	9 14.7	13 14.6
Plecoptera	127 12.8	92 35.8	33 23.7	86 19.1	29 24.6	21 34.4	18 20.2
Ephemeroptera	495 49.8	111 43.2	54 38.9	213 47.3	15 12.7	3 4.9	25 28.1
Megaloptera	3 0.3	0 0.0	0 0.0	6 1.3	0 0.0	4 6.6	0 0.0
Diptera	82 18.4	34 13.2	41 29.5	37 8.2	46 39.0	16 26.2	24 27.0
Odonata	1 0.1	0 0.0	0 0.0	0 0.0	0 0.0	1 1.6	6 6.7
Coleoptera	20 2.0	0 0.0	0 0.0	0 0.0	0 0.0	2 3.3	3 3.4
Decapoda	14 1.4	5 1.9	2 1.4	8 1.8	4 3.4	4 6.6	0 0.0
Haplotaenidia	0 0.0	2 0.8	0 0.0	76 16.8	5 4.2	1 1.6	0 0.0
Branchiobdellida	26 2.6	0 0.0	0 0.0	1 0.2	0 0.0	0 0.0	0 0.0
Tricladia	1 0.1	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0
Total	993	257	139	451	118	61	89

## Conclusions

The measures of number of taxa, mean number of specimens/m<sup>2</sup>, and the Shannon-Weaver index suggest that the benthic community structure changes generally with increasing flow. Due to the negative influence of acid tributaries, the chemical water quality declines as flow increases. The South Fork (Station 1) has the best chemical water quality and supports the most numerous and diverse benthic community. But problems arise from the fact that the two tributaries, which are inferred to be responsible for most of the decline in the chemical water quality of the main stream, support more diverse and numerous benthic populations than any main stream site. The benthic community does not seem to be structured relative to the criteria by which the water quality has been evaluated. The biological data suggest that in spite of the acid nature of the Cranberry River tributaries, these reaches provide a more stable environment for habitation by benthic macroinvertebrates than does the main stream.

These inferences are consistent with the discussion of Vannote et al. (1980), Webster et al. (1983), and Minshall et al. (1983). Webster et al. (1983) suggested that ecological stability involves the ability of an ecosystem to respond to disturbance. Large, inertial, slow ecosystem components (e.g. detritus in streams) provide resistance to disturbance, and rapid turnover of ecosystem components (e.g. annual leaf fall) provides resilience. Vannote et al. (1980) proposed that stream ecosystems remain in equilibrium because of the dynamic balancing of physical forces that tend to disrupt (e.g. floods) against those that tend to stabilize (e.g. debris dams). Viewing the system in this manner, unperturbed smaller streams are expected to be more stable than intermediate-sized streams for a number of reasons (Webster et al., 1983; Minshall et al., 1983).

The factors controlling the distribution of benthic communities in the Cranberry River are related to some unidentified environmental factor(s) that varies with increasing stream channel size. Correlation between flow level and chemical water quality has been established (Menendez, 1982). Stream flow and its inherent link to the food resource base may be a reasonable avenue of further investigation. Compared to other nearby watersheds of similar size and geomorphic setting, Cranberry River benthic communities are as diverse taxonomically but have fewer individual organisms. Individual population numbers of benthos are higher in these nearby watersheds and progressive downstream declines have not been observed (Phares and Oldham 1977; Tarter 1980). These observations suggest that the chem-

ical nature of the water quality in the Cranberry River may be the factor limiting benthic population numbers.

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# Psychology Section

## Personality Variables Related to Viewing Sports on TV

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### Abstract

Fourteen college students completed items on the Aggression, Dominance, and Succorance scales of the Edwards Personal Preference Schedule (EPPS), then watched the 1988 University of Pittsburgh-Pennsylvania State University football game on television. Students completed the same three EPPS scale 10 minutes after the game, and again 24 hours after the game.

Separate repeated measures analyses of variance, and Newman-Keuls posttests, showed that students' mean Aggression and Dominance scores were significantly higher 10 minutes after the game than they were just before or 24 hours after the game. The mean Succorance score was lowest 10 minutes after the game, although not significantly so. Together, these analyses show an increase in "nastiness" after subjects viewed football on TV, but a nastiness which dissipates within 24 hours.

### Introduction

In recent years, a number of studies have focused on the short-term effects of viewing violence on human behavior. The general finding is that viewing violence, at least in the short run, increases aggressiveness (e.g., Geen, 1978; Geen, 1983; Geen & Thomas, 1986; Huesmann & Malamuth, 1986). Similarly, recent studies in the psychology of sport have shown that watching violent sport, whether in person (e.g., Goldstein & Arms, 1971) or in the media (e.g., Geen, 1978) increases aggressiveness. Together, these findings provide strong support for the notion that aggression is a behavior which is

affected, at least in part, by what one observes. Relatively few studies have explored the impact of watching violent sport on personality variables other than aggression, nor have they attempted to measure how long viewing-related effects last. The present study measured the short- and long-term effects of watching a television broadcast of a college football game on these personality variables: aggression, dominance, and succorance. We hypothesized that dominance and aggression would increase immediately after a violent sport was watched on television, and that succorance would decrease.

### Materials and Methods

Subjects were seven female and seven male undergraduate students between the ages of 18 and 22 who volunteered for participation in the study in order to receive extra credit in an introductory psychology course. On the day before the 1988 University of Pittsburgh versus Pennsylvania State University (Pitt-Penn State) football game, subjects completed the Aggression, Dominance, and Succorance scales of the Edwards Personal Preference Schedule (EPPS: Edwards, 1959). Each EPPS scale used contained 28 forced-choice items; subjects required about five minutes to complete the three scales. This was done to acquaint the subjects with the scales, and to minimize the possibility that practice effects might contaminate our results. On the day of the Pitt-Penn State football game, subjects met in a group setting, and completed the Aggression, Dominance, and Succorance scales of the EPPS just prior to the game. As a group, the subjects watched the game on television, then completed the three EPPS scales, starting 10 minutes after the game. Finally, subjects completed the three EPPS scales 24 hours after the game was over. Following the entire procedure, subjects were debriefed as to the nature of the study, and its major findings.

### Results

Independent 2X3 mixed-design analyses of variance (between subjects variable = subject gender, within-subjects variable = pregame, ten minute postgame, 24-hour postgame scale completions), and Newman-Keuls posttests, where needed, were conducted for each of the three EPPS scales. The only statistically significant effect on the Aggression scale was for repeated scale completions,  $F(2,24) = 7.454$ ,  $p < .01$ . One-tailed Newman-Keuls posttests showed that the mean Aggression score was significantly higher immediately after the game than on either other administration (see Table 1).

The Dominance scale analysis showed results similar to those for the Aggression scale, with a significant effect of repeated scale completions,  $F(2,24) = 3.621$ ,  $p < .05$ . Newman-Keuls posttests showed that the mean Dominance score was significantly higher immediately after the game than on either other administration (see Table 1). The Succorance scale analysis showed no significant comparisons, although the effect of repeated scale completions approached statistical significance,  $F(2,24) = 2.974$ ,  $.05 < p < .10$ , with the mean Succorance score immediately after the game being the lowest (see Table 1). No other  $F$ -ratio in the latter two analyses approached statistical significance.

**Table 1.** Mean Scores of Subjects (Male and Female) on the Aggression, Dominance, and Succorance Scales, All Administrations.

Scale	Pregame	10-min Postgame	24-hr Postgame
Aggression	9.93( $\pm 1.20$ )	11.36( $\pm 1.19$ )*	8.21( $\pm 1.12$ )
Dominance	9.64( $\pm 1.19$ )	12.14( $\pm 1.59$ )*	9.00( $\pm 1.11$ )
Succorance	11.14( $\pm 0.80$ )	9.93( $\pm 0.74$ )	11.79( $\pm 0.81$ )

\* $p < .05$

## Discussion

The present study confirms prior findings that aggression increases after viewing aggression in general, or sports violence in particular. Further, this study shows that another personality variable -- dominance -- also may be influenced by watching violent sports on television. Finally, this study shows that such effects are transient; 24 hours after they viewed the football game subjects' scores on the three personality scales studied were back to normal levels.

Subject gender did not produce any main or interactive effects in the analyses of variance we ran. One possible explanation is that our group sizes were too small. On the other hand, most studies of viewer's responses to watching violent sport do not report gender differences. If this variable is explored in the future, larger sample sizes should be considered.

The transience of the personality variable changes fits well with prior research (e.g., Doob and Climie, 1972). However, the present

study does not show whether the changes last a matter of minutes, or perhaps even hours. Future research could address this issue by providing frequent, repeated administrations of the personality variable scales.

Although more comprehensive tests of the effects of violent sport viewing on personality would be interesting, practically such testing may be impossible. For instance, the full EPPS contains 15 scales, each the length of the three used in the present study. Use of the full EPPS, while providing data on many more personality variables, would take about an hour to administer. That amount of administration time might begin to interfere with very transient personality effects. Nevertheless, future studies should explore the effect of watching violent sport on personality variables other than those considered in this study.

A final important consideration in interpreting these data is that subjects self-selected for this study. A fair assumption is that all or most of the subjects wanted to see the Pitt-Penn State football game, and cared about the game result. Perhaps only those who care about the outcome of a violent sporting event become "nastier" after watching it, or perhaps nastiness varies as a function of whether the team one supports wins or loses. Also, it is possible that something other than game violence -- outcome uncertainty, perhaps -- may cause the observed effects. These are issues we will address in future research.

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# Zoology Section

## Nest Building in White-Footed Mice, *Peromyscus leucopus*, from Western West Virginia

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### Abstract

Nest-building behavior was investigated in wild-caught *Peromyscus leucopus noveboracensis* captured in western West Virginia. Mice were captured in spring and acclimated to lab conditions (12 hr of light and 12 hr of dark) prior to testing. Using the amount of cotton pulled into the cage as a daily measure of nest-building, we found no differences between males (n=8) and females (n=2) at either of two ambient temperatures (22<sup>o</sup> vs. 5<sup>o</sup> C). Likewise, maintaining mice in the cold (5<sup>o</sup> C) did not significantly change the amount of cotton used to construct a nest. Both the magnitude and the direction of these findings are consistent with those reported in the majority of previous studies examining nest-building in this genus. Based on a review of these studies, we conclude that nest-building behavior in *Peromyscus leucopus* varies little among populations.

### Introduction

Nest-building is one of the most ubiquitous activities of many small rodents. Within the genus *Peromyscus*, the extent to which individuals engage in this behavior increases as daylength shortens in au-

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turn (Lynch, 1972), suggesting, as has been demonstrated by Sealander (1952), that a nest confers upon its occupant thermoregulatory benefits associated with overwintering survival. Indeed, in *P. leucopus*, the presence of a nest has been shown to decrease metabolic rates in cold environments (Glaser and Lustick, 1975; Vogt and Lynch, 1982), thereby lowering the demand for food at a time of year when it may be scarce.

*Peromyscus leucopus*, the white-footed mouse, is one of the most abundant and wide-ranging small mammals in North America (Hall, 1981). In western West Virginia, *P. l. noveboracensis* occupies mixed deciduous woodlands in the Ohio River floodplain. Much of our knowledge of nest-building in *Peromyscus* derives from studies seeking to elucidate differences between *P. leucopus* and other species (Eedy, 1973; Layne, 1969; Tadlock and Klein, 1979; Wolfe, 1970), and from those examining the effects of sex or habitat use on intraspecific variation (Judd and Lopez, 1980; Wolfe, 1970). These studies, however, provide conflicting results regarding the influence of sex on nest-building, and only a single study (Jaslove and McManus, 1972) has examined the role played by ambient temperature in nest-building. Furthermore, there is a paucity of information about nest-building in *P. leucopus* from West Virginia. Therefore, the present study was designed to assess nest-building in *P. leucopus* living in this area so as to provide baseline data for comparison to other populations. A secondary aim of this study was to determine the effect of ambient temperature on this thermoregulatory behavior.

## Materials and Methods

Eleven *Peromyscus leucopus noveboracensis* were captured in March 1987 in mixed deciduous forest in LeSage and Barboursville, Cabell County, West Virginia, using Sherman live traps. The results from one pregnant female were excluded from the analysis because she gave birth during the middle of the study. Mice underwent a period of acclimatization of seven days in the laboratory and were allowed access to food and water ad libitum. The mice were individually housed in plastic cages, 29 X 18 X 13 cm, with a stainless steel top through which mice had access to food, water and cotton. Room temperature was  $22^{\circ}\text{C} \pm 1^{\circ}\text{C}$  and photoperiod was 12L:12D.

Each morning for eight days, a preweighed amount (15-20 g) of non-absorbent cotton was placed in each cage's food hopper. Mice pulled cotton through the cage top and built nests in the home cage.

Once each day, all nests were removed from the cages and weighed to the nearest 0.01 g. The amount of cotton remaining in the food hopper was also weighed. On day 9 the animals were moved to an incubator maintained at  $5.0^{\circ}\text{C} \pm 1^{\circ}\text{C}$  under a 12L:12D photoperiod. Nest-building in the cold was assessed on days 10-16; under these conditions, mice were given 30 g cotton daily.

Nest-building was assessed in a total of eight males and two females at both temperatures. Mean values for each individual under each temperature were calculated and used to compute group means. Data were statistically analyzed using two-way ANOVA with sex and temperature as main effects. The 0.05 level of significance was used as a rejection criterion in all tests of null hypotheses.

## Results and Discussion

Each of the ten mice pulled cotton and constructed nests on each of the days that nest-building behavior was assessed. Both the smallest (5.24 g) and largest (28.70 g) nests were constructed by males at  $5^{\circ}\text{C}$ . The mean amount of cotton pulled by all wild-caught West Virginia *P. leucopus* held at  $22^{\circ}\text{C}$  was 14.36 g. Of other *P. leucopus* held at "room" temperature, only those from northern New York (Tadlock and Klein, 1979) built larger (35.6 g) cotton nests, whereas populations from Texas (Judd and Lopez, 1980), New York (Layne, 1969), and Illinois and Mississippi (Wolfe, 1970) used less (3.25 - 11.6 g) cotton to construct their nests. Analysis of these data reveal no geographic trends; in fact, Wolfe (1970) reported almost identical nesting scores for Illinois and Mississippi mice.

We found no significant differences in the amount of cotton pulled by male versus female *P. leucopus* (Table 1), although our sample size was probably too small to conclude that males and females use equivalent amounts of cotton. These results agree with those reported for several other populations of this species (Layne, 1969; Tadlock and Klein, 1979; Wolfe, 1970). Furthermore, *Peromyscus maniculatus gracilis*, *P. m. bairdii*, *P. polionotus*, and *P. floridanus* from the Eastern United States did not display any sexual differences in the tendency to build nests (King et al., 1964). However, Judd and Lopez (1980) reported differential nest-building behavior in male and female Texas *P. leucopus* given cotton for nesting. Similarly, Jaslove and McManus (1972) observed sexual differences in the sizes of nests built from shredded paper by New Jersey mice. These inconsistent findings may arise from methodological differences in these studies, as mice were

captured in different seasons using different techniques, were given different periods to acclimate to lab conditions, and, most likely, were not given cotton of the same density with which to construct nests.

**Table 1.** Nest-building by wild-caught West Virginia *Peromyscus leucopus noveboracensis* held at 12L:12D at 22 or 5 C. Values given are mean  $\pm$  s.e. grams of cotton pulled per day per individual.

	Warm (22° C)	Cold(5° C)	Total (grams)
Male (n = 8)	14.35 $\pm$ 1.48	17.71 $\pm$ 3.64	16.03
Female (n = 2)	14.38 $\pm$ 1.09	16.26 $\pm$ 4.45	15.32
Total (n = 10)	14.36	17.42	

Although mice at 5° C pulled approximately 3.1 g more cotton per day than did those at 22° C, this difference was not significant (Table 1), perhaps due to the wide variation at the colder temperature or to small sample size. Jaslove and McManus (1972) observed an increase in nest-building activity in wild-caught New Jersey *P. leucopus* as ambient temperature was lowered from 30° C to 20° C; however, as they lowered temperature below this point, no compensatory increases in nest-building were found. The thermoneutral zone for most *Peromyscus* species is above about 25° C (Hill, 1983); both in our study and in that of Jaslove and McManus, nesting may have been maximized at relatively high temperatures, and the addition of material to the nest may not have increased its insulating effectiveness (Wrabetz, 1980). Interestingly, Wolfe and Barnett (1977) found that *Mus musculus* maintained in the cold used less material to build nests of better quality compared to mice in a warm environment. In the current study, three of the mice in the cold displayed a progressive decrease in the amount of cotton pulled over the six-day period of assessment, perhaps because the increased activity associated with nest-building led to a greater loss of heat.

In conclusion, with regard to laboratory-based measures of nest-building, *Peromyscus leucopus* from West Virginia appear to be-

have similarly to other populations of *Peromyscus*. The thermoregulatory importance of the nest to young mice leads to the prediction that pregnant or lactating females should engage in nest-building more so than males (Judd and Lopez, 1980). We could not evaluate this prediction in our study. Furthermore, differences in ambient temperature appear not to influence nest-building activity in this population. It is likely that the neural mechanisms controlling this behavior are not very plastic, such that nest-building in *Peromyscus* may be relatively immune to modifications in response to environmental challenges.

### Acknowledgements

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# First Records of Water Bears (Phylum: Tardigrada) from West Virginia

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## Abstract

Eighteen species of tardigrades, including one new species, representing ten genera (*Diphascon*, *Hypechiniscus*, *Hypsibius*, *Isohypsibius*, *Itaquascon*, *Macrobiotus*, *Milnesium*, *Minibiotus*, *Pseudechiniscus*, *Ramazzottius*), were collected from Spruce Mountain, West Virginia. The tardigrades were collected from mosses (*Amblystegium serpens*, *Anomodon attenuatus*, *A. rostratus*, *Atrichum augustatum*, *Brachythecium salebrosum*, *Dicranum fulvum*, *D. polysetum*, *D. scoparium*, *Endodon cladorrhizans*, *Hedwigia ciliata*, *Hypnum pratense*, *Leucobryum glacum*, *Platydictya subtile*, *Thuidium delicatulum*, *Ulota crispa*) on the ground, rocks, and trees (beech, elm, red and sugar maples, yellow birch, red spruce). The collections were from elevations of 2800 ft (853 m), 3800 ft (1158 m), and 4800 ft (1463 m). The most abundant species were *Macrobiotus hufelandi* Schultze and *Milnesium tardigradum* Doyere. The species reported in this investigation constitute the first records of tardigrades from West Virginia.

## Introduction

Tardigrades (water bears) are cosmopolitan in distribution. From the Arctic to the Antarctic, they inhabit a diversity of niches in sand, soil, mosses, liverworts, and aquatic plants (Nelson, 1975). Since their discovery in 1773, more than 500 species have been described

throughout the world, mainly in Europe. Despite their cosmopolitan distribution, the tardigrade fauna of North America is poorly known. Regionally, species have been reported from a few places in eastern Tennessee, western North Carolina, and southern Virginia, but none from West Virginia have been cited in the literature.

### Study Area

Spruce Mountain is located in Pendleton County. The elevation at the summit of Spruce Mountain is 4860 ft (1481 m), the highest point in West Virginia (Core, 1966). Spruce Knob has a sparse covering of red spruce trees. The northern hardwoods are characterized by the alternation of deciduous, coniferous, and mixed forest communities. In the primary deciduous communities, mostly in a zone from 3000 ft (814 m) to 4000 ft (1219 m) in elevation, sugar maple, beech and yellow birch are usual dominants.

The State of West Virginia affords an excellent collecting area for mosses (Ammons, 1934). Several species are found in the Appalachian Mountains extending in a north-easterly and south-west-erly direction in the eastern part of the state.

### Materials and Methods

Mosses were collected from the ground, rocks, and trees at elevations of approximately 2800 ft (853 m), 3800 ft (1158 m), and 4800 ft (1463 m) on all slopes (NEWS). The moss samples were returned to the laboratory for identification and removal of tardigrades. In the laboratory, the moss samples were soaked in a stoppered funnel in tap water overnight. Following the soaking process, the moss was removed and the remaining water squeezed into a beaker. After the debris settled, the top layer of water was decanted and the bottom layer searched for tardigrades. Tardigrades were killed by the addition of boiling alcohol to coagulate the proteins. An Irwin loop (200  $\mu$ m X 500  $\mu$ m) was used to transfer the tardigrades from Petri dishes to slides. Finally, tardigrades were mounted in Hoyer's medium and oriented under a small coverslip for identification under an Olympus BH phase contrast compound microscope. Tardigrades were identified according to Ramazzotti and Maucci (1983).

### Results and Discussion

Eighteen species of tardigrades, including one new species, representing ten genera (*Diphascon*, *Hypechiniscus*, *Hypsibius*,

*Isohypsibius*, *Itaquascon*, *Macrobiotus*, *Milnesium*, *Minibiotus*, *Pseudechiniscus*, *Ramazzottius*) were identified from Spruce Mountain (Table 1). These species constitute the first records of tardigrades from West Virginia. The most common species were *Macrobiotus hufelandi* and *Milnesium tardigradum*.

**Table 1.** Checklist of Tardigrades from Spruce Mountain, West Virginia

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Class Heterotardigrada

Order Echiniscoides

Family Echiniscidae

*Hypechiniscus gladiator* (Murray, 1905)

*Pseudechiniscus suillus* (Ehrenberg, 1853)

Class Eutardigrada

Order Parachela

Family Macrobiotidae

*Macrobiotus harmsworthi* Murray, 1907

*M. hufelandi* Shultze, 1833

*M. occidentalis* Murray, 1910

*M. richtersi* Murray, 1911

*Minibiotus intermedius* (Plate, 1888)

Family Hypsibiidae

*Hypsibius convergens* (Urbanowicz, 1925)

*H. dujardini* (Doyere, 1840)

*H. maculatus* Iharos, 1969

*Ramazzottius oberhaeuseri* (Doyere, 1840)

*Isohypsibius macrodactylus* (Maucci, 1978)

*Itaquascon placophorum* Maucci, 1972

*Diphascon* near *higginsii* Binda, 1971

*D. scoticum* Murray, 1905

*D. prorsirostre* Thulin, 1928

*D.* n. sp.

Order Apochela

Family Milnesiidae

*Milnesium tardigradum* Doyere, 1840

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A total of 141 moss samples were collected from Spruce Mountain. Sixty-five percent (91) of the mosses yielded tardigrades. The following mosses contained tardigrades: *Amblystegium serpens*,

*Anomodon attenuatus*, *A. rostratus*, *Atrichum augustatum*, *Brachythecium salebrosum*, *Dicranum fulvum*, *D. polysetum*, *D. scoparium*, *Endodon cladorrhizans*, *Hedwigia ciliata*, *Hypnum pratense*, *Leucobryum glacum*, *Platydictya subtile*, *Thuidium delicatulum*, and *Ulotia crispa*. The mosses *Ulotia crispa* and *Anomodon attenuatus* provided the greatest number of tardigrades.

Many of the tardigrade species are found in other parts of the world. Seven of the 17 species are cosmopolitan: *Hypechiniscus gladiator*, *Ramazzottius oberhaeuseri*, *Macrobiotus harmsworthi*, *M. hufelandi*, *Milnesium tardigradum*, *Minibiotus intermedius*, and *Pseudechiniscus suillus*.

Future papers will describe the new species and discuss ecological comparisons of tardigrade populations from the different elevations on Spruce Mountain.

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# New State Record of the Mayfly *Baetisca gibbera* Berner for West Virginia

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## Abstract

*Baetisca gibbera* is reported for the first time from West Virginia. Nymphs were collected from Indian Creek in Monroe County. Available records from the literature indicate a disjunct distribution. The species occurs in Alabama, Florida, Georgia, Mississippi, South Carolina, Tennessee, and Virginia. Additionally, state distribution records of the genus *Baetisca* are reviewed from the literature, and characters separating these species from sister species are discussed.

## Introduction

*Baetisca gibbera* Berner is reported for the first time from West Virginia. Nymphs were collected from Indian Creek, Monroe County, West Virginia. They were collected in a rapidly flowing stream over sand and small gravel.

The endemic family Baetiscidae is monotypic, containing only the genus *Baetisca* (Walsh, 1962). Presently, there are 10 species of *Baetisca* known from the United States (Pescador and Berner, 1981). Berner (1955) described the holotype nymph of *Baetisca gibbera* from Escambia River, Escambia County, Florida. *Baetisca gibbera* has been recorded from seven states (AL, FL, GA, MS, SC, TN, VA) (Kondratieff and Harris, 1986; Pescador and Berner, 1981; and Berner, 1977). Generally, nymphs are collected in rather swiftly flowing streams where they live beneath logs and among thin overlapping layer of small pebbles (Berner, 1955; Berner and Pescador, 1980).

## Discussion

Prior to this state record, five species of *Baetisca* have been reported from West Virginia: (1) *B. carolina* (Monongalia County) (Needham et al., 1935); (2) *B. callosa* Traver (Greenbrier, Mineral and Preston counties) (Needham et al., 1935 and Faulkner and Tarter,

1977); (3) *B. bajkovi* Neave (= *B. lacustris* McDunnough) (Lewis, Lincoln, Pleasants and Wayne counties) (Faulkner and Tarter, 1977); *B. berner* (Mingo County) (Tarter and Kirchner, 1978); and *B. rubescens* (Provancher) (Tucker County) (Tarter and Pettry, 1983). Pescador and Berner (1981), after studying the paratypes of *B. callosa* from West Virginia, concluded that the species is not valid.

*Baetisca gibbera* is a sister species of *B. rogersi* Berner and *B. becki* Schneider and Berner. Nymphs can be separated by the following characters (Pescador and Berner, 1981); (1) length of mesonotal shield is subequal to width and lateral spines are short; (2) mesonotal shield lacks dorsal projection and medial hump; and (3) abdominal sterna have no defined markings.

The species now occurring in the extreme Southeastern United States (*B. becki*, *B. escambiensis*, *B. gibbera*, *B. rogersi* and perhaps *B. obesa*) constitute a group that was pushed southward by Pleistocene glaciation and remained adapted to warm temperatures. *B. gibbera* is an exception as it also is found in the cool mountain streams of the Appalachian mountains. Pescador and Berner (1981) noted the disjunct distribution of *B. gibbera* could possibly be the result of an insufficient number of specimens or the mountain population might be a distinct species. If the species is not distinct, then the present distribution pattern indicates that *B. gibbera* became adapted to cool waters and invaded the Appalachian streams as the ice sheet receded while continuing to inhabit the warmer coastal streams.

We are grateful to Fred Kirchner, Boris Kondratieff and Kimberly Ruggles for assistance in the field collections. We thank Dr. Lewis Berner for identification of the mayfly. Special thanks to Lu Ann South for typing the manuscript.

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# Clues to the Neural Control of Primate Locomotion: Lessons Learned From Comparative Patterns of Joint Activity

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## Abstract

Kinematic/kinetic studies have been demonstrated to provide excellent evidence reflecting principles underlying the neural control of locomotion. This study, which compares the multiarticular body segment motion of the *Lemur fulvus* and *Cercopithecus aethiops* leap, uses kinematic/kinetic data in an effort to draw some general, but basic, conclusions about the neural control of locomotion. It is suggested that changes between *active* and *stabilizing* joint roles, as evidenced by concentric and eccentric muscle contraction, follow a similar pattern in both primates and provide a means for predicting recruitment patterns of muscle. This basic information, which is available to the nervous system proprioceptively, allows the body to respond to current, and to predict future, locomotor events.

## Introduction

Locomotion requires the complex interaction of muscles and external forces acting upon a link system in a systematic fashion. Thus, in addition to forces arising from muscle contraction, gravitational and interactive forces may also influence limb trajectory. These interactive forces which produce the so called "motion dependent torque" at any particular joint along the link system, are a consequence of forces related to linear and angular velocities and accelerations. The influence of these motion dependent torques is especially pronounced when the movement of the limb, involving several joint and segment combinations, is accomplished with high velocity. It is also important to note that during such high velocity motions, proprioceptive reflexes are particularly adept at monitoring changes in limb dynamics. Therefore, as noted by Smith and Zernick (1987), "Supraspinal centers do not necessarily have to preplan compensatory muscle actions, and feed back at

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spinal segments may allow for neural adaptations of these ongoing limb dynamics."

The role of muscle in these rapid moves, which often involves substantial contribution of inertial forces, may be quite complex and may be seen to contribute primarily to the following: 1) Initiate movement and bring about acceleration of a particular body segment; 2) Control the trajectory of the body segment in space, that is (for instance) prevent unwarranted abduction or adduction; 3) Decelerate limb segments by eccentric contraction of muscles; 4) Counteract torques arising from the mechanical interaction which may come about by the movement of one segment upon another segment which is itself already in motion; and 5) most importantly, serve to stabilize a body segment or segments so that muscles in more distal segments may work against a stable base of support.

Hogan (1985) suggested that the role of the "motor controller" is not just to achieve a particular spatial position, but to arrange the posture of the whole body and reconstruct all of the musculature in order to provide for the body's mechanical response to locomotor needs.

As is pointed out by Vilensky (1987) neuromechanisms may optimize kinematic parameters using different muscular interactions dependent upon environmental conditions. If this is the case, then detailed kinematic studies may provide the best direct evidence reflecting principles underlying the neural control of locomotion.

Detailed kinematic/kinetic studies using techniques basic to this research are represented in the pioneering work of the following authors (Manter, 1938); (Dempster, 1935); (Plagenhoef, 1962); (Plagenhoef, 1971); (Grand, 1977); (Jouffroy, 1974); (Winter, 1979).

The following discussion focuses upon common parameters found in kinematic/kinetic studies of the leaping strategies of two primates, the old world monkey *Cercopithecus aethiops* and *Lemur fulvus*. A conventional application of these data usually involves detailed comparison of individual or multisegment motions aimed at deriving an understanding of specific morphological questions. In this case, however, the data is viewed from a more general perspective, seeking similar overall patterns of multisegment contributions to motion. It is suggested that the pattern of changes in joint role is a basic and principle factor in locomotor neural control. This pattern consists of changes between *active* and *stabilizing* joint roles and is evidenced by concentric and eccentric muscle contractions. While these observations are based

upon a limited sample of data, the implication for understanding the relationship between neural control of locomotion and kinetic/kinematic variable seems worthy of noting at this point. Further detailed interpretation awaits repeat measurements.

## Methods and Materials

### Body Segment Parameters

Determination of the role of various muscle groups in moving associated body segments requires calculation and joint moments of force. A brief outline of the procedure used to determine these parameters follow. Each point will then be discussed more fully. For additional methodological information please see the following: (Wells and Tebbetts, 1975); (Wells and Wood, 1975); (Wells, et. al., 1977); (Wells and Dementhon, 1987).

1. Divide the body into its functional component segments: for example, *leg* from the talo-crural joint to the knee joint.
2. Measure the length of all body segments as a distance between proximal and distal joint centers.
3. Determine segment weights by direct measurement of the dissected cadaver.
4. Locate the center of gravity and determine its spatial relationship to the proximal and distal ends of the segment.
5. Take high speed films of the desired locomotor sequences.
6. From these film sequences digitize the joint center locations in two-dimensional space.
7. Determine the kinematics of the motion.
8. With the kinematic and anthropometric data, determine the kinetics of the motion.

In this analysis the body was treated as a series of linked segments. In motion, these segments work interdependently, affecting one another via their interconnecting joints. The anatomical link system was selected for this study on the basis of locomotor observations in a semi-natural substrate, and from a series of X-rays taken of an anes-

thetized animal with the limbs, trunk, and tail manipulated to aid in joint center determination. Body segment data collection was conducted as outlined in Wells and Dementhon (1987).

Starting at the foot (the fixed point of each locomotor sequence), the anatomical link system was composed as follows: (a) foot: from the metatarso-phalangeal joint to the talo-crural joint; (b) leg: from the talo-crural joint to the knee joint; (c) thigh: from the knee joint to the hip joint; (d) pelvic portion of the trunk: from the hip joint to the lumbo-sacral joint; (e) abdominal portion of the trunk: from the lumbo-sacral joint to the lumbo-thoracic vertebral joint; (f) thoracic portion of the trunk: from the lumbo-thoracic vertebral joint to the thoraco-cervical vertebral joint; (g) head and neck: from the thoraco-cervical vertebral joint to the supra-orbital ridge; (h) arm: from the glenohumeral joint to the radiohumeral joint; (i) forearm: from the radiohumeral joint to the radiocarpal joint; and (j) hand: from the radiocarpal joint to the metacarpo-phalangeal joint. The tail in this study was treated as part of the pelvic segment and assumed to be extended, based on observations of leaping.

Specimens of *L. fulvus* were dissected into component body segments and data obtained on segment weight, length, and center of gravity. These data were analyzed and published (Wells and Dementhon, 1987)

#### Kinematic/Kinetic Analysis

Film sequences to be biomechanically analyzed were taken with a tripod mounted 16 mm Action Master 500 camera equipped with 2.2 mm Angenieux zoom lens in a semi-natural environment at the Natural Bridge Zoo, in Natural Bridge, VA. Vertical leaps were filmed at 200 frames per second.

Film sequences were digitized yielding X and Y coordinates for each of the joint locations with the aid of Science Accessories 36" X 36" digitizer. From these data the following information was generated:

1. Location of segment centers of mass in two dimensions.
2. Calculation of linear velocity and acceleration of the segment centers of mass.
3. Determination of the absolute angle from the right horizontal.

4. Calculation of angular velocity and angular acceleration as first and second derivations of the displacement curve.
5. Calculation of resultant horizontal and vertical forces and moments of force.

The kinetics of the motion were generated by computer analysis of the kinematic data and the biomechanical properties of the body segments (I.e., segments' mass, length, center of gravity, and moment of inertia). External or inertial forces (forces of motion) were computed, and moments of force, that is, torque about each joint in the link system, were determined by starting at the free end of the link system and working backward to the ground, after (Plagenhoef, 1971).

## Results

The following discussion focuses on a kinematic/kinetic analysis of vertical leaping in *Lemur fulvus* followed by a comparison with published data on vertical leaping in *Cercopithecus aethiops*. This discussion is used to illustrate the treatise of this paper, that is, that roles of stability versus active segment contribution, may be critical variables for understanding the neural control of locomotion.

*Lemur fulvus* was filmed performing a vertical leap from a horizontal substrate. This analysis focuses upon the foot, leg, and thigh data only and presents data from one of several virtually identical leaps. For this discussion the comparative general pattern as opposed to specifics of subtle variation from one leap to another are focused upon.

### Lemur fulvus leap:

The movement may be divided into three phases. The first phase is best described as the *preparatory* phase, the second phase as the *transition* phase and the final phase as the *lifting* phase (see Figure 1).

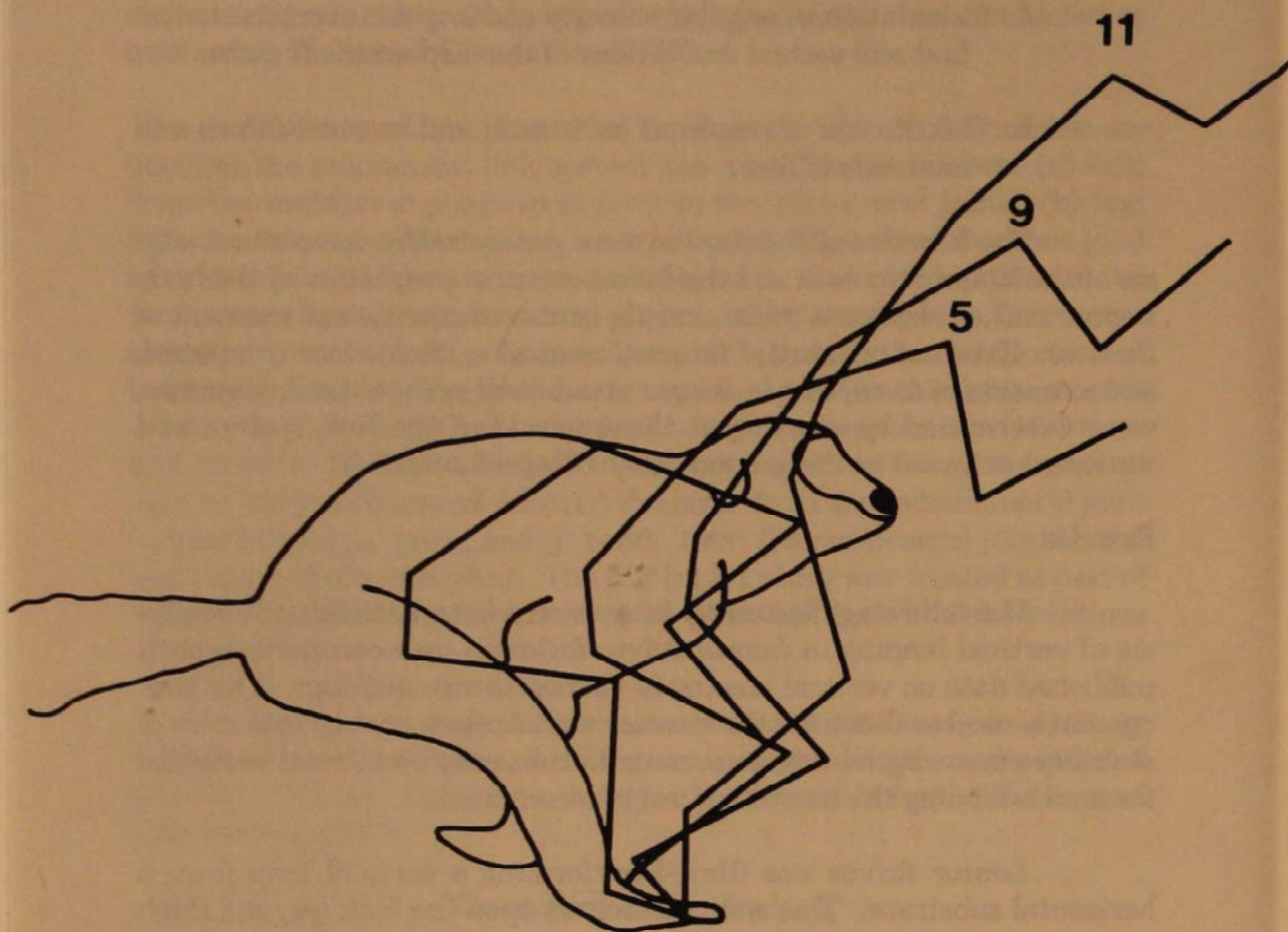


Fig. 1. A "stick-figure" sequence is illustrated for the initial frame in each of phase; *preparatory, transition, and lifting.*

The following three illustrations are provided in support of the discussion relating the kinematic pattern to the kinetic pattern, in order to determine segment role in terms of stability or active contribution to motion. Figure 2 illustrates the segment displacements for the lower limb. Figure 3 provides a rationale for interpreting the kinematic pattern shown in Figure 4. In Figure 3, a positive moment is signified by counter-clock wise torque, according to convention. Figure 4 presents the kinetic analysis and when correlated with Figure 3 (kinematic pattern) allows for derivation of the following discussion.

# Segment Displacements for Lemur fulvus LEAP

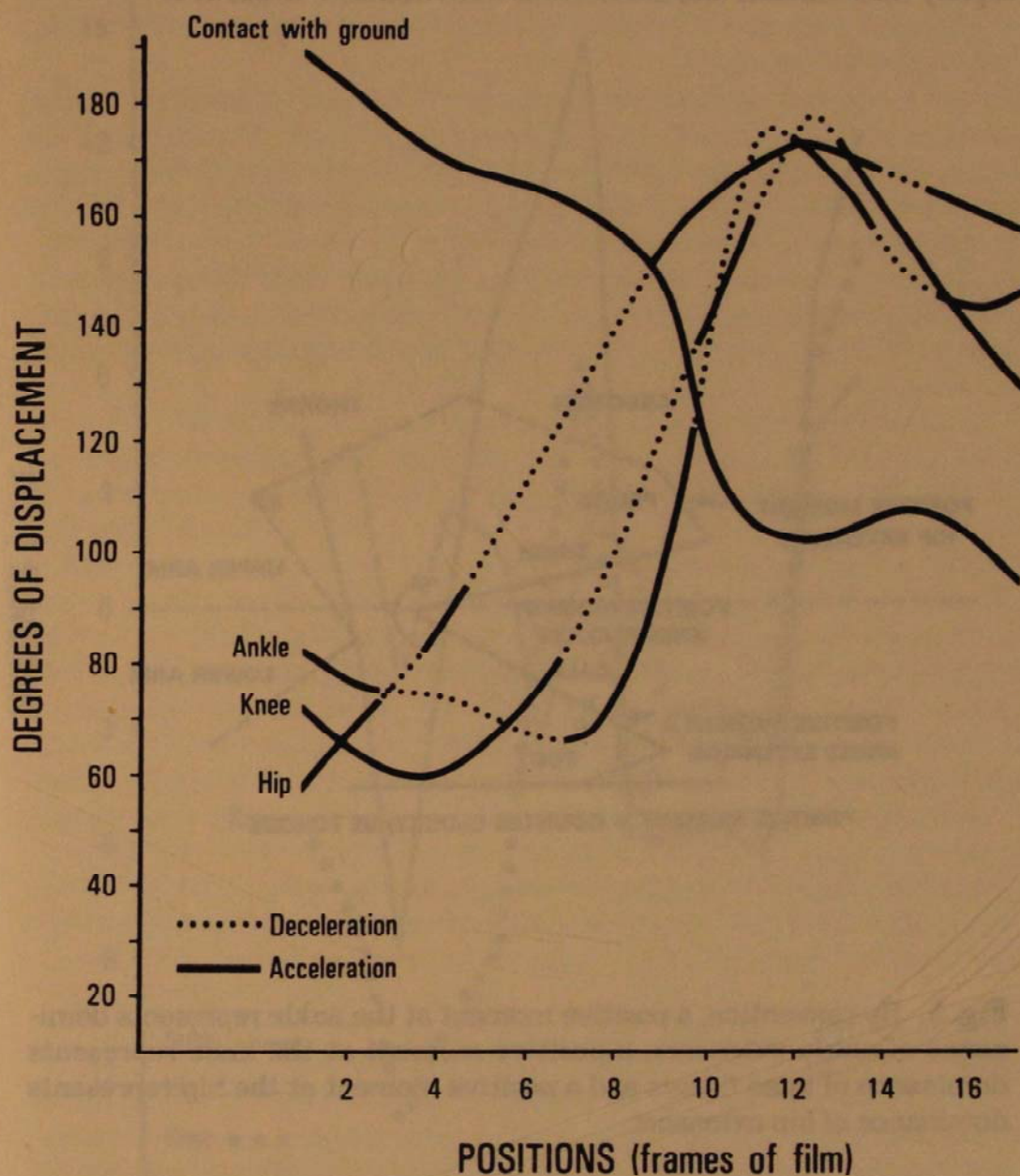


Fig. 2. Displacement for the lower limb including the hip are shown. The dotted line signifies deceleration, a solid line acceleration. The ver-

tical axis on the graph denotes degrees of segment opening or closure<sup>2</sup> and the horizontal axis of the graph shows positions, or frames of film. Using the knee as an example, from frames 1 to 5, the knee closes rapidly then extends and decelerates from frames 5 to about 9.

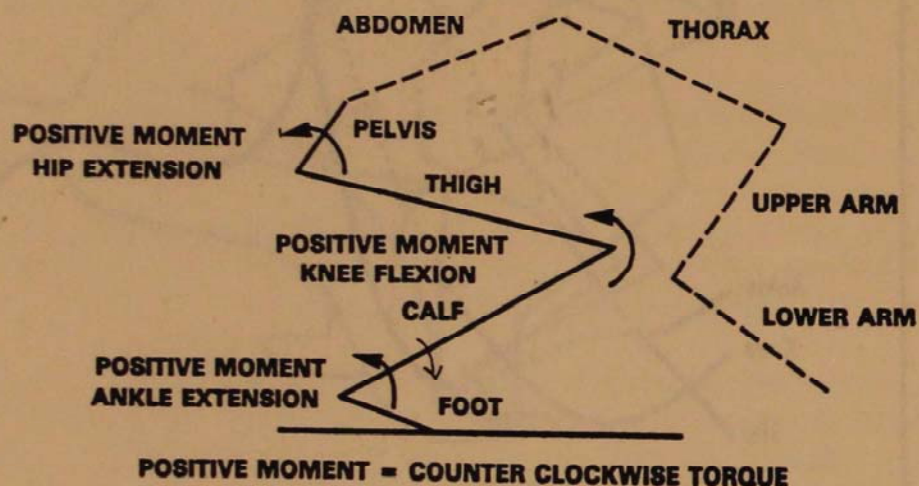


Fig. 3. By convention, a positive moment at the ankle represents dominance of ankle extensors, a positive moment at the knee represents dominance of knee flexors and a positive moment at the hip represents dominance of hip extensors.

<sup>2</sup>Opening and closure of segments upon one another is used instead of flexion and extension as not to imply dominance of extensor or flexor musculature at any point in the kinematic discussion.

# JOINT MOMENTS for Lemur fulvus LEAP

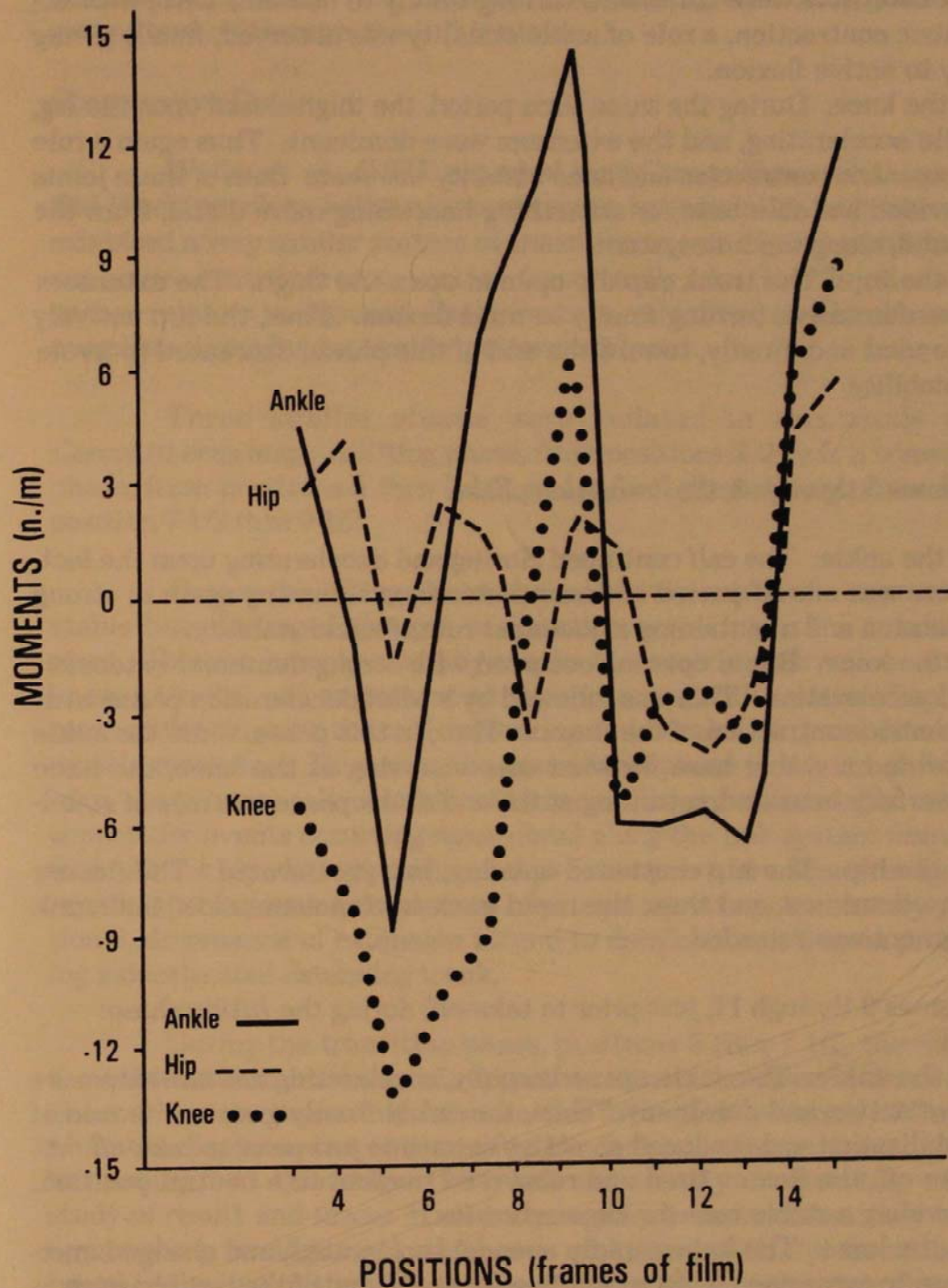


Fig. 4. A plot of joint moments is shown. Example: During the preparatory phase (in Fig. 3), at the knee, note that the joint was closing and accelerating. However, in Fig. 4, note that the knee extensors were dominant in these frames. Therefore, eccentric contraction and knee stability are functional roles.

Frames 1 through 5, the *preparatory* phase:

At the ankle: Initially the leg closed upon the foot while decelerating. The extensors were dominant, turning finally to flexion. Thus, with eccentric contraction, a role of ankle stability was observed, finally giving way to active flexion.

At the knee: During the same time period, the thigh closed upon the leg, while accelerating, and the extensors were dominant. Thus again a role of eccentric contraction and knee stability was seen. Both of these joints provided a stable base for something happening more distal, from the ground, along the link system.

At the hip: The trunk rapidly opened upon the thigh. The extensors were dominant, turning finally to mild flexion. Thus, the hip actively extended and, finally, toward the end of this phase, decreased to a role of stability.

Frames 5 through 8, the *transition* phase:

At the ankle: The calf continued closing and decelerating upon the foot. There was a brief period of flexor dominance returning again to strong extension and maintaining a dominant role of ankle stability.

At the knee: Rapid opening occurred with strong dominant extension and acceleration. This was followed by a brief deceleration phase with eccentric contraction of the flexors. Thus, in this phase, while the ankle provided a stable base for what was occurring at the knee, the knee powerfully extended, returning at the end of the phase to a role of stability.

At the hip: The hip continued opening, but decelerated. The flexors were dominant and thus, the rapid backward movement of the trunk segment was retarded.

Frames 9 through 11, just prior to take-off, during the *lifting* phase:

At the ankle: The ankle opened rapidly, accelerating and the extensors were active and dominant. Thus, the ankle finally gave up its role of stabilization and produced an active extension just prior to take-off. At take-off, the flexors fired and recovered the foot to a neutral position, providing a stable base for knee extension.

At the knee: The knee rapidly opened, accelerated, and changed once more to extension. Thus, stability seen at the end of the last phase gave way again to active extension.

At the hip: The trunk opened upon the thigh, accelerating. Flexion or retardation gave way to extension, and returned to flexion. Overall,

flexors were dominant, retarding the backward movement of the trunk as the knee extended. It is important to note that during the first part of this last phase, the knee was stable so that the lifting forces developed at the extending ankle would not be lost, passing its force against the ground and up through the link system.

#### Comparative Data:

Wells, et. al., (1977) reported that *Cercopithecus aethiops*, an Old World monkey, habitually much more terrestrial in its locomotion exhibited a very similar pattern of transition in role of joint stability versus active contribution to motion for virtually identical functional response relative to segment displacements, velocities, accelerations and moments throughout a similar pattern of phases.

Three similar phases were isolated in this study of a *Cercopithecus* leap. A lifting phase, from positions 2 thru 5, a transition phase, from positions 5 thru 7 1/2, and a final preparatory phase from position 7 1/2 thru 9 1/2.

During the lifting phase, the role of the ankle was to provide a stable base for rapid changes in direction occurring in the trunk segment. This was brought about by a state of eccentric contraction. At the knee, a similar and consistent situation existed with relative displacement of the thigh on the calf decreasing and decelerating and dominant muscle extension. Thus as in the case of this phase in the lemur *fulvus* leap, the primary role of ankle and knee are to provide a stable base of support for events occurring more distal along the link system from the foot. At the hip, during position 2 thru 5, the pelvis are accelerating and rapidly opening with a dominance of extension. At approximately position 5, dominance of extension turned to dominance of flexion producing a decelerated extending trunk.

During the transition phase, positions 5 thru 7 1/2, the role of the ankle as a stable basis of support remained the same and was evidenced by eccentric contraction in the form of dominance of flexors while the displacement of the calf on the foot had changed from closure to opening. At this stage, the trunk was rapidly decelerating and a study of result and forces of all body segments showed that they were approaching an alignment which was consistent with the direction of travel in the just initiated leap. The thigh rapidly opened upon the calf, accelerating, and knee extensors were dominant throughout the phase. At the hip, deceleration of the rapidly hyperextending trunk was brought about by a dominance of the flexor musculature.

During the preparatory phase, just prior to take off, the ankle extended vigorously as the leg on the foot opened in a state of acceleration. It should be noted however, that as the vertical force was reduced at this point, not much work was being accomplished by this final thrust. The knee accelerated and opened rapidly while flexors were dominant. Thus, its role was to allow the upward momentum of trunk and arms to lift the lower limbs from the surface of the ground and at the same time permit the forces generated by the extension of the ankle not to be lost in knee flexion. The hip continued to decelerate until just prior to take-off. The extensors were dominant, but of low magnitude.

While intriguing these similarities are not surprising in that a basic pattern of segment interrelationships seems essential in the production of a similar kind of locomotor bout even when minor morphological differences in musculature and skeletal architecture are found. A future comparative study of *Lemur catta*, a more terrestrial primate within the same genus should allow for detailed comparison of noted differences within the predicted similar pattern.

### Conclusions

A similar pattern of static to dynamic change along the lower limb link segments with only minor internal perturbations, is found in studies of the leap of the *Lemur fulvus* and the Old World monkey *Cercopithecus aethiops* and are hinted at by preliminary studies of the similar leaping modality in the lemuroid primate *Lemur catta*. It is suggested here that the key element to understanding recruitment patterns of muscle and other parameters of neural control of locomotion, may lie in a detailed understanding of the patterns of change in *role* of body segment joints during movement.

The basic focus of information used by the nervous system to provide for locomotion may lie in proprioceptive data organized about a temporal theme of *joint role* as a stabilizer permitting events occurring elsewhere in the limb system, or as active contributor to motion.

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**Minutes of the Annual Business Meeting  
West Virginia Academy of Science  
64th Annual Meeting  
West Virginia School of Osteopathic Medicine  
Lewisburg, West Virginia 24901**

April 1, 1989

Meeting called to order at 10:04 by Dr. Steven L. Stephenson.

Members present:

Robert Hogan	John Chisler	Larry Davis
Steven Stephenson	Larry Reichart	Phillip Cottrill
John Parks	Jim Joy	Don Gasper
Vernon Kerns	Jim Wells	Carl Bell
Brett Gasper	Ralph Taylor	John Schiefer
Charles Woodward	Elizabeth Swiger	Don Cooper
Carl Fezer	Ashton Berdine	Roy Clarkson
Don Tarter	Tom Weeks	E. E. Hutton
Gary Snyder		

Welcoming comments were presented by Ms. Jean Dickens, Vice-President WVSOM.

Dr. Swiger moved that the meetings at Shepherd College be held on April 7, 1990. Dr. Woodward seconded -- motion carried.

Dr. Clarkson presented the Treasurer's report and distributed copies to the members present. The records have not yet been audited, and Dr. Clarkson indicated that he would send corrected copies to members if there were discrepancies.

Dr. Taylor inquired as to why an organization of this type has such a large balance of funds -- \$10,000+. Dr. Clarkson explained that proceedings not yet published would be responsible for consuming most of that excess money.

Dr. Swiger and Dr. Stephenson indicated that they had experience auditing books and volunteered to audit the books for the academy. Dr.

Clarkson agreed to supply the books to Drs. Swiger and Stephenson as soon as possible.

Dr. Chisler spoke concerning outstanding teacher awards.

Dr. Taylor explained some of the outstanding attributes of Hazel Bowen, a former recipient. Dr. Parks discussed the Center for Excellence for Teachers at West Virginia Tech. Jim Wells suggested working at the county level to identify outstanding teachers, Brett Gasper suggested the use of test scores of students to identify outstanding teachers. Dr. Woodward suggested using the Governor's Honors Academy participants to write letters of nomination.

Dr. Taylor asked about the status of the proceedings. Dr. Stephenson indicated that the turnaround time has improved and that papers are now being published within one calendar year of their acceptance. Dr. Chisler stated that the final printing of last year's papers will bring the proceedings up to date.

Dr. Fezer asked if the proceedings were abstracted by an abstracting service. Dr. Stephenson indicated that they were.

There being no further business, Dr. Stephenson declared the meeting adjourned.

Gary W. Snyder  
Secretary

# WEST VIRGINIA ACADEMY OF SCIENCE ANNUAL TREASURER'S REPORT

1988

April 1, 1989  
WVAS Annual Meeting  
West Virginia School of  
Osteopathic Medicine  
Lewisburg, West Virginia

January 1, 1988 to December 31, 1988

## CASH RECEIPTS

Balance on Hand January 1, 1988.....\$11,640.79

Dues .....	1,660.00
Institutional Membership .....	1,000.00
Proceedings (Libraries) .....	1,095.00
Contributions (Talent Search) .....	215.00
Annual Meeting .....	411.50
Page Charges .....	447.75
Interest (Checking Account) .....	231.01
Interest (12-mo. CD) .....	334.98
Interest (passbook, closed 4/15/88) .....	88.75
Advertisements .....	225.00
Abstract Charges .....	78.00
Contributions Union Carbide .....	1,000.00
John Chisler .....	<u>20.00</u>

**TOTAL RECEIPTS FOR YEAR . . . . \$6,806.99**

**TOTAL RECEIPTS & BALANCE ON HAND . . \$18,447.78**

## CASH DISBURSEMENTS

Printing (McClain) .....	\$6,246.67
Annual Meeting .....	855.44
Postage .....	160.94

National Assoc. of Academy  
of Science (dues) .....27.00  
Miscellaneous .....601.19  
Talent Search .....270.65  
Science Teacher Awards .....98.85

**TOTAL DISBURSEMENTS .....\$8,260.94**

**BALANCE DECEMBER 31, 1988 .....\$10,186.84**

(Checking ----- \$4,400.75)  
(Certificate of Deposit - \$5,786.09)  
(First National Bank of Morgantown  
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Respectively submitted,

Roy B. Clarkson, Treasurer, WVAS

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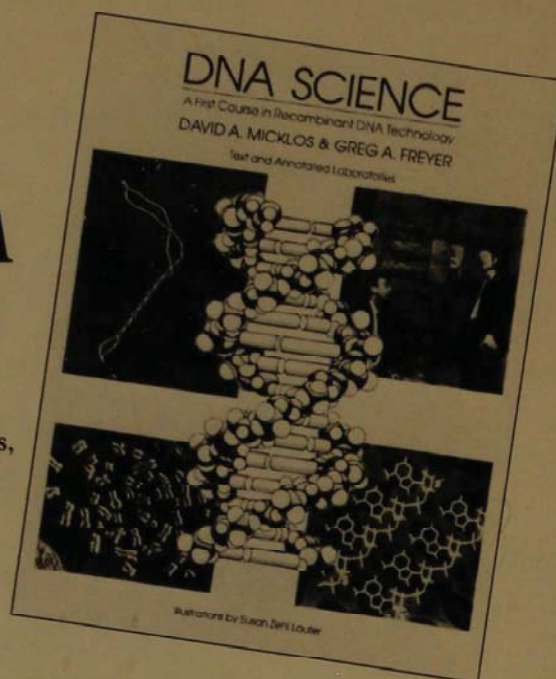
# ***DNA Science: A First Course in Recombinant DNA Technology***

David A. Micklos, DNA Learning Center,  
Cold Spring Harbor Laboratory  
Greg A. Freyer, College of Physicians & Surgeons,  
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This new laboratory text combines the theory, practice, and applications of recombinant DNA technology into one articulated package. Unlike super texts that can only be sampled by even the most ambitious instructor or student, *DNA Science* is designed to be read from cover to cover. The eight text chapters are written in a semi-journalistic style and adopt a historical perspective to explain where DNA science has come from and where it is going. Combining the unique perspectives of a research biologist and a science writer, the topical treatment integrates up-to-the-minute examples drawn directly from the research literature.

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