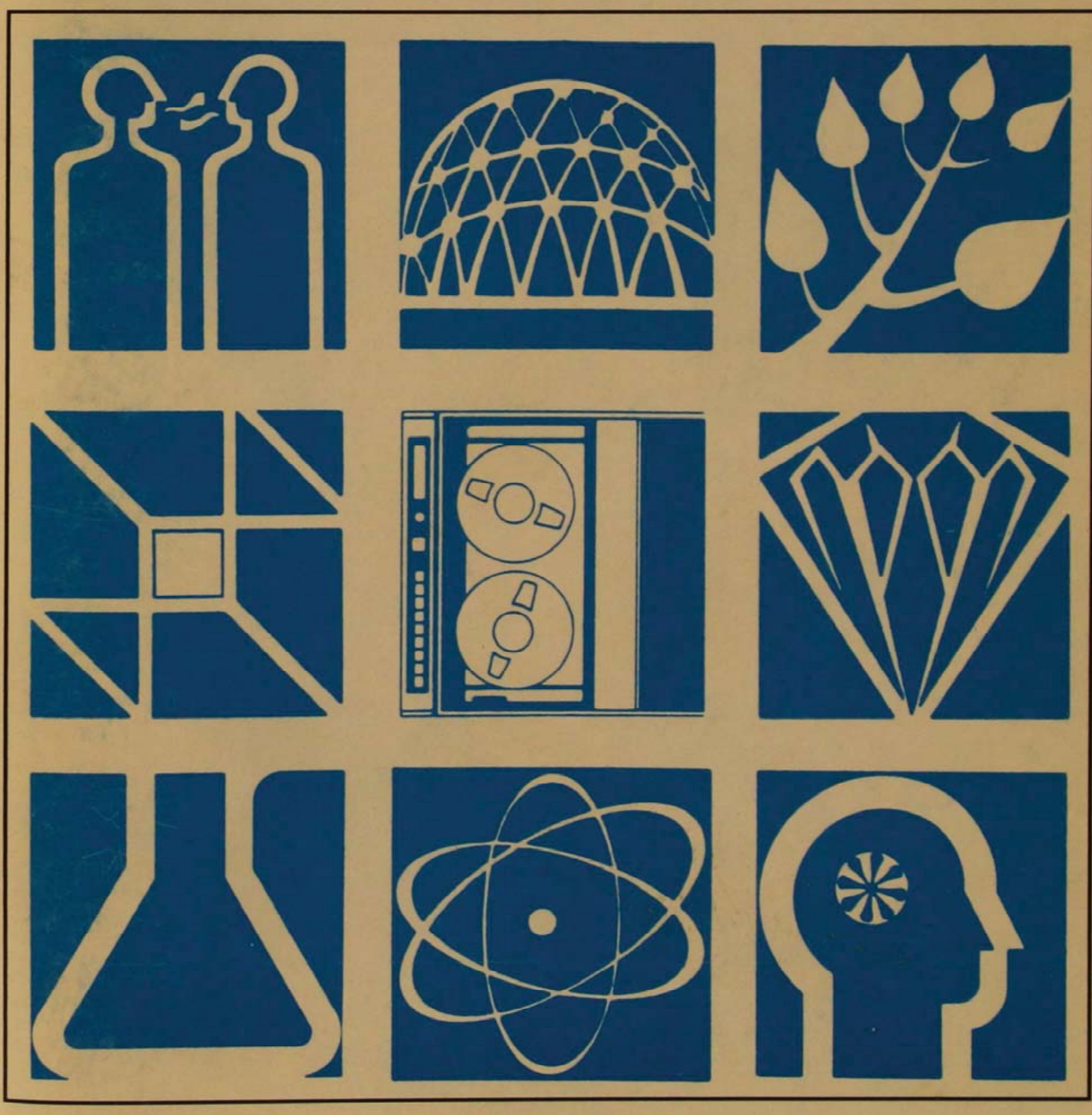
Volume 62, Numbers 2, 3, and 4

Proceedings of the West Virginia Academy of Science 1990

Papers of
the Sixty-Fifth Annual Session



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Vol. 62 -- No. 2, 3, and 4
PAPERS OF THE SIXTY-FIFTH ANNUAL SESSION

Shepherd College
Shepherdstown, West Virginia
April 7, 1990

Printed by
Office of Publications
Marshall University
Huntington, West Virginia

Cover Design
Meredith Pearce
West Virginia University
Office of Publications
Morgantown

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AWARDS

At its 1990 Annual Meeting, The West Virginia Academy of Science recognized "Outstanding West Virginia Secondary School Teachers of Science or Mathematics". These annual awards are sponsored by a special grant from Union Carbide Corporation.

In 1990 two teachers were recognized because they have contributed significantly to the education of secondary students. These teachers are continuing to stimulate and help secondary school science aspirants attain lofty goals and achievements. The Academy congratulates:

Mrs. Patsy Brannon, Valley High School in Fayette County,

and

Mrs. Beverly McDonald, North Middle School in Berkeley County.

The Papers of the 1990 Meeting

Biology Section

Discovery of *Potamanthus myops* (Walsh), a New State Record Mayfly, in Indian Creek, West Virginia, with Discussion on the Questionable Status of *P. distinctus* Traver in the State

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and

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Abstract

The mayfly *Potamanthus myops* (Walsh) is reported for the first time in West Virginia. Adults and naiads were collected from Indian Creek, a third order stream, in Monroe County. Naiads were found in shallow water under gravel substrate. Adults were attracted to a black light trap on 28 June 1989. This species has been reported from 11 central and northeastern states. The questionable status of *P. distinctus* in West Virginia is resolved. Adults and naiads were collected from Indian Creek on several occasions. Additionally, taxonomic characters used to separate the adults and naiads of the two species will be reviewed.

Discussion

Potamanthus myops (Walsh) is recorded for the first time from West Virginia. Naiads were collected in shallow water under gravel substrate in Indian Creek, a tributary of the New River, in Monroe County. Adults were collected with a black light trap on 28 June 1989.

The family Potamanthidae is one of the most primitive families of the sprawling Ephemeroidea (Edmunds et al., 1976). The family is most diverse in the Oriental realm and in Palearctic Asia. The genus *Potamanthus*, which is the only genus of the family in North America, is Holarctic in distribution. Eight *Potomanthus* species are found mainly east of the Mississippi River except for records from Arkansas, Mississippi, Kansas and Iowa (McCafferty, 1975). Naiads are most commonly found on the bottom amid silt, sand, and gravel or on stones in rather swiftly flowing shallow waters (Edmunds et al., 1976).

Potamanthus myops was first described by Walsh (1863) in the genus *Ephemera* Linnaeus, and was transferred to *Potamanthus* by McDunnough (1926). Burks (1953) synonymized *P. medius* Banks with *P. myops*. This species has been recorded from AR, IA, IL, IN, KY, MI, NB, OH, TN, and WI (McCafferty, 1975).

Potamanthus distinctus Traver is the most common eastern species. It has been recorded from AR, GA, NC, NY, OH, PA, TN, and WV (McCafferty, 1975). However, the West Virginia record is somewhat questionable (McCafferty, 1975). Needham et at. (1935) reported mayflies quite similar to *P. distinctus* from two localities in West Virginia (Justice, Smoke Hole). We have confirmed the distribution of *P. distinctus* in West Virginia by collecting several adults and naiads from Indian Creek. Based on these collections, the two congeners of *Potamanthus* are distributed sympatrically in Indian Creek. However, *P. distinctus* is the predominant population.

We are grateful to Y. J. Bae, Research Associate, Department of Entomology, Purdue University, for identification of the two species. Additionally, we thank Kimberly Ruggles and Fred Kirchner for assistance in the field collections. Special thanks to Lu Ann South for typing the manuscript.

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Effect of Temperature Variations on Oxygen Consumption Rates of Naiadal *Potamanthus distinctus* Traver (Ephemeroptera: Potamanthidae)

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Abstract

Respiratory studies involving the effects of temperature variations (10 and 17 °C) were performed in the laboratory of *Potamanthus distinctus* naiads using a Gilson respirometer. The mean oxygen consumption rates were 3.048 and 1.321 µl/mg dry wt/hr, 17 and 10 °C, respectively. The mean dry weight in both trials was 3.645 mg. A student t-test was calculated and indicated that the two means were significantly different (0.05 confidence level). Linear regression analysis was used to determine the influence of body weight on the respiratory rates at the two temperatures. The correlation coefficients of -0.60755 and -0.50405, 17 and 10 °C, respectively, were determined. These values are significant at the 0.05 confidence level and indicate a strong inverse relationship between body size and oxygen consumption rates. The slopes of the lines were compared to a z-distribution. The oxygen rates were significantly different at the 0.05 confidence level, and indicates that there is a difference in the relationships of body size to oxygen consumption rates at each of the two temperatures.

Introduction

Temperature is a crucial ecological parameter in the aquatic environment. Due to poor thermoregulatory control mechanisms, temperature variations alter the physiology of many organisms and can drastically change the composition of communities. The purpose of this laboratory investigation was to determine what effects, if any, temperature variations have on the oxygen consumption rates of

Potamanthus distinctus naiads. Very little information is available on the ecology or life histories of the species, and no environmental studies appear in the literature for this genus. *P. distinctus* was first described by Traver (Needham et al., 1935).

The respiratory physiology of the orders Ephemeroptera and Plecoptera have been examined. Knight and Gaufin (1966) found that temperature, body size, life-cycle stage, sex, and genetic background influence respiration rates in various plecopterans. Respiration was found to increase with an increase in temperature in *Isonychia bicolor* (Sweeney, 1978). Modlin and Jayne (1981) investigated three species of *(Isoperla)* and determined that respiratory rates are directly related to body weight and environmental temperatures. All results were obtained using a Gilson differential respirometer.

Taxonomy and Distribution

Potamanthus is holarctic in distribution with one doubtful record from India, and is the North American representative of the sprawling Ephemeroptera. *Potamanthus* is the only genus of the family Potamanthidae found in the United States. Eight species have been described with the largest number occurring in the eastern half of the country (McCafferty, 1975).

P. distinctus is the most common eastern species of the genus. It has been recorded from AR, GA, NC. NY, OH, PA, TN, and WV with the West Virginia record being questionable until now (McCafferty, 1975).

Materials and Methods

The collection area is above a riffle in Indian Creek , Monroe County, West Virginia. Indian Creek originates in the limestone sinks of Monroe County and flows generally southwestward until it empties into the New River just over the southeastern border of Summers County. This third order stream runs 34 miles (54.72 km) with a total fall of 765 feet (233.17 m) (Reger et al., 1926).

Field Studies

The naiads were collected from Indian Creek on March 31, 1989, via the kick methods using a wire mesh screen. They were then removed from the screen and placed in a styrofoam cooler with rocks and some plant material for transport to the laboratory. The water in the cooler was continuously aerated until the specimens were removed for study within 72 hours.

The following physical and chemical water parameters were measured at the site with a Hach portable water test kit (Model AL-36B): pH, dissolved oxygen (mg/L), temperature (C), carbon dioxide (mg/L), and total hardness (mg/L $CaCO_3$).

Laboratory Studies

The effects of temperature variations on oxygen consumption rates were measured using a Gilson single-valve differential respirometer. Changes in gas volume resulting from chemical or biological activity are recorded by a volumometer. This device is a combination manometer-micometer with a digital readout indicating volume changes in microliters.

In the temperature trials, each of eleven naiads was placed in a reaction flask along with 7 ml of water from Indian Creek (pH 7.4). The center well contained 0.2 ml of 10% KOH and a folded piece of filter paper to act as a wick. The flask was lowered into the water bath. The naiads were given one hour to acclimate before the system was closed by means of the valve and readings were begun. Readings were taken at two different temperatures for three hours each. The temperatures, 17 °C and 10 °C are representative of the spring/summer and fall/winter temperatures, respectively, of Indian Creek. The acclimation for the 10 °C trial was two hours.

After completion of all trials, the naiads were removed from the reaction flask, sacrificed in boiling water and placed in a drying oven at 92 °C. They remained there for 19 hours and were then weighed using a Sartorius electronic double-beam analytical scale (Model 1702).

The pH and dissolved oxygen values of the water were remeasured before use of the Gilson respirometer to correct for any changes in water chemistry from the time of collection.

Statistical Analysis

The data obtained were used to calculate oxygen consumption in µl/mg dry wt/hr. For both temperatures, mean values and standard deviations were calculated for oxygen consumption. Student's t-test was used to test the null hypothesis which states that mean oxygen consumption at 17 °C is equal to mean oxygen consumption at 10 °C.

Linear regression analysis was used to determine the influence of body weight on the respiration rates at the two temperatures. A z-distribution was performed to determine if there was a significant difference in the slopes of the two regression lines.

Table 1. Dry weights (mg) and oxygen consumption rates (µl/mg dry wt/hr) of *Potamanthus distinctus* naiads at 17 °C.

DRY WEIGHT	OXYGEN CONSUMPTION (µl/mg dry wt/hr)
3.2	3.041
4.9	0.721
0.8	3.213
1.5	4.353
6.0	1.962
4.5	2.549
4.0	4.325
5.8	2.298
2.9	4.438
3.1	2.797
3.4	3.832
$\bar{X}$ = 3.645 s = 1.626	$\bar{X}$ = 3.048 s = 1.157

Results and Discussion

Water Analysis

The stream temperature was 11 °C on March 31, 1989. The pH was 10.0 and the dissolved oxygen was 10 mg/L. These values fall within expected ranges for Indian Creek. Prior to the temperature trials, the pH was 7.4 and the dissolved oxygen was 9 mg/L. The fall in pH and dissolved oxygen was probably due to an increase in respiration rates caused by the stress of collection and transport.

Table 2. Dry weights (mg) and oxygen consumption rates (µl/mg dry wt/hr) of *Potamanthus distinctus* naiads at 10 °C.

DRY WEIGHT	OXYGEN CONSUMPTION (µl/mg dry wtr/hr)
3.2	0.772
0.8	3.588
1.5	1.600
6.0	1.138
4.5	0.933
4.0	1.383
5.8	1.448
2.9	0.714
3.1	0.967
3.4	0.668
$\bar{X}$ = 3.645 s = 1.626	$\bar{X}$ = 1.321 s = 0.859

Oxygen Consumption

The data from the Gilson respirometer are summarized in Tables 1 and 2. The mean oxygen consumption rate at 17 °C was 3.048 µl/mg dry wt/hr (s = 1.157, N = 11). The mean oxygen consumption rate at 10 °C was 1.321 µl/mg dry wt/hr (s = 0.859, N = 11). The mean dry weight of the animals in both trials was 3.645 mg (s = 1.626, N = 11).

The calculated student-t was 3.845. In a two-tailed test, this value is greater than 3.153, the student t-value at the 0.05 confidence

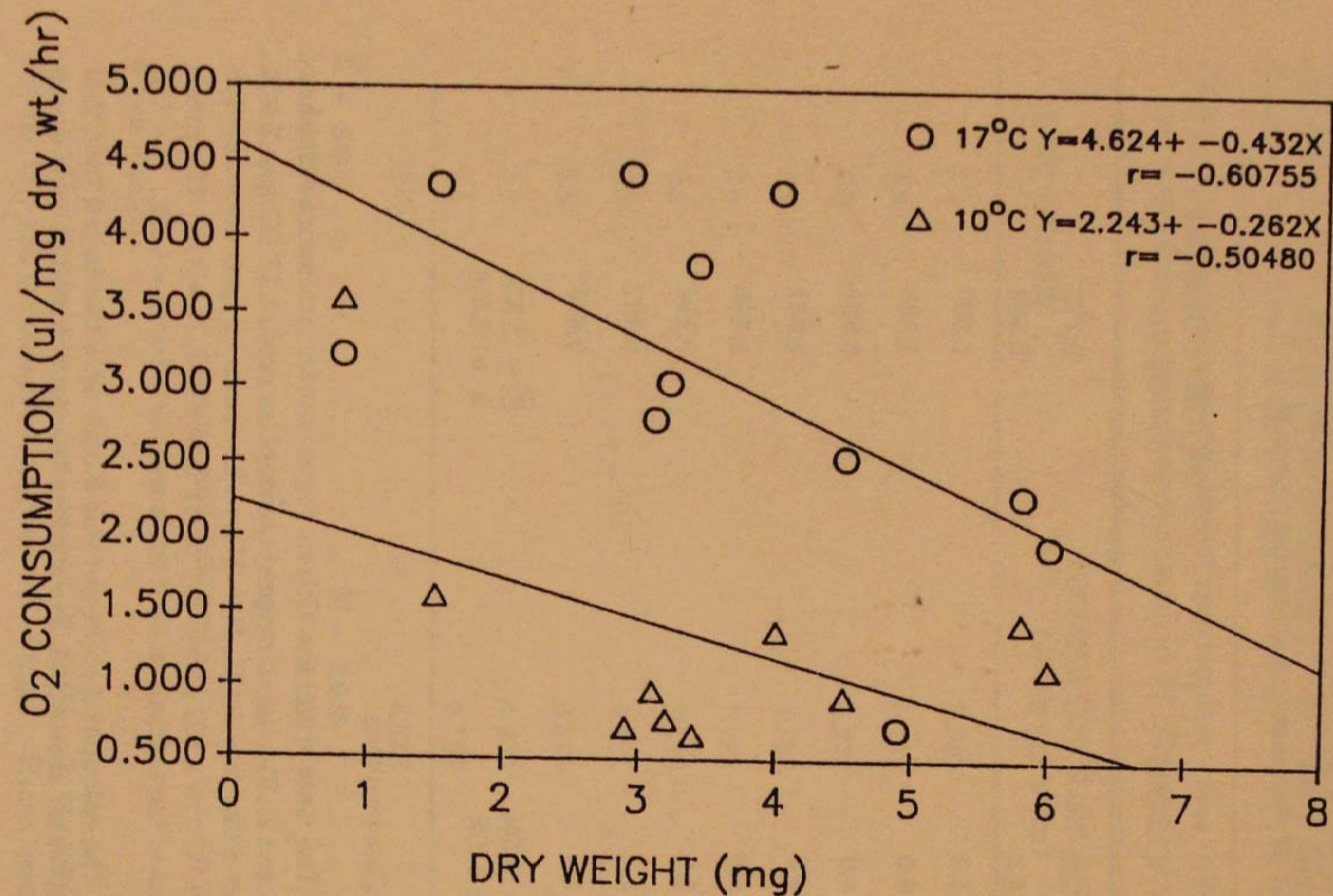

Figure 1. Comparison of oxygen consumption rates of *Potamanthus distinctus* naiads at 10 and 17 °C.

level. This indicates that the two means were significantly different and the null hypothesis is rejected.

This difference in oxygen consumption at the two temperatures reflects a change in the metabolism of the animals. Poikilotherms have poor thermoregulation and their body temperatures change with that of their environment. In poikilotherms the rate of metabolism, thus oxygen consumption, varies according to van't Hoff's rule. For every temperature drop of 10 ^{o}C, the rate of oxygen consumption is cut in half (Smith, 1980). As winter arrives in temperature regions and the temperature drops, so does the metabolic rate, thus decreasing the demand for food. Since food supply is limited during this season, this adaptation provides a survival advantage.

The correlation coefficients were -0.60755, and -0.50480, 17 and 10 ^{o}C, respectively (Figure 1). This demonstrates a significant inverse relationship between oxygen consumption and dry weight at the 0.05 confidence level. These data support the findings in the literature that respiration rates decrease with an increase in body size. This is probably because older, larger organisms have lower metabolic rates when compared to younger, smaller ones. Older organisms have lower proportions of active tissue and a greater amount of adipose tissue, requiring less metabolic activity (Knight and Gaufin, 1966).

The slopes of the two regression lines were compared to a z-distribution, giving a z-value of 3.657. This value is significant at the 0.05 confidence level and supports the conclusion that there is a significant difference in the relationship of body weight to oxygen consumption at the two temperatures.

Acknowledgments

We would like to express our sincere appreciation to Y. J. Bae for his assistance in identifying the specimens, and Kimberly Ruggles and Fred Kirchner for their assistance in the field collections. Special thanks to Lu Ann South for typing the manuscript.

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Gut Analysis of the Green Salamander *(Aneides aeneus)* in West Virginia

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Abstract

Green salamanders from the West Virginia Biological Survey representing populations collected throughout the state during every month except November and December were examined for prey items present in the stomach and small intestine. Thirty-nine of 96 specimens were devoid of food, and 24 contained fragments of digested food in the large intestine. All age classes examined showed considerable variations in snout-vent lengths, but not in the size of food items consumed. Insects constituted 92.1% of the number of all identifiable food items recovered and were found in all specimens containing food. Spiders and mites comprised the remaining 7.9%. Hymenopterans and Coleopterans comprised 83.9% of all prey, and 82.5% of hymenopterans were ants. Orthopterans, dipterans, hemipterans, and lepidopterans comprised the remaining 16.1% of insects.

Introduction

Much of what has been written about the feeding habits of salamanders has been limited to gut analyses of adults, and little is known about the diet of larvae, juveniles, and subadults. Davic (1991) conducted one of the most recent studies on all age classes of *Desmognathus quadramaculatus*. Likewise, much work has been done on aquatic and semi-aquatic species and little is known about the feeding behavior and diet of terrestrial species such as *Aneides aeneus*. The purpose of this study was to examine the gut contents of *A. aeneus* to determine if different age classes and populations in West Virginia feed on the same invertebrate taxa. We examined whether different age classes fed on the same invertebrate species, whether any seasonal variation in prey items consumed existed, and whether different populations fed on the same invertebrate taxa.

Methods and Materials

Ninety-six specimens from the West Virginia Biological Survey representing populations throughout the state and collections from every month (except November and December) were examined for prey items. The specimens used in this study were preserved in 10% formaldehyde and represented collections dating back to the early 1930's until the present. Prey items were removed from the stomach and small intestine and identified using Borror and White (1970) and Borror and Delong (1970). Salamanders were measured for snout-vent length using a vernier caliper and classified into age classes according to their size (Woods 1968). Specimens were also grouped by month captured so that any seasonal patterns in prey items could be examined. Prey items consumed by each age (size) class were compared taxonomically and by size. Prey items identified from 57 specimens were used to compute the percentage of each invertebrate group represented. A T-test was used to determine if any significant differences existed between mean number of invertebrate groups consumed per month.

Results

Of the 96 specimens examined, 39 (40.6%) were devoid of food and 24 of these contained pieces of digested food in the large intestine. Prey items recovered from the large intestine were not used in the analysis of gut contents because they were usually too difficult to identify. Insects constituted 92.1% of all prey items recovered and were found in all specimens containing prey. Spiders and mites made up the remaining 7.9% of the prey items recovered. Hymenopterans and coleopterans were the major insects in the gut and comprised 93.9% of the prey items. Ants made up 82.5% of all hymenopterans recovered while orthopterans, dipterans, hemipterans, and lepidopterans constituted the remaining 16.1% of insects identified from the gut. Table 1 summarizes the percentages that each taxonomic group comprised. All age classes of *A. aeneus* were examined and showed considerable variations in snout-vent lengths (SVL), but not in the size of food items recovered except for adults who took larger coleopterans than other age classes. Adults (n = 38) averaged 49.7 mm in SVL and 8.2 mm in head width (HW), immatures (n = 15) averaged 39.1 mm in SVL and 6.9 mm in HW, and hatchlings (n = 6) averaged 15.4 mm in SVL and 3.8 mm in HW. All age classes were found to feed on the same invertebrate species, but hatchlings, probably due to their size, consumed more mites than any of the other invertebrates. There was no significant difference ($p > 0.05$) between the invertebrate groups recovered per month.

Table 1. Gut analyses of *A. aeneus* specimens from the West Virginia Biological Survey.

Invertebrate Group	Percent of Total Numbered Recovered
Hymenoptera	60.2
Coleoptera	23.7
Mites	5.0
Orthoptera	4.5
Spiders	2.9
Diptera: Culicidae	1.8
Hemiptera	1.3
Lepidoptera	0.5

Discussion

This study indicated that there was little variation in the types of prey items consumed between populations. Lee and Norden (1973) found that 25 specimens from Cooper's Rock State Forest fed mostly on insects which comprised 75.7% of the diet. They found that beetles, mosquitoes, and ants comprised 68.5% of all items consumed and that the types of food consumed were similar for all size groups. Their study as well as results collected in the present study indicated that *A. aeneus* feeds mainly on beetles and ants throughout the year and that no seasonal patterns in the types of prey consumed appeared to exist.

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Addition of *Fundulus catenatus* (Storer) to West Virginia's Ichthyofauna

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Abstract

On 14 August 1987, while conducting a rotenone survey on Middle Grave Creek (Moundsville, Marshall County) of the Ohio River drainage, seven specimens (4.1 - 8.4 cm TL) of *Fundulus catenatus* (northern studfish) were collected. This account represents the first record of this species from West Virginia. The survey was one of four recent efforts to gather baseline data to evaluate the effects of a proposed U. S. Soil Conservation Service flood control project within the watershed. Three 1982 surveys (two electrofishing and one seining) performed in the project area did not reveal the presence of the northern studfish. Since this species occurrence is a significant range extension from the nearest Ohio River drainage populations of eastern Kentucky and central Indiana, it is presumed to have been introduced to the area. The collection of *Phenacobius mirabilis* (suckermouth minnow) and *Clinostomus elongatus* (redside dace) which represents state distributional records are discussed. A list of fishes for the Middle Grave Creek drainage is also provided.

Discussion

Ichthyofaunal checklists for West Virginia have been compiled by several investigators (see Cincotta et al. 1986). Published species lists for major state drainages also exist (Jenkins et al. 1972, Stauffer et al. 1978, Stauffer et al. 1982, Hocutt et al. 1986), but with the exception of Cincotta (1988), are applicable in entirety to only a few West Virginia drainages (i. e., due to river drainages that transcend state boundaries). Cincotta et al. (1986), Cincotta and Hoeft (1987), and Cincotta (1988) present updates concerning the fishes of the state and indicate that published data are needed to refine the distributions of several species. A review of Lee et al. (1980) reveals that information is particularly lacking for minor drainages in the northwestern portions of the state. The main purpose of this paper is to report the addition of *Fundulus catenatus* (northern studfish) to the state fauna. Secondary objectives are to discuss state distributional records for *Clinostomus elongatus* (redside dace) and *Phenacobius mirabilis* (suckermouth minnow), and provide a checklist of fishes for a northern panhandle drainage of West Virginia.

The U.S. Soil Conservation Service (SCS) has been evaluating flood control measures in the northern panhandle counties of West Virginia for several years (Shutts pers. comm.). The project discussed herein, is located in Moundsville, Marshall County on Middle Grave Creek of the Grave Creek drainage. Grave Creek, which is a direct tributary of the Ohio River, has an average gradient of 7.0 m/km and drains 197 km^2 of the Appalachian Plateau province (Menendez and Robinson 1964). The mouth of Middle Grave Creek is 1.2 km above the confluence of Grave Creek and the Ohio River. The lower reaches of both creeks are inundated by Ohio River backwaters, a result of the U.S. Army Corps of Engineers' Hannibal Dam. During the impact assessment period (1982 - 1987) the Wildlife Resources Section of the Division of Natural Resources (WVWR) conducted four pretreatment stream surveys in the Middle Grave Creek drainage. The following summarizes these surveys, three of which were conducted in 1982 and one in 1987.

On 16 August 1982, two electrofishing (110 AC backpack shocker) surveys were conducted where channelization was being proposed. The Stations were: 1) at the 12th Street bridge, Moundsville; and 2) exactly 1.7 stream km above Station 1 along State Rt. 34. In addition, on 17 August 1982 a seining survey at a proposed impoundment site along State Rt. 34 was performed 2 km above Knoxville (Station 3; ca. 14 stream km upstream of Station 1). Twenty-eight species of fishes (see Robins et al. 1991 for nomenclature) were collected from these three sites and deposited into the WVWR fish museum at Elkins. The species and collection localities (station numbers in parenthesis) were : *Campostoma anomalum*, central stoneroller minnow (1,2,3); *Clinostomus elongatus* (3); *Cyprinella spiloptera*, spotfin shiner (1,2); *Cyprinus carpio*, common carp (1); *Ericymba buccata*, silverjaw minnow,(1,3); *Luxilus chrysocephalus*, striped shiner (1,2,3); *Nocomis micropogon*, river chub (1,2); *Notropis atherinoides*, emerald shiner(1,2); *N. rubellus*, rosyface shiner (1); *N. stramineus*, sand shiner (1); *Phenacobius mirabilis* (1); *Pimephales notatus*, bluntnose minnow (1,3); *Rhinichthys atratulus*, blacknose dace (1,2,3); *Semotilus atromaculatus*, creek chub (1,2,3); *Catostomus commersoni*, white sucker (1,2,3); *Hypentelium nigricans*, northern hog sucker (1,2,3); *Moxostoma erythrurum*, golden redhorse (1); *Noturus flavus*, stonecat (1,2); *Ambloplites rupestris*, rock bass (1); *Lepomis cyanellus*, green sunfish (1,2); *L. macrochirus*, bluegill (1); *L. megalotus*, longear sunfish (1,2); *Micropterus dolomieu*, smallmouth bass (1,2); *Etheostoma blennioides*, greenside darter (1); *E. caeruleum*, rainbow darter (1,2,3); *E. flabellare*, fantail darter (1,2,3); *E. nigrum*, johnny darter (3); and, *Percina caprodes*, logperch (1). Although the species composition was typical to the minor tributaries of the upper Ohio River (see Trautman 1981, Lee et al. 1980, Morrison and Cincotta in review), the collections of *Phenacobius mirabilis* from Station 1 and *Clinostomus elongatus* from Station 3 are noteworthy.

According to Trautman (1981), the plains-inhabiting *Phenacobius mirabilis* has gradually extended its range in the Ohio River drainage since the 1800's. He attributes its migration to an increase in sedimentation and siltation in the upper river. Its collection here represents an upstream distributional record for the Ohio River drainage (Rohde 1980, Trautman 1981). The record of *Clinostomus elongatus,* a glacial relict in this region, represents the first published West Virginia record of this species from waters outside the Monongahela River drainage (Gilbert 1980). The nearest record of this species relative to Marshall County is from Belmont County, Ohio (Trautman 1981); in West Virginia, its closest locality is Whiteday Creek of the Monongahela River, Marion County (unpubl. data; WVWR Fish Museum Cat. No. 401).

After learning that the SCS received funding for a 1.7 km channelization project on Middle Grave Creek, the WVWR on 13 August 1987 performed a rotenone survey in the proposed reach to quantify the preconstruction resources. This survey was located between Stations 1 and 2 and collected 19 species of fishes. All fishes taken were present in the 1982 surveys, with the exception of *Dorosoma cepedianum* (gizzard shad), *Ameiurus natalis* (yellow bullhead) and *Fundulus catenatus*. Although the former two fishes are native to this region, the collection of *F. catenatus* represents the first record of this species from West Virginia.

Fundulus catenatus is found primarily in the Mississippi River drainages of the central United States. This species usually inhabits Ozark and Ouachita mountain drainages west of the Mississippi River, and upland streams of the Tennessee, Cumberland and Green rivers to the east; disjunct populations occur in Mississippi and Indiana (Shute 1980). *F. catenatus* usually inhabits silt free streams of various sizes that have moderate to high gradients and predominantly clean sand, gravel, and/or rubble bottoms (Pflieger 1975). The collection locality here averaged 4.3 m (maximum of 8.2 m) in width and averaged 25.4 cm (maximum 50.8 cm) in depth. The substrate was composed primarily of bedrock (ca. 75%), rubble (20%), and boulders (5%), and was covered with a fine layer of silt. The discharge was estimated to be 0.06 m^3/s and water temperature was 23 C^o.

Seven specimens of *Fundulus catenatus* were collected. Their size range of 4.1 - 8.4 cm TL suggests the population is reproducing in Middle Grave Creek. Since the 1982 surveys did not yield *F. catenatus* (particularly from Stations 1 and 2), it is believed that this population is the result of human introduction. Although this species may have been missed during the 1982 surveys, it seems more logical to explain its presence as an aquarium or bait-bucket release, or possibly as an escapee from a farm pond. The hardiness of killifishes make them valuable to aquarium hobbyists as pets; fishermen for bait; and pond owners for mosquito control and forage (Pflieger 1975). Evidence to support these contentions is the fact that one of the authors (DAC) has observed non-indigenous fishes in state bait and aquarium shops that must have originated from other states and has been contacted by landowners for sources of killifishes for ponds. Moreover, the nearest records of the northern studfish to Marshall County are from central Indiana (Shute 1980) and eastern Kentucky (Burr and Warren 1986).

Acknowledgments

Appreciation is extended to the Soil Conservation Service, particularly Lynn Shutts and Gary Gwinn for their assistance in the field collections. Mr. Dan Rice (Ohio Department of Natural Resources), Dr. Tim Cavender (Ohio State University) and Dr. Jay Stauffer (Pennsylvania State University) provided fish distribution information relative to upper Ohio River fishes. Special thanks is provided to Traci Phillips and Patty Fordyce for typing the manuscript.

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Updates on the Vascular Flora of West Virginia. VI.

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Abstract

On-going studies at the West Virginia University Herbarium (WVA) have uncovered nine species of vascular plants as new or noteworthy additions to the flora of West Virginia (based on Strausbaugh and Core, 1978). Unless otherwise noted, the nomenclature and distribution information follows Fernald, 1950.

Discussion

The new species are as follows:

LILIACEAE. *Zigadenus elegans* subsp. *glaucus* (Nutt.) Hulten. Pendleton County: Rodney L. Bartgis s.n., July 29, 1987. A species to our north and west, this is a southeastern range extension.

IRIDACEAE. *Iris versicolor* L. Jefferson County: Rodney L. Bartgis s.n., June 29, 1984. This plant is a native to our immediate north and is therefore to be expected.

CARYOPHYLLACEAE. *Gypsophila elegans* Bieb. Jefferson County: Rodney L. Bartgis 1137, G. R. Welsh and C. Reider, November 1, 1987. This species is cultivated and is spreading to roadsides and waste places. It is native to Eurasia.

BRASSICACEAE. *Lobularia maritima* (L.) Desv. Jefferson County: Rodney L. Bartgis 1134, G. R. Welsh and C. Reider, November 1, 1987. An introduction from Europe, this species is cultivated and is becoming naturalized as an escape.

BRASSICACEAE. *Lunaria annua* L. Pendleton County: Rodney L. Bartgis s.n., May 2, 1984. According to Tutin, et al, this species is native only to southeastern Europe and possibly Italy. Here the species is planted and often escapes.

EUPHORBIACEAE. *Croton capitatus* Michx. Lewis County: Jamey Darlington s.n., August 24, 1989. We are in the midst of this plant's range and it is, therefor, to be expected.

CISTACEAE. *Helianthemum bicknellii* Fern. Pocahontas County: Roy B. Clarkson 3341, August 8, 1959, Nicholas County: Bob Richardson s.n., May 25, 1986, August 3, 1986 and September 1, 1986. This plant is to be expected since we are in the midst of it's range.

SCROPHULARIACEAE. *Linaria moroccana* Hook.f. Jefferson County: Rodney L. Bartgis, G. R. Welsh and C. Reider s.n., November 1, 1987. This species has been introduced from North Africa for cultivation and is escaping and becoming naturalized.

ASTERACEAE. *Hieracium florentinum* All. Randolph County: Sam Norris s.n., August 1, 1989. This species is naturalized from Europe and is found all over the northeastern United States and is to be expected.

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Leaf Shredding, Under Laboratory Conditions, by Naiadal *Peltoperla tarteri* Stark and Kondratieff (Plecoptera: Peltoperlidae)

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Abstract

Naiadal *Peltoperla tarteri* were placed in containers with aerated stream water at 15° C and autumn-shed leaves from 12 species of trees (American beech, green ash, basswood, cucumber magnolia, pignut hickory, red maple, red oak, sugar maple, sycamore, tulip poplar, white oak, and yellow birch). Additionally, naiads were exposed to different leaf combinations to determine preferential consumption. After two weeks, naiadal *Peltoperla* were weighed and ashed in a muffle furnace at 550° C. Leaves were dried in an oven and weighed. Naiads fed selectively on the cuticle, epidermis, and mesophyll of the leaves. Cucumber magnolia, hickory, tulip poplar, green ash and sugar maple were the most preferred leaves; American beech, white oak, and sycamore were the least preferred. The average tannin and lignin content of the water with the feeding *Peltoperla* was higher than the controls, apparently due to increased leaching from the finely ground leaf material in the fecal pellets.

Introduction

In low-order woodland streams, the major source of detritus is autumnal leaf-fall which provides both refugia and food resources for stream micro- and macroconsumers. Benthic shredders play a prominent role in the processing of this large-particle detritus, facilitating energy flow in streams both through direct conversion of detrital energy into shredder biomass and by production of fine particulate organic matter (FPOM) (Perry et al., 1987).

The stonefly, *Peltoperla tarteri*, is a stream detritivore which prefers crenon habitats of the higher, central Appalachian Mountains. Naiads of this species were found consistently in leaf packets accumulated in current areas of a first order stream located in Fayette County, West Virginia. The purpose of this study was to present observations on the feeding habits of the shredder, *P. tarteri*, including some of their preferences and amounts of leaf material consumed.

Materials and Methods

P. tarteri naiads were collected from the study site at Big Hollow in November 1988. The hand-picked method was used and naiads were transported to the laboratory in styrofoam buckets with stream water and leaves. Naiads were placed in glass bowls containing stream water and maintained in a biochemical oxygen demand incubator. The water temperature was maintained at 15°C. The water was constantly aerated and leaves taken from the stream were added to the bowls as a food source. An automatic timer was installed to supply a light regime similar to ambient stream conditions during that time of the year. Also taken from the site were several liters of stream water which were kept in plastic containers and aerated in the laboratory. At the same time, freshly fallen leaves of several different species of trees were also collected. Twelve species were chosen which represented the dominant trees present at the Big Hollow study site. The leaves were washed in the laboratory, and preleached. After 10 days, the leaves were removed from the water and placed in an oven to dry for 24 hours at 95° C. They were then removed from the oven and stored in desiccators with $CaSO_4$ until a constant dry weight was reached. The leaves were separated by species and ca. 500-mg portions of each leaf were measured on a Sartorius scale. Three groups representing four species of trees were randomly chosen. Each group contained five experimental containers and one control container. The plastic containers were approximately 20 X 28 X 8 cm. Nineteen hundred milliliters of stream water and the leaves were added to the containers. Group 1 contained leaves from white oak, *Quercus alba* L.; yellow birch, *Betula lutea* Michx. f.; pignut hickory, *Carya glabra* Mill. and tulip poplar, *Liriodendron tulipifera* L. Group 2 contained leaves from basswood, *Tilia americana* L.; cucumber magnolia, *Magnolia acuminata* L.; sycamore, *Platanus occidentalis* L. and red maple, *Acer rubrum* L. Group 3 contained leaves from red oak, *Quercus rubra* L.; green ash, *Fraxinus lanceolata* Borkh.; American beech, *Fagus grandifolia* Ehrh.; and sugar maple *Acer saccharum* Marsh. Leaves were soaked for 24 hours in covered containers in the biochemical oxygen demand incubator. To keep the leaves separated in the four corners of the containers, small washed pebbles were placed over each leaf portion. After the soaking, 15 naiads were added to each experimental container in all three groups. The experiment ran for two weeks in the biochemical oxygen demand incubator. During this time, the containers were checked daily to remove any dead naiads or exuviae which, if found, were dried and ashed in a muffle furnace to correct the final weights at the termination of the feeding experiment. The naiads did not deplete any of the weighed leaf portions, therefore, replenishment of the food sources was not necessary in this experiment. The naiads and leaves were removed from all containers following a two week run. Naiads were sacrificed in boiling water. The leaves and naiads were dried in an oven at 95^{o} C for 24 hours and were then transferred to desiccators for several days. The stream water was filtered to remove frass using Whatman No. 1 filter paper and vacuum filtration. The frass was dried on the filter paper in an oven at 95^{o} C for 48 hours.

Stream water was tested for tannin and lignin content using a Hach DR/2000 Direct Reading Spectrophotometer Model-44800-00. This test is not specific for tannin and lignin and is, therefore, expressed as tannic acid-like substances due to the possible presence of other reducing materials. The method followed was as described in the Hach DR/2000 Spectrophotometer Handbook for tannin and lignin testing. The naiads and leaves were weighed on a Sartorius scale. Naiads were ashed in a Thermolyne type 1400 muffle furnace at 550 ^{o}C for an ash-free dry weight. Finally, they were returned to the oven for 24 hours, transferred to desiccators for 24 hours, and then weighed. The average amount of leaf material eaten (dry weight in mg) per mg *P. tarteri* naiads (ash-free dry weight) was determined for each species of tree. These data were treated using the method of M rankings as reported by Norman and David (1969) to determine significantly high or low preferences for different leaves by the naiads.

Results and Discussion

When placed in the containers with the leaves, *P. tarteri* naiads congregated on the blades of certain leaves. The leaves on which they congregated are presumed to represent the most preferred food source. The naiads fed on the cuticle, epidermis and mesophyll of the leaves and avoided the xylem and phloem

Table 1. Average amount of leaf material (mg) eaten per milligram of *Peltoperla* (ash free dry wt) naiads in a 2 week period (weights based on dry-weight determinations).

Type of Leaf		Amount of material eaten (mg) per mg*Peltoperla*
	Group 1	
White Oak	(WO)	0.5168
Yellow Birch	(YB)	1.2041
Pignut Hickory	(PH)	2.3694
Tulip Poplar	(TP)	2,3842
	Average Total	1.6186
	Group 2	
Basswood	(B)	1.7167
Cucumber Magnolia	(CM)	2.9389
Sycamore	(S)	0.2092
Red Maple	(RM)	1.2065
	Average Total	1.5178
	Group 3	
Red Oak	(RO)	1.0648
Green Ash	(GA)	2.6335
American Beech	(AB)	0.9835
Sugar Maple	(SM)	2.1517
	Average Total	1.7084

Of the leaves in Group 1 (white oak, yellow birch, pignut hickory, and tulip poplar, tulip poplar and pignut hickory were the most preferred by the naiads (Table 1). White oak was the least preferred. Preference for the hickory was significantly high at the 0.05 confidence level, and oak was significantly low at the 0.05 confidence level (Table 2). Tulip poplar and yellow birch fell between these extremes. Pignut hickory leaves were preferred in 3 of 5 containers, with tulip poplar leaves preferred in 2 containers, White oak was least preferred in 3 containers, followed by yellow birch in 2 containers.

Table 2. Ranking of leaves according to consumption by *P. tarteri* naiads (mg dry weight leaf material/mg ash free weight of naiad). Max ranking sum = 20; min ranking sum = 18 (Norman and David, 1969).

Leaf Groupings	RANKING			
1	White Oak	Yellow Birch	Pignut Hickory	Tulip Poplar
	7 d	8	18 c	17
2	Basswood	Cucumber Magnolia	Sycamore	Red Maple
	14	20 a	5 b	11
3	Red Oak	Green Ash	American Beech	Sugar Maple
	9	19 c	6 d	16

Leaves in Group 2 included basswood, cucumber magnolia, sycamore, and red maple. Cucumber magnolia leaves were most preferred in all 5 containers, and were significantly high at the 0.01 confidence level (Table 1, 2). The least preferred in 5 containers was sycamore which was significantly low at the 0.01 confidence level. Basswood and red maple were between these extremes.

Group 3 consisted of red oak, green ash, American Beech, and sugar maple. Green ash was preferred in 4 of 5 containers and was significantly high at the 0.05 confidence level (Table 1, 2). American beech was least preferred in 4 of 5 containers and was significantly low at the 0.05 confidence level. Falling between these extremes were sugar maple, the most preferred in 1 of 5 containers, and red oak, the least preferred in 1 of 5 containers.

Tannin and lignin compounds (expressed as tannic acid) analysis on filtered water from the experimental containers revealed a higher average tannic acid content than in the corresponding controls. The water from feeding experiments in Group 1 average 1.65 mg/L tannic acid content versus 1.20 mg/L for the control. In Group 2, the average for the water from experimental containers was 1.96 mg/L versus 1.80 mg/L for the control. Group 3 had an average of 1.60 mg/L tannic acid content for the experimental waters versus 1.50 mg/L for the control. The tannic acid content of the original stream water used in the experiments was 0.0 mg/L.

Leaf packs are subject to size degradation through leaching, physical fragmentation, microbial metabolism, and animal feeding (Short and Maslin, 1977). Golladay (1981) introduced the leaf processing continuum in that leaves become conditioned in a stepwise manner related to their resistance to microbial metabolism. Hynes (1963) and Kaushik and Hynes (1968) reported that although much of the feeding of aquatic invertebrates on leaf material may be direct, the possible importance of bacteria and fungi should not be overlooked. Anderson and Cummings (1979) went as far to say that the relationship between organic matter and detritus is so intimate that independence is never observed in nature.

Kaushik and Hynes (1971) reported that fungi are far more important in the initial period of leaf decay than bacteria. It seems that the bacteria rely on the fungal "conditioning" of leaf matrix to release labile compounds through the action of extracellular enzymes. Reasons are obscure, but after the first eighteen weeks fungal activity declines and bacteria concentrations increase. Perhaps the bacteria are more capable of out-competing the fungi for soluble compounds released by fungal activity during this period by being able to more closely associate with fungal mycelia (Suberkropp et al., 1976). The ultimate role of the microbes, as a whole, is to condition the leaves through their own metabolism into intermediates of plant polymers (cellulose) which can be more readily metabolized by shredders. These insects lack the enzymatic capabilities to digest initial plant polymers. Furthermore, the microbial biomass may well provide more complete forms of nitrogen or other nutritional requirements (Cummings, 1979).

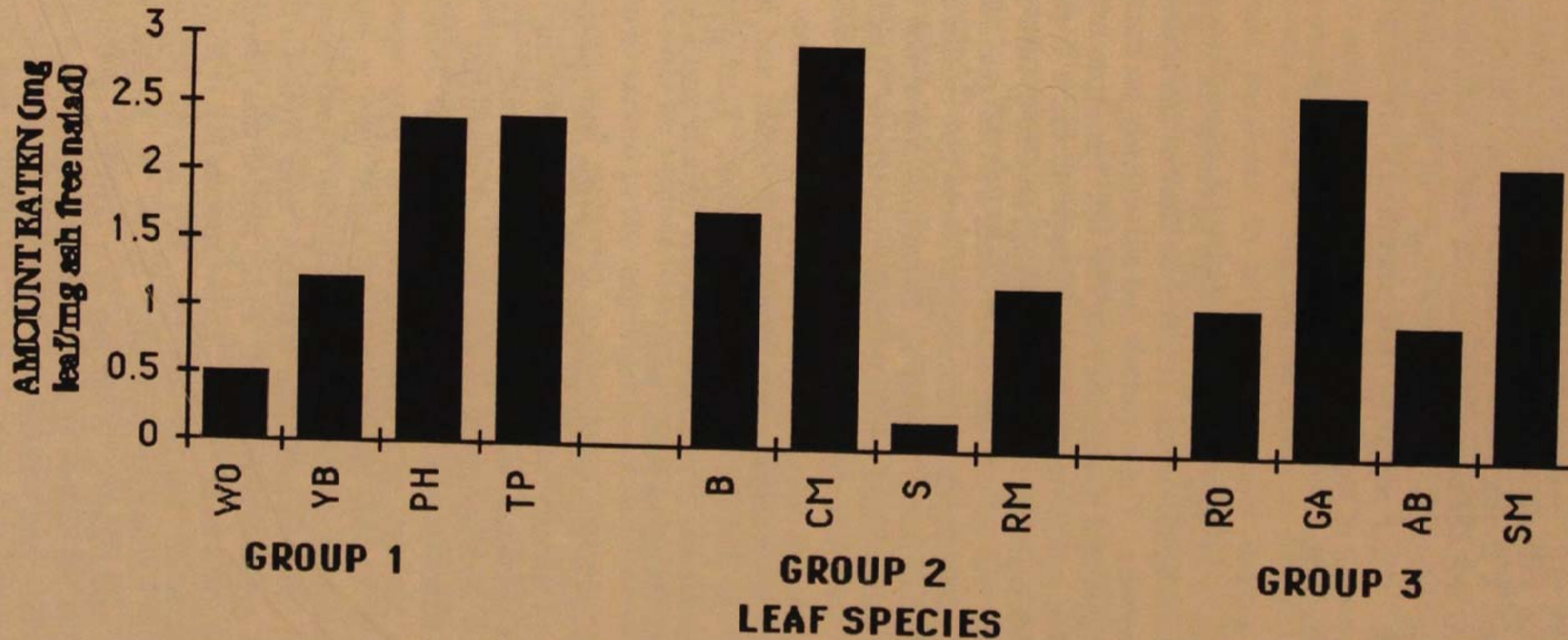

Figure 1. Amount of leaf material consumed by *P. tarteri* naiads (mg dry leaf weight/mg ash free naiads.

Group 1	White oak (WO, Yellow Birch (YB), Pignut Hickory (PH), Tulip Poplar (TP)
Group 2	Basswood (B), Cucumber Magnolia (CM), Sycamore (S), Red Maple (RM)
Group 3	Red Oak (RO), Green Ash (GA), American Beech (AB), Sugar Maple (SM)

The importance of microbial activity in the degradation of organic matter must be considered. However, the contribution of shredding insects plays a much more significant role. Microbial metabolism can occur in the absence of shredders, but an increase of 20% in the processing occurred in the presence of the stonefly *Pteronarcys californica*. This suggests that shredders are of great importance in the processing of leaf litter in a stream ecosystem with regard to nutrient availability of various collector species (Short and Maslin, 1977).

Ward and Woods (1986) compared fine particulate organic matter (FPOM) produced by microbial activity to that of the stonefly shredder *Tallapera cornelia*. These naiads fed selectively on cuticle, epidermal cells, and mesophyll tissue, leaving the leaf venation intact which strongly resembled processing by fungi. Fine particulate organic matter from these naiads containined 30% less lignin and 50 to 60% less cellulose than the whole leaves. On the other hand, FPOM generated from a nonselective feeder. *Tipula abdominalus*, was not noticeably macerated, rather egestion resulted only in fragmentation of the leaf material. Lignin, cellulose, and hemicellulose are three chemical compounds difficult for microbes and invertebrates to process. *Tallaperla cornelia* naiads fed selectively on the cuticle, epidermis, and mesophyll, all of which may contain less amounts of lignin and fiber than other portions of the leaf (Ward and Woods, 1986). This type of selective feeding was observed in *Peltoperla tarteri* naiads and also by *Tallaperla maria naiads* (Wallace et al., 1970).

Peltoperla naiads in this study preferred certain leaf species in all three groups. Pignut hickory was consistently preferred along with tulip poplar, green ash, cucumber magnolia. and basswood. These results generally agree with previous studies on leaf shredding. In a similar experiment, Wallace et al. (1970) found that naiads of *Tallaperla maria* also preferred hickory, and tulip poplar over other species. Smock and McGregor (1988) found that hickory had a higher nutritional quality than other species. Anderson (1979) found basswood to be a high quality food source, and Kaushik and Hynes (1971) reported that ash was preferred over oak. Tulip poplar was preferred over birch according to Irons et al. (1988). These species are referred to as being quickly processed. On the average, they are all higher in nitrogen and soluble carbohydrates and lower in amounts of polyphenols, tannins, and lignins. Nitrogen is a limiting resource to microbes as well as the shredders that feed upon them. Irons et al. (1988) reported that condensed tannins may decrease the availability of cell wall and membrane-bound protein to these organisms. Suberkropp et al. (1976) found that plant phenolics form complexes with proteins in leaves near the end of the growing season and these compounds effectively inactivate enzymes of insects and microorganisms. Also, these compounds combine with lignin and cellulose to form stable complexes that reduce the nitrogen source to insects.

Sugar maple and red maple were intermediates chosen in Groups 2 and 3. Maples are prone to microbial attack and showed a great increase in nitrogen content during prolonged processing according to Kaushik and Hynes (1971). Red maple was also an intermediate in the Wallace et al. (1970) experiment.

P. tarteri naiads avoided leaves of sycamore, red oak, white oak, yellow birch, and American beech. These leaves are slowly processed and contain high amounts of polyphenols, tannins, and lignins (Ward and Woods, 1986). Naiads of *Tallaperla maria* also avoided the oaks, American beech, and sycamore (Wallace et al., 1970). Kaushik and Hynes (1971) found beech leaves decompose very slowly. Harrison (1971) found oaks high in tannins. Irons et al. (1988) found birch to be least preferred after alder, poplar, and willow.

The higher tannin and lignin content of the water with the feeding naiads is probably due to increased leaching from the fecal pellets. The finely ground leaf material in the fecal pellets would probably be subject to more leaching than the intact leaves. This was also observed in the experiment by Wallace et al. (1970). The finely ground leaf material in the fecal pellets would then be carried downstream by water currents and made available as food to downstream filter or detritus feeders, as well as bacteria and other microorganisms (Wallace et al., 1970). Thus, the contribution of individuals of *P. tarteri* and other shredding insects may be slight.

Although the availability of both quickly and slowly processed leaf litter was sustained, because of the relatively short period of processing time in this experiment, the more slowly processed leaves were not conditioned. It would be interesting to see the results of an extended run and to see the effects of different leaf combinations. Sweeney and Vannote (1986) reported temperature exerted a greater influence on larvae growth, mortality, and production of the stonefly *Soyedina carolinesis* than did changing the leaves that the larvae were eating. Also, another area of interest that should be investigated further is the possibility that the age of the naiads and different combinations of leaves may influence feeding habits. Naiads in this study were half- to full-grown, but the feeding habits of early instars may differ from the more mature ones.

Acknowledgments

We express our thanks to Tom Weaks for the use of a muffle furnace, and to Lu Ann South for typing the manuscript.

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Discovery of the Central Mudminnow, *Umbra limi* (Kirtland), in the Greenbottom Wildlife Management Area, Cabell County, West Virginia

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Abstract

The central mudminnow, *Umbra limi* (Kirtland), is reported for the first time from West Virginia. The mudminnow was discovered in the Greenbottom Wildlife Management Area in Cabell County. This account represents an important range extension from the nearest Ohio records in Hocking County and the first record from southern Ohio River Drainages east of the Tennessee River. It was collected in shallow waters of Greenbottom Swamp over a muddy substrata in submerged vegetation.

Discussion

The central mudminnow, *Umbra limi* (Kirtland), was found at the Greenbottom Wildlife Management Area (GWMA) in Cabell County, West Virginia. Several investigators, including Raney (1947), Denoncourt et al.(1975), Cincotta and Miles (1982), Stauffer et al.

(1982), Cincotta et al.(1986), and Cincotta (1988), have summarized the state's ichthyofaunal literature. Although 166 fish species among 21 families are known to occur in West Virginia (Cincotta, 1988), no verifiable records of the family Umbridae had been documented.

Umbra limi is found from southern Manitoba, the Great Lakes, and St. Lawrence drainage south to northern Arkansas and northwestern Tennessee, and western Kentucky; western Pennsylvania west to eastern South Dakota (Scott and Crossman, 1973; Clay, 1975; Burr and Warren, 1986; Trautman, 1981). Throughout their range, mudminnows usually inhabit ponds, bogs, swamps, lakes and pools of sluggish streams with submerged vegetation and muddy bottoms (Hubbs and Lagler, 1947; Niering, 1985). Although its habitats are often degraded or destroyed by ditching, draining, and filling throughout its North American distribution, Gilbert (*in* Lee et al., 1980) indicated this species is still common, particularly in the northern part of its range. Regionally, the activities of humans have reduced the mudminnow's distribution (Trautman, 1981).

The GWMA (38^{o} 35' 35"N, 82^{o} 14' 55"W) is located along the Ohio River near Homestead, Cabell County, West Virginia. The area (ca. 338 ha), which is leased to the State by the U. S. Army Corps of Engineers as mitigation for Gallipolis lock construction impacts, was purchased primarily for its wetland habitat (ca. 57 ha). Although the main swamp is natural, it is known to have been heavily drained during the 1930's (Furry, pers. comm.). The average depth of the wetland varies seasonally from 0.46 to 1.23 m, and rarely drops below 0.5 m in the inner swamp (Furry, 1978). The wet area is dominated by buttonbush (*Cephalanthus occidentalis*). Duckweeds (*Lemna* spp., *Spirodella polyrhiza* and *Wolffia* spp.) are common floating plants throughout the area of standing water. Greenbottom is the largest swamp in southwestern West Virginia and the third largest statewide.

In the spring of 1989, while sampling wetlands for amphibians, Thomas Pauley (Marshall University) captured large numbers of the central mudminnow in minnow traps on the GWMA. His traps were located in flooded lands immediately adjacent to the main swamp. Subsequent sampling with minnow traps and dipnets by Marshall University personnel in October and November yielded 52 specimens (32.0 - 98.0 mm SL) representing several age classes. Capture depths were shallow (7.6 - 60.0 cm) over a muddy substrate in submerged vegetation. The grass pickerel, *Esox americanus*, was also captured in the traps with the central mudminnow. A representative sample of *Umbra limi* was deposited in the West Virginia Department of Natural

Resources, Wildlife Resources Division Fish Museum, at Elkins (Cat. No. WVWR-764).

Raney (1947) anticipated the mudminnow's presence in the state only as a rare possibility, probably due to known records in Ohio near West Virginia's northern panhandle. Denoncourt et al. (1975) and Cincotta and Miles (1982) also expected it to be found in state waters, and Pearson and Krumholz (1984) felt it could possibly occur in the main channel Ohio River. *Umbra limi* may have been collected in the Ohio River of West Virginia near Point Pleasant, Mason County, in 1980 (Geo-Marine, 1982). This record, however, could not be substantiated by one of the authors (DAC) nor by Pearson (pers. comm.). Thus, present account represents the first verifiable record of the central mudminnow in West Virginia (Cincotta, 1988), and the only southern Ohio River drainage record east of the main channel Tennessee River (Gilbert *in* Lee et at., 1980; Cooper, 1983; Burr and Warren, 1986).

The collection locality for the central mudminnow reported herein lies more than 100 km southeast of the nearest record found in Hocking County, Ohio, an unglaciated area of the state (Trautman, 1981). According to Trautman (1981), this species is found primarily in the glaciated portions of Ohio. The status of the GWMA population is presently regarded as native. This population has probably been overlooked by past investigators (e.g. Addair, 1944; Hardman et al. 1981; Stauffer et al., 1989), due to lack of sampling in small, sluggish waters and difficult swamp habitat. The species' ability to survive in marginal habitat (e. g. ditches) and tolerate environmental perturbations (Becker, 1983), lend credence to the thesis that this relict population found refuge along the Ohio River as habitat destruction progressed (Trautman, 1981). The possibility that this species was introduced, however, cannot be ignored. Becker (1983) indicated that fishermen value this species because of its hardiness in a bait bucket and on a hook. Due to the nearness of the GWMA to the Ohio River and the tendency of this species to migrate during high waters (Trautman 1981), it is feasible that it was introduced to the river by fishermen and then migrated into the swamp during a storm.

Investigations by Marshall University personnel are being conducted on the ecology and taxonomy of the central mudminnow. Ecological studies will focus on its reproductive biology (e. g. gonadal somatic ratio, fecundity), with particular attention given to spawning activities in the marsh during high water. Morphological and electrophoretic analysis will be used to determine the relationship of the Greenbottom population from the unglaciated area to *Umbra limi* from a glaciated area, and to *U. pygmaea* (DeKay) from the Atlantic slope. Additionally, comprehensive ichthyofaunal surveys of the GWMA and other mudminnow habitats adjacent to the Ohio River will be conducted to substantiate the presumed native status and to establish conservation recommendations for the West Virginia population.

Acknowledgments

We wish to express our gratitude to the U. S. Army Corps of Engineers, Huntington District, particularly John Furry and Edward Goodno, for providing materials and information relative to the Greenbottom Wildlife Management Area. T. K. Pauley (Marshall University, W. D. Pearson (University of Louisville), D. Rice (Ohio Department of Natural Resources), and T. M. Cavender (Ohio State University) graciously made regional distribution data for the central mudminnow available to us. Additionally, we thank Bob Miles, Wildlife Division, West Virginia Department of Natural Resources, for assistance in this project. Our appreciation is also extended to Traci Phillips and Lu Ann South for manuscript preparation.

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New Records of Caddisflies (Tricoptera) from West Virginia

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Abstract

Nine Species of caddisflies from three families are added to the known fauna of West Virginia. Known ranges of *Ceraclea ancylus* Vorhies, *Hydroptila amoena* Ross, *H. waubesiana* Betten, *Ochrotrichia shawnee* (Ross), *Orthotrichia aegerfasciella* (Chambers) *O. cristata* Morton, *Oxyethira coercens* Morton, *Polycentropus centralis* Banks, and *Stactobiella palmata* (Ross) are extended into the state. The number of caddisfly species now known from West Virginia is 185.

Introduction

Several investigations, including Ross (1944), Applin and Tarter (1977), Hill et at. (1977, 1978), Hill and Tarter (1978), Tarter and Hill (1979, 1982), Nugen and Tarter (1983), Tarter and Donahoe (1988), Glover and Tarter (1989), and Tarter (1990), have reported caddisfly records from West Virginia. Tarter (1990) recorded 176 species, representing 15 families and 60 genera, from West Virginia. Hydropsychidae ranked first in number of species (39), followed by Limnephilidae (30), Leptoceridae (27), Hydroptilidae (10), Rhyacophilidae (14), and Polycentropodidae (13); the additional nine families accounted for 37 species. In this investigation, we are recording an additional nine species, representing three families (Hydroptilidae, Leptoceridae, Polycentropodidae), bringing total state list to 185 species of caddisflies. Included are important range extensions for *Ochrotrichia shawnee, O. cristata, Oxyethira coercens* and *Stactobiella palmata.*

Results

Hydroptilidae

Hydroptila amoena Ross

West Virginia distribution: Lewis Co., Stonewall Jackson Lake, 13 July 1988; 1 male.

Goegraphic range: Thirteen states (AL, AR, IL, KY, MN, NE, NH, OH, OK, SC, TN, VA, WI) (Brigham et al., 1982; Etnier and Schuster, 1979; Harris, 1986; Huryn and Foote, 1981; Longridge and Hilsenhoff, 1973; Morse and Blickle, 1953; Parker and Voshell, 1981; Resh, 1975; Ross, 1984; and Unzicker et al., 1970).

H. waubesiana Betten

West Virginia distribution: Kanawha Co., Winfield Locks, Kanawha River, 5 August 1981; 2 males. Kanawha Co., Marmet Locks, Kanawha River, 10 August 1981: 1 male.

Geographic range: Fifteen states (AL, AR, DE, IL, IN, KS, KY, MI, MN, NC, NY, OH, SC, VA, WI) (Betten, 1934; Brigham, 1934; Brigham et al., 1982; Etnier, 1965; Harris, 1986: Hamilton and Schuster, 1978; Lake, 1984; Leonard and Leonard, 1949; Longridge and Hilsenhoff, 1973; McElravy and Foote, 1978; Parker and Voshell, 1981; Resh, 1975; Ross, 1944; and Unzicker, 1970).

Ochrotrichia shawnee (Ross)

West Virginia distribution: Braxton Co., Burnsville Lake, Little Kanawha River, 22 June 1981; 1 male/2 females.

Geographic range: Five states (AL, IL, KY, NH, TN) (Edwards, 1966; Harris, 1986; Morse and Blickle, 1953; Resh, 1975; and Ross, 1944).

Orthotrichia aegerfasciella (Chambers)

West Virginia distribution: Taylor Co., Tygart River Lake, 17 August 1988; 5 males.

Geographic range: Eleven states (AL, DE, KY, KS, MA, NC, OH, SC, TN, VA, WI) (Brigham et at., 1982; Etnier and Schuster, 1979; Hamilton and Schuster, 1978; Harris, 1986; Lake, 1984; McElravy and Foote, 1978; Neves, 1979; Parker and Voshell, 1981; Resh, 1975; and Steven and Hilsenhoff, 1984).

O. cristata Morton

West Virginia distribution: Taylor Co., Tygart River Lake, 13 July 1988; 1 male.

Geographic range: Fourteen states (AL, DE, IL, KS, KY, MI, MN, NC, OK, SC, TN, TX, VA, WI) (Brigham et al, 1982; Etnier, 1965; Etnier and Schuster, 1978; Hamilton and Schuster, 1978; Harris, 1986; Lake, 1984; Leonard and Leonard, 1949; Longridge and Hilsenhoff, 1977; Parker and Voshell, 1981; Resh, 1975; and Ross, 1944).

Oxyethira coercens Morton

West Virginia distribution: Taylor Co., Tygart River Lake, 14 July 1988; 1 male.

Geographic range: Seven states (AL, IL, IN, MN, NY, OK, VA) (Betten, 1934; Etnier, 1965; Harris, 1986; Parker and Voshell, 1982; and Ross, 1944).

Stactobiella palmata (Ross)

West Virginia distribution: Nicholas Co., Gauley River below Summersville Dam; 6 July 1981; 319 males.

Geographic range: Twelve states (AL, IL, KS, KY, ME, NH, NC, OK, SC, TN, VA, WI) (Brigham et al., 1982; Etnier and Schuster, 1979; Hamilton and Schuster, 1978; Harris, 1986; Longridge and Hilsenhoff, 1973; Parker and Voshell, 1981; Resh, 1975; and Ross, 1944).

Leptoceridae

Ceraclea ancylus Vorhies

West Virginia distribution: Taylor Co., Tygart River Lake, 13 July 1988; 12 males.

Geographic range: Fifteen states (AR, DE, GA, IL, KY, MA, MN, NC, NY, OH, OK, SC, TN, VA, WI) (Betten, 1934; Brigham et al., 1982; Edwards, 1966; Etnier, 1965; Lake, 1984; Longridge and Hilsenhoff, 1973; Neves, 1979; Parker and Voshell, 1981; Resh, 1975, 1976; Ross, 1944; and Unzicker et al., 1970).

Polycentropodidae

Polycentropus centralis Banks

West Virginia Distribution: Taylor Co., Tygart River Lake, 13 July 1988; 1 male.

Geographic range: Twelve states (AL, AR, IL, KS, MO, NY, OH, OK, PA, TN, TX, WI) (Etnier and Schuster, 1979; Hamilton and Schuster, 1980; Lago and Harris, 1987; Peterson and Foots, 1980; Steven and Hilsenhoff, 1984; Ross, 1944; and Unzicker et al., 1970).

Acknowledgments

The authors are grateful to Dr. Oliver S. Flint, Jr. for identification of certain adults and to Lu Ann South for typing the manuscript.

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Ecology Section

Breeding Ecology of the Golden-winged Warbler (*Vermivora chrysoptera*) in Raleigh County, West Virginia

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Abstract

The breeding ecology of the Golden-winged Warbler (*Vermivora chrysoptera*) was studied in Raleigh County, West Virginia during the breeding seasons (April through August) in 1987, 1988, and 1989. First-seen spring dates, last-seen fall dates, and number of breeding pairs were recorded in the study area during each breeding season. Data were collected on habitat availability and preference, nest building, egg laying, length of the incubation period, care of fledglings, location of nests, nest dimensions, feeding habits, behavior after young leave the nest, locality of birds after breeding and nesting activity, presence of unpaired birds, and effects of habitat destruction on breeding activity.

Introduction

The Golden-winged Warbler, *Vermivora chrysoptera*, is one of 57 members of the North American wood warblers belonging to the Family Emberizidae, Subfamily Parulinae (Farrand, 1983). Adult males are neutral gray with a bright yellow crown and wing patch. Other diagnostic characteristics are a black throat and ear patch. Adult females are similar, but have a duller yellow crown, and gray facial patterns instead of black. Golden-winged Warblers inhabit brushy fields, overgrown pastures, openings in deciduous forests, woodland edges, and dry hillside thickets. Their range extends from southeastern Manitoba, central Ontario, northern Michigan, and southern New

England south to Iowa, northern Illinois, Ohio, Pennsylvania, and in the Appalachians to northern Georgia (Farrand, 1983).

According to Harrison (1984), the increasing decline of the Golden-winged Warbler throughout its range is well documented in the literature, and appears to be correlated with the range expansion and an increasing population of the Blue-winged Warbler, *V. pinus*. Presently, Blue-winged Warblers are expanding their range northward and eastward into the range of Golden-winged Warblers. Gill (1980) indicated that arrival and colonization of Blue-winged Warblers into populations of Golden-winged Warblers brings about local extinction within 50 years or less.

Theories explaining the replacement of Golden-winged Warblers by Blue-winged Warblers are varied and interactions between these two species are complex. Confer and Knapp (1981) offered a current explanation for the replacement of Golden-winged Warblers by Blue-winged Warblers in addition to the ecological competition (Ficken and Ficken, 1968c) and genetic introgression (Short, 1963; Ficken and Ficken, 1968a; Gill, 1980) theories proposed in the past. They concluded that Blue-winged Warblers can adapt to more generalized habitat types than the more specialized Golden-winged Warbler, whose habitat exist for only a brief period of time during succession of plants from abandoned farmlands to brushy fields. They found Golden-winged Warblers require the shrub stage of successional habitat to nest; whereas, Blue-winged Warblers use both earlier and later stages of plant succession. Golden-winged Warblers usually occupy higher and drier areas than Blue-winged Warblers, although they overlap broadly in habitat in both allopatric and sympatric situations (Ficken and Ficken, 1968c; Farrand, 1983; Harrison, 1984). The purpose of this study was to examine the breeding ecology, habitat preference, and status of the Golden-winged Warbler in an area where Blue-winged Warblers are not known to occur.

Materials and Methods

STUDY AREA.- A 168 ha area was studied near Metalton, Raleigh County, West Virginia. The area is in the Allegheny Plateau Physiographic Province, characterized by floodplain and upland deciduous forests interspersed by overgrown fields. Forests are dominated by oak (*Quercus* spp.), and hickory (*Carya* spp.). Some fields are dominated by goldenrod (*Solidago* spp.), blackberry (*Rubus* spp.), and multiflora rose (*Rosa multiflora*). Others are in later stages of succession with white pine (*Pinus strobus*), black locust (*Robinia pseudo-acacia*), choke cherry (*Prunus virginiana*), sumac (*Rhus* spp.) and sassafras (*Sassafras albidum*) interspersed with brushy thickets. The average elevation is 691 m.

Figure 1. Female Golden-winged Warbler on nest.

PROCEDURE.- The study area was divided into three districts based on habitat types present. The Metalton Bottom district is characterized by bottomland overgrown fields, streamside thickets

(Miller's Camp Branch), and marshes. Cochran Farm district is characterized by dry hillside thickets with pitch pine (*P. rigida*) and a swamp of mostly maple (*Acer* spp.), black locust (*Robinia pseudo-acacia*), and willow (*Salix* spp.). The swamp and dry hillside thickets have been altered by mine disturbances forming a brushy habitat inhabited by Golden-winged Warblers. The Lilly Mountain district consists of openings in deciduous forests and old field habitats along deciduous forest edges.

POPULATION SIZE, HABITAT SELECTION, AND TEMPORAL MEASUREMENTS.- Field trips were made almost daily during early April through late August for three consecutive breeding seasons (1987 - 1989) to determine arrival dates, number of birds in study area, and last seen fall dates. Field trips started at 0600 - 0800 and lasted throughout the day. A singing-male census was performed in late April through July and observations were made to determine habitat preference and number of breeding pairs during each breeding season. I examined the effects of habitat destruction on the breeding activity in relation to number of territorial males present during each season. The number of singing males per year is a good indicator of habitat availability and/or population size.

SPATIAL MEASUREMENTS.- Territorial size was determined by measuring the amount of area covered by territorial males during singing and defending of territories. Defense of territories was evident by the fact that males sang to attract mates, patrolled their territories, and chased away intruding males. Territories were roughly mapped by observing the positions of males over a period of several weeks. Song playback facilitated territorial size determination since males often arrived upon hearing another male's song in their territory. Once males established territories and pairs formed, observations were made throughout the breeding seasons to determine if unpaired birds existed in the study area. Paired territorial males were distinguished from unpaired ones by the presence of a mate throughout the breeding season. Observations of females were also recorded to determine if any were unpaired. It was difficult to determine if any females were unpaired because they do not sing and establish territories.

BEHAVIORAL MEASUREMENTS.- Field observations were also made to determine the period of courtship behavior, nest building, egg laying, incubation, and care of young. A stop watch was used to record the intervals in which females carried material to the nest, and the location of each nest was recorded. Nests were collected at the end of each breeding season and measured using a metric ruler to determine whether they varied in dimensions. Nest dimensions were also compared to their contents to see if there was a correlation between nest size and contents. After the nesting period, I monitored the locality and behavior of the birds by recording their location (proximity to nest site and territory) and activity (feeding, care of fledglings).

Following the procedures of Ficken and Ficken (1968c), I recorded adult feeding habits by monitoring frequencies of different feeding patterns (gleaning, hovering, hanging back downward, and probing). Feeding habits were measured with a stop watch to record intervals in which young were fed.

Results and Discussion

SPRING ARRIVAL.- First-seen dates (29 April 1987, 23 April 1988, and 27 April 1989) correlate with those of Hall (1983). Hall points out that Golden-winged Warblers arrive in West Virginia in the last week of April and migrants leave by the third week in May. In Raleigh County, arrival was evident by the relatively large number of birds from late April to mid-May, but by late May only a few resident birds were found. The earlier arriving birds were found nesting by late May while many of the migrants had departed. Ficken and Ficken (1968c) also found that early arriving (mid-to-late April) birds remained to nest while the larger wave of migrants that came through in early May departed by the beginning of nesting activity in late May. Males were first seen in the study area and females followed a day or two later. Bent (1963) and Ficken and Ficken (1968c) also found that males generally arrived before females.

BEHAVIOR.- Data collected in Raleigh County on Golden-winged Warbler behavior agree in part with data collected by Bent (1963), Baird (1967), and Ficken and Ficken (1967, 1968a, b, d) in that the general pattern of courtship, pair formation, singing behavior (singing period and perches), and nesting were similar. Males used dead black locust and sumacs as singing perches, but were occasionally observed singing from the tops of large oaks that bordered their old field habitat. Singing ceased by late June and early July. Golden-winged Warblers occupied territories ranging from 0.2 - 1.0 ha. Overgrown field territories were larger than dry hillsides. For example, in 1989 one male Golden-winged Warbler occupied a 1 ha overgrown field. However, four territorial males were found defending dry hillsides of 0.2 - 0.4 ha. Murray and Gill (1976) found Golden-winged Warblers occupying larger territories in Michigan, averaging 1.9 and 2.7 ha at their study sites. In the present study, dry hillside thickets were more abundant, smaller in size, and in later stages of succession than old fields. Thus, territorial size in Raleigh County may be related to the amount of suitable habitat.

STUDY AREA POPULATION SIZE.- Fifteen pairs were observed in the study area in 1987, 12 pairs in 1988, and 8 pairs in 1989. The only unpaired male observed during the study was in 1989. No unpaired females were observed.

HABITAT PREFERENCE.- Overgrown fields and dry hillsides habitats were occupied considerably more than streamside thickets (Table 1). Only one pair was found in streamside habitat (observed pair feeding nestlings on 26 May 1988). Brushy thicket areas along Miller's Camp Branch stream are in later stages of succession than overgrown fields and dry hillside thickets, and have considerably more trees and less goldenrods and shrubs. This would provide additional evidence to support Confer and Knapp (1981) theory that Golden-winged Warblers are habitat specialists and require early stages of plant succession to nest.

Table 1. Habitat preference of territorial male Golden-winged Warblers in Raleigh County, West Virginia.

Habitats	Number of singing males		
	1987	1988	1989
Openings in deciduous forests	3	2	2
Dry hillside thickets	4	2	4
Overgrown field	7	5	2
Streamside thicket	0	1	0
Swamp	1	2	1

NESTING ECOLOGY.- Data were collected on four breeding pairs, but only two pairs will be discussed in this section. There was no correlation between nest contents and dimensions (Table 2).

Table 2. Contents and dimensions of four Golden-winged Warbler nests in Raleigh County, West Virginia.

	Dimensions (cm)			
Contents of nest	Outside Diameter	Inside Diameter	Height	Depth
6 Eggs	7.6	6.3	9.5	6.3
4 Nestlings and 1 egg	12.7	6.0	14.6	6.3
3 Nestlings	11.4	6.3	14.0	5.9
4 Eggs	8.2	5.6	10.2	3.8

The dimensions of the nests were similar to those reported elsewhere (Harrison, 1975). Nests were built by females on or near the ground in clumps of goldenrods, grasses, ferns, and/or blackberries. Nest building was completed in five days as described by Harrison (1975). Males sang throughout nest building activity. Males followed their mates back and forth to the nest site during the first day of nest building, but became somewhat less conspicuous through later days of nest building and during incubation. Several males were observed feeding their mates during incubation. Males did not sing much in the vicinity of their nest sites and spent most of their time searching for food for their mates or nestlings.

In one pair studied during summer of 1989, a female was observed building a nest on 4 June at 0701 am and the nest was completed on 8 June. This female made trips to the nest site throughout the day, but slowed somewhat during hot afternoons. During a three hour observation period, she carried nest material to the nest in intervals ranging from two minutes 27 seconds to four minutes 56 seconds. This female laid her first egg on 9 June and one each day until 12 June. Incubation was done entirely by the female. This female as well as other females observed was very protective of her brood and would not flush until almost touched. Like other females observed on the nest, she exhibited a gaping behavior and moved away in a crippling manner after being flushed from the nest. Three eggs hatched on 22 June and the fourth hatched on 23 June. Nestlings left the nest on 2 July.

On 29 May 1988 a nest of six eggs was found by observing a female as she approached her nest. All eggs hatched on 5 June and the young birds left the nest on 13 June.

In summary, Golden-winged Warblers in Raleigh County lay from 3 - 6 eggs and incubate them for 10 days. Nestlings remain in the nest for 9 - 10 days. Nesting activity occurs from late May through early July. A synopsis of this species nesting ecology can be found in Bent (1963). Bent reported a similar reproductive strategy as reported here.

CARE OF YOUNG.- Both parents shared in the care and feeding of the young birds. In one observation of a pair feeding five fledglings on 14 June 1988, the male fed two fledglings while the female fed the other three. The male made 12 trips within 30 minutes with food to the fledglings. This female was more secretive than other females during feeding of the fledglings. Observations of a different pair revealed that the female made 10 trips with food in 20 minutes to four nestlings. Males announced their presence with a call note when approaching the nest with food and would sometimes pause to sing after feeding the nestlings and before continuing their search for food. Parents were very protective of their nestlings and would sometimes fly at my head in attempts to protect their progeny. Young birds would call to their parents with a fine chip note.

BEHAVIOR AFTER NESTING.- Nestlings, after leaving the nest, remained motionless in dense vegetation cover waiting to be fed. During the fledgling period, Golden-winged Warbler families became somewhat inconspicuous and males rarely sung. Golden-winged families remained in the nesting vicinity for three to five days apparently until the fledglings became strong enough to follow their parents.

FEEDING HABITS.- Terminology on feeding habits, where applicable, follows that of Ficken and Ficken (1968c). During spring (late April through mid-June), when food was less abundant, Golden-winged Warblers fed mostly by probing and hanging back downward. Of 66 feeding observations, 53 (80.3%) were by probing, 11 (16.7%) were by hanging back downward, and 2 (3%) were by gleaning. The hovering method of feeding was not observed. Ficken and Ficken (1968c) also found probing to be the most common method of feeding in May during which 162 (84%) of 193 observations were by probing. During the fledgling period, when insects were more abundant, they fed more by gleaning (16 or 80% of 20 observations). Golden-winged Warblers foraged primarily from tops of trees and shrubs. They used willows and maples as foraging sites in spring, but switched more to oaks in the later part of the breeding season. Willows and maples flower earlier than oaks and provide a place to find an abundance of insects when most trees are in the leafless condition. Usually only peripheral portions of shrubs and trees were used for feeding, however, one female was observed carrying insects that were collected from the interior of a shrub to nestlings on 26 June 1988. Caterpillars were used primarily to feed the offspring.

FALL DISPERSAL.- By mid-July and early August Golden-winged Warblers disappeared from the study area. Last-seen dates for this species in the study area were 27 July 1987, 29 July 1988, and 17 July 1989. Hall (1983) indicates that Golden-winged Warblers depart from West Virginia in the second half of August and only a few birds remain into September.

HABITAT DESTRUCTION.- During late fall of 1988 in the Metalton Bottom district, a powerline right-of-way was cut through overgrown field habitat of Golden-winged Warblers. Five pairs of Golden-winged Warblers were found in Metalton Bottom in 1988. Three of these five pairs were found in the area that was cut-over. Only two pairs of Golden-winged Warblers were found at Metalton Bottom in 1989 and none were found in the cut area. The decline of the Golden-winged Warbler in Raleigh County may be due to habitat alterations and/or destruction. Arrival and encroachment of Blue-winged Warblers may add to the decline of this species through competition and introgressive hybridization. Additional documentation of declining numbers of Golden-winged Warblers in southern West Virginia, such as in Kanawha County, can be found in Hall (1983). Hall discussed the disappearance of this species in relation to their declining brushy habitat in southern West Virginia and range expansion of Blue-winged Warblers.

Acknowledgments

I thank Dr. Laurence E. Bayless of Concord College for his guidance during this research and Dollie Stover for her assistance in the field.

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Leachate Analysis From Three Mine Spoils as Affected by Fly Ash Amendment and Cropping[1]

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Abstract

Growing concern for groundwater and stream contamination with inorganic pollutants from abandoned mine spoils and also those reclaimed with urban and industrial wastes prompted this greenhouse pot study. The objective was to examine the inorganic composition of leachate from mine spoils being reclaimed with fly ash. Three extremely acid (pH 3.3 to 3.9) WV mine spoils that were high in Al, Mn, and S were amended with fly ash at up to 67% of the mix. Five successive crops -- two corn and three alfalfa -- were grown on the treated mine spoils. Each pot contained a drainage hole with plastic tubing from which leachate was collected during and after the growth of each crop. Applications of fly ash increased pH, electrical conductivity, Ca, K, Mg, and Na concentrations and decreased Al, Cu, Fe, Mn, and Zn concentrations in the leachate. Phosphorus concentration was not affected. Concentrations of all elements in the mine spoils decreased with each successive cropping. Leachate from fly ash, which may be used to reclaim extremely acid mine spoils, will change the composition of groundwater and streams and techniques need to be developed to avoid these environmental problems.

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[1]Contribution from the Division of Plant and Soil Sciences, Box 6108, West Virginia Univ., Morgantown, WV 26506-6108. Published with the approval of the Director of the West Virginia Agricultural and Forestry Experiment Station as Scientific Paper No. 2080. This research was supported with funds appropriated under the Hatch Act.

Introduction

Surface water of Appalachia is being polluted from acid mine drainage derived from deep and surface coal mines. All methods of coal mining, whether surface or underground, contribute to this pollution problem. Much stream pollution is caused by abandoned surface mines. Most of this acid load results from the oxidation of pyrite exposed to air and water. Some lignite spoils exposed to air have resulted in oxidation of pyrite to sulfuric acid (Senkayi et al., 1981). Sulfide minerals were also found to release H^+ ions to produce "free" acid (Barnhisel and Massey, 1969). The severity of acid conditions in spoils was determined by the amount of pyrite present and the relative rates of oxidation (Massey and Barnhisel, 1972). Properties of mine spoil parent material determine the degree of acidity present (Pedersen et al., 1978) with the surface reaction varying from extremely acid to calcareous (Indorante et al., 1981). Plants have grown poorly on very acid mine spoils (e. g. pH 4.7) due to detrimental effects of Al (Foy, 1975; Keefer et al., 1979, 1983; and Singh et al., 1982) and Mn (Snider, 1943; and Barnhisel and Massey, 1969). Capp and Gillmore (1974) pointed out that some of the acidity of extremely acid mine sites could be neutralized by the addition of fly ash. Studies by Keefer et al. (1979,

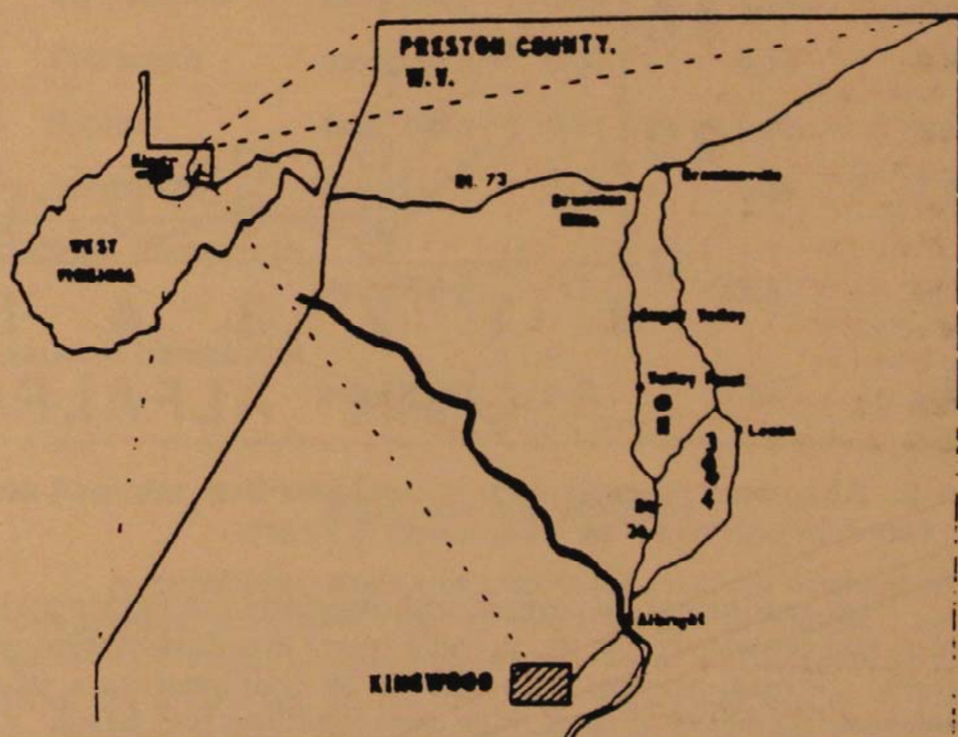

Figure 1. Location of sites in Preston County, West Virginia.

1983) and Singh et al. (1982) showed that mixing mine spoil with fly ash decreased the toxic levels of Al and Mn. Phung et al. (1978) pointed out that fly ash applied to acid soils neutralized acidity equivalent to 20 to 30% of reagent grade $CaCO_3$. The neutralization value of fly ash was due to the presence of CaO and MgO (Martens et al., 1970; and Martens, 1971). Surface mine spoil can probably be reclaimed by surface application of fly ash in large quantities as the properties of the fly ash should neutralize the highly acidic spoil providing an environment satisfactory for plant growth.

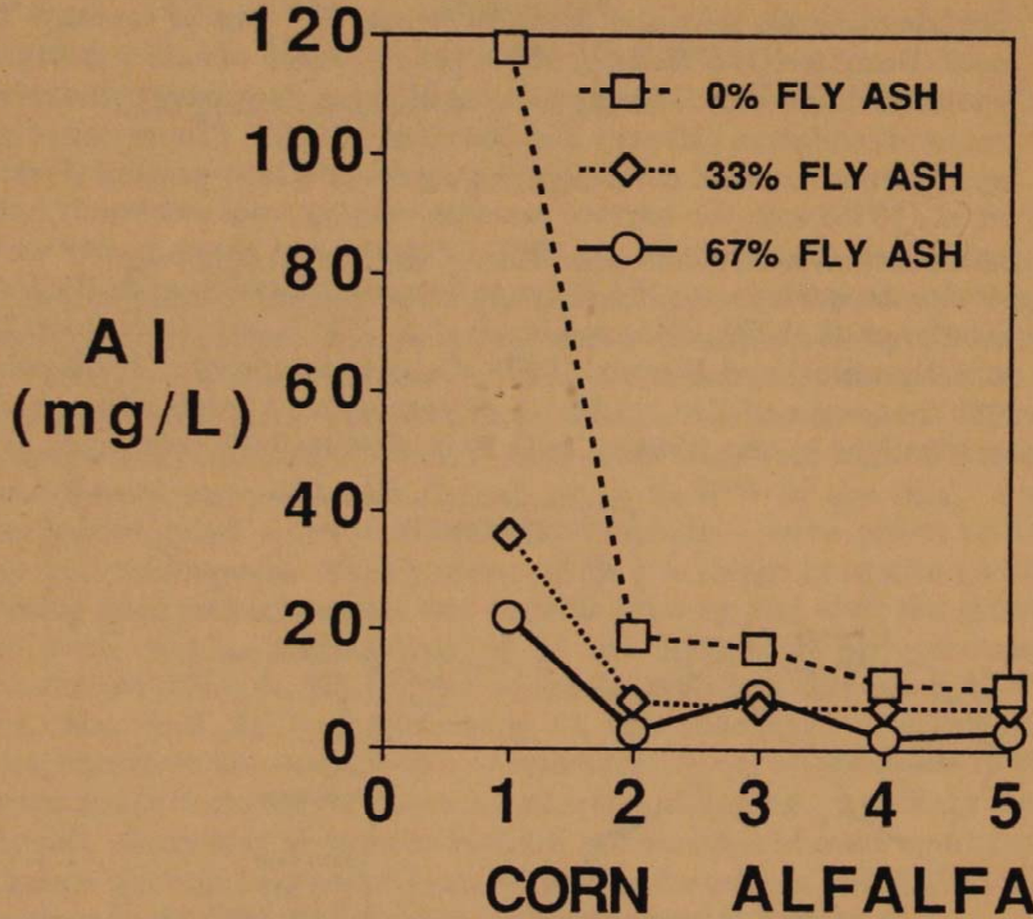

Figure 2. Aluminum concentration in leachates from minesoil near Lenox for pots receiving 0, 33, and 67 % fly ash.

Mine spoils must be covered with vegetation to reduce pyrite oxidation and control erosion which could result in sedimentation and pollution. Several revegetation efforts by coal operators using conventional techniques at these mine spoil locations had failed. The purpose of this study was to examine the inorganic composition of leachate from three spoils being reclaimed with fly ash.

Table 1. Some properties of the three mine spoils used in the greenhouse study.

Soil Properties	Units	Location		
		Valley Point	Lenox	Westover
Texture		loam	clay loam	loam
pH		3.3	3.8	3.4
Organic Matter	%	1.71	1.14	4.81
Total Sulfur	%	0.17	0.23	0.24
Cation Exchange Capacity	meq/100 g	7.04	11.27	9.89
Exchangeable cations:				
Calcium	meq/100 g	0.48	1.39	0.66
Magnesium	meq/100 g	0.39	1.55	1.27
Potassium	meq/100 g	0.06	0.13	0.07
Sodium	meq/100 g	0.04	0.08	0.15
Aluminum	meq/100 g	2.64	5.38	3.41
Available Manganese	meq/100 g	6.7	32.5	59.6
Available Phosphorus	meq/100 g	1.21	1.36	1.15

Materials and Methods

A greenhouse study was conducted on three abandoned mine spoils located in Preston (Fig. 1) and Monongalia counties, in north central West Virginia. These mine spoils resulted from surface mining during the 1960's and 1970's before the establishment of regulations that require covering of potentially toxic mine spoil material with non-toxic overburden. The removal of coal by surface mining was followed by haphazard placement of overburden material resulting in exposure of extremely acidic material on the surface.

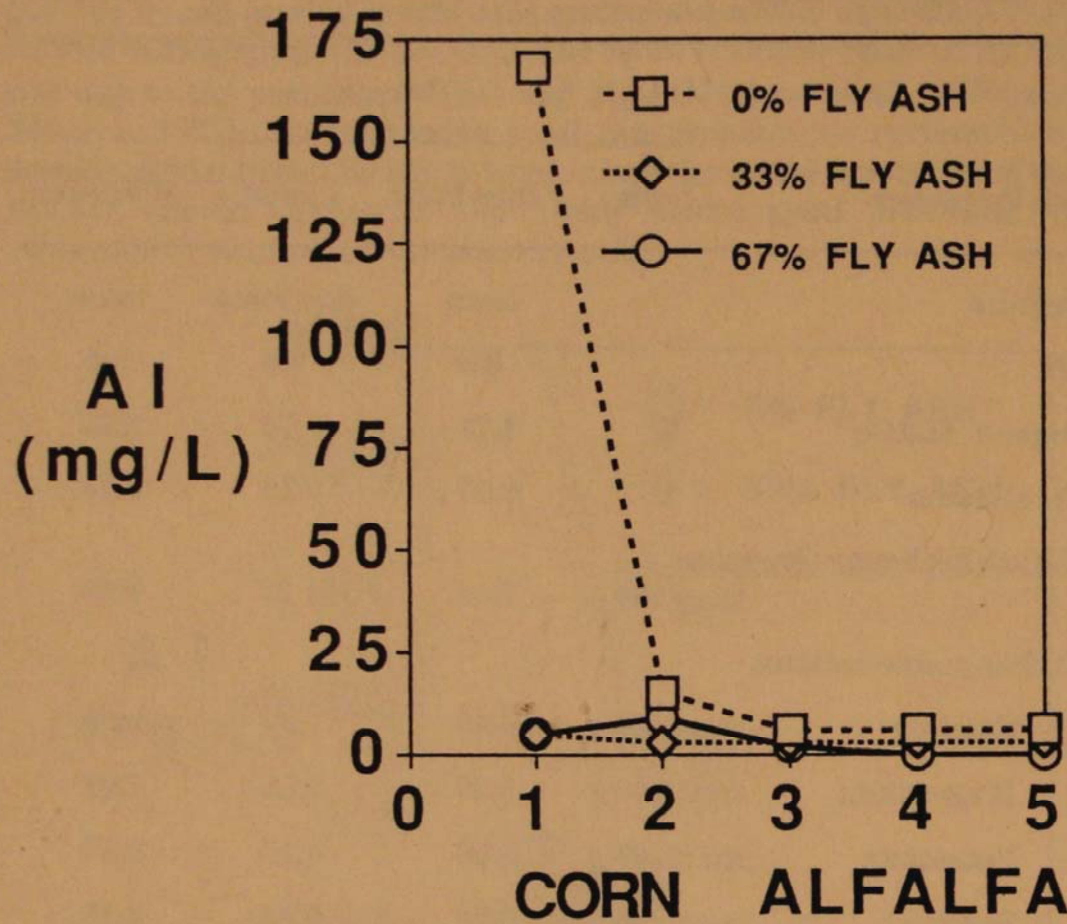

Figure 3. Aluminum concentration in leachates from minesoil near Wesrover for pots receiving 0, 33, and 67 % fly ash.

Bulk spoil samples were collected from, three abandoned mine sites in WV located near Lenox (LX) and Valley Point (VP) in Preston County, and Westover (WO) in Monongalia County, air dried, sieved through a 2 mm screen and analyzed (Table 1). The spoils were mixed with fly ash from the John Amos Power Station near St. Albans, WV at three rates -- 0, 33, and 67% of the growth medium, replicated three times, and placed in plastic pots each containing 2 kg of soil. Each pot received 83 mg of K as KCl, 35 mg of N as KNO_3, 100 mg of P as rock phosphate, was planted with eight corn seeds, and arranged randomly within each replication on greenhouse benches. Distilled water was added as needed. Each pot had a drainage hole with plastic tubing connected with a 125 ml plastic bottle for leachate collection. Five successive crops -- two corn and three alfalfa -- were grown. Leachate was collected during and after the growth of each crop and filtered if cloudy.

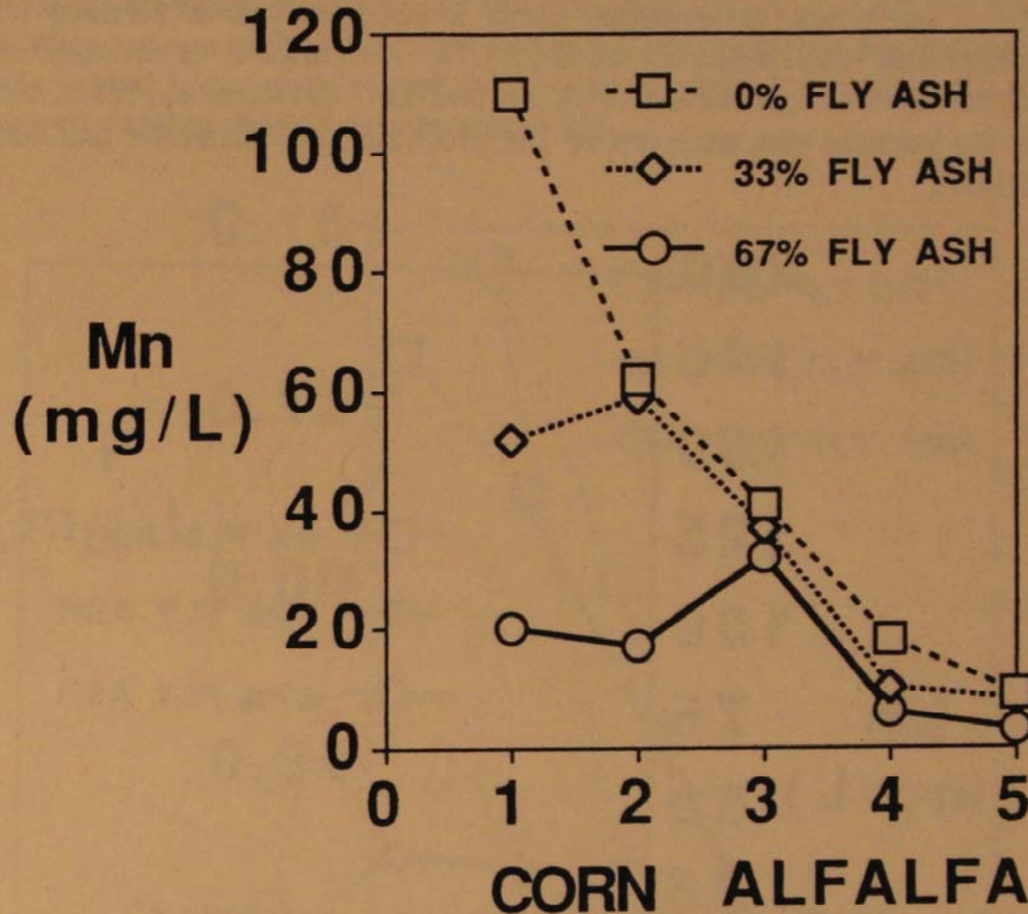

Figure 4. Manganese concentration in leachates from minesoil near Lenox for pots receiving 0, 33, and 67 fly ash.

The pH of spoils, fly ash, and leachate was measured with a Corning Model 12 pH meter. Leachate was analyzed as collected with K and Na determined by flame emission and the remaining elements by atomic absorption spectroscopy. Spoil was analyzed for particle size distribution by the pipette method described by Kilmer and Alexander (1949), total organic matter (OM) by the wet combustion method of Peech et al. (1947), exchangeable Ca, Mg, Na, and K by the 1 *N* NH_4OAc extraction procedure of Jackson (1958), followed by flame emission for K and Na and atomic absorption spectrophotometry for Ca and Mg. Exchangeable Al and available Mn were extracted from the spoil with 1 *N* KCl (Coleman et al., 1959) and determined by atomic absorption spectroscopy. The Fe in the spoil was determined by the procedure of Jackson (1958), whereas free Fe was determined by atomic absorption (Raad et al., 1969) following sodium dithionitecitrate-bicarbonate extraction (Jackson, 1956). Total S in fly ash and mine spoils was determined using a Leco induction furnace with automatic titrator (Grube et al., 1973). Available P in the spoil was determined by extraction with 0.5 *N* $NaHCO_3$ (Olsen et al., 1954), and P in the leachate was analyzed by the procedure of Watanabe and Olsen (1965).

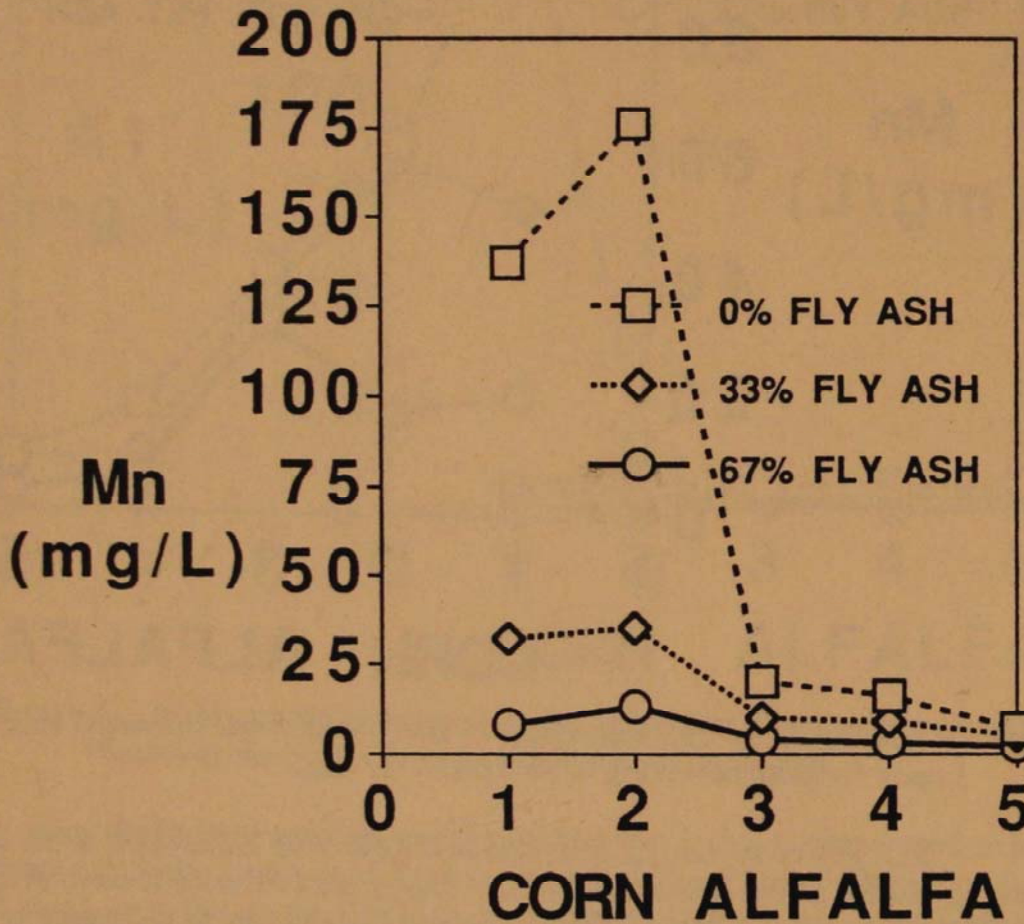

Figure 5. Manganese concentration in leachates from minesoil near Westover for pots receiving 0, 33, and 67 % fly ash.

Results and Discussion

PHYSICAL AND CHEMICAL PROPERTIES OF MINE SPOILS

The mine spoil reaction (pH) was between 3.3 and 3.8 indicating the presence of free acid in these spoils (Table 1). This is supported by the total S that varied between 0.17 and 0.24% and was considerably higher than found in the weathered rock material. At these locations, the presence of "wet spots", even during dry periods, demonstrated the production of sulfuric acid from oxidation of pyrite exposed to the atmosphere. The acid attacked the primary and secondary minerals and released considerable amounts of Al and Fe and other cations such as Mg. The amount of exchangeable Mg in these spoils varied between 0.39 and 1.55 meq/100g with the minespoil at Lenox containing the highest amount of Mg.

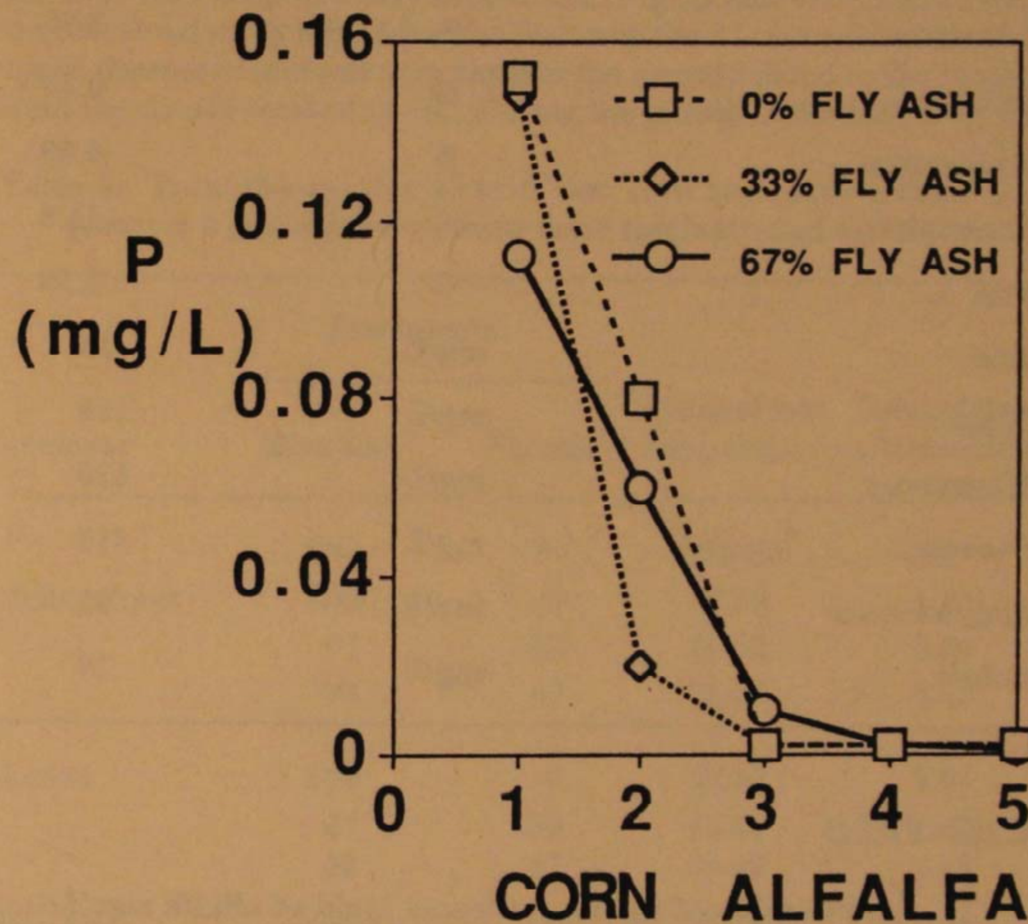

Figure 6. Phosphorus concentration in leachates from minesoil near Lenox for pots receiving 0, 33, and 67 % fly ash.

TOTAL ANALYSIS OF FLY ASH

The fly ash used contained considerable amounts of plant nutrients; however, it also contained high amounts of Al (11.8%), Fe (2.16%), and medium amounts of B (419 mg/L)(Table 2).

Table 2. Total analysis of fly ash from John Amos power plant.

Elements	Units	
Phosphorus	%	0.24
Potassium	%	2.96
Calcium	%	0.46
Magnesium	%	0.49
Aluminum	%	11.8
Iron	%	2.16
Zinc	mg/L	79
Copper	mg/L	106
Manganese	mg/L	139
Boron	mg/L	419
Molybdenum	mg/L	90
Cobalt	mg/L	79

CROP YIELD

Application of fly ash increased yield of alfalfa significantly (Table 3); however, it failed to increase yield of corn significantly. Perhaps the high amount of B present in the fly ash retarded corn growth and thus its yield. Alfalfa, that needs more B for growth, showed increase in yield when fly ash was applied.

CHEMICAL ANALYSIS OF LEACHATE

The pH of mine spoil and the amendment material used for reclamation have both direct and indirect effects on the biota and the composition of leachate seeping from the mine spoil. Plant growth may be directly affected by the H^+ concentration and indirectly by an increase in the solution concentration of potentially toxic elements such as Al, Mn, Fe, and also by changes in nutrient concentrations, such as N, P, K, Ca, Mg, and Na.

ALUMINUM

Aluminum concentration in the leachate during the growth of the first corn crop was very high in LX (Fig. 2) and WO (Fig. 3) spoils that received no fly ash. After the first crop the Al concentration in both spoils decreased and was very close to the amount found in the leachate from the fly ash-treated spoils. During the growth of the fifth crop, the

Table 3. Total dry matter yield of two corn and three alfalfa crops grown in a greenhouse on three mine spoils treated with fly ash.

Location	Treatments		Total of two corn crops	Total of three alfalfa crops
	Mine soil	Fly ash		
	(%)	(%)	(g/pot)*	(g/pot)*
Valley Point	100	0	27.03	1.84
	67	33	30.02	5.29
	33	67	25.26	6.72
Lenox	100	0	24.54	1.04
	67	33	15.85	1.73
	33	67	20.39	3.58
Westover	100	0	12.19	0.09
	67	33	14.88	1.44
	33	67	17.34	3.51
LSD (0.05)			9.82	0.79

* pot = 2 kg of spoil

concentration of Al was negligible in both fly ash-treated and untreated spoils. The low level of Al in the leachate from the fly ash-treated spoil was probably due to the dilution of the spoil by fly ash and immobilization of exchangeable Al by an increase in pH from the fly ash that contained CaO.

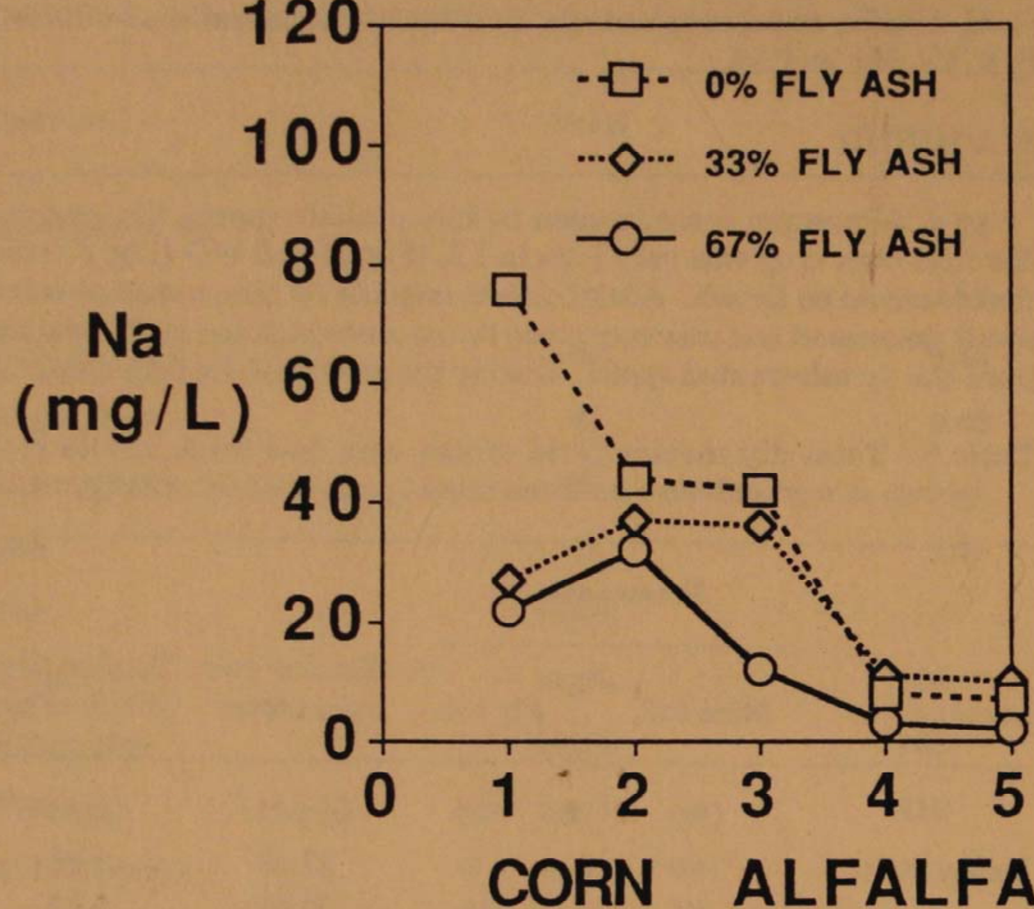

Figure 7. Sodium concentration in leachates from minesoil near Valley Point for pots receiving 0, 33, and 67 % fly ash.

MANGANESE

The concentration of Mn in the leachate from non-fly ash-treated LX spoils (Fig. 4) and WO spoil (Fig. 5) were at phytotoxic levels. The WO spoil that contained over 50 mg/L KCl extractable Mn released the highest amount of Mn (175 mg/L) in the leachate compared to the LX spoil (115 mg/L). On the other hand, mine spoils treated with 33% fly ash showed only 50 mg/L Mn in LX spoil (Fig. 4) and 40 mg/L in WO spoil (Fig. 5). Application of 67% fly ash reduced the concentrations of Mn in the leachate from LX spoil to 25 mg/L and in WO spoil to 115 mg/L during the growth of the first crop. With a few exceptions, the concentrations of Mn in the leachate decreased each successive cropping in both spoils.

Both Fe and Mn are subject to valence state transformations in the range of pH and Eh conditions commonly found in mine spoils. The activity of Fe and Mn are accentuated under anoxic, low pH conditions. Soluble ferrous (Fe^{2+}) and manganous (Mn^{2+} ions will oxidize to the more insoluble ferric (Fe^{3+}) and manganic (Mn^{4+}) forms when exposed to oxygenated conditions. Application of fly ash increased oxygenated conditions in the spoils by providing CaO and also diluted the amount of Mn in the spoil.

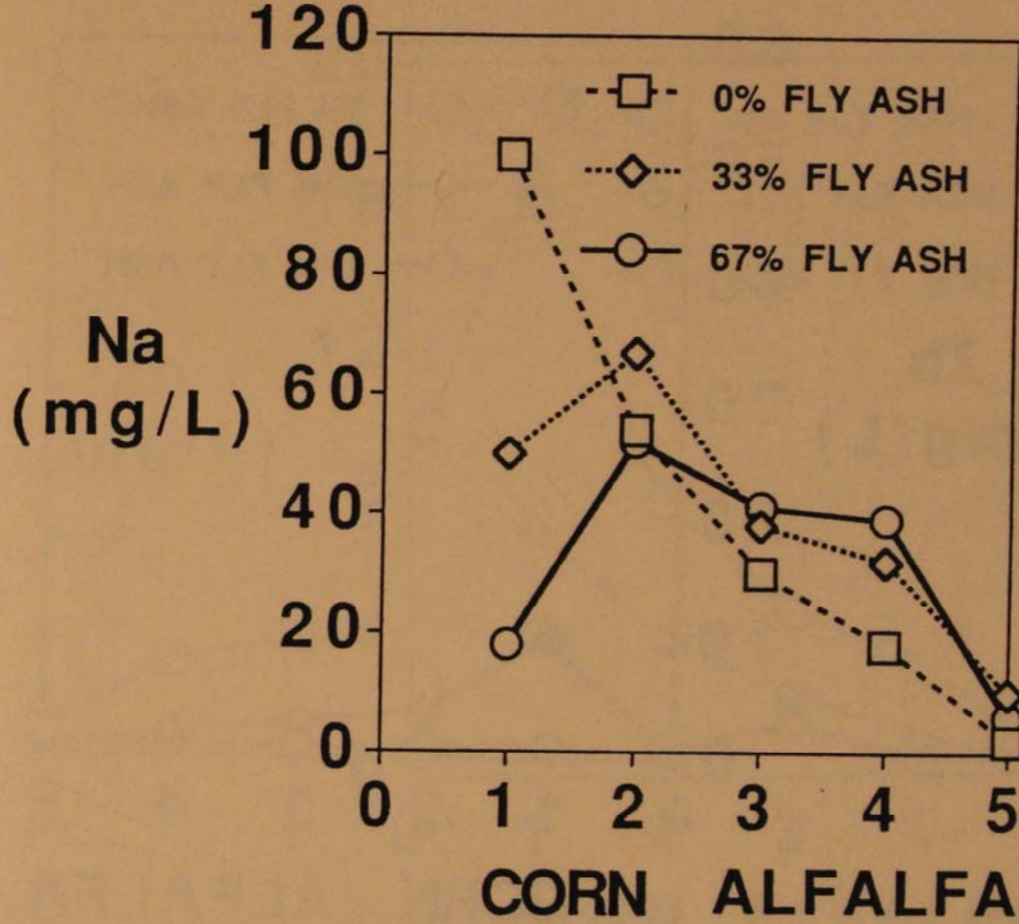

Figure 8. Sodium concentration in leachates fro, minesoil near Westover for pots receiving 0, 33, and 67 % fly ash.

PHOSPHORUS

The highly reactive nature of P and oxidizing conditions that are likely to occur in the presence of fly ash in the spoils would immobilize P so that its leaching would not be a problem. Considerable P (0.10 to 0.15 mg/L) was present in the leachate (Fig. 6) from the LX spoil, but only negligible amount of P were detected in the leachate from VP and WO spoils.

Several efforts by the coal operators to revegetate the LX spoil with lime and P fertilizer in the field failed. When this spoil was brought into the greenhouse and incubated with lime, native P may have been released. It is well known that an increase in the activity of OH^- ions in the soil generally results in the release of P from oxides and hydroxides of Al and Fe. Thus, during the early cropping, some of the P was released into the leachate.

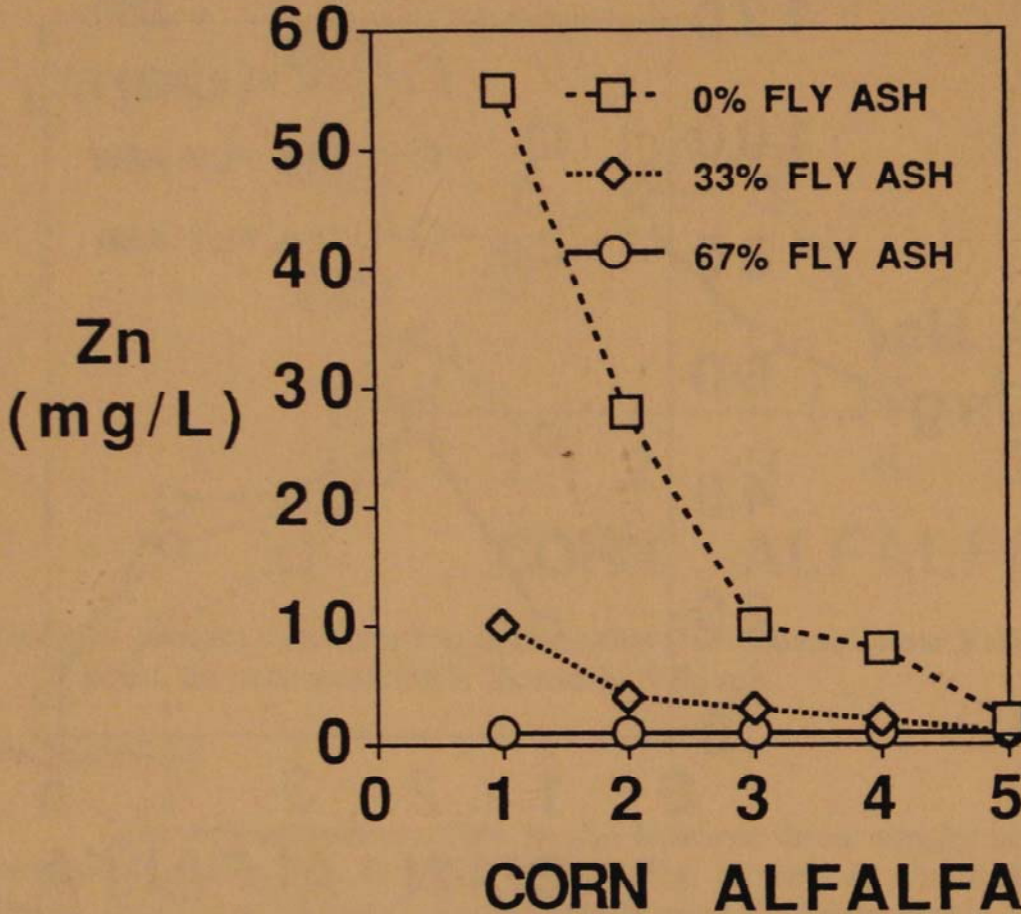

Figure 9. Zinc concentration in leachates from minesoil near Westover for pots receiving 0, 33, and 67 % fly ash.

SODIUM

The Na concentration in the leachate from non-fly ash-treated spoils (Fig. 7 and 8) was as much as 20 times higher than that of most typical agricultural soils in the northeastern U. S. With each successive crop, the Na concentration decreased, so that only very little Na was present at the end of the fifth crop (Fig. 7 and 8). Lower Na concentrations were found in the leachate from fly ash-treated spoil than from non-fly ash-treated spoil. During the growth of the second crop, the concentration of Na in the leachate increased. Perhaps application of fly ash diluted the Na in the spoil and retarded weathering of Na minerals during the growth of the first crop and thus released less Na then. However, with time as the second crop grew, the weathering of Na minerals resumed again and resulted in greater amounts of Na in the leachate. With subsequent cropping and leaching, the Na concentration in the leachate decreased steadily.

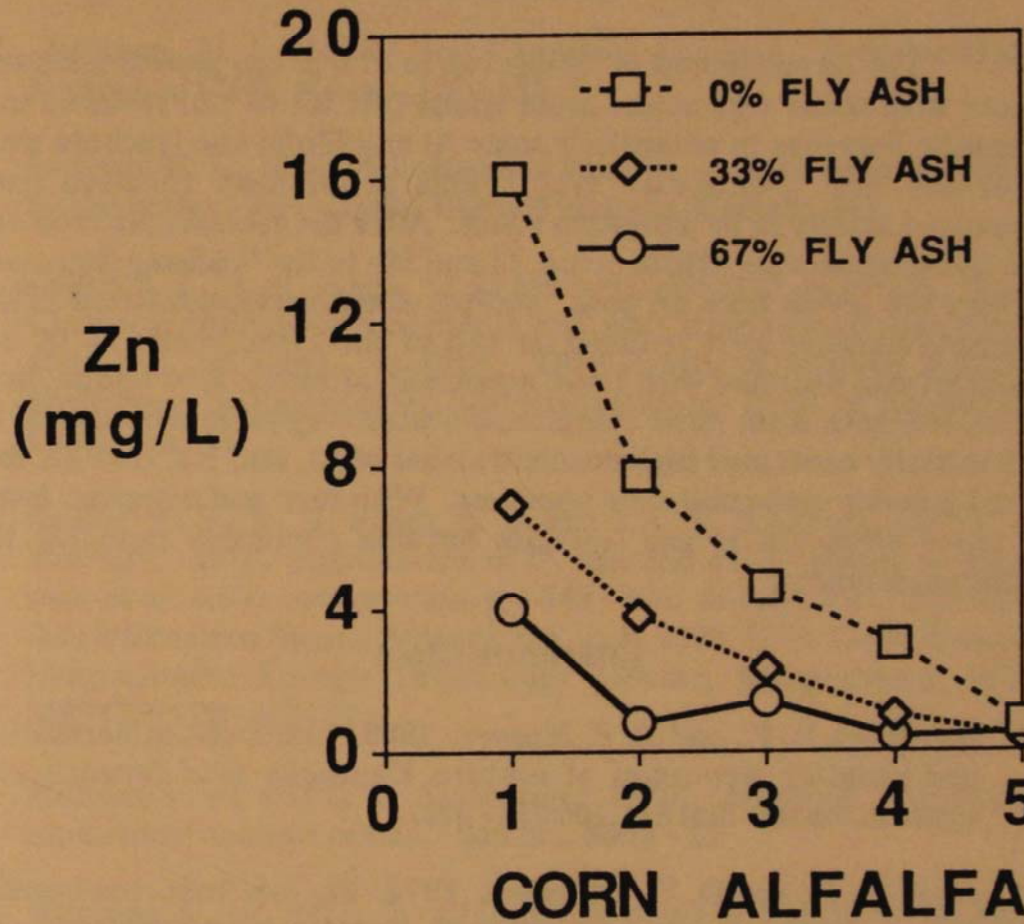

Figure 10. Zinc concentration in leachates from minesoil near Lenox for pots receiving 0, 33, and 67 % flt ash.

ZINC

Zinc concentration in the leachate from non-fly ash-treated spoils (Fig. 9 and 10) were considerably higher than those that received fly ash. With each successive cropping, Zn concentrations in the leachate decreased, so that by the fifth crop the concentration of Zn in the non-fly ash and fly ash-treated spoils were very low (< 1 mg/L).

These levels may require supplemental Zn fertilization for adequate crop growth.

Oxidation of pyrite and the associated acid conditions in the non-fly ash-treated spoils resulted in greater release of Zn to the leachate. Successive cropping and leaching resulted in depleting Zn in the spoils with concomitant increase of Zn in the leachate.

Conclusions

The large amount of fly ash (up to 67% of the growth medium) mixed with these very acidic mine spoils (pH 3.3 to 3.8) resulted in a dramatic decrease in potentially toxic Al and Mn in the leachate even after the first greenhouse crop. This could have resulted from decreased acidity or by a dilution effect. After the second corn crop and the three succeeding alfalfa crops, Al and Mn in the leachate decreased to very low levels from all pots. Sodium and Zn concentrations in the leachate likewise were reduced for two of the three spoils by fly ash addition and declined with time, especially after the first alfalfa crop. Thus, leachate from mine spoils mixed with very large amounts of fly ash initially contained high concentrations of Al, Mn, Na, and Zn that could possibly cause pollution problems. With time and cropping, levels of these elements in the leachate became negligible reducing the pollution problem.

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Recolonization of Benthic Populations Following Catastrophic Flood in two West Virginia Streams

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Abstract

In November 1985, Hurricane Juan and another storm system produced 13.5 inches (34 cm) of precipitation during a five day period and flooded Seneca Creek and the North Fork of the South Branch of the Potomac River. After the flood, the functional feeding group structure of both streams was dominated by collectors (gatherers and filterers). Predators declined sharply after the flood and never returned to the preflood percentages during the two year study period. In addition to the old channel of Seneca Creek, a new channel was formed after the flood in a nearby floodplain area. Collectors also dominated the functional feeding groups in the new channel. In the North Fork of the South Branch, species richness (number of taxa) declined slightly after the flood; it returned to preflood values within one year. In Seneca Creek, species richness did not differ significantly between pre- and postflood populations. In the North Fork of the South Branch, species diversity and equitability were reduced after the flood but increased slightly after two years. In Seneca Creek, species diversity and equitability increased slightly following the flood but returned to preflood values within one year. In both streams, plecopteran and dipteran taxa recolonized rapidly and were fairly constant in pre- and postflood samples. Numbers of ephemeropteran taxa increased after the flood but returned to preflood numbers within two years in both streams. Although abundant in preflood samples, the mayfly genera *Ephemerella* (North Fork of South Branch) and *Epeorus* (Seneca Creek) were never found in the samples two years following the flood. Tricopteran taxa recovered in Seneca Creek but were drastically reduced and never recolonized in the North Fork of the South Branch. The caddisfly genera *Chimarra* (both streams) and *Polycentropus* (Seneca Creek) were not found after the flood. Of the minor insect orders, the genera eliminated by the flood were *Boyeria, Sialis* and *Dineutus* from the North Fork of the South Branch and *Psephenus* from Seneca Creek. In both streams, the coefficient of community

similarity was lowest immediately after the flood and increased over the following 18 months. Overall, these results indicate a high degree of resiliency of benthic populations in both streams. Benthic populations in the two streams were not affected equally by the flooding. Some populations were eliminated entirely, while others were able to adapt to, or avoid, the extreme flooding.

Introduction

High waters resulting from five days of steady rain (13.5 inch/34 cm) from Hurricane Juan and another storm system roared down the hollows and valleys of Pendleton County, West Virginia, in early November 1985.

The most frequent agent of stream disturbance is flooding (Fisher et al., 1982). Several authors, including Anderson and Luhmkuhl (1968), Fisher et al. (1982), Hoopes (1974), Hynes (1968), Jones (1951), Maitland (1964), Tebo (1955), and Waters (1972), have reported the detrimental effects of a catastrophic flood on the structure of benthic populations. The dislodged benthic populations constitute catastrophic drift (Waters, 1965). Many benthic populations seek refuge in the interstitial habitat of deep gravel beds during flooding (Williams and Hynes, 1974; Clifford, 1966; and Badcock, 1953). The time required for recolonization for benthic populations following flooding varied greatly depending upon stream type, severity of disturbance, and parameter measured (Hoopes, 1974; Bilby, 1977; Siegfried and Knight, 1977; and Bane and Lind. 1978). Generally, several months to a year or more are necessary for complete recolonization. The flood of 1985 provided the opportunity to observe the recolonization of benthic populations in two West Virginia mountain streams.

Study Sites

Seneca Creek, a second order stream and the largest tributary of the North Fork of the South Branch of Potomac River heads between Spruce Mountain and Allegheny Mountain northwest of Spruce Knob (Price and Heck, 1939) and flows northeast to east along a deep V-shaped valley for 19.3 mi (31.05 km).

The North Fork of the South Branch of the Potomac River, a third order stream, heads between Middle and Allegheny Mountain. On the Virginia and West Virginia border, it flows primarily northeast by east for 57.7 mi (92.84 km) and joins South Branch 4 mi (6.44 km) west of Petersburg, West Virginia (Price and Heck, 1939).

Materials and Methods

The benthic populations were sampled four times during the investigation: preflood (October/fall 1965), and postflood (March/spring, November/fall, 1986 and November/fall 1987). Collections were made by the kick sampling techniques. The benthic populations were dislodged from the rocky substrate and drifted into a net attached to a long handled dredge. Samples were preserved in 10% formalin and identified to the lowest possible taxonomic level (usually genus). Pre- and postflood community analyses included richness (number of taxa). Shannon-Weaver species diversity, species equitability and similarity index. The coefficient of community similarity, $c = \frac{2w}{a+b}$ (Smith, 1980), was used to compare postflood conditions with preflood collections at both streams. Additionally, functional feeding groups (predators, shredders, collectors, and grazers) were used to analyze the changes in taxa and numbers (Merritt and Cummings, 1984; Vannote et al., 1980). When more than one functional group was listed for a single taxon, the taxon was placed in all functional groups.

Results and Discussion

North Fork of South Branch

FUNCTIONAL FEEDING GROUPS. Based on the preflood samples (fall, 1985), the percentage compositions of the functional feeding groups were: predators (37.4%), collectors (43.0%), shredders (1.9%) and grazers (17.7%) (Tables 1, 2, and Fig. 1). In the postflood samples, the percentage compositions were: spring, 1986 (predators - 16.8%, collectors - 64.1%, shredders - 2.7%, and grazers 16.4%); fall 1986 (predators - 30.4%, collectors - 60.3 %, shredders - 8.1% and grazers - 1.2%); and fall, 1987 (predators - 32.1%, collectors - 53.3%, shredders - 0.3%, and grazers - 14.3%) (Tables 1, 2 and Fig 1). Predators declined sharply following the flood. After one year, they had almost returned to preflood percentages. Throughout the postflood recolonization, collectors were the most abundant benthic populations(Fig. 1). This is not surprising since there was an abundance of allochthonous detritus (fine particulate organic matter) in the stream following the flood.

Table 1. Summary of benthic population taxa by functional feeding groups (P = Predator, S = Shredder, G = Grazer, and C = Collector) at sites A (Seneca Creek/old channel), B (Seneca Creek/new channel), and C (North Fork of South Branch) in the postflood samples.

TAXA	FUNCTIONAL GROUP(S)	SITES
Acroneuria	P	A, B, C
Agapetus	C, G	A
Allonarcys	P, S, G	A, B, C
Alloperla	P, C	A
Atherix	P	A, B, C
Baetis	C, G	A, B, C
Baetisca	C, G	A
Boyeria	P	C
Branchycentrus	C	C
Cheumatopsyche	C	A, B
Chimarra	C	A, C
Chironomidae	P, S, C	A, B, C
Corydalus	P	C
Dineutus	P	C
Diplectrona	C	B
Dolophilodes	C	A, B, C
Epeorus	C, G	A, B, C
Ephemerella	C, G	A, B, C
Ephemera	P, C	A, C
Goerita	G	A

Table 1. Continued.

TAXA	FUNCTIONAL GROUP(S)	SITES
Hastagenia	P	A
Heptagenia	C, G	A, B, C
Hydropsyche	C	A, B, C
Isonychia	P, C	A, B, C
Lanthus	P	A, B, C
Leuctra	S	B, C
Limnephilidae	C, S, G	B
Limnophila	P	A, B, C
Neophylax	G	A, B
Neureclipsis	S, C	C
Nigronia	P	A, B, C
Paragnetina	P	A, B, C
Paraleptophlebia	S, C	A, B, C
Peltoperla	S	A, B
Perlesta	P, C	C
Perlodidae	P, C, G	B
Phasganophora	P	A
Polycentropus	P, C	A, C
Pseuphenus	G	A, C
Pseudocloeon	C, G	A, B, C
Pycnopsyche	S, G	B
Rhyacophila	P, S, C, G	A, B
Sialis	P, C	C

Table 1. Continued.

TAXA	FUNCTIONAL GROUP(S)	SITES
Simulium	C	C
Stenacron	C, G	A
Stenonerma	C, G, C, G	A, B, C
Tabanidae	P	A
Tipula	P, C, S, G	A, B, C

Warren et al. (1964) noted that stream discharge removed large quantities of allochthonous detritus. Shredders and grazers, remained relatively constant following the flood (Fig. 1).

Seneca Creek/Old Channel

FUNCTIONAL FEEDING GROUPS. Preflood samples (fall, 1985), had the following percentage compositions for functional feeding groups: predators (45.6%), collectors (36.3%), shredders (4.4%), and grazers (13.7%) (Tables 1, 2, and Fig. 2). In the postflood samples, the percentage compositions were as follows: spring, 1986 (predators - 28.8%, collectors - 37.7%, shredders - 6.5%, and grazers - 29.0%); fall, 1986 (predators - 25.5%, collectors - 51.4%, shredders - 4.0%, and grazers - 19.1%); and fall, 1987(predators - 15.8%, collectors - 56.6%, shredders - 6.0%, and grazers - 21.6%). Predators declined sharply following the flood and continued to decline throughout the postflood conditions (Fig. 2). Collectors remained fairly constant after the flood but increased sharply during the remaining postflood recovery months (Fig. 2). Shredders remained fairly constant throughout the pre- and postflood collecting periods (Fig. 2). Percentage composition of grazers increased sharply after the flood but returned to near preflood percentages during the postflood recover period (Fig. 2).

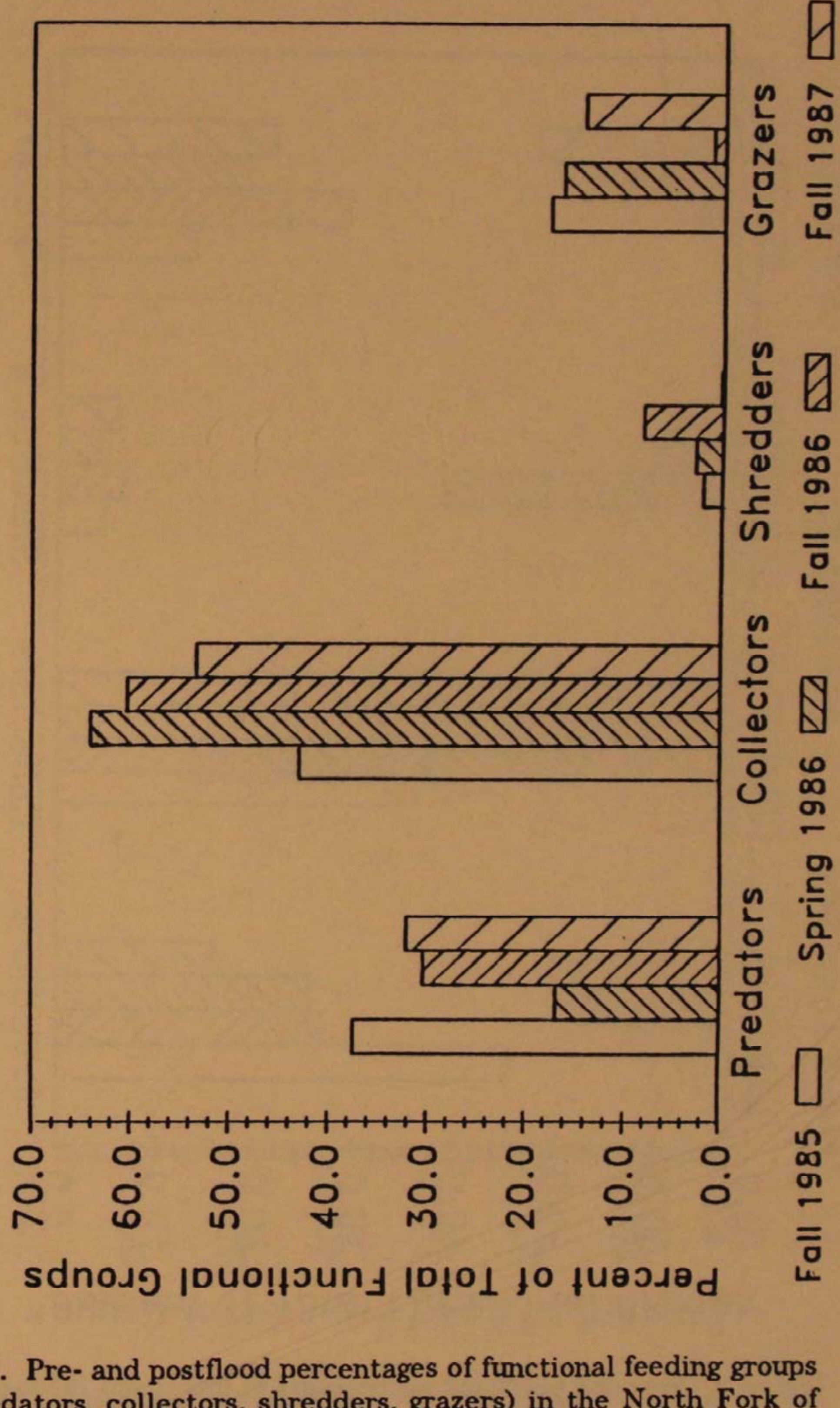

Figure 1. Pre- and postflood percentages of functional feeding groups (predators, collectors, shredders, grazers) in the North Fork of South Branch of the Potomac River, Pendleton County, West Virginia.

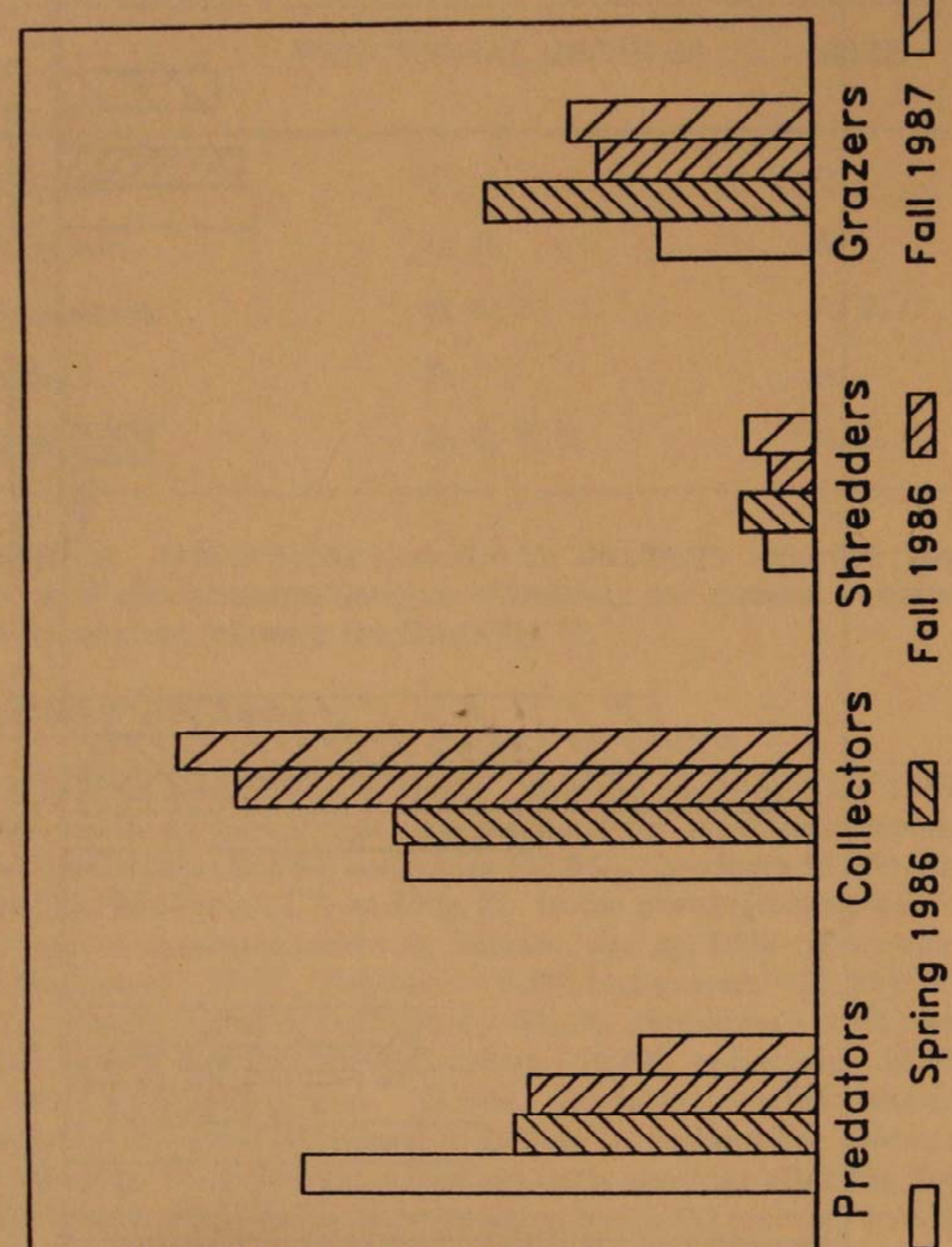

Figure 2. Pre- and postflood percentages of functional feeding groups (predators, collectors, shredders, grazers) in Seneca Creek/old channel, Pendleton County, West Virginia.

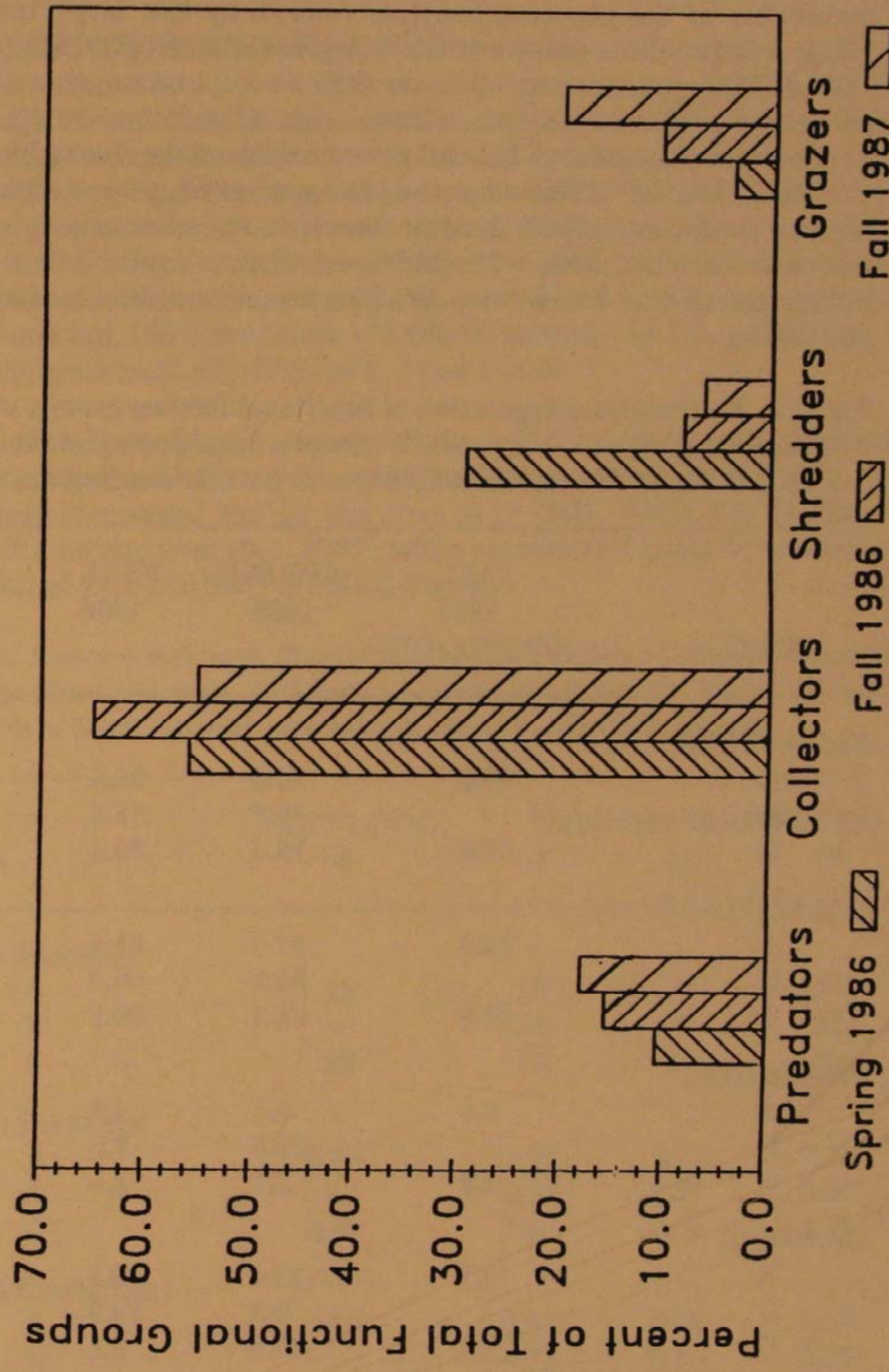

Figure 3. Postflood percentages of functional feeding groups (predators, collectors, shredders, grazers) in Seneca Creek/new channel, Pendleton County, West Virginia.

After the flood, the functional feeding group structure of both streams was dominated by collectors (gatherers and filterers). Instability of the physical habitat, caused by the large input and transportation of the fine particulate organic matter (FPOM), probably provided the general list collectors with a competitive advantage and consequent dominant role (Cummings and Klug, 1979). In a manipulated stress, Mink Creek in the foothills of the Rocky Mountains of Idaho, Minshall (1981) reported that grazers decreased about 9% in relative abundance in year 2, while distribution (collectors + shredders) increased almost 30%. He believed that a major effect of the manipulation was to increase the detritus retention capacity of the streambed.

Table 2. Percentage composition of functional feeding groups at sites A (Seneca Creek/old channel), B (Seneca Creek/new channel), and C (North Fork of South Branch) for each postflood collection period.

SITES	FALL 1985 (PREFLOOD)	SPRING 1986	FALL 1986	FALL 1987
PREDATORS				
A	45.6	26.8	25.5	15.8
B	-	10.6	15.6	18.0
C	37.4	16.8	30.4	32.1
COLLECTORS				
A	36.3	37.7	51.4	56.6
B	-	55.9	65.0	55.1
C	43.0	64.1	60.3	53.3
SHREDDERS				
A	4.4	6.5	4.0	6.0
B	-	29.6	8.5	6.5
C	1.9	2.7	8.1	0.3
GRAZERS				
A	13.7	29.0	19.1	21.6
B	-	3.9	10.9	20.4
C	17.7	16.4	1.2	14.3

Seneca Creek/New Channel

FUNCTIONAL FEEDING GROUPS. Prior to heavy flooding, a nearby floodplain area was covered with some herbaceous vegetation. After the flood, a new channel had been formed with rocks and cobble. The new channel is separate from the old channel by a small "island". In the postflood samples, the percentage compositions of the functional feeding groups were as follows: spring, 1986 (predators - 10.6%, collectors - 55.9%, shredders - 29.6%, and grazers 3.9%); fall, 1986 predators - 15.6%, collectors - 65.0%, shredders - 8.5%, and grazers 10.9%); and fall, 1987 (predators - 18.0%, collectors - 55.1%, shredders - 6.5%, and grazers 20.4%) (Tables 1, 2 and Fig. 3).

The percentage composition of predators and grazers gradually increased during the postflood collections (Table 2, Fig. 3). Collectors increased during the first year (fall, 1986) but declined during the second year (fall, 1987), while shredders declined drastically in the fall of 1986 and 1987 (Table 2, Fig. 3).

Table 3. Species richness, diversity, and equitability at sites A (Seneca Creek/old channel), B (Seneca Creek/new channel), and C (North Fork of South Branch) for each postflood collection period.

SITES	PREFLOOD 0	MONTHS POSTFLOOD 4	12	24
Species Richness				
A	19	19	21	20
B	-	19	20	22
C	22	19	19	17
Species Diversity				
A	3.45	3.55	3.24	3.23
B	-	3.26	2.51	3.54
C	3.40	3.19	2.58	2.66
Species Equitability				
A	0.84	0.89	0.52	0.57
B	-	0.74	0.40	0.77
C	0.68	0.68	0.52	0.53

SPECIES RICHNESS, EQUITABILITY, AND DIVERSITY. Species richness (number of taxa) declined slightly after the flood in the North Fork of the South Branch (Table 3) but returned to preflood values within one year. In Seneca Creek, species richness remained constant after the flood and during the postflood samples (Table 3). Following the flood, species richness in Seneca Creek/new channel is comparable to values in Seneca Creek/old channel (Table 3).

Species diversity and equitability were reduced after the flood for one year in the North Fork of the South Branch, but started to increase slightly after two years (Table 3, Figs. 4, 5). In Seneca Creek/old channel, species diversity and equitability increased slightly following the flood but were reduced within one year (Table 3, Figs. 4, 5). Following the flood, species diversity and equitability in Seneca Creek/new channel increased but were reduced within twelve months (Table 3, Figs. 4, 5).

Nulty (1980) noted the effect of high river discharge on populations in Neosha River, a left hand tributary of the Arkansas River. On 26 June 1973, the diversity per individual ($\bar{d}$) dropped from 3.31 to 2.52 following a period of high discharge.

North Fork of the South Branch

RECOLONIZATION OF TAXA. The number of ephemeropteran taxa doubled after the flood but returned to preflood values in one year (Table 4). The genera *Stenonema, Isonychia,* and *Baetis* were present in all samples throughout the two-year study. However, the genus *Ephemerella* was present in the preflood samples but absent in postflood samples. The genus *Pseudocloeon* was absent in preflood samples but present in postflood samples.

The number of plecopteran taxa remained fairly constant throughout the two-year study period (Table 4). The genera *Acroneuria, Paragnetina,* and *Allonarcys* were found in pre- and postflood samples.

Trichopteran taxa were drastically reduced following the flood and did not recolonize during the study period to preflood values (Table 4). The genera *Brachycentrus* and *Hydropsyche* were in pre- and postflood collections. The genus *Chimarra* was found in the preflood samples but absent in the postflood samples. The genus *Neureclipsis* was absent in the preflood samples but present in the postflood samples.

Table 4. Number of taxa of naiads of the major insect orders at sites A (Seneca Creek/old channel), B (Seneca Creek/new channel), and C (North Fork of South Branch) for each postflood collection period.

TAXA	PREFLOOD 0	MONTHS POSTFLOOD 4	12	24
Ephemeroptera				
A	4	5	8	4
B	-	5	5	5
C	4	8	3	4
Plecoptera				
A	4	3	3	5
B	-	5	5	5
C	3	4	3	2
Trichoptera				
A	4	4	4	4
B	-	5	5	4
C	5	2	2	3
Diptera				
A	3	3	4	4
B	-	0	2	4
C	3	4	2	2

The number of dipteran taxa remained fairly constant throughout the two-year study period (Table 4). The genus *Atherix* and family Chironomidae were found in pre- and postflood samples.

Of the minor insect taxa, the following genera were in preflood samples but absent in the postflood samples: *Boyeria* (odonate), *Sialis* (alderfly), and *Dineutus* (Beetle).

Seneca Creek/Old Channel

RECOLONIZATION OF TAXA. The number of ephemeropteran taxa remained fairly constant immediately after the flood (Table 4). Within one year, they doubled the preflood values; however, the number of taxa returned to preflood values within two years. The genera *Stenonema* and *Isonychia* were found in the pre- and postflood

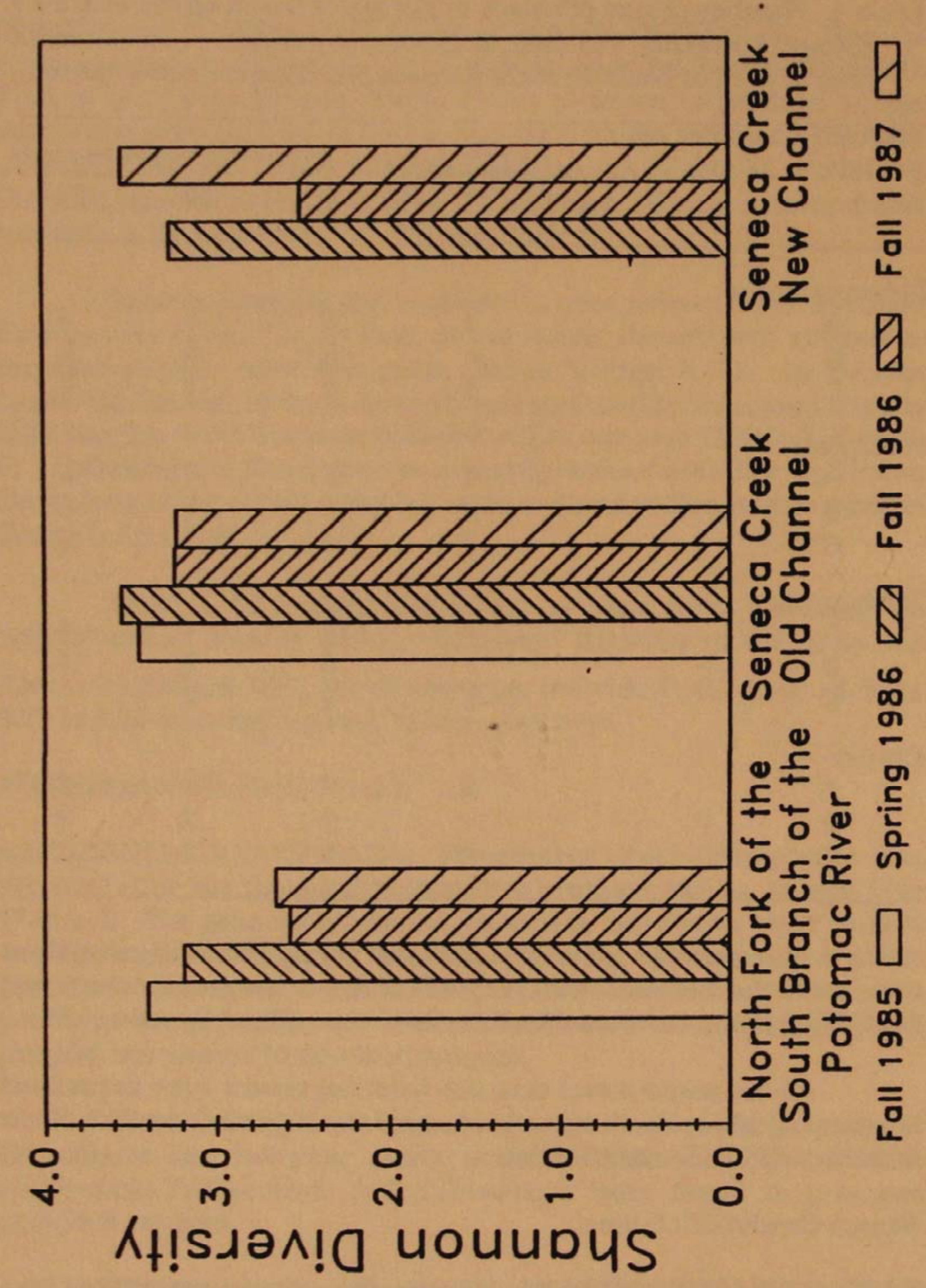

Figure 4. Pre- and postflood species diversity values in the North Fork of the South Branch of the Potomac River and Seneca Creek/old and new channels, Pendleton County, West Virginia.

samples. The genus *Epeorus* was found in the preflood samples but absent in the postflood samples. The genera *Paraleptophlebia*, *Pseudocloeon*, *Ephemerella*, and *Baetis* were in postflood samples but absent from preflood samples.

The number of plecopteran taxa remained fairly constant throughout the two-year study period (Table 4). The genera *Acroneuria*, *Allonarcys*, and *Paragnetina* were found in the pre- and postflood samples. The genera *Neophasganophora* and *Hastaperla* were found in postflood samples but absent in preflood samples.

The number of tricopteran taxa was the same throughout the two-year collecting period (Table 4). The genus *Hydropsyche* was found in pre- and postflood samples. The genera *Cheumatopsyche* and *Goerita* were found in postflood samples but absent in preflood samples. The genus *Dolophilodes* was present in the preflood samples, absent after the flood, but was collected in the postflood samples after one year. The genera *Polycentropus* and *Chimarra* were found in the preflood samples but were absent from the postflood samples.

Of the minor taxa, the genus *Pseuphenus* (beetle) was found in the preflood samples but absent in postflood samples. The genus *Atherix* (snipefly) was present in preflood samples but absent immediately after the flood; however, it was found in the samples within one year.

Coefficient of Community Similarity. In the North Fork of the South Branch, the lowest coefficient of community similarity (37.48) was calculated four months after the flood. The coefficient of community similarity had increased to 40.41 and 48.73, one and two years, respectively. after the flood.

In Seneca Creek, the lowest coefficient of community similarity (31.36) was also recorded four months after the flood. The coefficient of community similarity had increased to 55.46 one year after the flood; a slight decline (52.01) was recorded two years after the flood.

In both streams, the recolonization of the benthic populations within one year was demonstrated with the use of the coefficient of community similarity. In the fall of 1989 (four years postflood), benthic collections will be made and compared with the community similarity index.

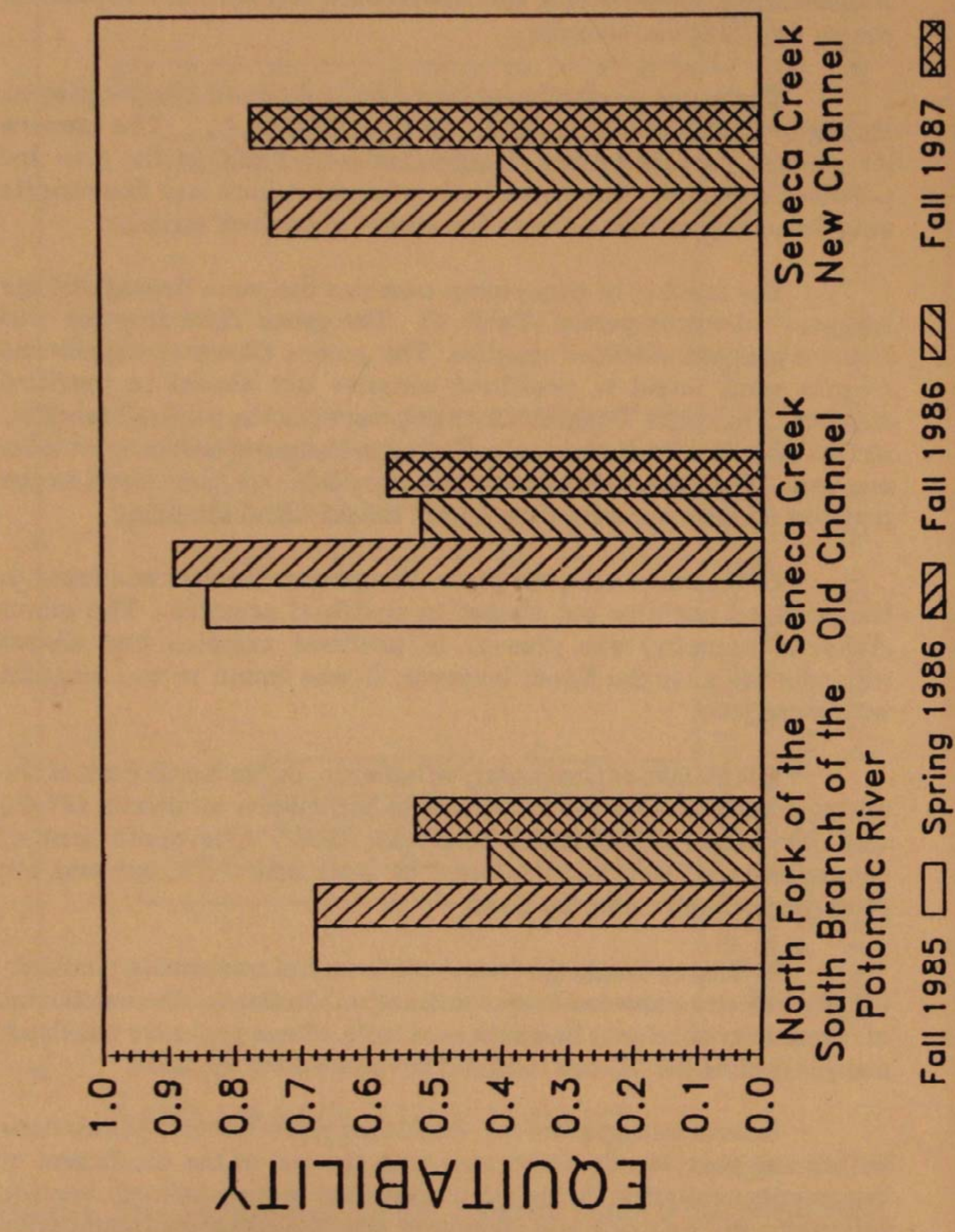

Figure 5. Pre- and postflood species equitability values in the North Fork of the South Branch of the Potomac River and Seneca Creek/old and new channels, Pendleton County, West Virginia.

Molles (1985) noted a similar trend in the coefficient of community similarity index following a flood in Tesuque Creek, Santa Fe National Forest, New Mexico. The index declined after the flood but increased within 12 months.

Williams and Hynes (1976) identified four principle recolonization pathways of stream benthos: aerial movements, downstream drift, upstream movement and vertical movements from deep substrate. Although all four pathways may contribute colonists, previous studies indicate that one pathway usually dominates. In permanent streams, downstream drift is most important (Townsend and Hildrew, 1976; Williams and Hynes, 1976).

Several investigators have documented the relationships among catastrophic flooding and such variables as species diversity and trophic relationships.

Molles (1985) noted that a flash flood severely reduced total numbers and biomass of invertebrates in Tesuque Creek, Santa Fe National Forest, New Mexico. One year after the flood, the invertebrate community of flooded and unflooded forks were similar in biomas, numbers, and species diversity. However, some differences in community composition remained even after 2 years. Among insects, dipterans recovered rapidly. Ephemeropterans, plecopterans, and trichopterans recovered at intermediate rates. and coleopterans recovered most slowly.

Moffett (1936) noted that South Willow Creek in Utah suffered from a cloudburst on 7 August 1934. This produced the first major flood in 50 years and completely altered the streambed. On 20 August, no benthic macroinvertebrates could be found but by late September recovery had begun, and this continued into November with some loss during the winter months. In the recovery phase, the Chironomidae and Simuliidae, which have short life cycles, dominated the samples. The mayflies, caddisflies, and stoneflies reappeared only slowly, probably from the headwaters.

Minckley (1963) reported that a severe flood, emanating primarily from the large spring in the headwaters of Doe Run, reduced the benthic macroinvertebrate fauna near the spring but increased it in areas further downstream. He noted that *Gammarus* was much less affected than *Asellus*.

Hoopes (1974) reported on the effects of Hurricane Agnes on a macrobenthic community in an infertile headwater stream in central Pennsylvania. Except for species diversity, other parameters (e.g. number of individuals, number of taxa, displacement) remained significantly depressed four months after the flood.

Siegfried and Knight (1977) noted that repeated washouts in Squirrel Creek, California, reduced benthic standing crop by more than 95% from October to January. Recover appears to be based on recruitment from newly hatched eggs and the availability of autochthonous energy sources.

Minshall (1981) studied the seasonal and temporal variations of the benthic macrofauna in Mink Creek, Idaho, a 3rd order trout stream. Most benthic populations showed consistent seasonal patterns in a two year study. Experimental manipulation of the stream had no immediate effect on total numbers, but a flood which occurred soon after reduced the benthic fauna to the lowest level recorded in two years. However, values returned to preflood levels within a month.

Penrose et al. (1982) studied the macroinvertebrates from nine stations on the Upper French Broad River in North Carolina. All stations seemed to have a "refuge" from scouring. Following the 1979 spring flood (800 cfs), the number of benthic invertebrates did not appear much lower than those obtained in the spring of 1978, despite a lower 1978 flow. Extremely high flow appeared to have minimal effect on the benthic fauna in the French Broad River.

Minshall (1968) studied the community dynamics of the benthic macroinvertebrates in a small woodland stream, Morgan's Creek, Kentucky. High discharge following a Marsha spate severely devastated the fauna but had little lasting effect on the community. Species with short life cycles were able to recoup their losses quite rapidly and showed an increase in numbers soon after the flood; those with long life cycles were more seriously affected and decreased in numbers or only managed to maintain themselves following resumption of more normal discharge. The nonseasonal fauna showed the greatest decrease in numbers as a result of the spate, but their recover was faster than for species with long seasonal cycles.

Harrell and Dorris (1968) reported on the effects of flood on the benthic populations in the Otter Creek drainage basin, a 6th order intermittant system located in Garfield and Logan counties, Oklahoma. Between the August and September benthic collections more than 16 cm of rain fell, causing flooding and scouring of the streambed. Total numbers of organisms were reduced from $2470/m^2$ in August to $565/m^2$ in September. Tendipedid larvae decreased from 48% ($1049/m^2$) in August to 8% ($47/m^2$) in September.

Patrick (1970) noted that benthic populations of all species are not affected equally. Some species may be eliminated entirely, while others are able to adapt to, avoid or otherwise withstand high-velocity conditions. Perhaps flooding provides a selective, short-term stress which reduces diversity and population size, with each species being affected in proportion to its resistance to flooding. Sublette (1956) reported that larval chironomids, with their largely tubicolous habit, survived best during flooding of Clear Creek in Arkansas. From 8.8% of the total before flooding, chironomids rose to 25%, while other groups decreased in relative percentage. Depending on the rate of recover, the effects of flooding may be evident for a varying length of time. Minshall and Winger (1968) noted that stream drift, which is also highly dependent on variations in discharge, is an important mechanism for biological recovery. In certain situations, drift may be an equalizing process, since benthic populations that do not normally inhabit an area may become temporary residents even if the habitat is unsuitable for permanent residents. Possibly one major effect of flooding is to equalize benthic populations from habitats that may be ecologically dissimilar before flooding. For the Clinch River in southwestern Virginia, Crossman et al. (1974) suggested that one of the effects of flooding and stream drift may be to cause benthic populations to be distributed more uniformly throughout a stream, thereby, resulting in greater similarity among samples.

Conclusions

In Seneca Creek and the North Fork of the South Branch of the Potomac River in West Virginia, the functional feeding groups were dominated by collectors (gatherers and filterers) after the flood. Predators declined sharply and never returned to preflood percentages. In the North Fork of the South Branch, species richness (number of taxa) declined slightly after the flood; it returned to preflood values within one year. Species diversity and equitability were reduced after the flood; they started to increase slightly after two years. In Seneca Creek, species richness remained constant after the flood. Species diversity and equitability increased slightly following the flood but returned to preflood values within one year. In both streams, plecopteran and dipteran taxa recolonized rapidly and were fairly constant in pre- and postflood samples. Ephemeropteran taxa increased immediately after the flood but returned to preflood values within two years in both streams. Trichopteran taxa recovered fairly rapidly in Seneca Creek but were drastically reduced and never recolonized in the North Fork of the South Branch. Emergence periods of certain insect taxa could result in various species being absent from some samples due to the time of the year. In both streams, the coefficient of community similarity was lowest immediately after the flood and increased over the following 18 months. Overall, these results indicate a high degree of resiliency of benthic populations in both streams.

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An Altitudinal Comparison of the Tardigrade Fauna (Phylum: Tardigrada) from Mosses on Spruce Mountain, West Virginia

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Abstract

Seventeen species of tardigrades, representing ten genera (*Diphascon*, *Hypechiniscus*, *Hypsibius*, *Isohypsibius*, *Itaquascon*, *Macrobiotus*, *Milnesium*, *Minibiotus*, *Pseudechiniscus*, *Ramazzottius*), were collected from mosses on trees, rocks, and the ground at three altitudes on Spruce Mountain, Pendleton County, West Virginia. Five species (Hypechiniscus gladiator, *Pseudechiniscus suillus*, *Macrobiotus occidentalis*, *Hypsibius maculatus*, *Diphascon scoticum*) were found only at the lowest altitude. *Ramazzottius oberhaeuseri* and *Diphascon prorsirostre* were collected only at the highest altitude. Three species (*Diphascon* cf. *higginsi*, *Itaquascon placophorum*, and *Hypsibius dujardini*) were collected at two of the three sites. Seven species (*Macrobiotus hufelandi*, *M. harmsworthi*, *M. richtersi*, *Minibiotus intermedius*, *Hypsibius convergens*, *Isohypsibius macrodactylus*, and *Milnesium tardigradum*) were found at all three altitudes: 853 m, 1158 m, and 1463 m. The majority of tardigrades were more common on the north slope. *Hypechiniscus gladiator*, *Pseudechiniscus suillus*, *Minibiotus intermedius*, and *Hypsibius maculatus* were found only on the north slope. Based on the Fisher Exact Probability one-tailed test, there was a significant difference ($p < 0.05$ CL) in the distribution of *Milnesium tardigradum* between altitudes and habitats (trees vs rocks and ground). The distribution of *Isohypsibius macrodactylus* was

significantly different between the two lower altitudes on tree substrates.

Introduction

Although tardigrades (water bears) are cosmopolitan in distribution, only 70 different species from 22 states have been reported from the United States, compared with, for example, 204 for Italy alone (Maucci, 1987). The difference in species diversity is, however, a reflection of collection effort and numbers of studies rather than a true geographical difference. Regionally, species have been reported from a few places in eastern Tennessee, western North Carolina, southwestern Virginia, and West Virginia (Tarter et al., 1989).

The primary objectives of this investigation were: (1) to identify the species of tardigrades on mosses from the ground, rocks, and trees at selected altitudes on Spruce Mountain, and (2) to determine any correlation of tardigrade distribution with moss habitat, altitude, and slope aspect.

Study Area

Spruce Mountain is located in Pendleton County, West Virginia. The elevation at the summit of Spruce Knob is 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 primary deciduous communities, mostly in a zone from 914 m to 1219 m, sugar maple, beech, and yellow birch are the usual dominants.

Materials and Methods

Mosses were collected from the ground, rocks, and trees at altitudes of 853 m (2800'), 1158 m (3800'), and 1463 m (4800') on all slopes (North, East, South, West). The number of samples was as follows: total from trees, 50, consisting of 20, 19, 11 samples from 853 m, 1158 m, and 1463 m, respectively; total from non-trees (rocks and ground), 22, consisting of 8, 4, 10 from 853 m, 1158 m, and 1463 m, respectively. 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. After the soaking process, moss was removed and squeezed over the funnel to remove the remaining water and tardigrades. The funnel contents were drained into a beaker, and after the debris settled, the top layer of water was decanted and a small aliquot of the remaining layer was placed into a gridded petri dish and searched for active tardigrades. If the sample was positive for tardigrades, the entire sample was fixed by the addition of hot alcohol. An Irwin loop (200 µm X 500 µm) was used to transfer tardigrades from petri dishes to slides. Tardigrades were mounted in Hoyer's medium and oriented under small coverslips for identification under an Olympus 'BH phase contrast compound microscope. Up to 10 tardigrades were removed from each sample, depending on the abundance of tardigrades in the sample. Tardigrades were identified primarily with keys and descriptions in Ramazzotti and Maucci (1983).

Since much of the data did not meet the assumptions of parametric tests, statistical comparisons of study sites were made using the nonparametric Fisher Exact Probability test ($p < 0.05$ CL) (Siegel, 1956). Contingency tables were set up for each of the 17 species found on Spruce Mountain. Rows represented the independent groups (stations) being compared. Column headings were (1) the number of samples in which the tardigrades were present and (2) the number of samples in which the species was absent.

Results

Systematic Account

Seventeen species were identified from Spruce Mountain. *Hypechiniscus* and *Pseudechiniscus* are heterotardigrades; the others are eutardigrades. See Tables 1 - 3 for additional information.

Hypechiniscus gladiator (Murray, 1905)

H. gladiator was found only at 853 m in *Dicranum fulvum* on a tree.

Pseudechiniscus suillus (Ehrenberg, 1853)

P. suillus was found only from three samples at 853 m. This species was found in the following mosses on trees and on the ground: sp., *Hypnum* sp., and *Leucobryon glacum.*

Table 1. Frequency, rank, and constancy of tardigrades from trees on Spruce Mountain, West Virginia

TARDIGRADES	FREQUENCY(%) 2800'	3800'	4800'	ALL	*RANK	CONSTANCY (%)
Diphascon cf. *higginsi*	0.0	0.0	0.0	0.0	-	0
D. prorsirostre	0.0	0.0	9.1	2.0	6R	33
D. scoticum	0.0	0.0	0.0	0.0	-	0
Hypechiniscus gladiator	5.0	0.0	0.0	2.0	6R	33
Hypsibius convergens	0.0	10.5	9.1	6.0	4R	67
H. dujardini	0.0	5.3	0.0	2.0	6R	33
H. maculatus	5.0	0.0	0.0	2.0	6R	33
Isohypsibius macrodactylus	0.0	26.3	9.1	12.0	2R	67
Itaquascon placophorum	10.0	5.3	0.0	6.0	4R	67
Macrobiotus harmsworthi	10.0	15.8	9.1	12.0	2R	100
M. hufelandi	50.0	36.8	45.5	44.0	1C	100
M. occidentalis	0.0	0.0	0.0	0.0	-	0
M. richtersi	10.0	10.5	27.3	14.0	1R	100
Milnesium tardigradum	35.0	31.6	0.0	26.0	2C	67
Minibiotus intermedius	10.0	10.5	9.1	10.0	3R	100

Table 1. Continued.

TARDIGRADES	FREQUENCY(%) 2800'	3800'	4800'	ALL	*RANK	CONSTANCY (%)
Pseudechiniscus suillus	10.0	0.0	0.0	4.0	5R	33
Ramazzottius oberhaeuseri	0.0	0.0	0.0	0.0	-	0
TOTAL NUMBER OF SPECIES	9	9	7	13	-	-
TOTAL NUMBER OF SAMPLES	20	19	11	50	-	-

*A = Abundant (70 - 100%)
C = Common (20 - 70%)
R = Rare (0 - 20%)

Macrobiotus harmsworthi Murray, 1907

M. harmsworthi, a tentative identification until confirmed with eggs, was found in six samples from 853 m, 1158 m and 2463 m. This species was found in the following mosses on trees and rocks: *Hypnum* sp., *Platydictya subtile*, and *Ulota crispa*.

Macrobiotus hufelandi Schultze, 1833

M. hufelandi, a common species on Spruce Mountain, was collected from 26 samples from 853 m, 1158 m. and 1463 m. Eggs were not found. This species was collected from more samples than any other tardigrade (27% of the positive samples) and was found in the following mosses on trees, rocks and the ground: *Amblystegium serpens*, *Anomodon attenuatus*, *Atrichum augustatum*, *Dicranum fulvum*, *D. scoparum*, *Hedwigia ciliata*, *Hypnum pratense*, *Leucobyron glacum*, *Thuidium delicatulum*, and *Ulota crispa*.

Macrobiotus occidentalis Murray, 1910

M. occidentalis was collected only at 853 m in *Mnium* sp. on a rock.

Macrobiotus richtersi Murray, 1911

M. richtersi was collected from seven samples from 853 m, 1158 m, and 1463 m. This species was found in the following mosses on trees and rocks: *Amblystegium serpens, Brachythecium salebrosum, Hedwigia ciliata* and *Ulota crispa.*

Minibiotus intermedius (Plate, 1888)

M. intermedius was collected from six samples at 853 m, 1158 m, and 1463 m. This species was collected from the mosses *Amblystegium serpens, Anomodon attenuatus,* and *Dicranum fulvum.*

Table 2. Frequency, rank, and constancy of tardigrades from non-trees (rocks and ground) on Spruce Mountain, West Virginia

	FREQUENCY(%)					
TARDIGRADES	2800'	3800'	4800'	ALL	*RANK	CONSTANCY (%)
Diphascon cf. *higginsi*	12.5	25.0	0.0	9.1	2R	67
D. prorsirostre	0.0	0.0	0.0	0.0-	-	0
D. scoticum	25.0	0.0	0.0	9.1	2R	33
Hypechiniscus gladiator	0.0	0.0	0.0	0.0	-	0
Hypsibius convergens	12.5	0.0	0.0	4.5	4R	33
H. dujardini	0.0	0.0	10.0	4.5	4R	33

Table 2. Continued.

TARDIGRADES	FREQUENCY(%) 2800'	3800'	4800'	ALL	*RANK	CONSTANCY (%)
H. maculatus	0.0	0.0	0.0	0.0	-	0
Isohypsibius macrodactylus	12.5	25.0	10.0	13.6	1R	100
Itaquascon placophorum	12.5	0.0	0.0	4.5	4R	33
Macrobiotus harmsworthi	12.5	25.0	0.0	9.1	2R	67
M. hufelandi	45.5	0.0	30.3	36.4	2C	67
M. occidentalis	12.5	0.0	0.0	4.5	4R	33
M. richtersi	0.0	25.0	40.0	22.7	3C	67
Milnesium tardigradum	62.5	75.0	60.0	63.6	1C	100
Minibiotus intermedius	0.0	0.0	0.0	0.0	-	0
Pseudechiniscus suillus	12.5	0.0	0.0	4.5	4R	33
Ramazzottius oberhaeuseri	0.0	0.0	20.0	9.1	2R	0
TOTAL NUMBER OF SPECIES	10	5	6	13	-	-
TOTAL NUMBER OF SAMPLES	8	4	10	22	-	-

*A = Abundant (70 - 100%); C = Common (20 - 70%); R = Rare (0 - 20%)
Hypsibius convergens (Urbanowicz, 1925)

H. convergens was collected from three samples at 853 m, 1158 m, and 1463 m. This species was found in the mosses *Amblystegium serpens*, *Anomodon attenuatus*, and *Thuidium delicatulum*.

Hypsibius dujardini (Doyere, 1840)

H. dujardini was collected only from two samples at 1158 m and 1463 m. This species was collected from the mosses *Anomodon attenuatus* and *Hedwigia ciliata*.

Hypsibius maculatus Tharos, 1969

H. maculatus was found only in one sample. It was present at 853 m in an unknown moss sample from a tree.

Ramazzottius oberhaeuseri (Doyere, 1840)

R. oberhaeuseri was found only in two samples at 1463 m: *Hedwigia ciliata* on rocks and an unknown moss on the ground.

Isohypsibius macrodactylus (Maucci, 1978)

I. macrodacytlus was collected in seven samples at 853 m, 1158 m, and 1463 m. This species was collected from the mosses *Anomodon attenuatus* and *A. rostratus* on trees and the ground.

Itaquascon placophorum Maucci, 1972

I. placophorum was found in three samples at 853 m and 1158 m. This species was collected from the mosses *Brachythecium salebrosum*, *Leucobryon glacum* and *Thuidium delicatulum* on trees and the ground.

Diphascon cf. *higginsi* Binda, 1971

D. cf. *higginsi* was found only in two samples at 853 m and 1158 m from unidentified mosses on rocks. The identification of this tardigrade species is tentative until more specimens are examined and compared with reference material.

Table 3. Frequency, rank, and constancy of tardigrades from trees and non-trees on Spruce Mountain, West Virginia

TARDIGRADES	FREQUENCY(%) 2800'	3800'	4800'	ALL	*RANK	CONSTANCY (%)
Diphascon cf. higginsi	3.6	4.4	0.0	2.8	7R	67
D. prorsirostre	0.0	0.0	4,8	1.1	8	33
D. scoticum	7.1	0.0	0.0	2.8	7R	33
Hypechiniscus gladiator	3.6	0.0	0.0	1.4	8R	22
Hypsibius convergens	3.6	8.7	4.8	5.6	5R	100
H. dujardini	0.0	4.4	4.8	2.8	7R	67
H. maculatus	3.6	0.0	0.0	1.4	8R	33
Isohypsibius macrodactylus	3.6	26.2	9.5	12.5	2	100
Itaquascon placophorum	10.7	4.4	0.0	5.6	5R	67
Macrobiotus harmsworthi	10.7	17.4	4.8	11.1	3R	100
M. hufelandi	53.6	30.4	38.1	41.7	1C	100
M. occidentalis	3.6	0.0	0.0	1.4	8R	33
M. richtersi	7.1	13.0	33.3	16.7	1	100
Milnesium tardigradum	42.9	39.1	28.6	37.5	2C	100
Minibiotus intermedius	7.1	8.7	4.8	6.9	4	0

Table 3. Continued.

TARDIGRADES	FREQUENCY(%) 2800'	3800'	4800'	ALL	*RANK	CONSTANCY (%)
Pseudechiniscus suillus	10.7	0.0	0.0	4.1	6R	33
Ramazzottius oberhaeuseri	0.0	0.0	9.5	2.8	7R	33
TOTAL NUMBER OF SPECIES	14	10	10	17	--	--
TOTAL NUMBER OF SAMPLES	28	23	21	72	--	--

*A = Abundant (70 - 100%)
C = Common (20 - 70%)
R = Rare (0 - 20%)

Diphascon scoticum Murray, 1905

D. scoticum was collected only from two samples at 853 m. This species was found in the moss *Thuidium delicatulum* on rocks and the ground.

Diphascon prorsirostre Thulin, 1928

D. prorsirostre was collected only from one sample at 1463 m. The species was found in the moss *Dicranum filvum* on a tree.

Milnesium tardigradum Doyere, 1840

M. tardigradum, a common species on Spruce Mountain, was collected from 23 samples from 853 m, 1158 m, and 1463 m. Other than *Macrobiotus hufelandi*, this species was present in more samples than any other tardigrade on Spruce Mountain (24% of the positive samples). This species was found in the following mosses from trees, rocks and on the ground: *Amblystegium serpens*, *Anomodon* *attenuatus*, *Atrichum augustatum*, *Brachythecium salebrosum*, *Hedwigia ciliata*, and *Ulota crispa*.

Distribution of Tardigrades of Spruce Mountain

The species-presence method was used as an indicator of distribution. Two measurements were calculated: (1) constancy, the number of altitudes where the tardigrade species was found divided by the total number of altitudes, and (2) frequency, the number of samples in which a tardigrade occurred divided by the total number of samples. Constancy, the occurrence of a species at an altitude, indicates the range of a species; however, indications of presence or absence alone may give a false impression of the distribution of a particular species. Frequency indicates the relative dispersion of tardigrades among the moss samples.

The distribution on Spruce Mountain of 17 species of tardigrades is presented in terms of frequency (%) and constancy(%) in Tables 1 - 3. Species were ranked according to frequency as follows: 70% - 100%, abundant; 20% - 70%, common; and 0% - 20%, rare (Nelson, 1975). Thirteen species (76%) of tardigrades were found on trees and non-trees (rocks and ground) (Table 1.2).

On trees, very little overlap existed in the distribution of the species at the various altitudes (Table 1). Four species had a constancy of 100%, i.e. they occurred at all three altitudes. Four species were present at two of the three altitudes (constancy, 67%). *Hypsibius convergens* and *Isohypsibius macrodactylus* were absent from the lowest altitude (85 m), while *Itaquascon placophorum*, and *Milnesium tardigradum* were absent from the highest altitude (1463 m). Five species were present at one altitude (constancy, 33%). *Diphascon prorsirostre* was found only at 1463 m, while *H. gladiator*, *H. maculatus*, and *P. suillus* were found only at 853 m. Four species, which were found on soil and rocks, were not found on the trees. Four species were found only on trees and not the other substrates. *Macrobiotus hufelandi* and *Milnesium tardigradum* were the most frequent tardigrades found on mosses from trees.

On non-trees (rocks and ground; Table 2), only two species of tardigrades (*Isohypsibius macrodactylus* and *Milnesium tardigradum*) overlapped at all altitudes (constancy, 100%). Four species were present at two of the altitudes (constancy, 67%). *Diphascon* cf. *higginsi* and *M. harmsworthi* were absent from the highest altitude (1463m),

Table 4. Fisher Exact Probabilities of tardigrades from Spruce Mountain, West Virginia (L = low 853 m; M = middle, 1158 m; H = high 1463 m; T = trees, NY = non-trees. Significant tests ($p < 0.05$ confidence level) underlined.

TARDIGRADES	FISHER EXACT PROBABILITIES							
	LT vs MT	LT vs HT	LT vs LNT	LT vs MNT	LT vs HNT	MT vs HT	MT vs LNT	MT vs MNT
Diphascon cf. higginsi	100.0	100.0	28.57	16.67	100.0	100.0	29.63	17.39
D. prorsirostre	100.0	35.48	100.0	100.0	100.0	36.37	100.0	100.0
D. scoticum	100.0	100.0	7.41	100.0	100.0	100.0	7.98	100.0
Hypechiniscus gladiator	51.28	64.52	71.43	83.33	66.67	100.0	100.0	100.0
Hypsibius convergens	23.08	35.48	28.57	100.0	100.0	46.33	46.77	67.59
H. dujardini	48.72	100.0	100.0	100.0	33.33	63.33	70.37	82.61
H. maculatus	51.28	64.52	71.43	83.33	66.67	100.0	100.0	100.0
Isohypsibius macrodactylus	<u>2.20</u>	35.48	28.57	16.67	33.33	21.54	31.43	46.08
Itaquascon placophorum	39.50	40.86	46.40	68.84	43.68	63.33	43.30	82.61
Macrobiotus harmsworthi	31.98	46.50	46.40	37.55	43.68	38.89	44.17	43.77
M. hufelandi	18.25	28.40	27.63	9.42	18.51	26.91	16.23	20.55
M. occidentalis	100.0	100.0	28.57	100.0	100.0	100.0	29.63	100.0
M. richtersi	39.50	18.45	50.26	37.55	6.72	19.80	48.72	38.62
Milnesium tardigradum	25.89	<u>2.95</u>	14.27	15.81	13.59	<u>4.57</u>	11.65	13.28
Minibiotus intermedius	39.50	46.50	51.26	68.84	43.68	46.33	48.72	67.59
Pseudechiniscus suillus	25.64	40.86	46.40	68.84	43.68	100.0	29.63	100.0
Ramazzottius oberhaeuseri	100.0	100.0	100.0	100.0	10.34	100.0	100.0	100.0

Table 4. Continued.

TARDIGRADES	FISHER EXACT PROBABILITIES						
	MY vs HT	HT vs LNT	HT vs MNT	HT vs HNT	LNT vs MNT	LNT vs HNT	MNT vs HNT
Diphascon cf. higginsi	100.0	42.11	26.67	100.0	24.24	44.44	28.57
D. prorsirostre	100.0	57.89	73.33	52.38	100.0	100.0	100.0
D. scoticum	100.0	16.37	100.0	100.0	42.42	18.30	100.0
Hypechiniscus gladiator	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Hypsibius convergens	42.12	51.46	73.33	52.38	66.67	44.44	100.0
H. dujardini	46.80	100.0	100.0	47.62	100.0	55.56	71.43
H. maculatus	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Isohypsibius macrodactylus	24.48	51.46	41.90	52.38	48.48	52.29	43.96
Itaquascon placophorum	65.52	42.11	100.0	100.0	66.67	44.44	100.0
Macrobiotus harmsworthi	26.52	51.46	41.90	52.38	48.48	44.44	28.57
M. hufelandi	30.19	28.01	15.38	27.24	7.07	15.36	32.97
M. occidentalis	100.0	42.10	100.0	100.0	66.67	44.44	100.0
M. richtersi	7.56	17.03	48.35	29.80	33.33	6.86	41.95

while *M. hufelandi* was absent from 1158 m; *M. richtersi* was absent from the lowest altitude (853 m). Seven species were present at only one altitude (constancy, 33%). *Diphascon scoticum*, *H. convergens*, *Itaquascon placophorum*, *M. occidentalis*, and *P. suillus* were found only at the lowest altitude (853 m), while *H. dujardini* and *R. oberhaeuseri* were found only at the highest altitude (1463 M). Four species were not found on rocks or on the ground. *Milnesium tardigradum* and *Macrobiotus hufelandi* were the most frequent tardigrades on mosses from rocks and the ground.

When all samples (trees and non-trees; Table 3) from Spruce Knob were combined, seven species of tardigrades overlapped at all altitudes (constancy, 100%). Three species were present at two of the altitudes (constancy, 67%). *Diphascon* cf. *higginsi* and *I. placophorum* were absent from the highest altitude (1463 m), while *H. dujardini* was absent from the lowest altitude (853 m). *Diphascon prorsirostre* and *Ramazzottius oberhaeuseri* were found only at the highest altitude (1463 m), while *D. scoticum*, *Hypechiniscus gladiator*, *Hypsibius maculatus*, *Macrobiotus occidentalis* and *P. suillus* were found only at the lowest altitude (853 m).

Based on the Fisher Exact Probability one-tailed test, six tests involving the altitudinal distribution of two species of tardigrades proved to be significant ($p < 0.05$ CL). (Table 4). The distribution of *Isohypsibius macrodactylus* was significantly different from 853 m (trees) to 1158 m (trees). The distribution of *Milnesium tardigradum* was significantly different between 853 m (trees) versus 1463 m (trees); 1158 m (trees) versus 1463 m (trees); 1463 m (trees) versus 853 m (non-trees), 1463 m (trees) versus 1158 m (non-trees); and 1463 m (trees) versus 1463 m (non-trees).

The following moss samples yielded tardigrades: *Amblystegium serpens*, *Anomodon attenuatus*, *A. rostratus*, *Atrichum augustatum*, *Brachythecium salebrosum*, *Dicranum fulvum*, *D. polysetum*, *D. scoparum*, *Endodon cladorrhizans*, *Hedwigia ciliata*, *Hypnum pratense*, *Leucobryon glacum*, *Platydictya subtile*, *Thuidium delicatulum*, and *Ulota crispa*. *Ulota crispa* on trees and *Anomodon attenuatus* on rocks and ground provided the greatest number of tardigrades. The moss samples with no tardigrades were *Hylocomnium splendens*, *Hypnum imponens*, *Nnium cuspidatum*, *Polytrichum junperinum* and *Sematophyllum adnatum*.

Discussion

The distribution of certain species of tardigrades on Spruce Mountain appeared to be associated with altitude. The interaction of decreasing temperatures and increasing precipitation may contribute to the altitudinal stratification of certain tardigrade species. The number of species of tardigrades decreased with an increase in altitude: 14 (853 m), 10 (1158 M), and 10 (1463 m) (Tables 1 - 3). The number of species present, both plant and animal, usually decreases with an increase in altitude in a mountain range (Allee and Schmidt, 1951). Beasley (1988) noted a species reduction of tardigrades at different altitudinal zones (1000-ft intervals) in New Mexico. Bartos (1938, 1939) reported no reduction in tardigrade species number with altitude. Rodriquez-Roda (1951) and Dastych (1987) noted an increase in the number of tardigrade species with an increase in altitude in Spain and Poland, respectively. In the United States, Nelson (1975) found an increase in the number of tardigrade species with an increase in altitude on Roan Mountain, Tennessee. Kathman (1988) reported that numbers of species were similar at each altitude from five mountains on Vancouver Island, British Columbia, Canada.

The majority of tardigrade species appeared to be more common on north slopes. *Hypechiniscus gladiator*, *Pseudechiniscus suillus*, *Minibiotus intermedius*, and *Hypsibius maculatus* were found only on north slopes. Nelson (1975) reported that the general exposure of the slope on Roan Mountain, Tennessee, significantly affected the distribution of four species of Tardigrades (*Echiniscus virginicus*, *H. gladiator*, *Macrobiotus harmsworthi*, *M. hufelandi*); these species were more frequent on the north than the south slopes. In an investigation of vegetation and macroclimate on north and south slopes, Cantlon (1953) reported that north-facing slopes may differ from adjoining south-facing slopes in soil and air temperature, soil and atmospheric moisture, light intensity, and wind velocity. Generally on the north slope, temperatures are lower and less extreme; atmospheric moisture is higher due to more precipitation, greater relative humidity, less evaporation and transpiration; and light intensity and wind velocity are lower.

No correlation was found between the various moss species and the species of tardigrades. Generally, tardigrades that were more frequent inhabited a greater variety of moss species. *Macrobiotus hufelandi* was found in eight different moss species, and *Milnesium tardigradum* was collected from six different moss species. Seven different species of tardigrades were found in the moss *Anomodon* *attenuatus*, while four different species were found in *Dicranum fulvum* and *Ulota crispa*. Five "eurytope" species (found in all types of mosses) were present on Spruce Mountain: *Macrobiotus harmsworthi, M. hufelandi, Minibiotus intermedius, Diphascon scoticum*, and *Milnesium tardigradum*. Nelson (1975) reported six "eurytope" species on Roan Mountain: *Macrobiotus harmsworthi, M. hufelandi, M. intermedius, Hypsibius pallidus, Diphascon scoticum*, and *Milnesium tardigradum*. Based on principle components analysis and cluster analysis, Kathman (1988) noted that distribution and abundance were not dependent on moss species from five mountains on Vancouver Island, British Columbia, Canada.

Environmental factors that regulate tardigrade distribution on the species level are relatively unknown. Population density and species diversity vary tremendously in apparently similar habitats, and even in samples of the same moss at the same site. Patchy distributions result from the interaction of many factors which are difficult to determine in the field. Various sampling techniques have been used in altitudinal studies, and few investigators have incorporated replicate samples and statistical analysis. Small sample size and the identification of few individuals from subsamples provide qualitative data and descriptive information. However, the collection of time-consuming quantitative data from replicate samples is needed to determine the validity of the variations.

Acknowledgments

We are grateful to the following graduate students at Marshall University for assistance in the laboratory: Frank Borsuk, Lisa Burgess, Carolyn Culp, Betsy Henry, Kevin Howerton, David Hunt, and Kimberly Ruggles. We thank Dan Evans and Tom Weaks for help in the identification of trees and mosses, and Lu Ann South for typing the report. Lastly, we express our appreciation to DeeDee Kathman for reviewing the manuscript and making valuable suggestions.

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Geology Section

Preliminary documentation of the occurrence and prehistoric utilization of chert from the Hillsdale Limestone of the Mississippian Greenbrier Group in Pocahontas and Greenbrier Counties, West Virginia

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Abstract

The basal (Hillsdale Limestone) member of the Mississippian Greenbrier Group in portions of Greenbrier and Pocahontas Counties, West Virginia contains nodular chert which was apparently used by prehistoric populations for stone tool manufacture. Two source locations of chert within the Hillsdale Limestone and adjacent prehistoric workshop loci are examined. The regional extent of Hillsdale chert and its potential for prehistoric exploitation in the study area are discussed.

Introduction

The determination of source locations for cherts used by prehistoric populations in stone tool manufacture may be useful in extracting data on settlement-subsistence adaptation, resource utilization patterns, ranges of movement and social interaction and exchange, particularly when such lithic sources are restricted in area. Previous research in the eastern West Virginia uplands has revealed the occurrence and prehistoric use of chert from the uppermost member of the Greenbrier Limestone in Randolph County. The occurrence of "Greenbrier chert" within the Alderson Limestone appears to be somewhat limited in extent and has been used to propose a tentative hypothesis of prehistoric settlement behavior in the area (Lesser, 1988; Brashler and Lesser, 1985). Attempts have since been made to locate additional sources of chert in the Greenbrier Group which may have been useful to prehistoric economies.

EXAMINATION OF CHERT IN THE BASAL MEMBER OF THE GREENBRIER LIMESTONE GROUP

The Mississippian Greenbrier Group of West Virginia is composed almost entirely of limestone rocks. In Pocahontas and Greenbrier Counties, its thickness varies from approximately 90 to 230 meters. The Greenbrier is overlaid by the Mauch Chunk Group and rests upon Maccrady Formation shales in the area under discussion. The Greenbrier Group consists of seven discrete limestone members in the study are. They are, in descending statigraphic order, the Alderson, Union, Pickaway, Taggard, Patton, Sinks Grove and Hillsdale limestone.

A review of the pertinent geological literature revealed the expected occurrence of chert in the Sinks Grove and Hillsdale limestones with mention of occasional nodules in the lower portion of the Pickaway and the Patton in Greenbrier County (Price and Heck, 1939:266 - 279; Price and Reger 1929:165 - 183; Davis, 1978). Recent field examination of Hillsdale limestone strata at Mill Point in Pocahontas County and Lewisburg, Greenbrier County, have revealed relatively abundant exposures of chert.

As the basal member of the Greenbrier Group, the Hillsdale Limestone was named by David B. Reger from its occurrence just east of Hillsdale, Monroe County, West Virginia (Reger, 1926). According to Price and Heck (1939), the Hillsdale is correlated to St. Louis age limestones of Kentucky. It is described in the study area as a grayish-blue to dark, hard massive limestone usually containing rounded and irregular nodules of black and gray chert. The Hillsdale Limestone varies in thickness from 9 to 30 meters in the study area. The chert is reported to occur only in the basal 4.5 meters of the Hillsdale in Pocahontas County. Diagnostic attributes of the Hillsdale include, besides the occurrence of chert nodules, silicified fossil corals (*Lithostrotion* sp.) which occur in compact colonies or in layers and due to weathering are frequently found scattered over the underlying Maccrady Series shales (Price and Heck, 1939:267 - 269; Price and Reger, 1929:166 - 183).

Two exposures of Hillsdale Limestone were examined by the author in 1989 in the vicinity of Mill Point, Pocahontas County. The first was located just east of U.S. Route 219, approximately one kilometer northeast of Mill Point. This is apparently the same exposure illustrated by Price and Reger (1929:176A, 176B) in the West Virginia Geological Survey Pocahontas County Report. The chert nodules exposed in cross section here appeared to be rather small, averaging approximately 8 centimeters in diameter. Another exposure of the Hillsdale in an adjacent wooded ravine revealed abundant chert nodules similar in size. The underlying Maccrady Formation shale was well exposed at this locale with the silicified coral *Lithostrotion* present. At Mill Point, one kilometer southwest, numerous specimens of *Lithostrotion* were noted adjacent to Route 219. While no exposure of the chert-bearing Hillsdale was evident in the immediate vicinity, an adjacent field and hilltop revealed quantities of flaking debris from an extensive prehistoric lithic workshop. Various stages of primary lithic reduction appeared to be evident with nodule fragments and cores of Hillsdale chert scattered about. Though this field was reported to have been heavily collected, one diagnostic stemmed projectile point noted by the author suggests a circa 4,000 B. P. occupation.

Another source of Hillsdale chert field checked in 1989 is located in Greenbrier County just south of U.S. Route 60 along the western corporate limits of Lewisburg at an elevation of 647 meters. Weathered, dark gray Hillsdale Limestone exposed here contains abundant irregularly shaped nodules of chert exposed in cross section and laying loosely on the surrounding ground surface. The nodules observed are, on average, much larger than those noted at the Mill Point locations with the largest more than 25 centimeters in diameter. No specimens of *Lithostrotion* were observed which agrees with the observations of Price and Heck (1937, 1939) at this site. A significant prehistoric lithic workshop site is located on a hilltop approximately 50 meters north of this source location. The site consists of abundant Hillsdale chert debitage and cores. No diagnostic artifacts were noted during field examination to suggest a period(s) of occupation.

REGIONAL EXTENT OF HILLSDALE CHERT

Within Pocahontas County, the Greenbrier Group is primarily limited to that portion west of the Greenbrier River. The Hillsdale Limestone has not been recorded farther north than Clover Lick. Therefore, Hillsdale chert source locations may not be expected to occur north of this point (Price and Reger, 1929:167, 181).

In Greenbrier County, the Greenbrier Group is also primarily limited to portions of the county west of the Greenbrier River. Surface exposure of the Greenbrier is extensive in the central Karst region of the county with relatively low relief, numerous sinks and the absence of an interconnecting valley system. Numerous exposures of chert-bearing Hillsdale Limestone may be expected to occur in this area (Price and Heck, 1939).

Summary and Conclusions

Literature review and preliminary field examination has revealed the expected occurrence of chert within the basal (Hillsdale) member of the Mississippian Greenbrier Group in central and southern Pocahontas and Greenbrier Counties, West Virginia. Examination of two prehistoric lithic workshop locales adjacent to sources of the chert suggest that the Hillsdale Limestone was an important source of lithic raw material for prehistoric populations in the study area. Additional source locations of Hillsdale chert are documented in the geological literature (Price and Reger, 1929; Price and Heck, 1939). Future research should be undertaken to map these sources, compare their physical attributes and conduct archaeological surveys to identify prehistoric quarry and workshop areas in association with the Hillsdale chert.

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Minutes of the Annual Business Meeting
West Virginia Academy of Science
65th Annual Meeting
Shepherd College
Shepherdstown, West Virginia

April 7, 1990

Minutes from the West Virginia Academy of Science business meeting held at Shepherd College on April 7, 1990:

1. Meeting opened at 10:12 A.M. with Dr. Steven Stephenson, President WVAS, in charge.

2. Dr. Donald Henry, chairman of the science department at Shepherd College presented welcoming remarks.

3. Dr. Stephenson conducted an election for President Elect and Recording Secretary. Dr. Tom Weaks, Marshall University, was nominated for President Elect and Dr. Phil Cottrill, Glenville State College, was nominated for Recording Secretary. Dr. Elizabeth Swiger, Fairmont State College, Moved to accept these officers. The motion was seconded, the motion carried.

4. President Tarter entertained a motion concerning the place and time for the 1991 Academy meeting. West Virginia Institute of Technology volunteered to have the meeting. The date chosen was April 6, 1991. Dr. John Parks, WV Tech, gave his O. K. for the place and time of The Annual Meeting. Dr. Swiger moved that the Academy accept WV Tech's invitation and Dr. Tarter seconded the motion. The motion carried.

5. Dr. Parks welcomed The Academy to WV Tech for the 1991 meeting and presented photographic slides of WV Tech's new science building.

6. Dr. John Chisler, Glenville State College, said that GSC would like to relinquish the State Science Fair. He stated that five (5) years was long enough to hold the fair at one institution. Dr. Stephenson asked that the representatives present at the meeting take the information back to their respective schools and ask members of their departments to volunteer to hold the Science Fair.

7. Dr. Stephenson announced the 1991 Earth Day Program to be held on the West Virginia State College Campus.

8. Dr. Stephenson announced that West Liberty College had volunteered to host the 1992 WVAS meeting.

9. Dr. Stephenson asked for a volunteer host institution for the 1993 meeting.

10. Dr. Roy Clarkson, West Virginia University, announced that the treasurer's books had been audited during the past year.

11. Dr. Stephenson conducted a discussion concerning the publishing of irregular papers by the WVAS on the "natural history of West Virginia." (Irregular papers were defined as papers not presented at the annual meeting of WVAS.) Dr. Marietta Hight, Marshall University, said we should check with other state academies and see what they do about such papers. Dr. Chisler said that we now publish such papers in the "Proceedings of the WVAS". Dr. Stephenson, Dr. Swiger, and Dr. Tarter formed a committee concerning the irregular papers. They are to report at the 1991 WVAS meeting. No motion was made concerning the papers.

12. Dr. Clarkson stated that the December 31, 1989 treasury balance was $4,812.03. The balance as of April 7, 1990 was $9,171.

13. The meeting was declared adjourned by Dr. Stephenson at 10:56 A.M.

Submitted by:

Dr. Phil Cottrill
Recording Secretary

The general program featured speaker Dr. Gary Larson, specialist in Arctic fungi, from the University of Alaska.

The Luncheon Program:

Dr. Stephenson introduced two public school science teachers for the recognition award:

I. Mrs. Patsy Brannon, Valley High School in Fayette County, and

II. Mrs. Beverly McDonald, North Middle School in Berkeley County.

Dr. Stephenson said good-bye as WVAS President.

Dr. Tarter acknowledged Dr. John Landolt, Shepherd College, for setting up the Shepherd meeting.

Dr. Tarter presented Dr. Stephenson a recognition award.

Luncheon meeting ended at 12:30 P.M.

West Virginia Academy of Science
Annual Treasurer's Report
January 1, 1989 to December 31. 1989

April 7, 1990
WVAS Annual Meeting
Shepherd College
Shepherdstown, WV

BANK BALANCE JANUARY 1, 1989		**$4,400.75**
CASH RECEIPTS		
Dues	$1,605.00	
Institutional Membership	1,400.00	
Libraries	798.00	
Contributions (Talent Search)	32.00	
Annual Meeting	628.50	
Page Charges	710.00	
Interest (Checking account)	305.68	
Advertisements	75.00	
Abstract Charges	86.00	
Contributions: Du Pont	150.00	
Membership Certificates	6.00	
Back Numbers (Davis & Elkins College)	225.00	
WVU Library (exchange copies)	325.00	
Till money for Annual Meeting	100.00	
TOTAL CASH RECEIPTS FOR YEAR	6,446.08	
TOTAL CASH RECEIPTS PLUS BALANCE JANUARY 1, 1969		$10,846.83
CASH DISBURSEMENTS		
Printing (McClain)	3,855.75	
Annual Meeting	850.05	
Postage	380.65	
National Association of Academy of Science (dues)	27.00	
Editorial Assistance	462.50	
Talent Search	258.85	
Best Student Paper	100.00	
Till money for annual meeting	100.00	
TOTAL DISBURSEMENTS	6,034.80	

BANK BALANCE DECEMBER 31, 1989 **$4,812.03**

IN ADDITION TO THE ABOVE: CD No. 001-D158099 is held by The First National Bank of Morgantown. Value on anniversary date April 8, 1989 was $6,141.86. Interest for 1989 was 436.16. Interest rate is 8.25%

Respectively submitted,

Roy B. Clarkson, WVAS