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An Examination of Periphyton in Perturbated Aquatic Environments in West Virginia

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Abstract

From May 1977 to February 1978, biweekly sampling of the periphyton of five different types of streams, located in southwestern Pennsylvania (1 site) and northern West Virginia (9 sites) was conducted. These streams included: 1) sewage effluents, 2) steel mill effluents, 3) mine drainage effluents, 4) the Ohio River, and 5) streams not receiving any one type of effluent. Findings indicated: 1) unique and different growth patterns for each algal genus within any one type of stream, 2) that the various periphyton genera grew differentially during the different months of the year, 3) that changes had occurred in the community structures of the various types of streams as a function of the type of effluent (or lack thereof) received.

There have been several studies aimed at understanding how the environment affects the growth of periphyton, those algae that grow attached to rocks, stones, logs, etc., in streams (Evans and Stockner, 1972; Patrick, Roberts, and Davis, 1968; Dillard, 1969; Jones, 1974; and Castenholz, 1961). In addition, several investigators have used artificial substrates to answer the questions of how the environment affects the colonization and growth of attached organisms. However, most of these studies have two basic limitations: 1) they are generally focused on understanding the diatom community and not the algae as a whole (Patrick, Hohn, and Wallace, 1954 and McIntire and Overton, 1971) or 2) the studies are concerned with understanding nonstressed environments (Lowe, 1972 and Siver, 1977). In this study we present evidence regard-

ing the periphyton community, growing on or attaching to artificial substrates in highly stressed aquatic environments. We also compare these results to the growth and attachment of organisms in a major river system and in certain nonstressed streams of West Virginia.

Materials and Methods

The data for this study were collected from ten aquatic sites in northern West Virginia and southwestern Pennsylvania from April 1977 through February 1978. The sites were chosen in order to assess five different aquatic environments. One site, in Harmon Creek near Weirton, West Virginia, received steel mill effluents. Two sites, Robinson Run and Camp Run, received mine drainage. Two sites, Falling Run and Pompano Run, received raw sewage from Morgantown and Star City, West Virginia. Two sites were located in the Ohio River near the cities of Wellsburg and Weirton, West Virginia. The last three sites included a site in Johnson Run, a site in White Day Creek, and another site in Harmon Creek upstream of the steel mill. These three sites which were located in Marion, Brooke, and Hancock Counties will be referred to as "clean" because these sites did not receive any appreciable steel mill, mine drainage, or sewage effluents.

Information on two physical variables, air temperature and total precipitation, were obtained for the interval April 1977 through February 1978 from the West Virginia climatological data available from the Department of Commerce for Morgantown and Wellsburg, West Virginia. The biweekly periphyton samples were obtained from standard 3″ x 1″ glass microscope slides placed in a periphyton sampler for a period of 14 days. The periphyton sampler used was a modification of three other periphyton sampler designs by Patrick, Han, and Wallace (1954); Patrick (1973); and Mitchell (1974). After the two-week exposure period the slides were removed and replacement slides placed into the sampler.

The algae on the slides were removed by scraping them into a petri dish. Stream water, from the sampled stream, was then added to bring the final volume of algae and stream water to 20 mls; which was then poured into a labeled seven dram vial. On return to the laboratory, one ml of the sample was removed and the algae were then preserved by replacing the one ml subsample with one ml of a 5% formalin solution. The periphyton were thereafter enumerated using a Naubauer hemocytometer and were identified to the generic or species level with a Bausch and Lomb compound microscope at a magnification of 430x.

The resultant data were analyzed using a AMDAHL 470 V /7A computer and the Statistical Analysis System (Barr, *et al.*, 1979) at West Virginia University. The curve smoothing technique (Anderson, 1971 and Tukey, 1977) was used on the ecological data in order to ascertain the general trends. The results of applying the curve smoothing technique to the ecological variables (algal biomass, Simpson's Index, number of genera, number of Chrysophyta, and generic richness) are presented in the next section. However, this smoothing technique was not applied to the two physical variables, air temperature and total precipitation, because these two variables were already reasonably smooth.

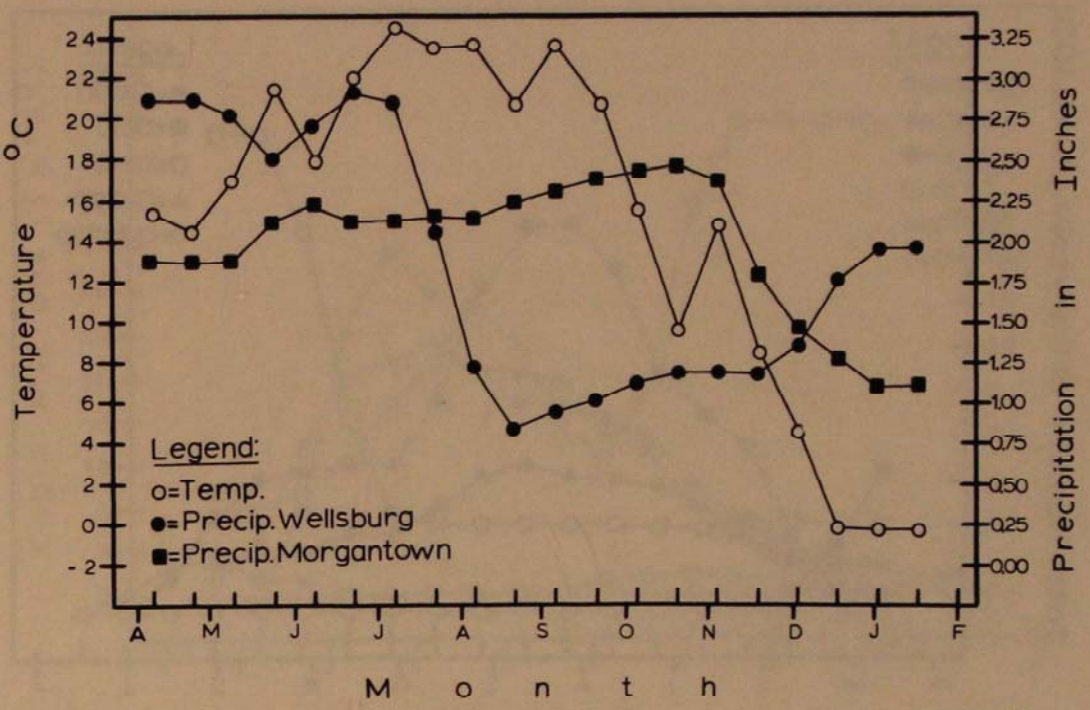

FIGURE 1. The non-smoothed total precipitation and air temperatures for Morgantown and Wellsburg, West Virginia, from April 1977 through February 1978.

Results

The plots of the two physical variables are shown in Figure 1. There is only one air temperature plotted for the Morgantown and Wellsburg areas because the maximum difference in temperature between these locations was less than one degree (celsius) and the linear correlation between the temperatures of the two study areas was very high ($r = 0.94$). An increase in temperature occurred from late April through early July, Figure 1. The temperature remained high, between 19° to 23°C, from early July through late September at which time there was a sharp decline to about 1.0°C in late December. The other two curves of Figure 1, illustrate the total precipitation of the two study areas during the biweekly sample intervals. The amount of total precipitation in the Morgantown area (sites 4 through 9) increased slightly from 1.80 inches in April to 2.25 inches in late October. This was followed by a sharp decline in precipitation to 1.15 inches in early January. The total precipitation in the Wellsburg area (sites 0 through 3) averaged about 2.8 inches from April to late June when there was a sharp decline in precipitation to 0.8 inches in mid-August. From mid-August a steady increase in the total precipitation occurred until February.

The predominant organisms found on the slides were members of the phylum Chrysophyta which accounted for 20 to 60 percent of all of the algae observed. Large changes were observed in only three of the environments (mine drainage streams, "clean" streams, and the Ohio River). The streams that had steel mill or sewage effluents, during only one or two sample periods, contained several genera of the Chrysophyta (Figure 2). Because there were so few data points greater than zero, the

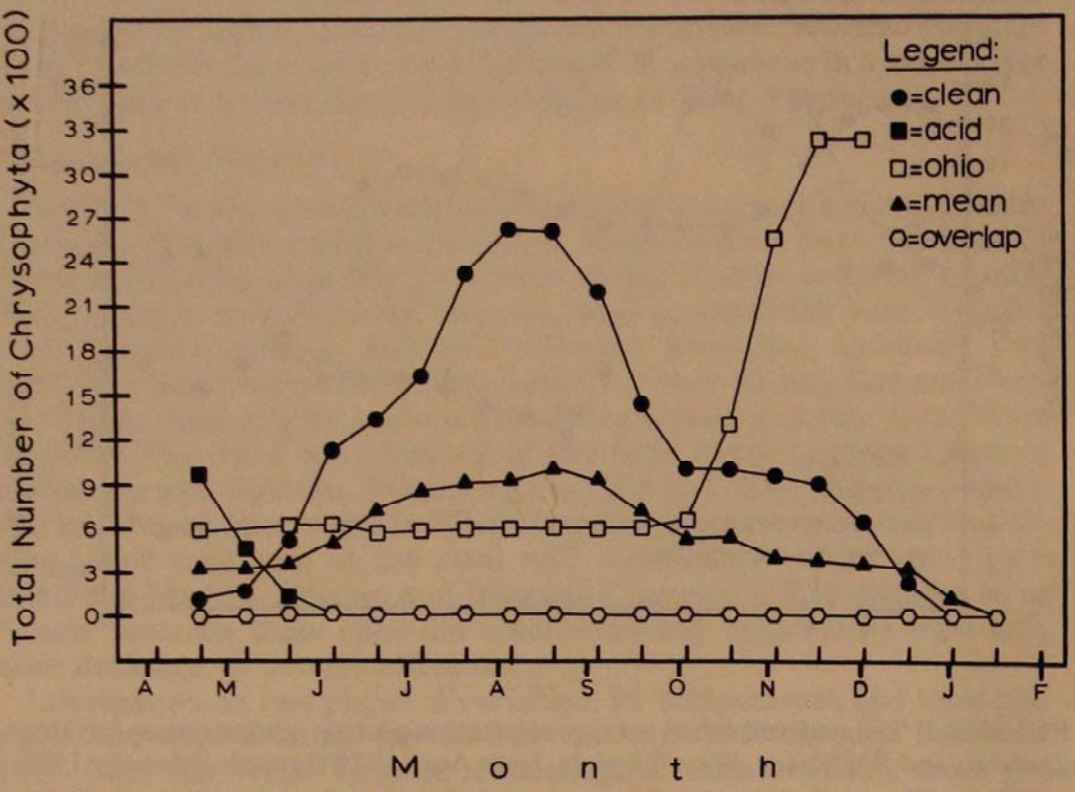

FIGURE 2. The smoothed curves of the total number of organisms of the phylum Chrysophyta present in the different environments sampled from April 1977 through February 1978.

smoothing technique tends to decrease these few points, for the sewage and steel mill streams, to near zero. In the "clean" environments, there were large increases in the number of Chrysophyta from June through late August when the numbers of these organisms declined until early October. During October and November the number of Chrysophyta remained nearly constant and then declined just prior to ice cover in late January. There were only small numbers of Chrysophyta in the Ohio River until early October at which time there was a sharp increase, from about 6 to 2,600 organisms. From early October there was a slow decline in the number of Chrysophyta until late January when ice cover prevented the further sampling of these sites. In the mine drainage streams, a small number of Chrysophyta were present in April, but these numbers declined to zero by early June and remained there throughout the rest of the study. Figure 2 also shows that the average numbers of Chrysophyta, without regard to the type of stream environment, increased from April through early September when their numbers drastically declined in January when ice covered the sites. These changes in the Chrysophyta reflect changes in the relative numbers of the four dominant genera (Diatoma, Navicula, Nitzschia, and Synedra) observed during the study.

Algal biomass, measured in cubic microns per slide, is illustrated in Figure 3. The biomass in the "clean" streams and the Ohio River showed an increase from late April through September in general correspond-

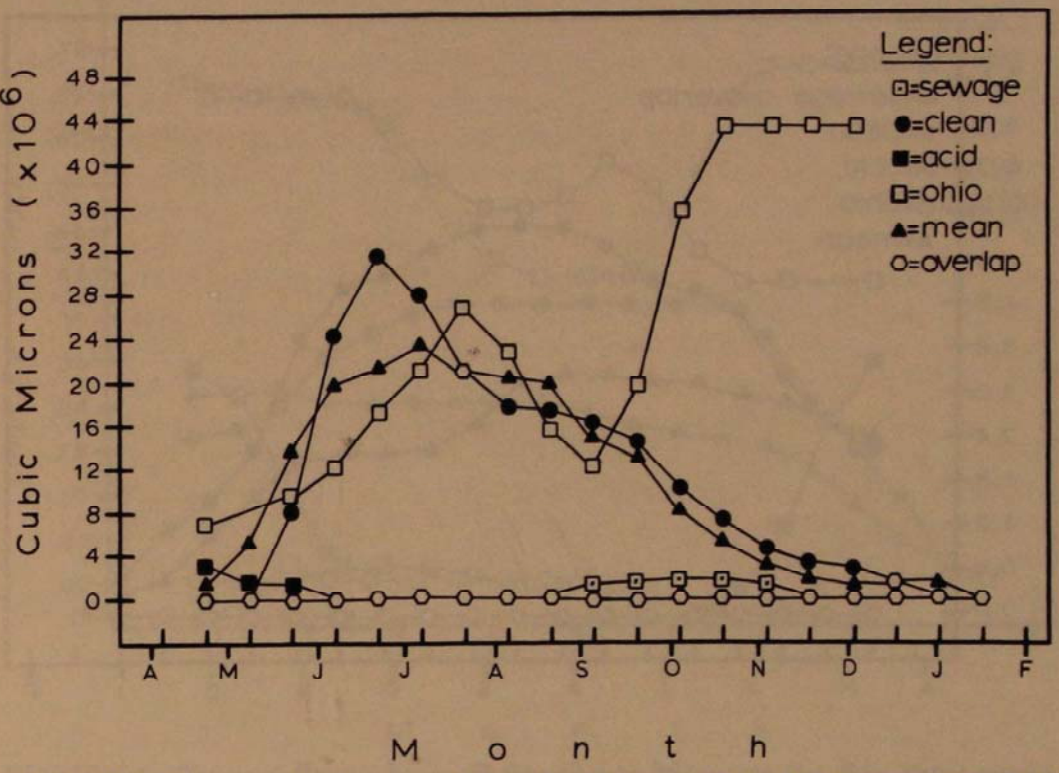

FIGURE 3. The smoothed curves of the algal biomass (in cubic microns per slide) in the different environments sampled from April 1977 through February 1978.

ence with the changes in temperature, Figure 1. The "clean" streams then showed a continual decline in biomass until the January ice cover. The biomass in the Ohio River increased during this same time probably in response to the changes in the total precipitation (Figure 1) that occurred at the Ohio River sites. The biomass recovered on the microscope slides in the mine drainage environment declined from April through June, primarily due to a general decrease in the numbers of four Chrysophyta genera (Diatoma, Navicula, Nitzschia, and Synedra) Figure 2. This may not reflect the actual changes in the biomass in the mine drainage environment because the dominant organism, *Euglena mutabilis* was not found to grow very well on the microscope slides. In the sewage effluent environment, the algal biomass increased only slightly during late August through late November because of an increase in the number of Euglena present. During the entire study the stream that received the steel mill effluents did not show more than a few organisms. In general, the artificial attached algal biomass was found to correspond with the changes in temperature from April until ice cover occurred in January.

One of the most common measures of community structure is the number of different types of organisms present in a particular environment. The smoothed curves for the total number of genera (Figure 4) show that the various environments have different numbers of genera present in those environments. In the "clean" streams and Ohio river sites there was an increase in the number of genera present during the late summer and early fall months.

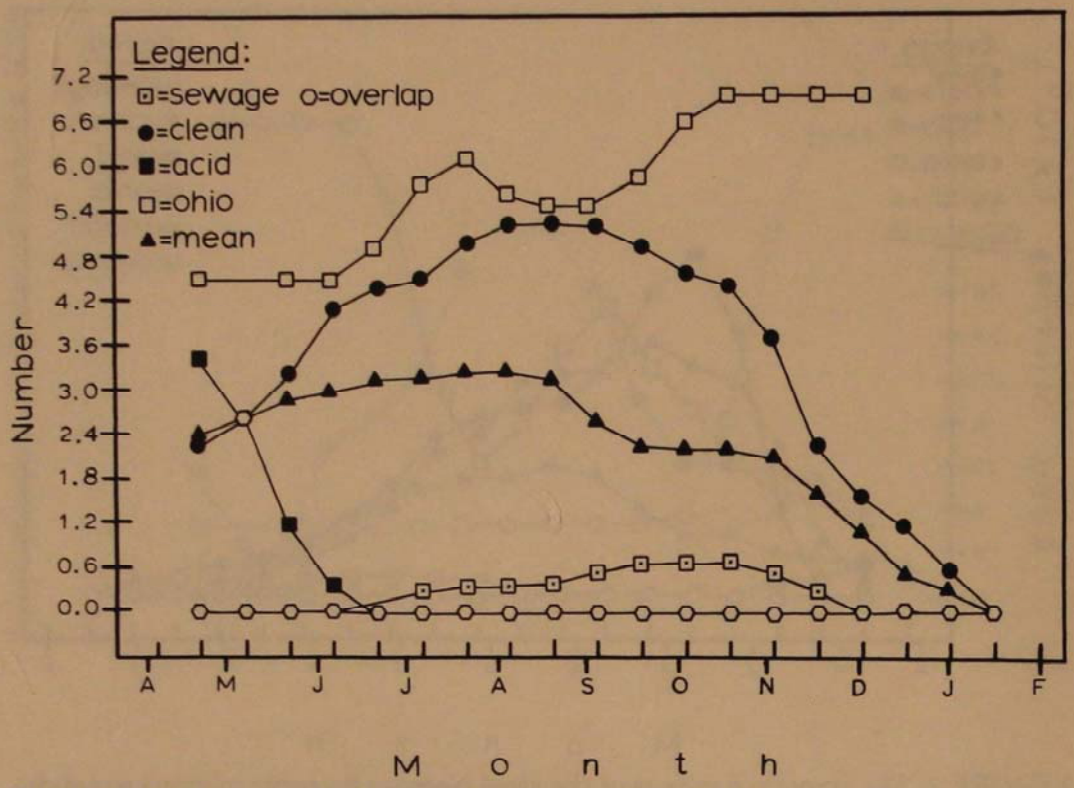

FIGURE 4. The smoothed curves for the number of different genera supported on artificial strata in different environments from April 1977 through February 1978.

The three highly stressed environments generally showed a lower number of genera than the nonstressed environments, in fact the steel mill site often lacked organisms. The streams that received mine drainage showed a sharp reduction in the number of different genera from April through late June. This reduction was due to a loss of four genera of the Chrysophyta (Diatoma, Navicula, Nitzschia, and Synedra). While showing an overall lack of organisms, samples from the sewage environment indicated that an increase in the number of genera occurred from late June through early December. This is probably due to an increase in the number of genera within the phyla Cyanophyta and Euglenophyta that occurred during this period. In general, there was an increase in the number of genera from late spring until early fall followed by a decline in the number of genera during the winter months.

Simpson's Index (Simpson, 1949), a second measure of community structure, showed the same general trends for the different environments as did the number of genera (Figures 4 and 5). However, there was a marked difference with regard to the Ohio River sites between the two indices. Simpson's Index showed a decline in the diversity in the Ohio River during the summer months, Figure 5. Because of the method of calculation of Simpson's Index, this decrease in diversity may be attributed to only one or two genera that are rapidly increasing relative to the increase in the numbers of other genera at the Ohio River sites.

The final measure of community structure presented (Figure 6) is algal

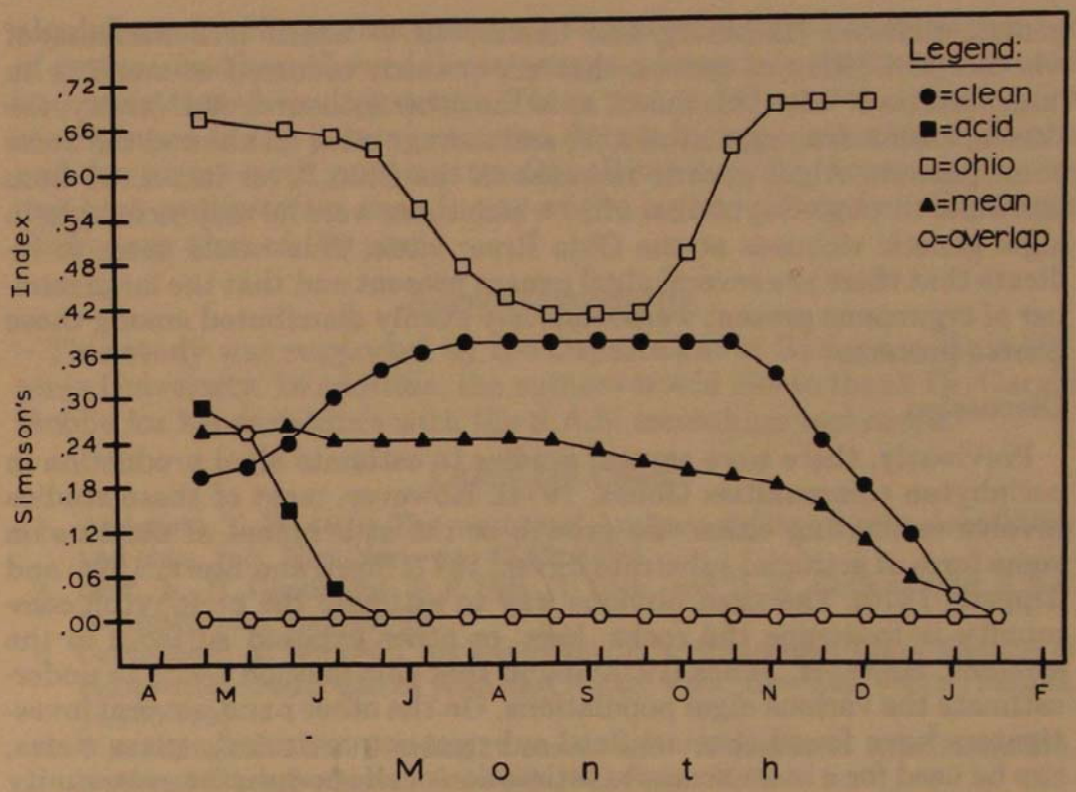

FIGURE 5. The smoothed curves of Simpson's Index for the five different environments sampled from April 1977 through February 1978.

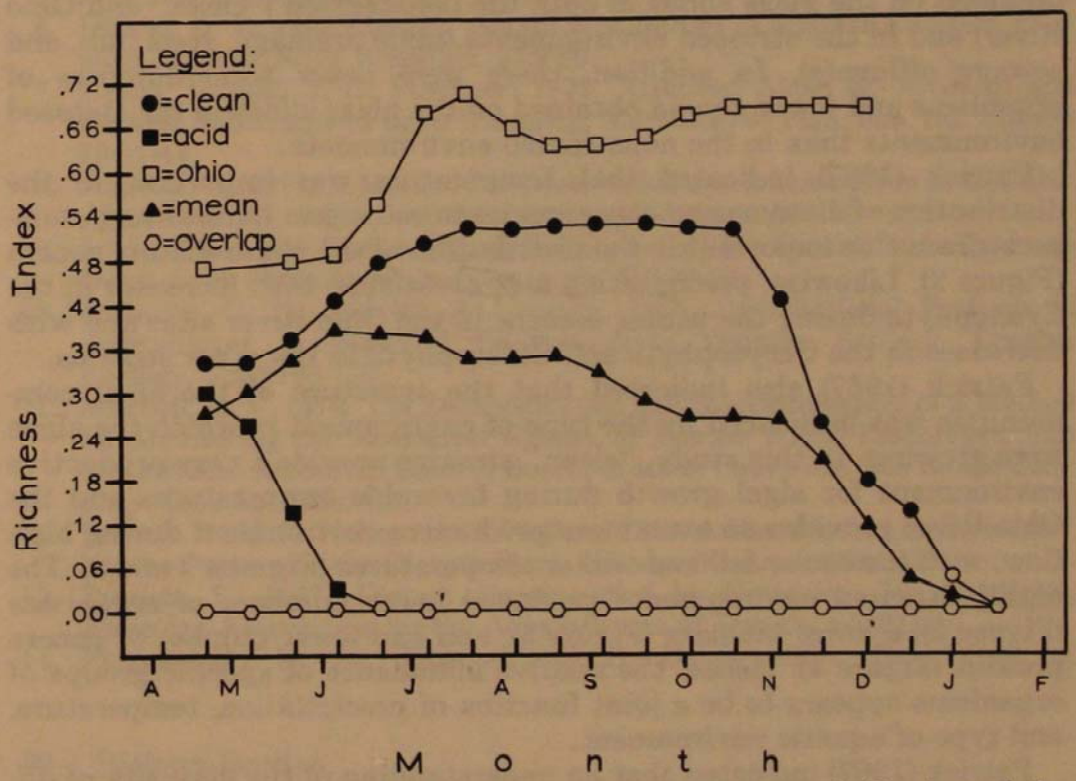

FIGURE 6. The smoothed curve for generic richness, an indication of the distribution of individuals within genera, for the various environments sampled from April 1977 through February 1978.

generic richness (Dahlberg and Odum, 1970) which is a measure of whether the different genera that are present occurred in small or in large numbers. With this index, as in the other measures of diversity, the "clean," mine drainage, steel mill, and sewage sites all showed the same basic pattern. Algal generic richness in the Ohio River increased from late June through September after which there were no major changes in algal generic richness at the Ohio River sites. This would seem to indicate that there are several algal genera present and that the large number of organisms present were relatively evenly distributed among those genera present.

Discussion

Previously, there were several studies to estimate algal production in periphyton communities (Jones, 1974). However, most of these studies involve estimating either the growth or the attachment of diatoms on some form of artificial substrate (Siver, 1977; Stern and Stern, 1975; and Tippett, 1970). The most obvious way to estimate the periphyton community is to scrape the rocks, logs, or other exposed surfaces in the streams. However, Jones (1974) found that this method tends to underestimate the various algal populations. On the other hand, several investigators have found that artificial substrates, particularly glass slides, can be used for a more accurate estimation of the periphyton community (Patrick, Hohn, and Wallace, 1954 and Castenholz, 1961). Four major phyla (Chlorophyta, Chrysophyta, Cyanophyta, and Euglenophyta) were obtained on the glass slides in both the nonstressed ("clean" and Ohio River) and in the stressed environments (mine drainage, steel mill, and sewage effluents). In addition, there were fewer total numbers of organisms and fewer genera obtained on the glass slides in the stressed environments than in the nonstressed environments.

Patrick (1967) indicated that temperature was important in the distribution of diatoms and other species in estuaries. In this study, temperature is also important in the distribution of the major diatom genera (Figure 2). Likewise, precipitation was associated with increases in the Cyanophyta during the winter months in the Ohio River sites and with decreases in the Chrysophyta and Chlorophyta in the other streams.

Patrick (1967) also indicated that the structure of the algal communities was influenced by the type of environment in which the algae were growing. In this study, "clean" streams provide a very productive environment for algal growth during favorable temperatures and the Ohio River provides an even more productive environment during high flow, with the cooler fall and winter temperatures (Figures 2 and 3). The highly stressed environments produced lower numbers of organisms (Figure 2), a lower biomass (Figure 3), and had fewer number of genera present (Figure 4). Hence, the relative abundance of specific groups of organisms appears to be a joint function of precipitation, temperature, and type of aquatic environment.

Patrick (1967) indicated that an understanding of the diversity of different communities is necessary in order to assess the flow of energy within the periphyton communities. The three different measures of

algal diversity (Simpson's Index, algal generic richness, and the number of genera) used here showed the same general trends in the highly stressed and nonstressed environments. These trends indicate that there were more genera in the "clean" streams during higher temperature months and there were more genera in the Ohio River during lower temperatures and high precipitation than in any of the highly stressed environments during any part of the year.

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The Status of the Freshwater Mussel *Quadrula quadrula* (Raf.) in the Upper Ohio River

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Abstract

Twelve hundred forty-four *Quadrula quadrula* were collected at 38 sites along the upper Ohio River (RM 0-341). No mussels were found in the first 90 miles of river. The remaining section under study produced occasional beds with good numbers of individuals. Age and growth data presented indicate a healthy population which may be expanding its range upstream.

Introduction

A survey of the freshwater mussels (naiades) of the upper Ohio River was conducted during the summer of 1979. As a result of the study 35 species of mussels were reported as occurring, within recent historical times, in this stretch of the river. By far the most abundant species found was the Maple Leaf, *Quadrula quadrula* (Raf., 1820). The purpose of this paper is to present data gathered on the present day status of this naiad in the Ohio River.

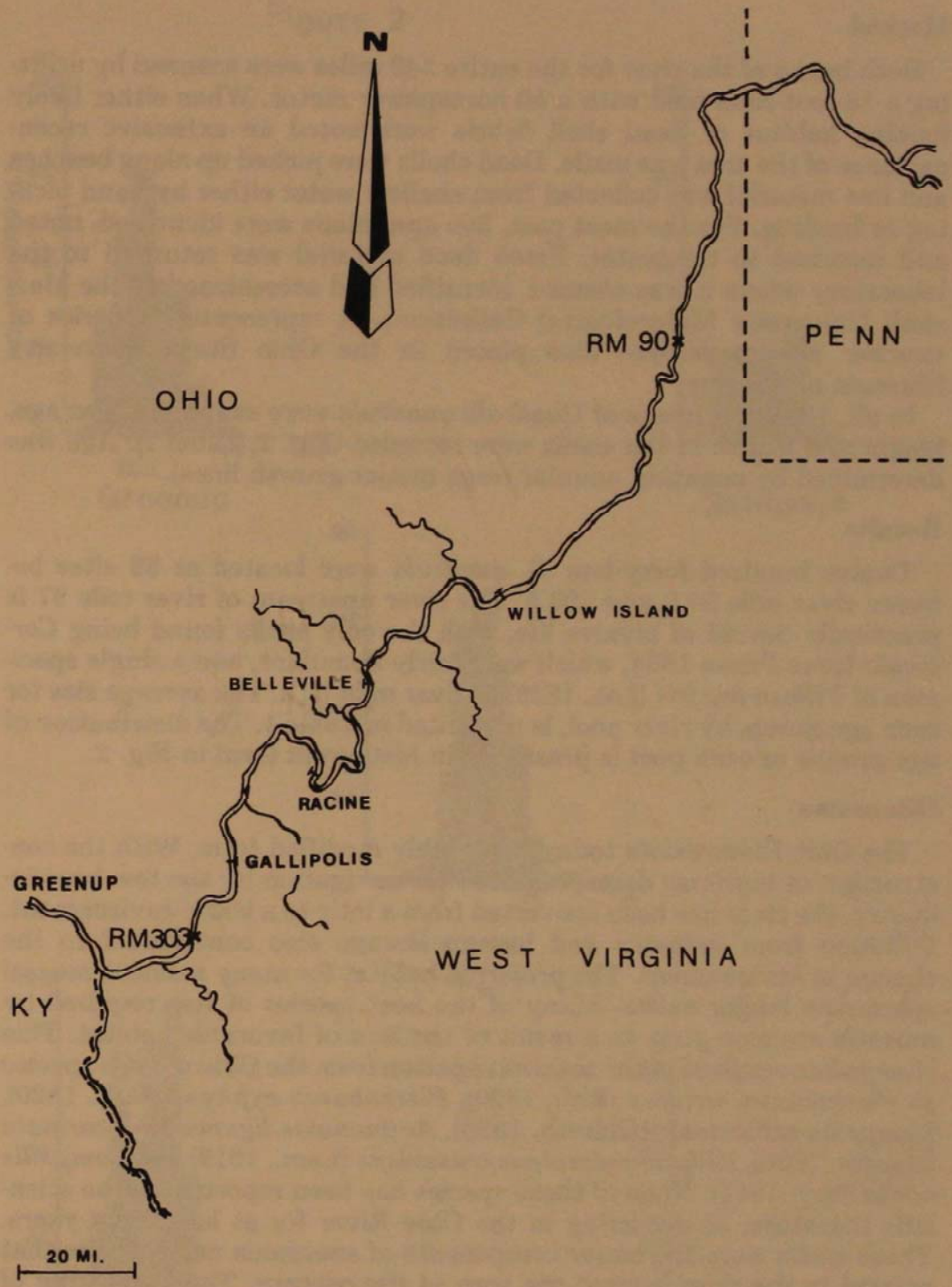


FIGURE 1. Survey area of Ohio River including river pools where *Quadrula quadrula* specimens were collected.

Study Area

The reach of the river surveyed extended from the origin at Pittsburgh, Pennsylvania (river mile 0.0), to the Greenup Locks and Dam (river mile 341.0) at Greenup, Kentucky (see map).

Method

Both banks of the river for the entire 340 miles were scanned by utilizing a 16-foot bass boat with a 50 horsepower motor. When either likely looking habitat or dead shell debris were noted an extensive reconnaisance of the area was made. Dead shells were picked up along beaches and live material was collected from shallow water either by hand picking or brailing. For the most part, live specimens were identified, noted and returned to the water. Fresh dead material was returned to the laboratory where it was cleaned, identified and accessioned to the Marshall University Malacological Collections. A representative series of voucher specimens was also placed in the Ohio State University Museum of Zoology.

In all, 1244 specimens of *Quadrula quadrula* were examined. The age, height and length of the shells were recorded (Fig. 2, Table 1). Age was determined by counting annular rings (major growth lines).

Results

Twelve hundred forty-four *Q. quadrula* were located at 38 sites between river mile 97.0 and 303.5. The river upstream of river mile 97 is practically devoid of bivalve life, with the only shells found being *Corbicula leana* Prime 1864, which were fairly abundant, and a single specimen of *Villosa iris iris* (Lea, 1829) at river mile 13.4. The average size for each age group, by river pool, is presented in Table 1. The distribution of age groups in each pool is presented in histogram form in Fig. 2.

Discussion

The Ohio River exists today in a highly modified form. With the construction of high-rise dams, required for navigation by the tow boat industry, the river has been converted from a lotic to a lentic environment. Pollution from industry and human sewage also contributed to the change in environment. The preferred habitat for many resident mussel species no longer exists. Many of the host species of fish required by mussels are also gone as a result of the loss of favorable habitat. This change has resulted in the total extirpation from the Ohio of such species as *Plethobasus striatus* (Raf., 1820), *Plethobasus cyphyus* (Raf., 1820), *Lampsilis orbiculata* (Hildreth, 1828), *Actinonaias ligamentina carinata* (Barnes, 1823), *Elliptio crassidens crassidens* (Lam., 1819) and *Lampsilis ovata* (Say, 1817). None of these species has been reported, in the scientific literature, as occurring in the Ohio River for at least fifty years. These shells were the major components of enormous mussel beds that existed in the river around the turn of the century. The harvesting of these beds produced thousands of tons of shells annually to supply the raw material for a burgeoning pearl button industry. At one time, as many as 23 button factories utilized the resources found in the Ohio and its major tributaries. The quantity of shells seemed endless.

This was not the case, however, as no mussel beds were found during the present study which were of commercial size or numbers—the mussels are gone. This phenomenon of change has been recorded for

Figure 2

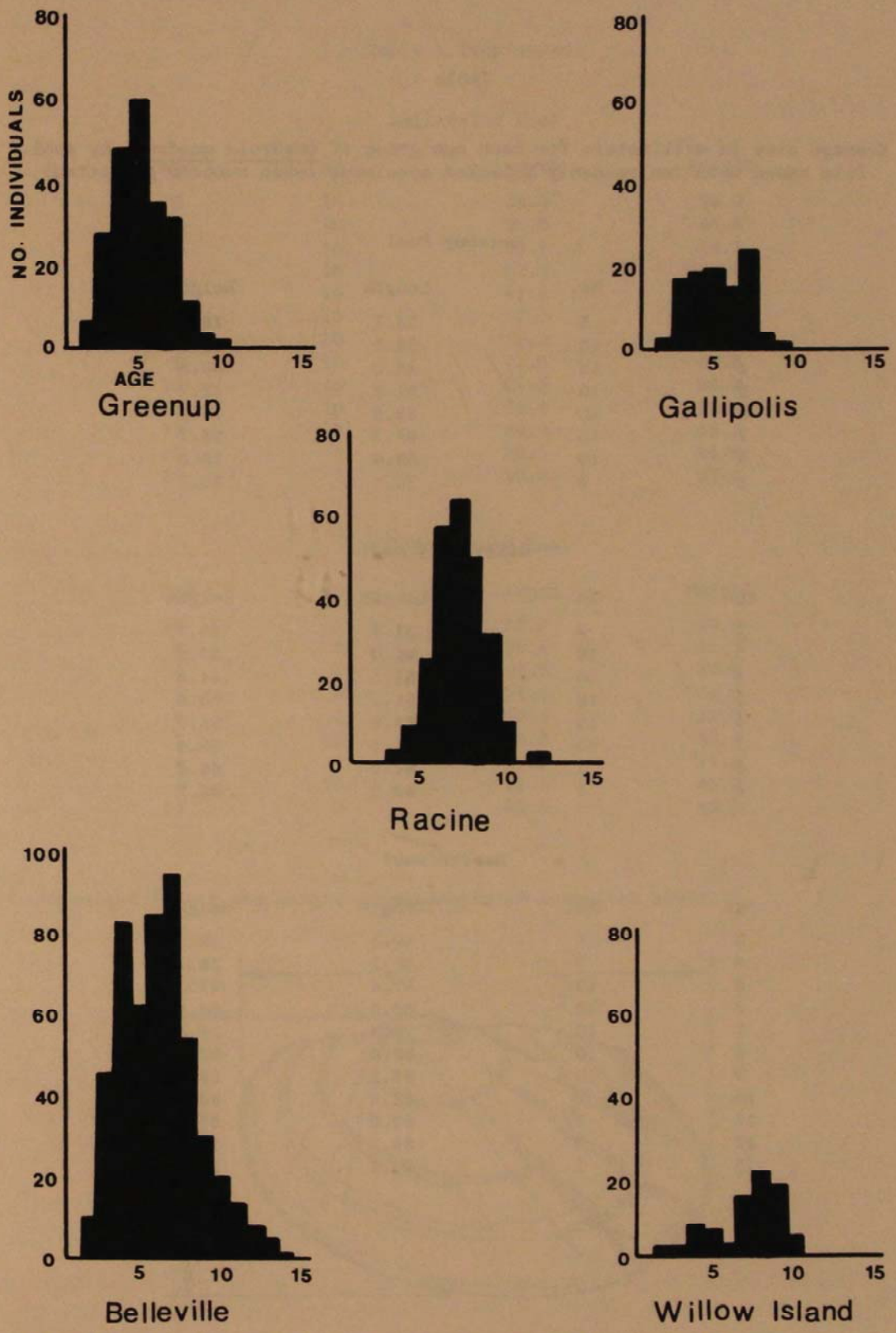


FIGURE 2. Age distribution of *Quadrula quadrula* by river pool.

Table 1

Average size in millimeters for each age group of Quadrula quadrula by pool.* Data based upon ten randomly selected specimens (when numbers permitted).

Greenup Pool

Age	No.	Length	Height
2	6	33.7	28.6
3	10	38.7	33.0
4	10	48.0	40.5
5	10	51.2	42.7
6	10	63.3	53.3
7	10	67.2	55.7
8	10	68.0	55.3
9	3	72.5	60.7

Gallipolis Pool

Age	No.	Length	Height
2	2	31.5	26.7
3	10	45.0	37.8
4	10	51.1	44.4
5	10	61.5	50.6
6	10	65.5	55.0
7	10	71.5	59.6
8	3	81.5	66.6
9	1	86.0	68.2

Racine Pool

Age	No.	Length	Height
3	3	40.3	32.9
4	9	45.1	38.7
5	10	57.4	47.3
6	10	60.9	50.8
7	10	70.5	55.9
8	10	80.0	62.1
9	10	85.6	66.1
10	9	82.4	64.9
11	1	85.0	65.6
12	2	89.2	70.0
13	1	90.5	64.9

Table 1 (continued)

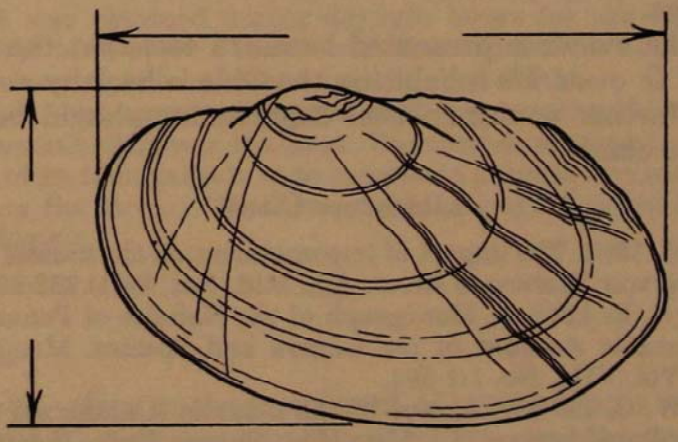
Belleville Pool

Age	No.	Length	Height
2	10	35.5	29.0
3	10	50.5	41.9
4	10	53.6	44.2
5	10	52.2	42.6
6	10	61.8	49.4
7	10	67.0	54.3
8	10	71.2	57.0
9	10	72.0	57.5
10	10	84.5	65.4
11	10	79.6	63.2
12	8	80.9	66.2
13	5	80.1	66.6
14	1	80.3	65.0

Willow Island Pool

Age	No.	Length	Height
2	1	32.7	27.5
3	1	39.5	31.7
4	8	49.2	40.9
5	6	53.6	44.6
6	3	55.4	45.7
7	10	73.2	58.9
8	9	77.1	61.4
9	10	81.5	65.4
10	5	79.8	65.0

*Greatest length and height measurements of a typical shell.



other impounded waterways (Starrett, Illinois River and Bates, Tennessee River). The story is not, however, as sad as it may seem for while it is true that the pre-impoundment/pre-pollution faunal assemblage is essentially gone, there is good evidence that a new group is filling the void. *Anodonta imbecillis* Say, 1829, *Anodonta grandis grandis* Say, 1829, *Anodonta grandis corpulenta* Cooper, 1834, and *Uniomerous tetralasmus* (Say, 1830) were reported for the first time by Taylor (1979) as being in the river. Several other species seem to be doing quite well. These include *Amblema plicata plicata* (Say, 1817), *Quadrula pustulosa pustulosa* (Lea, 1831), *Obliquaria reflexa* Raf., 1820, and *Quadrula quadrula* (Raf. 1820).

Q. quadrula, it seems, has in fact been helped rather than harmed by the modification of the river. Ortmann (1919) refers to *Q. quadrula* as a species which prefers lakes and larger rivers with muddy and sandy bottoms. He specifically locates the center of distribution as the Mississippi and lower Ohio Rivers. To the contrary, my study shows that this mussel is found in relatively large numbers as far upstream as river mile 97. On the upstream end of Halfway Island (river mile 178.1) a population numbering in the thousands exists. *Q. quadrula* was found in all pools of the river exclusive of the five upper-most pools near the origin.

The health of the population appears to be good. The data presented in Table 1 show a good number of individuals in the 2, 3 and 4 year age categories. This indicates a good recruitment of new young individuals into the resident breeding population. The Maple Leaf grows rather rapidly for the first five or six years then slower annual growth follows in subsequent years. As is the case for many other animals, mussels exhibit indeterminate growth and accrue some small increase in size until death. The vast majority of the population is composed of individuals in the 5 to 10 year age bracket (Fig. 2). Declining numbers of 11 to 14 year old (maximum age found) individuals also attest to the fact that this is a youthful, vigorous expanding population. A dying population is characterized by no or few young individuals and a preponderance of individuals approaching senescence. This population has few older individuals and none which approach the maximum age. Williams (1969) reports many specimens, found in the lower Ohio, which were well over 20 years of age.

Based on the evidence presented herein, I feel that the present day population of *Q. quadrula* inhabiting the Ohio is healthy and expanding and barring further environmental degradation should be around for many years to come.

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Autumnal Terrestrial and Aquatic Invertebrate Drift in a West Virginia Cold Water Stream

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Abstract

Diel stream drift of terrestrial and aquatic invertebrates was investigated in Roaring Creek, a third order brook trout stream in Preston County, West Virginia. The study of a 600 meter forested stream segment took place during a 24 hour period, October 21-22, 1977. Drifting invertebrates were divided into three major categories: (1) aquatic organisms indigenous to the stream, (2) terrestrial organisms associated with the forested stream valley, and (3) emergent aquatic organisms consisting of terrestrial adults of aquatic insects. Results extrapolated to 24 hour drift through a transverse stream section were: aquatic drift 6,495 organisms, terrestrial drift 4,818 organisms, and emergent aquatic drift 1,497 organisms. Aquatic organisms were night active with 69% of the aquatic drift occurring during the 12 hour dark period. Of the 30 aquatic taxa 26 reached maximum numbers between 6 P.M. and 6 A.M. Drift of both terrestrial and emergent aquatic organisms peaked between noon and 6 P.M. Of the total terrestrial drift 76% occurred during the 12 hour daylight period and a similar value of 70% was obtained during daylight hours for the emergent aquatic organisms. Drift of 34 of the 37 terrestrial taxa and 9 of the 11 emergent aquatic taxa had maximum numbers between 6 A.M. and 6 P.M.

The terrestrial and emergent aquatic drift was greatest during the daylight hours when aquatic drift was the least. The number of terrestrial organisms in the drift was of such magnitude as to constitute a significant seasonal import of organisms into the stream. This terrestrial component generally has been ignored by ecologists.

Introduction

Stream drift refers to the movement of invertebrates downstream as they are carried by stream currents. This movement may be passive if

the organism is introduced adventitiously, or it may be active if it is a behavioral adaptation of the organism. In reviews by Waters (1972) and Muller (1974) most of the studies have been concerned with diel periodicity of drifting aquatic organisms, with little attention given to diel periodicity of the drifting terrestrial component. This terrestrial component generally has been ignored by ecologists. The purpose of this investigation was to assess the diel abundance and taxonomic composition of the terrestrial drift relative to the aquatic drift during autumnal leaf fall. Results of this investigation are important in demonstrating that organisms associated with autumnal leaf fall represent a significant seasonal import of terrestrial organisms into streams. One direct consequence of such import is that of substantial contribution to food resources of resident stream fishes.

Methods

The study site was located at an elevation of 615 meters on Roaring Creek, a cold water brook trout stream, tributary to the Cheat River in Preston County, West Virginia. The valley forest at this elevation is mixed hardwood and hemlock with dense thickets of rhododendron along the stream margins. Stream parameters for the 600 meter segment of the stream were: mean width, 4.8 m; mean depth, 13 cm; and temperature, 9.0 C. The stream discharge of 0.225 m^3/sec was near base flow. Drift collections were made over a 24 hour period, October 21-22, 1977. The sampling employed three drift nets spaced 300 meters apart. Over the 24 hour period twelve sample collections were made for each of the three drift nets at nominal two hour intervals. Actual submergence time for the two hour interval was 110 minutes allowing 10 minutes for collection of the sample and replacement of the net. The Nitex drift nets with 0.47 mm mesh openings were attached to wooden frames 33.5 cm wide by 33.5 cm high. The bottom of each frame was secured to a baseboard held in place by two metal stakes. Net length was 1.4 m.

Drift invertebrates were divided into three major categories: (1) aquatic organisms indigenous to the stream, (2) terrestrial organisms associated with the forested stream valley, and (3) emergent aquatic organisms consisting of terrestrial adults of aquatic insects. Taxonomic lists were made for each of these categories. Taxa comprising less than one-tenth percent of the total drift were grouped as a category designated "other." Aquatic taxa were identified to either genus or family using Edmondson (1959), Merritt and Cummins (1978), and Usinger (1956). Most of the terrestrial taxa were keyed to family using Borror, Delong, and Triplehorn (1976). Identifications of emergent aquatic taxa to family were made with the aid of Borror, Delong, and Triplehorn (1976), Merritt and Cummins (1978), and Usinger (1956).

Mean organism numbers represent means for three nets adjusted for discharge. Because each of the three drift nets had a different discharge value, it was necessary to adjust numbers of organisms drifting to the discharge of one of the nets. Total drift values (Tables 3, 4, and 5) were corrected for time to 24 hours from an actual submergence time of 22 hours (twelve 110 minute periods). The actual submergence time of 110

Table 1. T-test Between the 12 Hour Dark Period and the 12 Hour Daylight Period for Each of Four Categories of Stream Drift.

Drift Category	*t value*	*Probability*
Aquatic	10.56	***
Terrestrial	3.61	***
Emergent Aquatic	2.86	**
Total	0.59	N.S.

N.S.—non-significant at the 0.05 level
*—significant at the 0.05 level
**—significant at the 0.01 level
***—significant at the 0.001 level

Table 2. Least Significant Difference (LSD) Between Periods Among Four Different Categories of Drift; Where Period 1 is 6 P.M. to 12 M, Period 2 is 12 M to 6 A.M., Period 3 is 6 A.M. to 12 N, and Period 4 is 12 N to 6 P.M.

Drift	*Comparison Periods (LSD prob.)*					
Category	*1 vs 2*	*1 vs 3*	*1 vs 4*	*2 vs 3*	*2 vs 4*	*3 vs 4*
Aquatic	N.S.	**	***	***	***	N.S.
Terrestrial	N.S.	N.S.	***	N.S.	***	***
Emergent Aquatic	N.S.	N.S.	***	N.S.	***	***
Total	N.S.	N.S.	N.S.	N.S.	**	***

N.S.—non-significant at the 0.05 level
*—significant at the 0.05 level
**—significant at the 0.01 level
***—significant at the 0.001 level

minutes was the time base used in Tables 1 and 2 and in Figures 1-4. T-tests, Table 1, were used to compare the mean number of organisms drifting during the 12 hour dark period versus the mean number of organisms drifting during the 12 hour light period. Sunrise was at 6:17 A.M. and sunset was at 6:12 P.M. The 24 hour cycle was also divided into four 6-hour time periods: period 1, 6 P.M. to 12 M; period 2, 12 M to 6 A.M. period 3, 6 A.M. to 12 N; and period 4, 12 N to 6 P.M. Least significant difference test (LSD), Table 2, was used to compare organism numbers for these four time periods.

Results

Figure 1 shows the diel distribution of total drift. Of the 12,810 organisms drifting over the 24 hour period, 47% drifted at night and

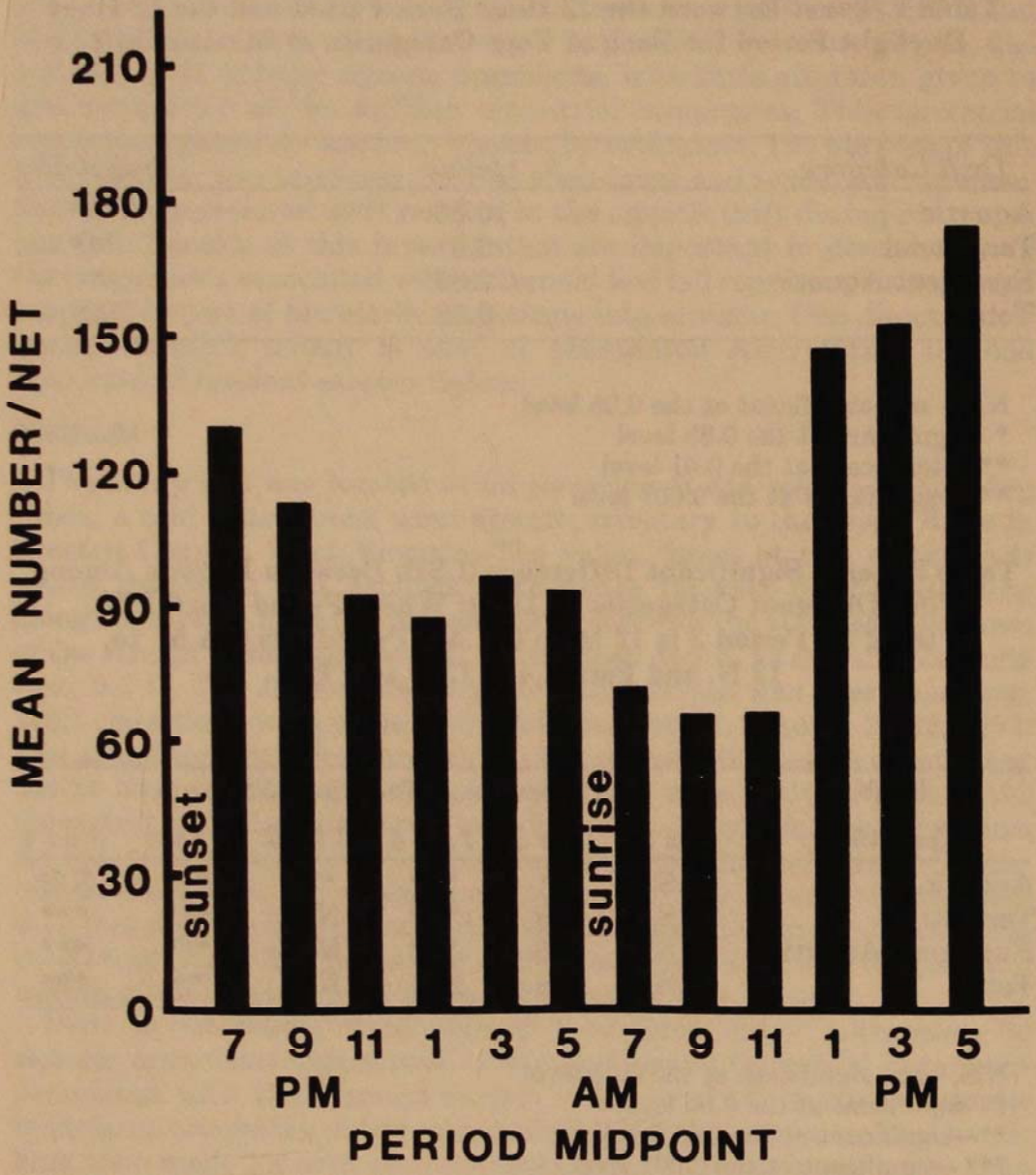

FIGURE 1. Total Drift. Mean number/net is for 110 minutes with the midpoint time as indicated.

53% drifted during the daylight hours. The t-test (Table 1) did not indicate a significant difference between night and day for the total drift.

The diel distribution of drifting aquatic organisms in Figure 2 indicates that most of the aquatic drift occurred at night although there were no distinct peaks during the 24 hour period. Of the 6,495 aquatic organisms, 69% drifted during the night and 26 of the 30 aquatic taxa had maximum numbers between 6 P.M. and 6 A.M. (Table 3). The t-test (Table 1) showed a significant difference between night drift and day drift. As indicated in Table 2, there was no significant difference between the two 6-hour dark periods (1 vs 2) and no significant difference between the two 6-hour light periods (3 vs 4). There were significant dif-

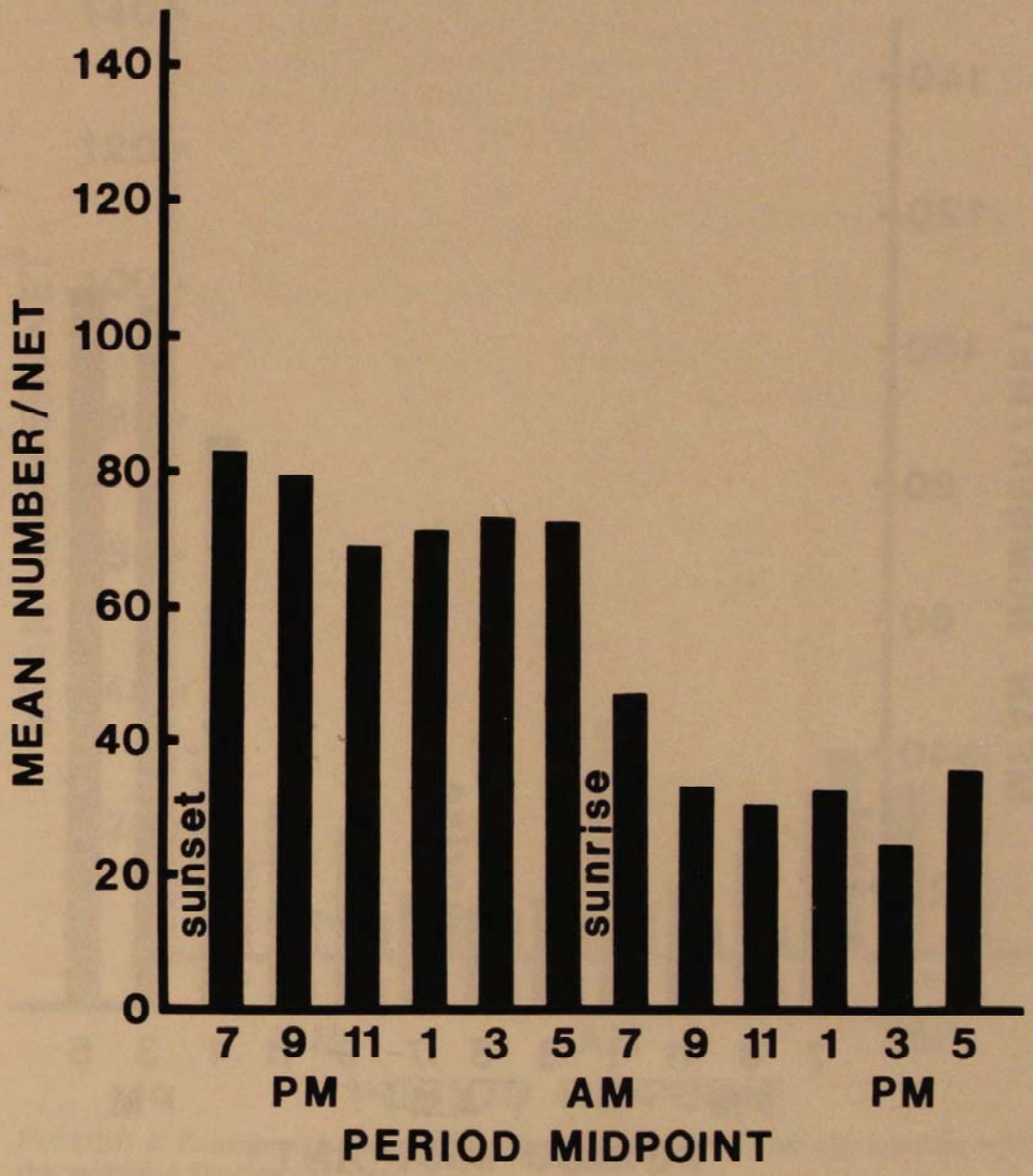

FIGURE 2. Aquatic Drift. Mean number/net is for 110 minutes with the midpoint time as indicated.

ferences between all comparisons of the 6-hour light versus 6-hour dark periods for the aquatic drift (Table 2).

Figure 3 shows a major peak of terrestrial drift for period 4, 12 N to 6 P.M. The least significant difference test (Table 2) shows a significant difference between period 4 and each of the other three periods. Period 4 includes 60% of the 4,818 terrestrial organisms which drifted over the 24 hour period. A t-test (Table 1) showed a significant difference between night and day drift with 76% of the terrestrial organisms drifting during the day. Also, 35 of the 37 terrestrial taxa had maximum numbers between 6 A.M. and 6 P.M.

Figure 4 shows the emergent aquatic drift. It is very similar to the ter-

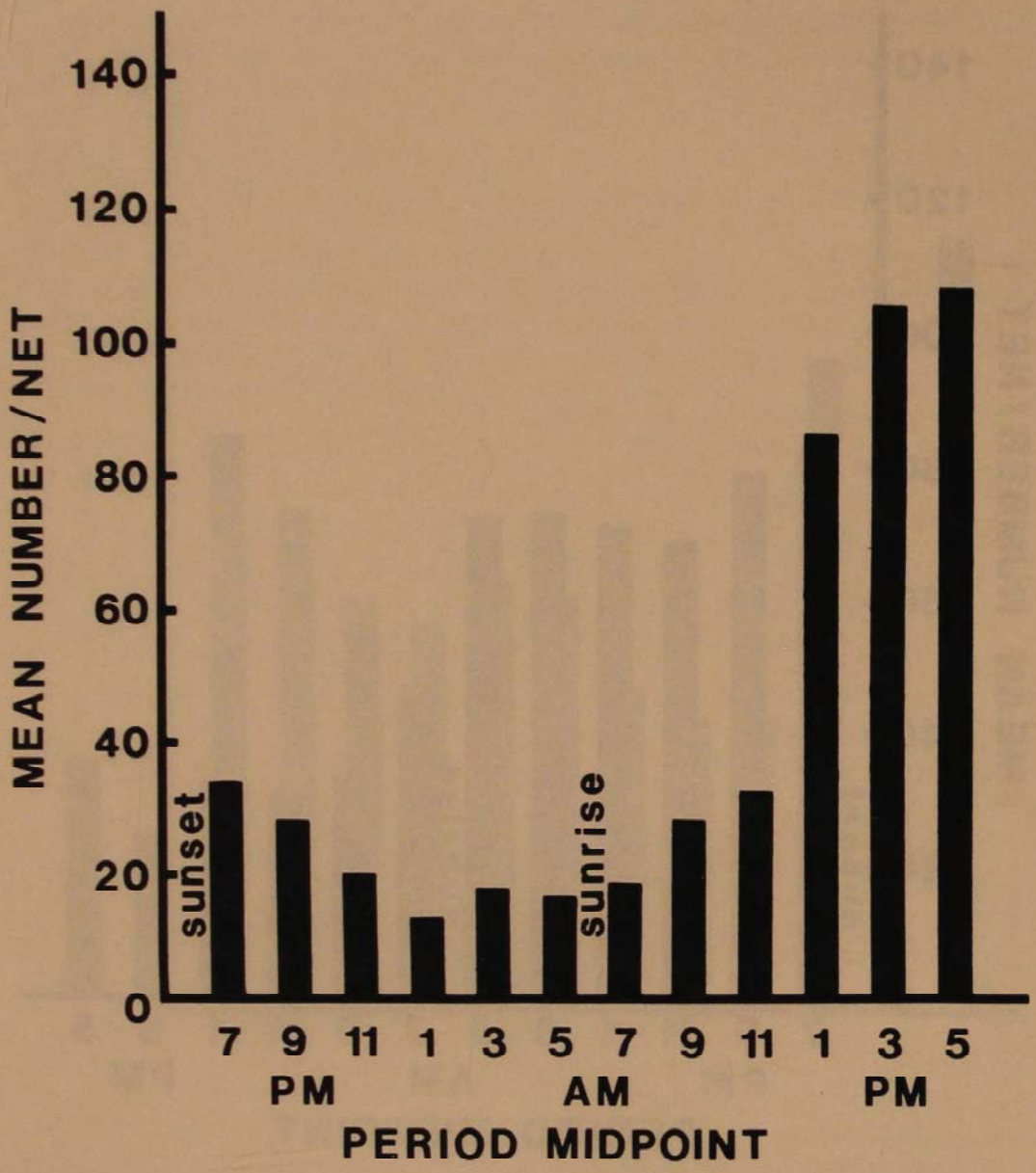

FIGURE 3. Terrestrial Drift. Mean number/net is for 110 minutes with the midpoint time as indicated.

restrial pattern of Figure 3 except that the numbers are fewer. The emergent aquatic organisms peaked during period 4, 12 N to 6 P.M. The number of emergent aquatic organisms drifting during period 4 is significantly different (Table 2) from the numbers during the other three periods and represents 57% of the 1,497 emergent aquatics drifting over the 24 hours. The t-test (Table 1) showed a significant difference between night and day with 70% of the emergent aquatics drifting during the day and with 9 of 11 emergent aquatic taxa having maximum numbers during the day.

Tables 3, 4, and 5 list the taxa of aquatic, terrestrial, and emergent aquatic drift respectively. A total of 157 taxa were identified. The

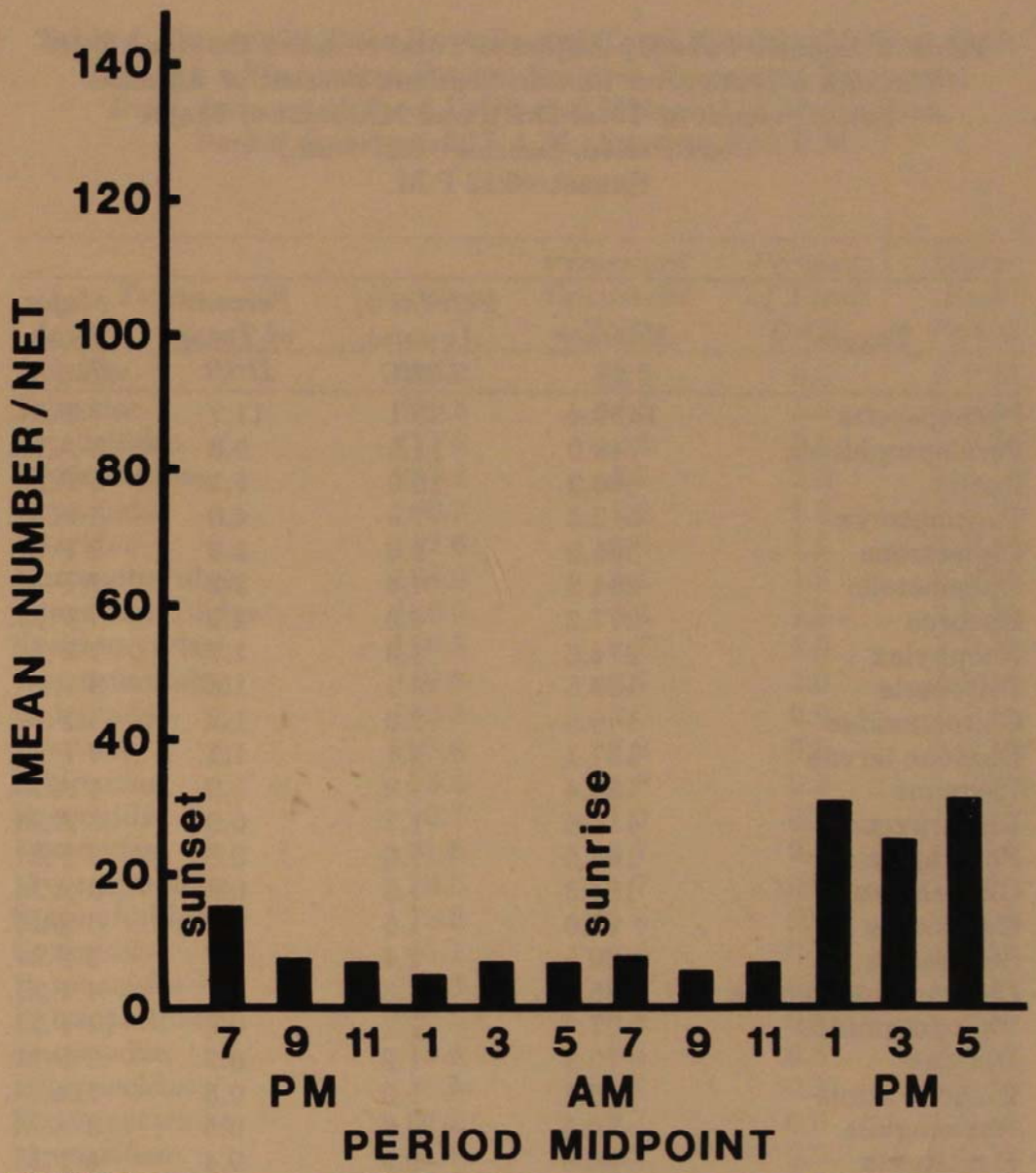

FIGURE 4. Emergent Aquatic Drift. Mean number/net is for 110 minutes with the midpoint time as indicated.

category designated as "other" in these tables contains 80 taxa representing only 3.2% of the total drift. The 77 taxa listed in the three tables account for 96.8% of the total drift. The percentages of the total drift represented by the three categories were: aquatic drift 51%, terrestrial drift 37.4% and emergent aquatic drift 11.8% (Tables 3, 4, and 5).

Discussion

All three categories of drifting organisms showed diel periodicity with significantly different levels of abundance for dark versus light periods. Aquatic forms drifted predominantly at night, terrestrial organisms drifted in maximum numbers between noon and 6 P.M., and emergent aquatic forms essentially followed the drift pattern of the terrestrial

Table 3. Aquatic Taxa By Adjusted Total Number (24 Hour Drift Through a Transverse Stream Section), Percent of Aquatic Drift, Percent of Total Drift, and Midpoint of Major Peak Period. Sunrise—6:17 A.M., Sunset—6:12 P.M.

Taxon	*Number*	*Percent of Aquatic Drift*	*Percent of Total Drift*	*Major Peak Period*
Pycnopsyche	1499.4	23.1	11.7	7 P.M.
Paraleptophlebia	749.0	11.5	5.8	3 A.M.
Baetis	646.9	10.0	5.1	5 A.M.
Taeniopteryx	512.4	7.9	4.0	3 A.M.
Diplectrona	365.9	5.6	2.9	9 P.M.
Ephemerella	284.2	4.4	2.2	7 P.M.
Epeorus	277.2	4.3	2.2	7 P.M.
Neophylax	214.6	3.3	1.7	7 P.M.
Peltoperla	199.5	3.1	1.6	3 A.M.
Chironomidae	149.5	2.3	1.2	7 P.M.
Elmidae larvae	137.1	2.1	1.1	7 P.M.
Isogenus	123.4	1.9	1.0	1 A.M.
Rhithrogena	111.6	1.7	0.9	5 A.M.
Paracapnia	104.5	1.6	0.8	7 P.M.
Oligochaeta	101.3	1.5	0.8	5 A.M.
Gammarus	95.0	1.5	0.7	5 A.M.
Stenonema	90.5	1.4	0.7	9 P.M.
Chironomidae pupae	85.5	1.3	0.7	7 P.M.
Philopotamidae	77.7	1.2	0.6	11 P.M.
Dixidae	75.5	1.2	0.6	9 P.M.
Elmidae adult	63.7	1.0	0.5	1 A.M.
Rhyacophila	60.3	0.9	0.5	9 A.M.
Hastaperla	56.6	0.9	0.4	5 P.M.
Simuliidae	52.9	0.8	0.4	1 P.M.
Isoperla	44.3	0.7	0.3	3 A.M.
Psychomyiinae	34.3	0.5	0.3	5 P.M.
Leuctra	32.8	0.5	0.3	7 P.M.
Hydropsyche	30.1	0.5	0.2	9 P.M.
Cheumatopsyche	22.4	0.3	0.2	1 A.M.
Polycentropodidae	19.6	0.3	0.2	5 A.M.
Other (29 taxa)*	176.9	2.7	1.4	
TOTAL	6494.6	100.0	51.0	

*Includes 35.3 (0.3%) Branchiobdellida presumably attached to crayfish at time of collection.

Table 4. Terrestrial Taxa By Adjusted Total Number (24 Hour Drift Through a Transverse Stream Section), Percent of Terrestrial Drift, Percent of Total Drift, and Midpoint of Major Peak Period. Sunrise—6:17 A.M., Sunset—6:12 P.M.

Taxon	*Number*	*Percent of Terrestrial Drift*	*Percent of Total Drift*	*Major Peak Period*
Aphidae	1083.2	22.5	8.5	3 P.M.
Sciaridae	699.3	14.5	5.5	5 P.M.
Cicadellidae	411.2	8.5	3.2	3 P.M.
Drosophilidae	257.2	5.3	2.0	7 A.M.
Formicidae	189.3	3.9	1.5	5 P.M.
Phoridae	187.6	3.9	1.5	3 P.M.
Entomobryidae	168.0	3.5	1.3	9 P.M.
Pseudocaeciliidae	156.0	3.2	1.2	3 P.M.
Cecidomyiidae	130.6	2.7	1.0	1 P.M.
Ichneumonidae	129.8	2.7	1.0	3 P.M.
Eulophidae	112.8	2.3	0.9	1 P.M.
Araneae	105.6	2.2	0.8	3 P.M.
Bibionidae	93.4	1.9	0.7	5 P.M.
Braconidae	90.7	1.9	0.7	1 P.M.
Diapriidae	81.8	1.7	0.6	1 P.M.
Mycetophilidae	79.6	1.7	0.6	7 A.M.
Staphylinidae	72.2	1.5	0.6	3 P.M.
Cynipidae	65.1	1.4	0.5	1 P.M.
Delphacidae	43.6	0.9	0.3	1 P.M.
Phlaeothripidae	40.2	0.8	0.3	5 P.M.
Encyrtidae	38.3	0.8	0.3	3 P.M.
Polypsocidae	35.5	0.7	0.3	5 P.M.
Platygasteridae	34.2	0.7	0.3	1 P.M.
Mymaridae	31.7	0.7	0.2	3 P.M.
Psyllidae	30.9	0.7	0.2	5 P.M.
Pteromalidae	27.6	0.6	0.2	3 P.M.
Curculionidae	26.7	0.6	0.2	5 P.M.
Ceraphronidae	26.6	0.6	0.2	5 P.M.
Chloropidae	26.3	0.5	0.2	1 P.M.
Lepidoptera larvae	24.9	0.5	0.2	3 P.M.
Gelechiidae	21.1	0.4	0.2	7 A.M.
Scelionidae	15.4	0.3	0.1	5 P.M.
Proctotrupidae	14.9	0.3	0.1	1 P.M.
Miridae	14.7	0.3	0.1	7 P.M.
Acarina	14.4	0.3	0.1	3 P.M.
Corylophidae	14.4	0.3	0.1	11 A.M.
Pentatomidae	13.0	0.3	0.1	5 P.M.
Other (46 taxa)	210.0	4.4	1.6	
TOTAL	4817.8	100.0	37.4	

Table 5. Emergent Aquatic Taxa By Adjusted Total Number (24 Hour Drift Through a Transverse Stream Section), Percent Of Emergent Aquatic Drift, Percent of Total Drift, and Midpoint of Major Peak Period. Sunrise—6:17 A.M., Sunset—6:12 P.M.

Taxon	*Number*	*Percent of Emergent Aquatic Drift*	*Percent of Total Drift*	*Major Peak Period*
Chironomidae	677.2	45.3	5.3	1 P.M.
Tipulidae	283.8	19.0	2.2	7 A.M.
Baetidae	122.7	8.2	1.0	3 P.M.
Simuliidae	111.9	7.5	0.9	1 P.M.
Psychodidae	79.9	5.3	0.6	7 P.M.
Dolichopodidae	57.9	3.9	0.5	3 P.M.
Leuctridae	47.1	3.1	0.4	5 P.M.
Dixidae	24.7	1.7	0.2	3 A.M.
Paraleptophlebia	24.5	1.6	0.2	5 P.M.
Ceratopogonidae	21.3	1.4	0.2	7 A.M.
Ephydridae	15.6	1.0	0.1	3 P.M.
Other (5 taxa)	29.9	2.0	0.2	
TOTAL	1496.5	100.0	11.8	

organisms. These drift patterns were determined in each of the three categories by many taxa, with each taxon a small percentage of the total and for the most part with each taxon showing distinct diel periodicity.

Of the aquatic organisms, 69% of the total number and 26 of 30 taxa drifted at night. More specific patterns with a peak after dusk and just before sunrise are indicated by peaks of 9 taxa at 7 P.M. and 5 taxa at 5 A.M. (Table 3). Diel periodicity of aquatic invertebrate drift has been demonstrated by many investigators (Muller, 1974). These aquatic organisms in the drift are alive and active (Muller, 1974). The definite peaks of individual taxa may be related to feeding activity. Thus, diel periodic drift of aquatic forms seems to represent the result of some behavioral adaptation.

Larimore (1972) in a study October 27-28, 1965, in the Upper Kaskaskia River, Chester, Illinois, recorded an unexpected abundance of terrestrial organisms from 8 A.M. to 5 P.M. which he described as the result of wind activity and falling leaves. He further stated that the leaf fall was much more important to increased terrestrial drift than the wind. During this study on Roaring Creek there was a noticeable increase in the wind and in the leaf fall beginning at about 8 A.M. and continuing through the afternoon. This combination of wind and leaf fall probably resulted in the 76% occurrence of terrestrial drift during the day. A similar value of 84% for terrestrial drift was extrapolated from Larimore's (1972) figures. In the Roaring Creek study the terrestrial

percentage of total drift was 38%, similar to the value of 47% obtained from Larimore's figures. In a similar study of the Couz Pavin, a stream in France, Neveu and Echaubard (1975) found an average of 25% for terrestrial organisms in the drift during June in three consecutive years. Larimore's value has a greater similarity possibly because both studies were done in October. The terrestrial drift represents drowned organisms which are catastrophically introduced into the stream. The movement of these forms downstream is passive not active as in aquatic drift forms. The diel peak periodicity of terrestrial forms in the stream drift appears to be related in part to the daytime activity of the terrestrial insects. It would appear that wind and leaf fall enhance the catastrophic introduction into the stream.

The emergent aquatic component of the drift was probably enhanced by the wind and leaf fall associated with period 4, 12 N to 6 P.M. This suggests that the drift relationship of the emergent aquatic organisms in the water is passive. The peak drift during period 4 possibly was related to the reproductive cycle of some of the emergent aquatic organisms returning to the stream to mate or deposit eggs. These emergents were day active with 70% drifting during the daylight hours. A similar value of 65% of emergent aquatic organisms drifting during the daylight hours was obtained from Larimore's figures.

In conclusion it is evident that the terrestrial drift was greatest during daylight hours when aquatic drift was least. The number of terrestrial organisms was of such magnitude as to constitute a significant seasonal import of organisms into the stream providing a substantial contribution to the food resources of resident brook trout.

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Proposed Environmental Impacts of the Gallipolis Locks and Dam Replacement, Ohio River Mile 279.2, on the Benthic Macroinvertebrates and Fishes of Flatfoot Creek, Mason County, West Virginia

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Abstract

The Gallipolis Locks and Dam at Ohio River Mile 279.2 is soon to be modified or replaced. Construction in the area will effect the lower portion of the drainage basin of Flatfoot Creek. Depending on the action taken, a large proportion of Flatfoot Creek and/or a tributary of Mud Run will have severe ecological alterations. For this reason, the fishes and benthos were investigated for baseline information.

The benthic populations ranged from a low species diversity ($\bar{d} = 0.36$) at the tailwaters to the highest value ($\bar{d} = 3.04$) at the headwaters. Dipteran larvae and aquatic oligochaetes inhabited the lower reaches while ephemeropterans, plecopterans, and trichopterans inhabited the upper reaches.

The fishes of Flatfoot Creek were dominated by forage species (e.g., Emerald shiner, Striped shiner and Creek chub). The rough and game fishes comprised a small portion of the specimens. Important among the rough fishes were the White sucker, Black and Yellow bullheads. Game fishes were predominantly Green sunfish, Bluegill, Black crappie, and Longear sunfish. The Southern Redbelly dace and the River shiner are listed as fishes of scientific interest on the tentative list of rare animal species for West Virginia.

The authors feel uniform disposal of dredge material from the canal over the bottomlands of Flatfoot Creek with the stream re-channeled will have the least detrimental effect on the environment.

Introduction

The Gallipolis Locks and Dam project is located on the Ohio River at Mile 279.2 near Apple Grove, West Virginia. The main purpose of this navigational dam was to raise the pool elevation sufficiently to maintain a minimum nine foot channel needed by barge traffic. The dam is approaching the end of its 50 year project life but has already become

somewhat obsolete. Small lock chambers located in an awkward position relative to the stream channel have caused costly time delays and accidents during its operation.

The U. S. Army Corps of Engineers, Huntington District, has proposed a construction project in the Gallipolis Locks and Dam area of the Ohio River. Three plans for disposal of dredged canal material have been developed. In Plan 1, 1.7 miles (2.7 km) of Flatfoot Creek will be destroyed and the stream directed to a relocated channel. Dredged material would then be uniformly deposited over the bottomlands adjacent to the canal. Plan 2 would provide for the preservation of the Flatfoot Creek stream channel but dredge material would then be disposed of in mounds along either side of the creek. Plan 3 is to haul dredged material to an off-site area in the Mud Run drainage basin of Crab Creek.

The objectives of this study were: (1) to sample and identify the populations of fishes and benthic macroinvertebrates within the Flatfoot Creek drainage basin, and (2) to suggest mitigations for possible reduction of impact upon the environment.

Study Area

The Gallipolis Locks and Dam is located on the Ohio River at Mile 279.2 below Pittsburgh. Constructed as an aid to navigation, it maintains a 9-foot depth for 41.7 (67.1 km) miles of the Ohio River and 31.1 (50.0 km) miles of the Kanawha River with a normal pool elevation of 538 msl (mean sea level). The structure was built in a bend of the river so that access to both chambers is restricted by the pathway of maneuvering barges. Modification of the structure as proposed by the U. S. Army Corps of Engineers would initially have an adverse effect on the environment of the construction area, in particular, the Flatfoot Creek drainage basin.

Flatfoot Creek is a stream located in Mason County, West Virginia. The mouth of this stream empties into the Ohio River near Apple Grove, West Virginia, at Mile 280.2 below Pittsburgh. Flatfoot Creek is approximately 8.2 miles (13.2 km) in length and drains 5.64 square miles (14.61 km^2). The lower 2.5 miles (4.0 km) transects the Ohio Floodplain, much of which is used for agriculture and pasture land.

Station 1 is located at the confluence of Flatfoot Creek with the Ohio River (Figure 1). The map coordinates are 82° 11′ 07″ West Longitude and 38° 40′ 07″ North Latitude. The banks are steep and tree cover is dense. The substrate is composed of deep mud, high in sand and silt.

Station 2 is located 1.5 miles (2.4 km) above the mouth and 100 yards below the Baltimore and Ohio railroad trestle. The map coordinates are 82° 10′ 36″ West Longitude and 38° 41′ 29″ North Latitude. This area is characterized by open pasture land with heavier vegetation only along the creek banks. The substrate is composed of loam soil, silt and small gravel.

Station 3 is located 4.5 miles above the mouth of the creek and 1 mile east of State Route 2. Map coordinates are 82° 09′ 22″ West Longitude and 38° 41′ 30″ North Latitude. This headwater station has a substrate composed of sand, gravel and rocks on a stone bedrock.

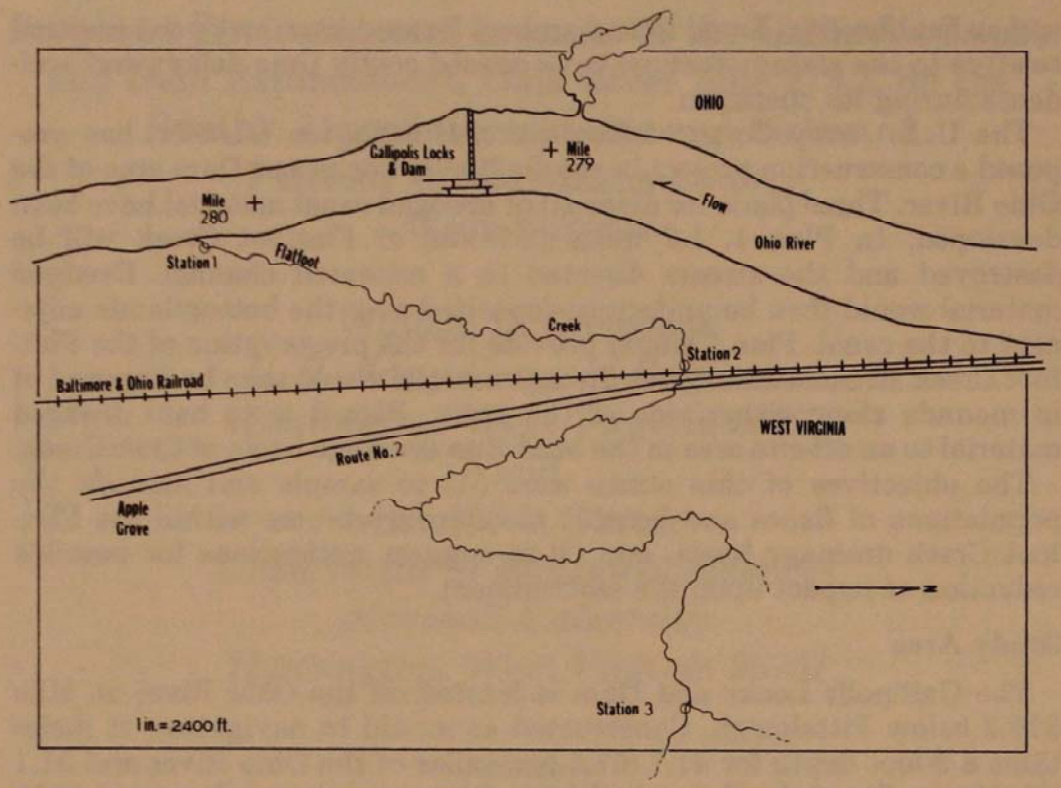

FIGURE 1. Station locations on Flatfoot Creek and Gallipolis Locks and Dam on Ohio River, Mile 279.2.

Materials and Methods

Benthic Macroinvertebrates. Three quantitative samples of the benthos of Flatfoot Creek were collected at each station for each season using a Surber square-foot sampler. The samples were preserved in the field with 10 percent formalin and brought back to the laboratory for sorting. Finally, they were stored in 70 percent ethanol. Each square-foot sample was blotted, dried and weighed on a Bosch S-2000 electric, single-pan balance. A Shannon-Weaver index of diversity and "equitability" were calculated for each sample.

Fishes. A nylon seine (4 x 15 feet) of 1/4 inch mesh was used in collecting the fishes. Specimens were placed in plastic containers with 10 percent formalin and labeled. The fishes were returned to the laboratory where they were rinsed, stored in 70 percent ethanol and identified to the species level.

Results and Discussion

Benthic Macroinvertebrates. A total of 7085 benthic macroinvertebrates were collected representing 15 orders, 37 families, 59 genera and approximately 65 species (Cremeans, 1979). Due to high water, no samples were collected in winter at Station 1.

Station 1. In spring (28-29 April), 181 invertebrates from 6 taxa were found. The aquatic oligochaetes (Naididae) occupied the greatest percent frequency (84.5) ($N = 153$, $\bar{x} = 51.0/ft^2$). Another oligochaete (Enchy-

traeidae) made up 7.7 percent (N = 14) of the total. The species diversity and equitability values were low, 0.95 and 0.32, respectively.

In summer (August 20), 752 invertebrates from 14 taxa were collected in the samples. Aquatic oligochaetes (Naididae) dominated the sample (93.9%, N = 706). The remaining taxa contained so relatively few numbers ($\bar{x}$ = 3.5/taxon) that they had little effect on the species diversity ($\bar{d}$ = 0.52) and equitability values (e = 0.21).

In fall (November 5), only 8 taxa (N = 484) were identified from the samples. Aquatic oligochaetes (Naididae) dominated with 95.4 percent (N = 462, $\bar{x}$ = 154/ft²). The species diversity (0.36) and equitability values (0.21) were the lowest for all stations and seasons.

This station was obviously dominated by aquatic oligochaetes (Naididae). Oligochaetes are tolerant to low levels of dissolved oxygen and are classified as facultative or tolerant to decomposable organic wastes (USEPA, 1973).

Station 2. In winter, 23 taxa (N = 1150) were identified from the samples. Chironomid larvae dominated the samples with a frequency of 57.6 percent (N = 663, $\bar{x}$ = 221/ft²). Dominant genera were *Trissocladius, Strictochironomus, Cricotopus* and *Eukiefferiella.* Sphaeriid clams ranked second in abundance with 18.3 percent (N = 211, $\bar{x}$ = 70/ft²). The index of diversity and equitability value were 2.01 and 0.23, respectively.

In spring, 21 taxa (N = 1780) were recorded from the samples. Chironomid larvae were in the greatest numbers (562) but many pupae were also taken (174). Together their dominance was 41 percent of the total ($\bar{x}$ = 245/ft²). Isopods (*Asellus*) ranked second in percentage frequency (21%, N = 380, $\bar{x}$ = 127/ft²). Naidid worms and mayflies (*Heptagenia* were the only other numerous taxa (N = 176 and 171, respectively). The index of diversity was 2.95 and the equitability value was 0.52.

In summer, 17 taxa (N = 1213) were identified from the samples. Naidid worms dominated the sample with 44.2 percent of the total (N = 231, $\bar{x}$ = 77/ft²). The next two most abundant taxa were chironomid larvae (24.5%, N = 128, $\bar{x}$ = 43/ft²) and sphaeriid clams (20%, N = 102, $\bar{x}$ = 34/ft²). The species diversity was 2.0 and the equitability value 0.59.

In fall, 17 taxa (N = 1213) were recorded at this station. Chironomid larvae (57.2%) ranked first in percent frequency (N = 694, $\bar{x}$ = 231/ft²). Naidid worms (19%, N = 241, $\bar{x}$ = 80/ft²) and sphaeriid clams (13%, N = 163, $\bar{x}$ = 54/ft²) ranked second and third, respectively. The index of diversity was 1.93 and the equitability value 0.42.

The dominance at station 2 is shared between chironomid larvae and naidid worms. These two taxa are tolerant to low oxygen levels and decomposable organic wastes (USEPA, 1973).

Station 3. In winter, 14 taxa (N = 111) were identified in the sample. *Cheumatopsyche* sp. ranked first in percentage frequency and numbers (42%, N = 47, $\bar{x}$ = 16/ft²). The mayfly genus *Ameletus* ranked second (15%, N = 16, $\bar{x}$ = 5/ft²) and the stonefly *Allocapnia vivipara* (10%, N = 11, $\bar{x}$ = 4/ft²) ranked third. The index of diversity was 2.83 and the equitability value 0.71.

In spring, the taxa increased to 24 (N = 711). The mayfly genus *Heptagenia* was the most abundant (30%, N = 215, $\bar{x}$ = 72/ft²) taxon. The beetle *Stenelmis crenata* (larvae and adults) ranked second (27%, N = 194, $\bar{x}$ = 65/ft²). The species diversity was the highest with 3.04 and the equitability value was 0.46.

In summer, 10 taxa (N = 76) were found in the collection. The mayfly genus *Caenis* was the most abundant with 18.4 percent of the total (N = 14, $\bar{x}$ = 5/ft²). Chironomid larvae ranked second (17%, N = 13, $\bar{x}$ = 4/ft²). However, the highest percentage (23.7) were unidentified dipteran larvae. The species diversity was 2.03 and the equitability value was 0.92.

In fall, 16 taxa (N = 105) were found for this station. The most abundant taxon was the caddisfly *Cheumatopsyche* (23%, N = 25, $\bar{x}$ = 8/ft²). Naidid worms ranked second (16%, N = 17, $\bar{x}$ = 6/ft²) in the sample. The index of diversity was 1.93 and the equitability value 0.42.

The samples at Station 3 showed the highest species diversity and equitability value of the three stations. The headwater station was not subjected to as much organic waste as stations 1 and 2 which were in an agricultural and pasture area. The species composition changed from annelids and dipterans to trichopterans and ephemeropterans which generally are more intolerant to adverse conditions.

Fishes

A total of 1183 fish representing 25 species in 7 families was collected from four seasons (Cremeans, 1979) (Table 1). All fishes were grouped into the following three categories: game, forage and rough fishes. Game fishes were represented by the families Centrarchidae and Scianidae. The forage fishes included Cyprinidae, Percidae, and Clupeidae. Catostomidae and Ictaluridae comprised the rough fishes. Due to high water, no samples were collected in winter at Station 1.

Station 1. In spring, forage fishes comprised 95.0 percent of the numbers (N = 147). The sample was dominated by the Emerald shiner, (80.0%, N = 112). The second most abundant species, another cyprinid, was the Sand shiner (7.1%). The remaining 5 species comprised no more than 5.7 percent for any one taxon. Game fishes, primarily Bluegill, composed 5 percent of the collection.

In summer, forage fishes comprised 76.6 percent of the numbers (N = 47). The dominating species was the Emerald shiner (N = 32) with 68.1 percent of the total numbers. Game fishes, primarily Bluegill, comprised 23.3 percent of the collection.

In fall, game fishes comprised 58.4 percent of the numbers. Again, the Emerald shiner was the most abundant fish (35.0%, N = 48) but the Black crappie was nearly as numerous (32.8%, N = 35) in the total numbers (N = 137).

Station 2. Forage fishes showed the highest numerical percentages for the study period in winter (95.7%) and spring (96.0%). Of the 47 fish collected in winter, 23 (48.9%) were the Bluntnose minnow. Of the 249 fish collected for spring, 99 (39.8%) were the Sand shiner.

In summer and fall, forage fishes again showed the highest numerical percentages, 94.5 and 85.5, respectively. This time the Creek chub was

Table 1. List of Fishes Collected From Flatfoot Creek, Mason County, West Virginia.

GAMES FISHES	
Family Centrarchidae—Basses and Sunfishes	
Lepomis cyanellus Rafinesque	Green Sunfish
L. gibbosus (Linnaeus)	Pumpkinseed
L. macrochirus Rafinesque	Bluegill
L. megalotis (Rafinesque)	Longear Sunfish
Pomoxis nigromaculatus (Lesueur)	Black Crappie
P. annularis Rafinesque	White Crappie
Family Scianidae—Drums	
Aplodinotus grunniens Rafinesque	Drum
FORAGE FISHES	
Family Cyprinidae—Minnows	
Campostoma anomalum (Rafinesque)	Stoneroller
Cyprinus carpio Linnaeus	Carp
Notropis atherinoides Rafinesque	Emerald Shiner
N. blennius (Girard)	River Shiner
N. cornutus (Mitchill)	Common Shiner
N. spilopterus (Cope)	Spotfin Shiner
N. stramineus (Cope)	Sand Shiner
Phoxinus erythrogaster (Rafinesque)	Southern Redbelly Dace
Pimephales notatus (Rafinesque)	Bluntnose Minnow
Rhinichthys atratulus (Hermann)	Blacknose Dace
Semotilus atromaculatus (Mitchill)	Creek Chub
N. volucellus Cope	Mimic Shiner
Family Percidae—Perches	
Etheostoma nigrum Rafinesque	Johnny Darter
Family Clupeidae—Herrings	
Dorosoma cepedianum (Lesueur)	Gizzard Shad
ROUGH FISHES	
Family Catostomidae—Suckers	
Catostomus commersoni (Lacepede)	White Sucker
Family Ictaluridae—Freshwater Catfishes	
Ictalurus melas (Rafinesque)	Black Bullhead
I. natalis (Lesueur)	Yellow Bullhead

the most abundant species in summer and fall with 60.4 and 48.4 percent, respectively.

Station 3. In winter, 143 fishes were collected of which 89 percent were forage fishes. The Creek chub and Striped shiner ranked first (27.9%) and second (22.3%), respectively, in percentage frequency.

In spring, 118 fishes were collected of which 94 percent were forage fishes. The Striped shiner made up 41.5 percent of the collection.

Forage fishes dominated the numerical percentage in summer (82.7%) and fall (96.0%). During both seasons, the Creek chub and Striped shiner ranked first and second in percentage frequency.

Conclusions and Recommendations

Based on the low species diversity of benthic macroinvertebrates ($\bar{d}$ = 0.36) at the tailwater stations and the similarity of fish populations at

the tailwater stations to the nearby Ohio River populations, the authors believe that uniform disposal over the bottomlands adjacent to the canal (plan 1) will have the least environmental impact.

Since the uniform disposal of dredge materials will destroy the lower reaches of Flatfoot Creek, the following fish taxa will be eliminated from stations 1 and 2: game fishes (Pumpkinseed sunfish, Black and White Crappies, Drum); and forage fishes (Carp, Emerald shiner, River shiner, Mimic shiner, Gizzard shad).

If the following ecological requirements are met in the relocated channel, a majority of these populations will enter the area from the nearby Ohio River:

(1) A proper riffle/pool ratio to provide adequate space requirements for spawning sites. The Stoneroller and Striped shiner, for example, require riffles while the White sucker requires pools.
(2) Proper substrates must be available for spawning activities.
    (a) Gravel (e.g., Creek chub, Longear sunfish, Green sunfish, Pumpkinseed sunfish, White sucker, Bluegill).
    (b) Sand (e.g., Emerald shiner, Bluntnose minnow).
    (c) Mud (e.g., Emerald shiner).
    (d) Flat Rocks (e.g., Johnny darter).
    (e) Logs (e.g., Yellow and Black Bullheads).
    (f) Leaves/twigs (e.g., Green sunfish).
    (g) Brush Piles (e.g., Black and White Crappies).
(3) Development of productive riffle areas using natural substrate to allow colonization by zoobenthic populations to provide fish food.
(4) Bank stability must be established through rip-rap and vegetation to decrease siltation. Also, a riparian canopy will provide shaded habitats.
(5) A meandering channel will provide more suitable habitat and help control stream velocities during heavy run-off.

Thirty-eight taxa of benthic macroinvertebrates will be destroyed at Stations 1 and 2. Only 8 taxa would be eliminated from the stream ecosystem: Crustacean (*Gammarus*); Insects—Mayfly (*Leptophlebia*); Hemipterans (*Sigara, Belostoma*); Megalopterans (*Chauliodes, Sialis*); Dipterans (*Hexatoma*, and *Pseudolimnephila*).

If proper ecological requirements are fulfilled, the amphipod crustacean *Gammarus* will repopulate the relocated channel from the Ohio River. The remaining taxa which are present upstream will populate the channel through catastrophic and behavioral drift. The following recommendations are made:

(1) Every effort must be made to transport natural riffle substrate to the relocated channel. Besides providing shelter, some zoobenthic populations feed locally on phytobenthos.
(2) The use of artificial substrate samplers will aid in transporting zoobenthic populations from the Ohio River (e.g., *Gammarus*) to the relocated channel for colonization.

(3) Allochthonous leaf detritus must be provided for herbivorous and detritivorous zoobenthic populations (e.g., mayflies, caddisflies). Until riparian vegetation develops, leaf detritus will probably be in inadequate supply despite what may wash downstream.

Although having an immediate detrimental effect, the authors believe that uniform disposal of spoils over the bottomlands of Flatfoot Creek will have the least long range environmental impact. Uniform dispersal maintaining a low gradient should retard siltation runoff. If proper ecological requirements are met, a relocated channel for Flatfoot Creek should repopulate within a couple of years.

Plan 2 (mounds along either side of Flatfoot Creek) will preserve the stream channel and the turbidity tolerant fish populations (e.g., White Crappie, Drum, Carp) but lose other populations intolerant to turbidity (e.g., Bluntnose Minnow, Sand Shiner Siltation from the large mounds, even if those mounds are ditched around, would cover up spawning areas and productive riffles well populated with benthic macroinvertebrates. The ecological food web would be drastically impaired and not support upper trophic levels. The increase of turbidity in the form of solids would deplete oxygen levels making even turbid tolerant fish seek other areas. The siltation will eventually flow into the Ohio River where sedimentation is a constant problem in maintaining navigational channels. From an aesthetic viewpoint, mounds 70-100 feet (23-31 m) tall are not at all typical of this river plain area.

Plan 3 (off-site disposal at Mud Run) would cause the same detrimental effects upon the biota of the Mud Run stream. Detrimental effects imposed upon the Mud Run headwaters will have further reaching effects. Besides effecting a normal community of forage fishes and benthic macroinvertebrates, allochthonous leaf detritus necessary to the ecological system through energy input, will become unbalanced and degrade not only Mud Run but Crab Creek. If the sediment dam constructed to contain the spoil materials was not adequate, siltation would then compound the degrading effects. Crab Creek provides spawning areas for Ohio River fishes and excellent habitat for waterfowl populations.

The Southern Redbelly Dace *Phoxinus* (= *Chrosomus*) *erythrogaster* composed 26 percent of the fishes taken from Station 1GAL10008 (Mud Run). The Southern Redbelly Dace is listed as a fish of scientific interest on the tentative list of rare animal species.

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A Limnological Investigation of the Fishes, Benthos and Water Quality of the West Fork of Twelvepole Creek, Mingo and Wayne Counties, West Virginia

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Abstract

Collections of fishes and benthos were made at nine stations on the West Fork of Twelvepole Creek in Mingo and Wayne Counties, West Virginia. Fishes representing 38 species from 7 families were present. Estimates of abundance and biomass of game, rough and forage fishes were as follows: 5.1, 83.5 and 11.4 percent, respectively, of the total number of fishes and 19.0, 58.1 and 22.9 percent, respectively, of total weight. Benthic macroinvertebrates represented 7 orders, 18 families, and about 24 species. The following numerical frequencies were determined: Ephemeroptera (54.3), Trichoptera (12.0), Plecoptera (11.4), Odonata (9.2), Diptera (7.6), Megaloptera (3.8) and Coleoptera (1.6). Investigation of five chemical and physical parameters indicated acceptable water quality.

Introduction

The West Fork of Twelvepole Creek is a 4th order stream that originates in the northern part of Mingo County, West Virginia. It flows across the county in a northwestern direction for 24 km and traverses Wayne County for 57.9 km before joining the East Fork, 1.6 km south of Wayne, West Virginia (Figure 1). The stream has a mean gradient of 3.8 meters per kilometer (Krebs and Teets, 1913). The West Fork is currently the only major tributary of the Twelvepole Creek basin not impounded for flood control. In the spring, the West Virginia Department of Natural Resources stocks trout in a 9.6 km section of the stream within Cabwaylingo State Forest.

Materials and Methods

Between September 14 and November 16, 1979, the following nine stations were sampled for five water quality parameters and fish and benthic populations (Figure 1):

Station 1: West Fork, Twelvepole Creek, along Co. Rt. 3/5, Breeden, WV, Mingo Co.
Station 2: West Fork, Twelvepole Creek, along Co. Rt. 35, Cabwaylingo State Forest
Station 3: Moses Creek, mouth along St. Rt. 152, Missouri Branch, WV

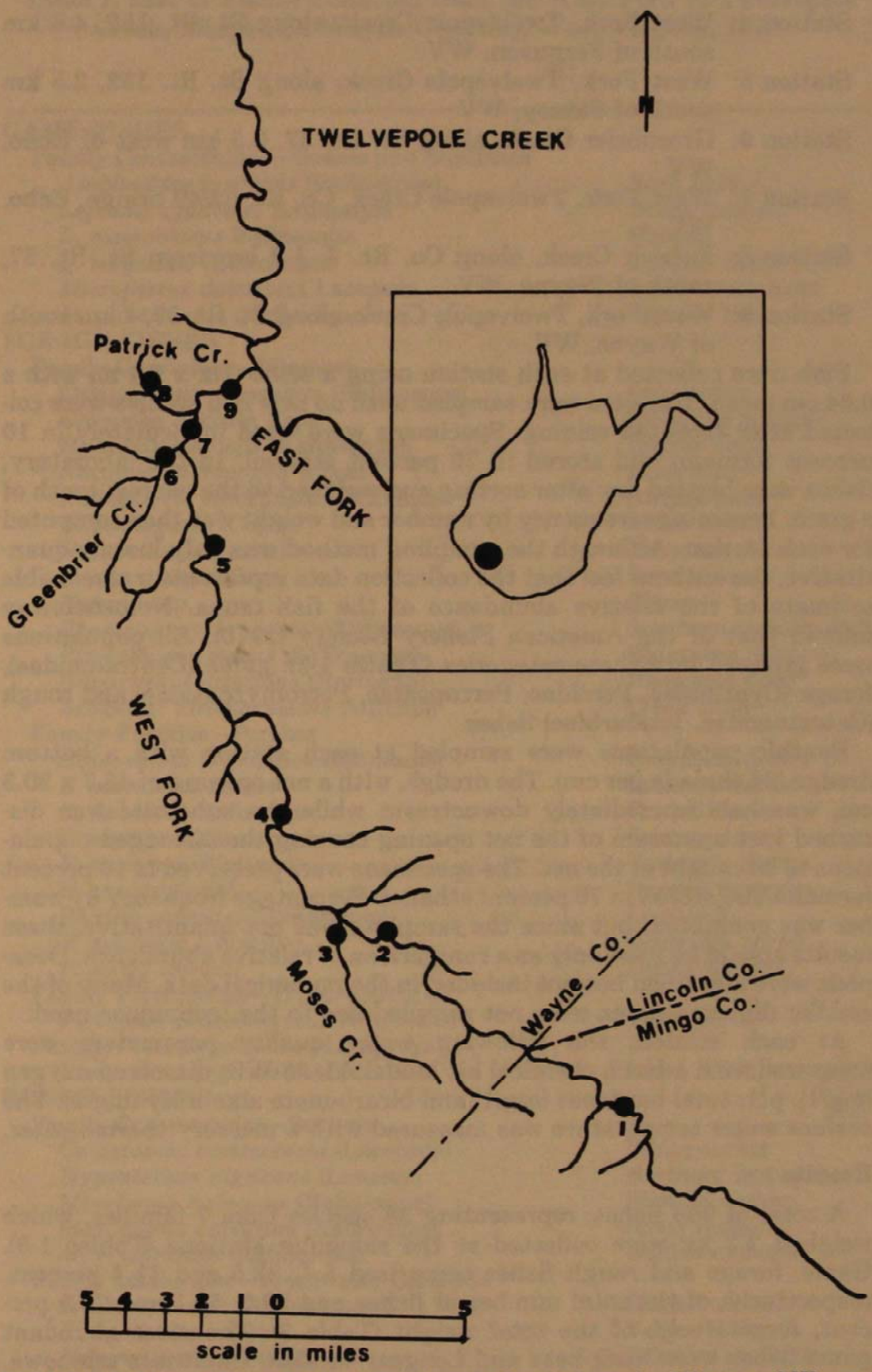

FIGURE 1. Map of West Fork of Twelvepole Creek, Lincoln, Mingo and Wayne Counties, West Virginia, showing locations of collecting stations (USGS, 1972).

Station 4: West Fork, Twelvepole Creek, along St. Rt. 152, 4.8 km south of Ferguson, WV
Station 5: West Fork, Twelvepole Creek, along St. Rt. 152, 2.5 km south of Sidney, WV
Station 6: Greenbrier Creek, along St. Rt. 37, 0.5 km west of Echo, WV
Station 7: West Fork, Twelvepole Creek, Co. Rt. 52/49 bridge, Echo, WV
Station 8: Patrick Creek, along Co. Rt. 7, 1.9 km from St. Rt. 37, south of Wayne, WV
Station 9: West Fork, Twelvepole Creek, along St. Rt. 37, 4 km south of Wayne, WV

Fish were collected at each station using a seine (1.2 x 2.4 m) with a 0.64 cm mesh. The sites were sampled until no new fish species were collected after repeated seining. Specimens were fixed immediately in 10 percent formalin and stored in 70 percent ethanol. In the laboratory, fishes were blotted dry after sorting and weighed to the nearest tenth of a gram. Percentage frequency by number and weight was then computed for each station. Although the sampling method was only loosely quantitative, the authors feel that the collection data represents a reasonable estimate of the relative abundance of the fish fauna. Nomenclature follows that of the American Fishery Society (1970). All populations were grouped into three categories (Tables 1-3): game (Centrarchidae), forage (Cyprinidae, Percidae, Percopsidae, Petromyzontidae) and rough (Catostomidae, Ictaluridae) fishes.

Benthic populations were sampled at each station with a bottom dredge (24 threads per cm). The dredge, with a net opening of 45.7 x 20.3 cm, was held immediately downstream while the substrate was disturbed just upstream of the net opening causing the dislodged populations to be caught in the net. The specimens were preserved in 10 percent formalin and stored in 70 percent ethanol. Percentage frequency by number was computed, but since the sampling was not quantitative, these results should be used only as a comparison of relative abundance. Decapods were identified but not included in the numerical data. Many of the smaller dipteran fauna were not sampled due to the techniques used.

At each station, the following water quality parameters were measured with a Hach chemical kit Model AL-36-WR: dissolved oxygen (mg/1), pH, total hardness (mg/1) and bicarbonate alkalinity (mg/1). The surface water temperature was measured with a mercury thermometer.

Results

A total of 966 fishes, representing 38 species from 7 families, which weighed 7.2 kg were collected at the sampling stations (Tables 1-3). Game, forage and rough fishes comprised 5.1, 83.5 and 11.4 percent, respectively, of the total number of fishes and 19.0, 58.1 and 22.9 percent, respectively, of the total weight (Table 3). The most abundant game fishes were Rock bass and Longear sunfish. Bluntnose minnows, Striped shiners and Creek chubs were the most abundant forage fishes. Common rough fishes included White suckers, Northern hog suckers,

Table 1. List of Fishes Collected from the West Fork of Twelvepole Creek, Mingo and Wayne Counties, West Virginia, 1979.

GAME FISHES	
Family Centrarchidae—Basses and Sunfishes	
Ambloplites rupestris (Rafinesque)	Rock bass
Lepomis cyanellus Rafinesque	Green sunfish
L. macrochirus Rafinesque	Bluegill
L. megalotis (Rafinesque)	Longear sunfish
Micropterus dolomieui Lacepede	Smallmouth bass
M. punctulatus (Rafinesque)	Spotted bass
FORAGE FISHES	
Family Cyprinidae—Minnows	
Campostoma anomalum (Rafinesque)	Stoneroller
Ericymba buccata Cope	Silverjaw minnow
Hybopsis amblops (Rafinesque)	Bigeye Chub
Nocomis micropogon (Cope)	River chub
Notropis chrysocephalus (Mitchill)	Striped shiner
N. photogenis (Cope)	Silver shiner
N. rubellus (Agassiz)	Rosyface shiner
N. stramineus (Cope)	Sand shiner
Notropis sp.	Shiner
Phoxinus erythrogaster (Rafinesque)	Southern redbelly dace
Pimephales notatus (Rafinesque)	Bluntnose minnow
Rhinichthys atratulus (Hermann)	Blacknose dace
Semotilus atromaculatus (Mitchill)	Creek chub
Family Percidae—Perches	
Etheostoma blennoides Rafinesque	Greenside darter
E. caeruleum Storer	Rainbow darter
E. flabellare Rafinesque	Fantail darter
E. nigrum Rafinesque	Johnny darter
E. variatum Kirttand	Variegate darter
E. zonale (Cope)	Banded darter
Percina caprodes (Rafinesque)	Logperch
P. maculata (Girard)	Blackside darter
P. sciera (Swain)	Dusky darter
Family Percopsidae—Trout—perches	
Percopsis omiscomaycus (Walbaum)	Trout-perch
Family Petromyzontidae—Lampreys	
Lampetra aepyptera (Abbott)	Least brook lamprey
ROUGH FISHES	
Family Catostomidae—Suckers	
Catostomus commersoni (Lacepede)	White sucker
Hypentelium nigricans (Lesueur)	Northern hog sucker
Minetrema melanops (Rafinesque)	Spotted sucker
Moxostoma anisurum (Rafinesque)	Silver redhorse
M. erythrurum (Rafinesque)	Golden redhorse
Family Ictaluridae—Freshwater Catfishes	
Ictalurus melas (Rafinesque)	Black bullhead
I. natalis (Lesueur)	Yellow bullhead
Noturus miurus Jordan	Brindled madtom

Table 2. Composition, Number (Parentheses) and Collecting Stations of Fishes in West Fork of Twelvepole Creek, Mingo and Wayne Counties, West Virginia, 1979.

GAME FISHES—49
- Basses
  - Rock bass (20) 1,2,4,5,6,7,9
  - Smallmouth bass (1) 1
  - Spotted bass (6) 2,4,7,9
- Sunfishes
  - Green sunfish (1) 3
  - Bluegill sunfish (5) 6,7,9
  - Longear sunfish (16) 1,2,4,6,9

FORAGE FISHES—807
- Minnows
  - Stoneroller (65) 1,2,7,8,9
  - Silverjaw minnow (39) 1,3,4,6,7
  - Bigeye chub (3) 1,4
  - River chub (5) 2,5,7,9
  - Striped shiner (137) 2,3,4,5,6,7,9
  - Silver shiner (4) 2
  - Rosyface shiner (22) 3,4,5,7,9
  - Sand shiner (13) 1,2
  - Shiner (unidentified) (9) 9
  - Southern redbelly dace (53) 8
  - Bluntnose minnow (141) 1,2,3,5,6,7,8,9
  - Blacknose dace (40) 8
  - Creek chub (103) 1,2,3,4,5,6,7,8,9
- Troutperches
  - Troutperch (1) 7
- Perches
  - Greenside darter (51) 1,2,4,5,7,9
  - Rainbow darter (10) 1,2,5
  - Fantail darter (25) 1,2,5,6,7,8,9
  - Johnny darter (22) 1,2,4,5,6,7,8,9
  - Variegate darter (9) 2,5,7
  - Banded darter (31) 1,2,3,4,5,7,9
  - Logperch (3) 9
  - Blackside darter (4) 2,6
  - Dusky darter (2) 7
- Lampreys
  - Least brook lamprey (15) 2,3,4,5,7,9

ROUGH FISHES—110
- Suckers
  - White Sucker (23) 1,2,3,6,7,8,9
  - Northern hog sucker (20), 1,3,4,5,6,7,9
  - Spotted sucker (3) 7
  - Silver redhorse (10) 7
  - Golden redhorse (20) 2,3,6,7,9
- Freshwater catfishes
  - Black bullhead (1) 7
  - Yellow bullhead (2) 6
  - Brindled madtom (31) 2,4,5,7,9

Table 3. Percentage Frequency of Total Numbers and Weight of Game, Forage and Rough Fishes in the West Fork of Twelvepole Creek, Mingo and Wayne Counties, West Virginia, 1979. N = Total Number and Weight.

Stations	Percentage Frequency (Numbers)			Percentage Frequency (Weight - kg)		
	Game	Forage	Rough	Game	Forage	Rough
1	9.7	86.4	3.9	22.0	58.5	19.5
2	6.4	80.0	13.6	33.8	44.3	21.9
3	1.6	87.5	10.9	3.7	57.0	39.3
4	10.2	65.3	24.5	34.3	35.0	30.7
5	3.9	89.6	6.5	6.1	88.9	5.0
6	5.2	83.6	11.2	20.3	41.5	38.2
7	4.8	75.7	19.5	3.4	17.8	78.8
8	0.0	97.7	2.3	0.0	98.4	1.6
9	9.5	73.4	17.1	47.3	40.5	12.2
Mean	5.1	83.5	7.6	19.0	58.1	22.9
N		966			7.2	

Golden redhorses and Brindled madtoms. Some of the least abundant fishes include Smallmouth bass and Troutperch.

One-hundred and eighty-four benthic macroinvertebrates were collected which represented 7 orders, 18 families, and about 24 species (Table 4). The following taxa were ranked according to decreasing numerical percentages: Ephemeroptera (54.3), Trichoptera (12.0), Plecoptera (11.4), Odonata (9.2), Diptera (7.6), Megaloptera (3.8) and Coleoptera (1.6). Ephemeropterans (mayflies) of the genera *Stenonema* and *Isonychia* comprised 31.0 and 10.9 percent, respectively, of the samples. The trichopteran (caddisflies) genus *Cheumatopsyche* accounted for 9.8 percent of the samples.

The following chemical and physical parameters were within the acceptable ranges of good water quality (USDI, 1968) (Table 5) mean and (range): dissolved oxygen, 8.9 (8.0-10.6) mg/1; pH, 7.2 (6.3-7.7); total hardness = 51.3 mg/1; bicarbonate alkalinity, 45.6 (34.2-68.4) mg/1 $CaCO_3$; and temperature, 15.1 (9.5-20.5) C.

Discussion

Seven families and 38 species of fishes were recorded for the West Fork of Twelvepole Creek. Tarter (1972) recorded 7 families and 38

Table 4. Composition, Number and Percentage Frequency (Parentheses) and Collecting Stations of the Benthic Fauna in West Fork of Twelvepole Creek, Mingo and Wayne Counties, 1979. N = 184

INSECTA
- EPHEMEROPTERA (100) (54.3%)
  - *Ameletus* sp. (8), 6,7,8
  - *Baetisca bajkovi* Neave (1) 4
  - *B. callosa* Traver (11) 2,4,9
  - *Caenis* sp. (1) 6
  - *Hexagenia* sp. (2) 2
  - *Isonychia* sp. (20) 1,2,5,6,7,9
  - *Stenonema* sp. (57) 1,2,4,5,6,7,8,9
- DIPTERA (14) (7.6%)
  - *Tipula* sp. (14) 1,2,3,5,6,7,9
- TRICHOPTERA (22) (12%)
  - *Cheumatopsyche* sp. (18) 2,5,6,7,8,9
  - *Hydropsyche* sp. (3) 1,2,7
  - *Pycnopsyche* sp. (1) 4
- ODONATA (17) (9.2%)
  - Zygoptera (Damselflies)
    - *Agrion* sp. (7) 1,6,7,8,9
  - Anisoptera (Dragonflies)
    - *Boyeria* sp. (3) 6,7
    - *Cordulegaster maculatus* Selys (4) 6,7,8
    - *Macromia* sp. (1) 2
    - *Ophiogomphus* sp. (2) 6
- COLEOPTERA (3) (1.6%)
  - *Psephenus* sp. (3)
- PLECOPTERA (21) (11.4%)
  - *Acroneuria lycorias* (Newman) (9) 2,8
  - *Eccoptura xanthenes* (Newman) (5) 5,7
  - *Isoperla* sp. (1) 5
  - *Taenionema* sp. (2) 5
  - *Taeniopteryx* sp. (4) 2
- MEGALOPTERA (7) (3.8%)
  - *Corydalus cornutus* (Linnaeus) (5) 1,2,7
  - *Sialis* sp. (2) 8,9
- CRUSTACEA
  - DECAPODA
    - *Cambarus robustus* Girard
    - *Orconectis sanbornii sanbornii* (Faxon)

species sampled by rotenone from the East Fork of Twelvepole Creek. Except for the following populations, all fish species were common to both forks: Southern redbelly dace (WF), Troutperch (WF), Largemouth bass (EF), Spotfin shiner (EF) and Brook silverside (EF). Game fishes

Table 5. Water Quality Analyses From the West Fork of Twelvepole Creek, Mingo and Lincoln Counties, West Virginia, 1979.

Stations	Temp., C	pH	Dissolved Oxygen, mg/l	Bicarbonate Alkalinity, mg/l	Total Hardness, mg/l $CaCO_3$
1	9.5	7.1	10.6	68.4	51.3
2	11.0	7.5	10.0	34.2	51.3
3	*	6.8	9.2	51.3	51.3
4	13.0	7.5	9.0	34.2	51.3
5	14.0	7.5	8.0	34.2	51.3
6	20.5	7.7	8.0	*	*
7	18.0	7.0	8.0	51.3	51.3
8	20.0	6.3	8.0	*	*
*9	—	—	—	—	—
Mean	15.1	7.2	8.9	45.6	51.3

*No measurements

comprised 5.1 percent of the number of fishes collected from the West Fork. In the nearby pre-impoundment area in Beech Fork of Twelvepole Creek (a main stream tributary), Olson and Tarter (1974) reported that game fishes, sampled by electroschocking, represented 5.4 percent of the samples. Tarter (1972) noted that game fishes composed 25.4 percent of the samples from the East Fork of Twelvepole Creek. Forage fishes accounted for 83.5 percent of the fishes from the West Fork. Olson and Tarter (1974) and Tarter (1972) noted that rough fish accounted for 10.1 and 14.1 percent, respectively, of the fishes in their studies.

In the West Fork of Twelvepole Creek, immatures of ephemeropterans, trichopterans and plecopterans composed 54.3, 12.0 and 11.4 percent, respectively, of the number of benthic organisms. Olson and Tarter (1974) reported that ephemeropterans, trichopterans and plecopterans comprised 29, 29 and 18 percent, respectively, of the benthic organisms from Beech Fork. In the East Fork of Twelvepole Creek, Tarter (1972) recorded that ephemeropterans, dipterans and trichopterans made up 43, 14 and 11 percent, respectively, of the benthic taxa.

The overall productivity of the West Fork appears somewhat low, as is typical of other streams in the region. However, the West Fork is still relatively unpolluted and undisturbed, and is important in preservation of native stream dwelling fauna. It is hoped that this study may serve as baseline data for any possible future development in the region.

Acknowledgements

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Preliminary Investigations of Adult, Juvenile, and Larval Fish of the Monongahela River and Tributary, Morgantown, West Virginia[1]

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Abstract

Studies were conducted during fall 1978, and spring and early summer 1979, to describe adult, juvenile, and larval fish populations of the Monongahela River

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near Morgantown, West Virginia. The study area included the Hildebrand and Morgantown Locks, various sites in the Morgantown pool, and two sites on Crooked Run, a tributary of the Monongahela River.

Twenty-eight taxa (6095 individuals) were identified in the adult fish collections, with *Notropis* (shiners) being the dominant genus. Seven species comprised 90 percent of the total number of individuals. Commonly named species included minnows, bullheads, catfish, suckers, darters, sunfish, perch, walleye, and muskellunge, which were other important components of the sampled fish populations.

Larger numbers of ichthyoplankton were collected during night samples and on the surface, as compared to daytime samples and deep tows. Eleven taxa (171 individuals) were identified and developmental stages were determined. *Cyprinus carpio* was the dominant taxa, followed by numerous unidentified cyprinids, *Lepomis* spp., and several species of darters.

Introduction

Selected stretches of the Monongahela River near Morgantown, West Virginia, were studied during fall 1978, and spring and summer 1979, as part of an environmental baseline investigation. The objectives of these initial surveillance programs were 1) to obtain a preliminary species profile of adult fish occurrence in representative areas of the river, 2) to document juvenile and larval fish occurrence, and 3) to relate findings of similar river studies to the present investigation.

The Monongahela River is located in north central West Virginia and is formed at Fairmont, West Virginia, at the confluence of the Tygart and West Fork rivers. The Monongahela flows generally northward to join the Allegheny River at Pittsburgh, Pennsylvania to form the Ohio River (U. S. Army Corps of Engineers, 1976). Along the entire 129-mile length of the river, the flow is interrupted by a series of locks and dams which are used strictly for navigation purposes. Due to this situation, extremely irratic flow conditions exist which do not follow normal seasonal trends (U. S. Army Corps of Engineers, 1974-1979). The river is utilized primarily for coal transportation via barges to the Pittsburgh industrial area and for recreational purposes.

During the 1960's, the Monongahela River was considered one of the most severely polluted rivers in the United States with few, if any, representative fish populations. In addition to direct industrial and municipal waste discharges, large quantities of acid mine drainage entered the river from its many tributaries. Since that time, the water quality of the basin has generally improved, partially by implementation of effective water pollution control programs by industries and municipalities within the basin (Ohio River Basin Commission, 1975). Fish populations have increased substantially through the cooperation and efforts of the West Virginia Department of Natural Resources conservation/stocking programs (Jernejcic and Courtney, 1979).

Methods and Materials

The study area on the Monongahela River included two lock and dam systems (Hildebrand L&D upstream of Morgantown and the Morgan-

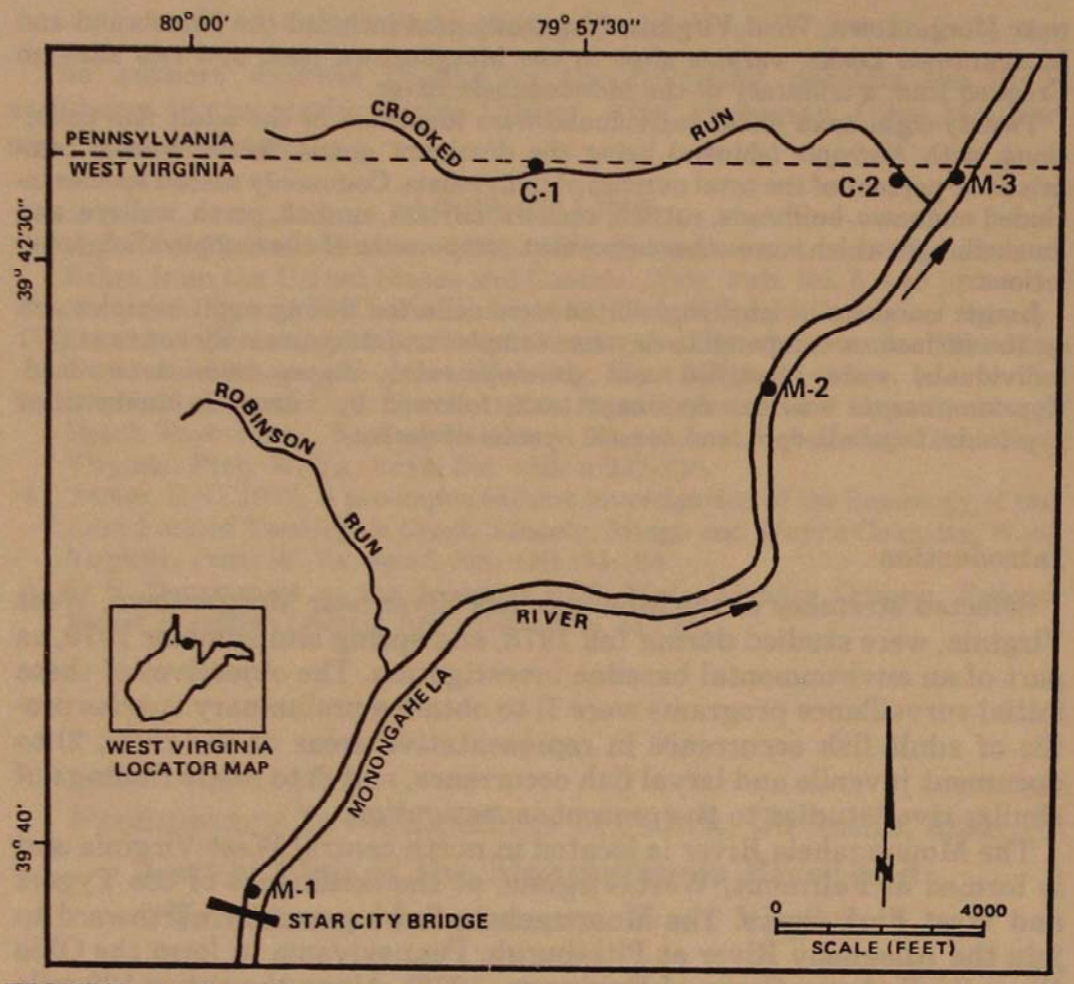

FIGURE 1. Sampling station locations on the Monongahela River and Tributaries.

town L&D) for adult fish, and the area upstream of M-2 (Figure 1) for adult, juvenile, and larval fish. Crooked Run, a tributary of the Monongahela River, was also surveyed for spawning activity.

Adult fish were collected in cooperation with the West Virginia Department of Natural Resources (DNR) using rotenone (lock and dam areas), experimental gill nets, dip nets, and electrofishing gear (M-2, M-3, C-1, and C-2). Representative specimens were identified, counted, weighed, and measured by DNR or Stearns-Roger Services, Inc., personnel. Literature used for identification purposes included Eddy and Underhill (1969, 1978), Scott and Crossman (1973), and Bailey (1970).

Juvenile and larval fish collections were completed using 760 mu nitex cloth plankton nets with 0.5 m stainless steel rings and calibrated flow meters. The nets were towed for 30-minute intervals at the surface and near the bottom during both day and night sampling periods in the vicinity of station M-2 (west side of river). The volume of water sampled (filtered) was in excess of $100m^3$ with all samples being sorted, preserved in 10 percent formalin, and delivered to the Appalachian Environmental Laboratory, Frostburg State College, Frostburg, Maryland, for iden-

tification. Specimen identification was verified by the Larval Fish Laboratory, Colorado State University, Fort Collins, Colorado. The following publications were used for identification: Fish (1932), Fuiman (1978), Hogue et al. (1976), Lippson and Moran (1974), May and Gasaway (1967), and Wang and Kernehan (1979). Specimen developmental stages were characterized according to Snyder (1976) by the following factors:

1. Protolarvae—absence of distinct median fin elements.
2. Mesolarvae—development of at least one principal ray in the median fins and absence of pelvic buds or fins.
3. Metalarvae—full compliment of principal median fin rays with pelvic buds or fins present.
4. Juveniles—loss of any remaining finfolds.
5. Adults—attainment of sexual maturity.

Results

Twenty-eight taxa of adult fish were collected at the Morgantown and Hildebrand locks by the West Virginia DNR (Table 1). The dominant genus, *Notropis* (shiners), included seven species with Emerald shiners, *N. antherionoides,* and sand shiners, *N. stramineus* comprising over 90 percent of the individuals and biomass within the genus. Other important taxa were the bluntnose minnow, *Pimephales notatus,* yellow bullhead, *Ictalurus natalis,* channel catfish *I. punctatus,* johnny darter, *Etheostoma nigrum,* and logperch, *Percina caprodes.* Common gamefish collected were bluegill, *Lepomis macrochirus,* pumpkinseed, *L. gibbosus,* green sunfish, *L. cyanellus,* largemouth bass, *Micropterus salmoides,* brown bullhead *I. nebulosus,* walleye, *Stizostedion vitreum,* and muskellunge, *Esox masquinongy.*

During May 1979, nine taxa of adult fish near M-2 were electroshocked (Table 2). The dominant species at M-2 were pumpkinseed, *Lepomis gibbosus,* and the bluntnose minnow, *Pimephales notatus.* Nests of centrarchids were found in shallow weeded areas along the entire length of the river. The carp genus *Cyprinus* was also observed in the surface waters of the river.

Seining and electrofishing in Crooked Run (C-1 and C-2, Table 2) resulted in the collection of four taxa with the river chub, *Nocomis micropogon,* as the dominant species. Spawning activity was also observed for white sucker, *Catostomus commersoni,* and johnny darter, *Etheostoma nigrum,* on Crooked Run above C-2.

Eleven taxa of larval and juvenile fish were identified from Station M-2 (Table 3) and three taxa from M-3 (Table 4). A total of 171 larval fish were collected (Table 4). The dominant taxa at M-2 were *Cyprinus carpio* and an unidentified cyprinid. An unidentified cyprinid and catostomid were the dominant taxa at M-3. Because of incomplete larval species descriptions in the literature, some taxa were identified only to family.

Larval and juvenile fish were present in the study area from May 14 through August 14, with concentrations greatest at both stations during the end of June and beginning of July. Similar peak larval concentrations have been found in late June and parts of July in the Cumberland (Hess and Winger 1976) and Missouri Rivers (Harrow et al., 1975).

Table 1. Adult Fish Collections in Two Lock and Dam Systems of the Monongahela River, Morgantown, West Virginia September 1978

Scientific Name	Common Name	Location: Morgantown Locks	Location: Hildebrand Locks
Centrarchidae	Sunfishes		
Lepomis cyanellus	Green sunfish	2	-
Lepomis gibbosus	Pumpkinseed	-	7
Lepomis macrochirus	Bluegill	-	6
Lepomis sp.	Unidentified hybrid	-	68
Micropterus salmoides	Largemouth bass	-	8
Pomoxis nigromaculatus	Black crappie	8	36
Clupeidae	Herrings		
Dorosoma cepedianum	Gizzard shad	1	-
Cyprinidae	Minnows and Carps		
Carassius auratus	Goldfish	-	2
Cyprinus carpio	Carp	1	2
Nocomis micropogon	River chub	1	-
Notemigonus crysoleucas	Golden shiner	1	6
Notropis atherinoides	Emerald shiner	288	1,398
Notropis atherinoides x[a] *N. stramineus*	Emerald shiner x[a] Sand shiner	1	1
Notropis buchanani	Ghost shiner	9	41
Notropis sp.	Unidentified shiner	2	91
Notropis spilopterus	Spotfin shiner	2	2
Notropis stramineus	Sand shiner	97	49
Notropis volucellus	Mimic shiner	4	6
Pimephales notatus	Bluntnose minnow	182	3,336
Semotilus atromaculatus	Creek chub	-	1
Esocidae	Pikes		
Esox masquinongy	Muskellunge	1	1
Ictaluridae	Catfishes		
Ictalurus catus	White catfish	2	-
Ictalurus natalis	Yellow bullhead	76	7
Ictalurus nebulosus	Brown bullhead	4	12
Ictalurus punctatus	Channel catfish	39	8
Percidae	Perches		
Etheostoma nigrum	Johnny darter	37	58
Percina caprodes	Logperch	40	-
Stizostedion vitreum	Walleye	4	6
	Total	802	5,152

[a]Hybrid fish species

The first taxa to appear in the larval collections were *Etheostoma nigrum* and an unidentified catostomid (Figure 2). The early appearance of these taxa is indicative of seasonal spawning behavior of fish taxa in site vicinity. Seasonal occurrences of larval fish have also been found in the Cumberland (Hess and Winger, 1976) and Missouri Rivers (Harrow et al., 1975). Seasonal parameters which may trigger spawning activity include water levels (Hassler, 1970), water temperature (Rawson, 1945), and day length (Snow et al. 1974).

Table 2. Adult Fish Collections on the Monongahela River and Crooked Run Near Morgantown, West Virginia May 1979

Scientific Name	Common Name	M-2 May 16	M-2 May 23	C-1 May 15	C-2 May 15
Catostomidae	Suckers				
Catostomus commersoni	White sucker	-	-	-	2
Centrarchidae	Sunfishes				
Lepomis cyanellus	Green sunfish	-	5	2	5
Lepomis gibbosus	Pumpkinseed	15	19	-	-
Lepomis macrochirus	Bluegill	-	3	-	1
Micropterus salmoides	Largemouth bass	-	1	-	1
Cyprinidae	Minnows and Carps				
Cyprinus carpio	Carp	-	3	-	-
Nocomis micropogon	River Chub	-	-	10	15
Notemigonus crysoleucas	Golden shiner	-	3	-	-
Notropis atherinoides	Emerald shiner	1	1	-	-
Pimephales notatus	Bluntnose minnow	10	35	-	-
Ictaluridae	Catfishes				
Ictalurus natalis	Yellow bullhead	-	6	-	-
Percidae	Perches				
Etheostoma nigrum	Johnny darter	-	-	-	3
Total		26	76	12	27

A larger number of larval fish were collected during the night than during the day, and more were collected in the surface than from the bottom (Table 3). Species capture susceptibility appears higher for surface/night tows than for day. According to Noble (1970), the effectiveness of either day or night sampling is often species and size-dependent, probably due to net avoidance with increasing size. Harrow et al. (1975) found fish larvae concentrations in the Missouri River to be highest near the surface, presumably because of the gradation of sediment load and density in the vertical section. Surface samples collected in the Monongahela River at M-2 contained 92 fish larvae, while samples collected from the river bottom at M-2 contained only 69.

Discussion and Conclusion

Results of these preliminary investigations indicate that the Monongahela River near Morgantown has a diversified and balanced adult fish population. However, present findings are based on limited adult fish

Table 3. Ichthyoplankton Collections in the Vicinity of M-2 on the Monongahela River, Morgantown, West Virginia May-August 1979

Collection Date	Tows Depth/Time	Species	Stage of Development	Number Collected	Range of Total Length	Approximate Spawning Date
5/15/79	SURFACE/NIGHT	Etheostoma nigrum	Protolarvae	2	6.1-6.2	4/30
5/23/79	SURFACE/NIGHT	Catostomidae spp.	Mesolarvae	1	14.5	5/1
5/29/79	SURFACE/NIGHT	Etheostoma nigrum	Protolarvae	3	5.3-5.9	5/15
5/29/79	BOTTOM/NIGHT	Catostomidae spp.	Mesolarvae	1	*	*
5/30/79	SURFACE/DAY	Etheostoma nigrum	Protolarvae	1	6.1	5/15
		Percidae: Etheostomatini	*	1	*	*
		Unidentifiable larvae	*	3	*	*
6/13/79	SURFACE/DAY	Cyprinidae spp.	Mesolarvae	2	6.5	**
6/14/79	SURFACE/NIGHT	Cyprinus carpio	Protolarvae	28	6.2-7.3	6/1
		Cyprinidae spp.	Mesolarvae	5	5.5-6.7	**
		Lepomis spp.	Mesolarvae	1	5.0	6/5
		Etheostoma nigrum	Mesolarvae	1	6.1	5/20
		Unidentifiable larvae	*	2	*	*
6/14/79	BOTTOM/DAY	Cyprinus carpio	Protolarvae	1	7.7	6/1
		Cyprinidae spp.	Protolarvae	3	5.6-6.0	**
		Etheostoma nigrum	Protolarvae	2	5.2-5.9	6/1
6/25/79	BOTTOM/NIGHT	Cyprinus carpio	Mesolarvae	2	7.4	6/10
		Lepomis spp.	Mesolarvae	4	5.5-5.6	6/10
6/25/79	SURFACE/NIGHT	Cyprinus carpio	Protolarvae	3	6.8-7.5	6/10
		Cyprinus carpio	Mesolarvae	7	9.7-10.7	6/5
		Cyprinus carpio	Metalarvae	3	11.4-11.7	6/1
		Cyprinidae spp.	Protolarvae	1	6.1	**
		Cyprinidae spp.	Mesolarvae	11	5.5-7.9	**
		Lepomis spp.	Mesolarvae	2	6.1	6/10
		Percidae: Etheostomatini	Mesolarvae	1	5.9	6/10
		Percidae: Etheostomatini	Metalarvae	1	7.4	6/1
6/26/79	BOTTOM/DAY	Lepomis spp.	Mesolarvae	2	5.9-6.4	6/10
7/18/79	SURFACE/NIGHT	Cyprinidae spp.	Mesolarvae	7	5.8-8.1	**
		Cyprinidae spp.	Metalarvae	1	9.8	**
		Lepomis spp.	Mesolarvae	15	4.6-9.8	7/1
		Lepomis spp.	Metalarvae	3	9.2-11.0	6/20
		Pomoxis spp.	Mesolarvae	1	8.9	6/20
		Unidentifiable larvae	*	4	*	*
7/18/79	BOTTOM/NIGHT	Notropis atherinodes	Juvenile	1	24	6/15
		Pimephales notatus	Juvenile	1	26.5	5/20
		Cyprinidae spp.	Mesolarvae	1	*	**
		Etheostoma nigrum	Juvenile	1	31.2	5/15
7/19/79	SURFACE/DAY	Cyprinidae spp.	Mesolarvae	1	7.1	**
		Unidentifiable larvae	*	5	*	*
7/19/79	BOTTOM/DAY	Cyprinidae spp.	Mesolarvae	1	4.4	**
		Lepomis spp.	Mesolarvae	6	5.2-6.5	7/4
		Unidentifiable larvae	*	3	*	*
7/25/79	SURFACE/NIGHT	Cyprinidae spp.	Mesolarvae	1	6.6	**
		Ictalurus nebulosus	Mesolarvae	1	10.5	7/12
		Unidentifiable larvae	*	1	*	*
7/25/79	BOTTOM/NIGHT	Cyprinidae spp.	Mesolarvae	3	6.6-8.6	**
		Ictalurus natalis	Metalarvae	2	14.1-16.0	7/1
		Lepomis spp.	Mesolarvae	3	5.1-5.3	7/10
7/26/79	SURFACE/DAY	Cyprinidae spp.	Mesolarvae	1	5.1	**
7/26/79	BOTTOM/DAY	Cyprinidae spp.	Mesolarvae	1	7.0	**
8/1/79	BOTTOM/NIGHT	Lepomis spp.	Juvenile	1	16.4	7/1
8/14/79	BOTTOM/NIGHT	Cyprinidae spp.	Mesolarvae	1	7.2	**

Note: * - Specimens mutilated by collection, handling, preservatives etc.
** - Developmental time varies greatly according to species

sampling in the lock and dam areas and along selected stretches of the river. Comparisons of these data with other studies in similar river systems reveal inconsistencies in adult species occurrence and abundance

Table 4. Summary of Ichthyoplankton Collections on the Monongahela River, Morgantown, West Virginia May-August 1979

Scientific Name	Common Name	Stage of Development	Station M-2	Station M-3
Catostomidae				
Unidentified	Sucker	Mesolarvae	2	-
		Metalarvae	-	4
		Juvenile	-	1
Centrarchidae				
Lepomis sp.	Sunfish	Mesolarvae	34	-
		Metalarvae	3	-
		Juvenile	1	-
Pomoxis sp.	Crappie	Metalarvae	1	-
Cyprinidae				
Cyprinus carpio	Carp	Protolarvae	32	-
		Mesolarvae	9	-
		Metalarvae	3	-
Notropis atherinoides	Emerald shiner	Juvenile	1	-
Pimephales notatus	Bluntnose minnow	Juvenile	1	1
Unidentified	Minnow	Protolarvae	4	-
		Mesolarvae	35	-
		Metalarvae	1	4
Ictaluridae				
Ictalurus natalis	Yellow bullhead	Metalarvae	2	-
Ictalurus nebulosus	Brown bullhead	Mesolarvae	1	-
Percidae				
Etheostoma nigrum	Johnny darter	Protolarvae	8	-
		Mesolarvae	1	-
		Juvenile	1	-
Etheostomatini	Darter	Mesolarvae	1	-
		Metalarvae	1	-
		Unidentified	1	-
Unidentified larvae and remains	-	-	18	-
Total			161	10

as related to habitat. Additional sampling of different habitats in other locations using varied methods may change these results to be more representative of the true river population. Adult fish data from the Crooked Run stations (C-1, C-2) reflected minimum numbers of species, possibly due to sampling techniques, schedules or collection frequency.

Due to the limited ichthyoplankton sampling schedule and small numbers of specimens collected, comparisons of results with existing literature show few recognizable trends in water flow, temperature, or biorhythmic fluctuations. The variable nature of the lock and dam river system cannot be directly correlated to a particular spawning time or condition. Water temperatures also did not correspond to known spawning patterns of collected species. Biorhythmic fluctuations were difficult to assess because of the one-season sampling schedule and small numbers of individuals. The absence of any of these trends could also be attributed to different sampling techniques, sampling areas, and

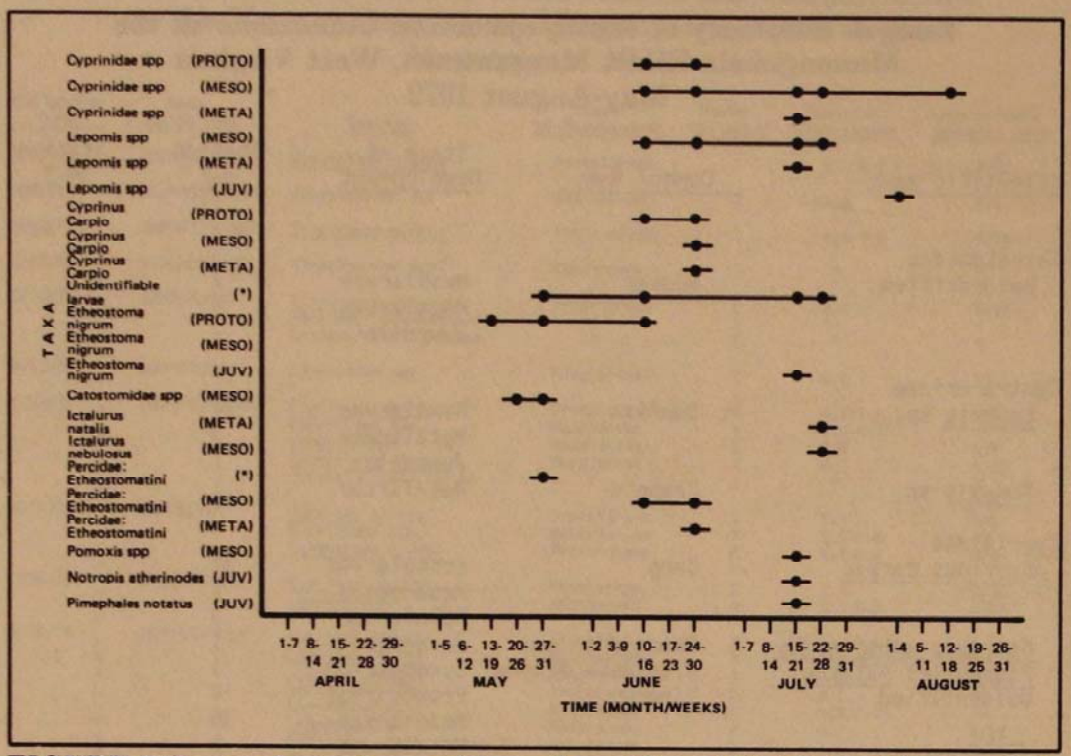

FIGURE 2. Seasonal occurrence of Juvenile and Larval Fish in the Monongahela River Near Morgantown, West Virginia.—May-August 1979.

whether or not the sampled populations originate from the same spawning areas or from naturally occurring drift populations.

Developmental stages of the sampled ichthyoplankton population included 51.3 percent mesolarvae, 27.5 percent protolarvae, 6.3 percent metalarvae, and 2.5 percent juveniles. As fish larvae mature, collection net avoidance increases and is reflected in the small numbers of older individuals collected.

Comparisons of the sampled adult, juvenile, and larval fish populations indicated that major species included Bluntnose minnows (59.1 percent) and adult Emerald shiners (28.4 percent). Ichthyoplankton samples included an unidentified minnow mesolarvae (21.7 percent), *Lepomis* spp. mesolarvae (21.2 percent), and *Cyprinus carpio* protolarvae (19.9 percent) as the major component species. Collected larval fish were similar to the dominant taxa of adult fish in the Monongahela River and Crooked Run. These taxa included *Lepomis* sp., *Pimephales notatus,* and *Etheostoma nigrum.* Only *Pomoxis* sp. was not sampled as an adult.

Although further investigation of the area fish populations is recommended, this study should provide an adequate documentation of species occurrence for selected areas of the Monongahela River and Crooked Run.

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Field Notes on the Distribution of Terrestrial Amphibians and Reptiles of the West Virginia Mountains Above 975 Meters

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Abstract

One hundred thirty-six areas above 975 m in the Allegheny Mountains of West Virginia were surveyed during the summers of 1976-1979 for terrestrial amphibians and reptiles. These herpetological collections produced 2,391 salamanders and 11 snakes. Of the salamanders, three species (*Plethodon cinereus*, *Plethodon nettingi*, and *Desmognathus ochrophaeus*) comprised 88.00 percent of the total count. The percentage of salamander occurrence within certain elevation ranges may suggest competitive interactions.

Introduction

There are several articles dealing with amphibians and reptiles in West Virginia, but only a few of these are concerned with studies in the higher elevations. Green (1939), Brooks (1945), and others reported on the occurrence and distribution of amphibians and reptiles in highlands and lowlands within the mountainous counties of West Virginia. Brooks (1948) and Highton (1971) cited aspects of certain species found in higher

elevations. This report is the result of a survey of terrestrial amphibians and reptiles made in areas above 975 m in five mountain counties of West Virginia during the summers of 1976-1979.

Methods and Materials

This survey was made on the following mountains which were almost entirely within the boundaries of the Monongahela National Forest (Figure 1): Cheat (Randolph and Pocahontas Counties), McGowan (Randolph and Tucker Counties), Green (Tucker County), Shavers (Randolph and Pocahontas Counties), Allegheny Front (Tucker, Randolph, Grant, and Pendleton Counties), Allegheny (Pendleton and Pocahontas Counties), Spruce (Pendleton County), Gauley (Pocahontas County), Rich, east of Cheat (Randolph County), Rich, west of Cheat (Randolph County), Backbone (Tucker County), Canaan (Tucker County), Mozark (Tucker County), Back Allegheny (Pocahontas County), Cabin (Tucker County), Middle (Randolph and Pocahontas Counties), Burner (Pocahontas County), Little Middle (Randolph County), and Yew (Pocahontas County). The elevation of these study sites ranged from 1469 m (4820 feet) at Thorny Flat, 1.5 miles south of the Snowshoe Ski area, to 975 m (3198 feet) on Back Allegheny Mountain, 1.9 miles south of Durbin.

Each site was surveyed by two or three collectors during the hours between 10 a.m. and 5 p.m. and usually within 48 hours of a rainfall. All observations were made during the months of May, June, July, August, September, and October of the respective years.

Results

Collections in 136 terrestrial sites produced nine species of salamanders (2,391 specimens), five species of snakes (11 specimens), and one species of toad (6 specimens). There were no frogs, lizards, or turtles observed.

There were 11 snakes of five species observed on five of the 19 mountains surveyed (Table 1). *Thamnophis s. sirtalis* was the most common snake of these five species.

The number of collecting sites and the major salamander species observed on each mountain are presented in Table 2. There are two reasons for the great difference in the number of collecting sites per mountain. First, the larger mountain ranges obviously had more sites. Second, this survey was done as part of a research project on the status of *P. nettingi,* and most sites were selected on strategically located mountains for this study. Four of the five species shown in Table 2 are of the genus *Plethodon* and one of the genus *Desmognathus. Plethodon cinereus, P. nettingi,* and *D. ochrophaeus* are all small salamanders, while *P. wehrlei* and *P. glutinosus* are somewhat larger.

Plethodon cinereus was the most abundant of all species, occurring on all 19 of the mountains and totalling 1,024 individuals. *Desmognathus ochrophaeus* was the next most common salamander observed, appearing on 17 of the 19 mountains and numbering 622 individuals. *Plethodon nettingi* was found on nine mountains, with 458 individuals observed.

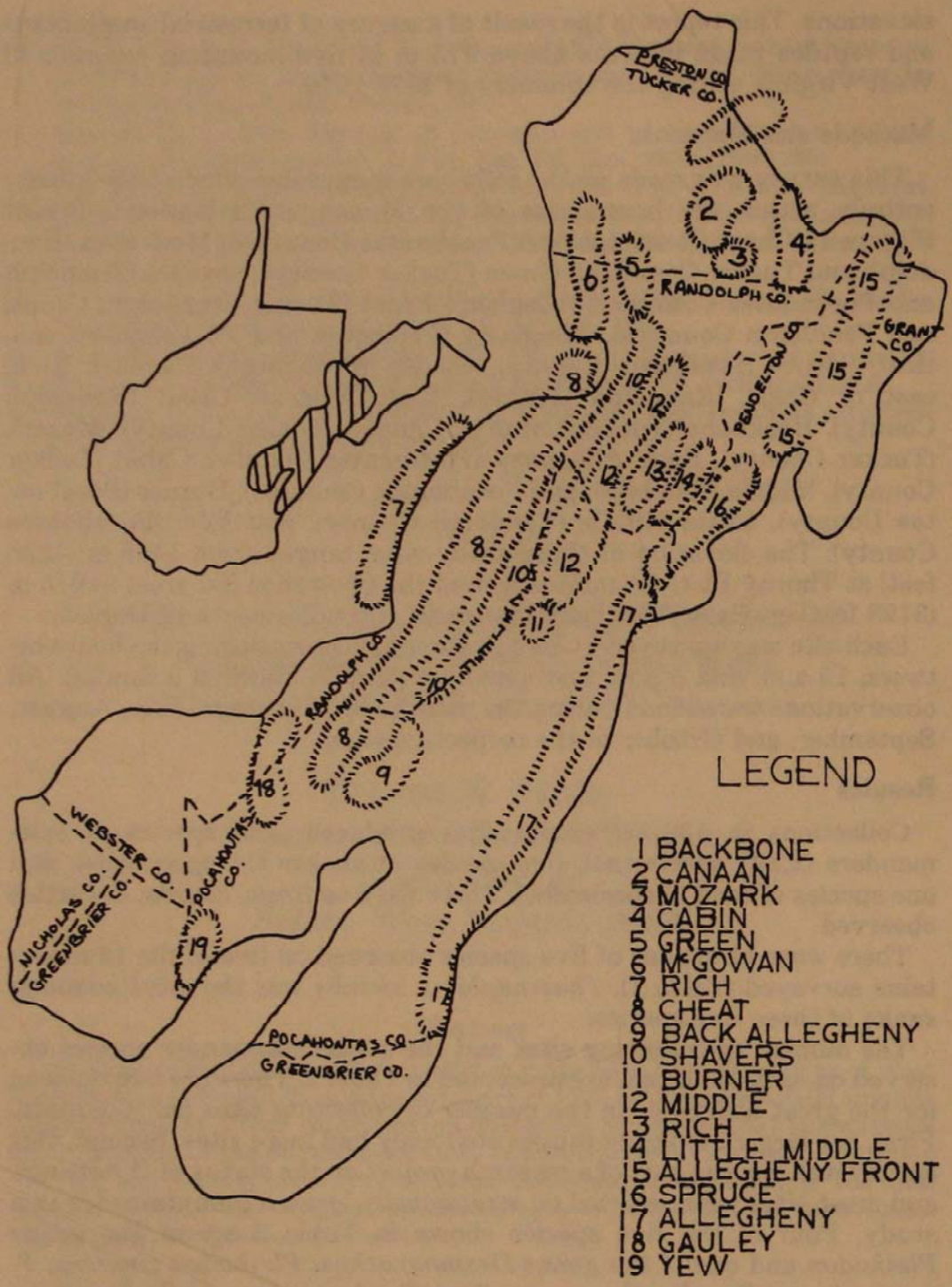

FIGURE 1. The nineteen mountains on which this study was made. The striped area in the West Virginia map represents the Monongahela National Forest.

Desmognathus ochrophaeus was the most abundant of all species (59.02%) at the lowest elevation range studied, 975 m (3198 ft) to 1,036 m

Table 1. The Location, Elevation and Species of Snakes Observed.

Mountain	Elevation	Species of Snakes	Number Observed
Cheat	1052 - 1158 m (3450-3800 ft)	Thamnophis s. sirtalis	2
Green	1067 m (3500 ft)	Thamnophis s. sirtalis	1
McGowan	975 m (3198 ft)	Crotalus horridus	1
Allegheny Front	1189 m (3900 ft)	Thamnophis s. sirtalis	2
Allegheny Front	1207 m (3960 ft)	Opheodrys vernalis	1
Allegheny Front	1189 m (3900 ft)	Storeria o. occipitomaculata	1
Spruce	1329 m (4360 ft)	Diadophis punctatus edwardsi	1
Spruce	1341 m (4400 ft)	Thamnophis s. sirtalis	2

Table 2. The number of Collecting Sites and the Number of Individuals per Major Salamander Species Observed.

Mountain	Number of Sites	cinereus	nettingi	wehrlei	glutinosus	ochrophaeus	TOTAL
Cheat	22	227	89	61	45	242	664
McGowen	3	66	89	7	4	17	183
Green	2	23	0	0	0	0	23
Shavers	14	142	61	23	12	30	268
Allegheny	9	54	0	6	14	24	98
Gauley	9	65	0	1	4	40	110
Rich (1)	1	35	0	0	1	3	39
Rich (2)	3	2	0	0	1	0	3
Backbone	3	20	0	2	3	24	49
Canaan	8	57	0	0	3	10	70
Mozark	1	6	1	5	1	8	21
Back Allegheny	9	26	6	0	8	16	56
Cabin	8	27	11	0	1	37	76
Middle	8	49	0	4	5	85	143
Burner	4	6	0	17	1	27	51
Little Middle	4	3	21	0	1	1	26
Yew	4	22	0	4	0	2	28
Allegheny Front	12	117	110	4	1	9	241
Spruce	12	77	70	3	2	47	199
TOTAL	136	1024	458	137	107	622	2348

Table 3. The Frequencies and Percentages of Salamander Occurrence at Different Elevation Ranges.

	975-1036m	1036-1097m	1097-1158m	1158-1219m	1219-1280m	1280-1341m	1341-1402m	1402-1463m
P. cinereus	(13) 21.31	(119) 45.77	(256) 44.44	(258) 43.22	(150) 51.90	(51) 27.27	(115) 36.05	(62) 60.78
P. nettingi	(0) 0	(8) 3.07	(88) 15.28	(162) 27.14	(29) 10.03	(54) 28.88	(100) 31.35	(17) 16.67
P. wehrlei	(0) 0	(6) 2.31	(13) 2.26	(39) 6.53	(21) 7.26	(16) 8.56	(20) 6.27	(22) 21.57
P. glutinosus	(9) 14.75	(24) 9.23	(22) 3.82	(13) 2.18	(28) 9.69	(6) 3.21	(5) 1.57	(0) 0
D. ochrophaeus	(36) 59.02	(99) 38.08	(189) 32.81	(119) 19.93	(55) 19.03	(51) 27.27	(73) 22.88	(0) 0
*Other species	(3) 4.92	(4) 1.54	(8) 1.39	(6) 1.00	(6) 2.08	(9) 4.81	(6) 1.88	(1) 0.98

Table 4. The Minor Salamander Species and the Number of Individuals and Elevation Ranges in Which They Were Observed.

Species	*Number of Individuals*	*Elevation Range*
D. fuscus	3	975-1341 m
D. monticola	3	1036-1341 m
G. p. porphyriticus	3	975-1280 m
N. v. viridescens (Eft)	17	975-1463 m
E. bislineata	6	975-1402 m
A. maculatum	4	1097-1280 m
H. scutatum	2	1158-1219 m
P. hoffmani	5	488-1402 m

(3,398 ft). *Plethodon nettingi* was the most common species (28.88%) at 1,280 m (4,200 ft) to 1,341 m (4,399 ft). *Plethodon cinereus* was the most abundant species at all other elevation ranges. It is of particular interest to note that at the elevation where *P. cinereus* was the predominant species, *P. nettingi* and *D. ochrophaeus* were less abundant (Table 3).

There was not as great a disparity in the occurrence of the larger *P. glutinosus* and *P. wehrlei.* While more individuals of *P. wehrlei* were observed, *P. glutinosus* was found on 17 of the 19 mountains and *P. wehrlei* on 12. *P. glutinosus* generally occurred more frequently at the lower elevations and *P. wehrlei* at the higher elevations (Table 3).

In addition to these five species, eight more species were found but much less frequently. These species, the number of individuals observed, and the elevation ranges in which they occurred are shown in Table 4.

Discussion

The discrepancy between the number of salamanders and snakes observed was large. Because this was a terrestrial study, the lack of frogs and turtles was expected. There are 22 species of snakes known to occur in West Virginia; hence, it would be expected that four summers of collecting would produce more than five species or 11 individuals. The Allegheny Physiographic Province is more moist and cool than the other physiographic provinces of West Virginia (Lee, personal communication), and it may be that this habitat is not conducive to the existence of many species of snakes. Since there are only five species of lizards known in West Virginia and because most species occur in dry habitats, the absence of lizards was expected.

In that the range of *Thamnophis s. sirtalis,* the Eastern Garter Snake, extends farther north than any other serpentes species (Conant, 1975), it is not surprising that this species was the most numerous (63.6%) in these higher areas. N. Bayard Green (personal communication) states that *Crotalus horridus* was somewhat common in these higher elevations during the 1920s and 1930s. As presented in Table 2, only one timber

rattlesnake was observed, and this one was at the lowest elevation level (975 m) in this study. The paucity of *C. horridus* in areas where they occurred in past years should be studied.

Plethodon cinereus is the most ubiquitous salamander throughout the greater part of its range, and it has a more northern distribution than any of the other species observed (Conant, 1975). It is not surprising, therefore, that this species is so successful in these higher elevations. Further, it was found that *P. cinereus* increases somewhat in percentage of occurrence with an increase in elevation (Table 3).

Desmognathus ochrophaeus was the second most common salamander species. In addition to being the most terrestrial of this genus (a genus that frequents springs and other moist habitats), *D. ochrophaeus,* the mountain dusky, is known to occur in high elevations throughout its range. This would explain why *D. ochrophaeus* was found to be abundant in these moist, high-elevation terrestrial areas.

Populations of *P. nettingi* were expected to occur since this species is found only above 1050 m in the Allegheny Physiographic Province of eastern West Virginia (Pauley, unpublished data). The distribution of *P. nettingi* was not nearly as extensive as *P. cinereus* and *D. ochrophaeus. Plethodon nettingi* occurred on only nine of the 19 mountains, while *D. ochrophaeus* was found on 17 of the 19 mountains and *P. cinereus* was found on all of the mountains. Highton (1971) suggests that *P. nettingi* may have been eliminated from other areas of the Cheat Mountains through competition with *P. cinereus.* I suggest that *D. ochrophaeus* is also in competition with *P. nettingi,* as well as *P. cinereus,* thereby establishing a three-way interaction.

This three-way interaction hypothesis may be further supported by data presented in Table 2. *Desmognathus ochrophaeus* was the most numerous species observed at the lowest elevation (975-1036 m), but they became less abundant in the higher elevations where *P. cinereus* was the dominant species. The numbers of *P. nettingi* generally increased in the higher elevations, but for the most part they were not as abundant as *P. cinereus.* It is particularly important to note that at elevations where *P. cinereus* was the most numerous, *P. nettingi* and *D. ochrophaeus* were less numerous.

Plethodon hoffmani was found on the eastern slope of the Allegheny Mountain, south of Cherry Grove, West Virginia. This is a species of the Valley and Ridge Physiographic Province (Highton, 1971). This study confirms that *P. hoffmani* does not extend beyond the eastern border of the Allegheny Physiographic Province. *Plethodon hoffmani* was found to have a broad elevation range, occurring from 488 m (1600 ft) near Seneca rocks to 1341-1402 m (4400-4599 ft) on Allegheny Mountain.

There was less of a difference between the number of individuals of *P. glutinosus* and *P. wehrlei* observed, as well as between the number of mountains on which these species occurred. However, the percentages of occurrence at the various elevation ranges appear to differ significantly. At the lowest elevation range, *P. glutinosus* comprised 14.75% of the total salamander population, while *P. wehrlei* was not found at all. With an increase in elevation, the reverse is true. *Plethodon wehrlei* comprised

21.57% of the total population at the highest elevation range, while *P. glutinosus* was absent.

Additional study is needed to determine the reasons for the distribution of these salamander species in regard to elevation range. It is suggested that the population changes along the elevation gradients are the result of either an influence from some environmental factor(s), or competitive interactions among salamander species of comparable size, or both.

Acknowledgements

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Updates on New and Noteworthy Plant Collections for West Virginia

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Abstract

At the West Virginia University Herbarium the author has gleaned the following information since the last Academy meeting. Eight new state records have been recorded and additions and corrections have been made for three county records.

The new state records here reported are:

Aegilops cylindrica Host., Wirt County (*Silcott* s.n.) July, 1955. (Naturalized from Europe and becoming a troublesome weed.)

Arundo donax L., Lincoln County (*Norma Cann* s.n.) 1960. (Introduced from the Mediterranean region as an ornamental in the south and is escaping northward.)

Avena fatua L., Monongalia County (*John Sheldon* 4309) August 1, 1911; Monongalia County (*Mr. & Mrs. H. A. Davis* s.n.) July 10, 1944; Braxton County (*F. J. Boggs* s.n.) June 29, 1953; Kanawha County (*Margaret E. Dennison* s.n.) July 4, 1969. (Naturalized from Europe and widely distributed in the n.e. in field and waste places.)

Panicum verrucosum Muhl., Monongalia County (*Jeff Dawson* s.n.) October 1978. (To be expected, distributed widely in the East.)

Pinellia ternata (Thunb.) Breit., Kanawha County (*J. W. Arthur* s.n.) June 1979. (Adventive from Eastern Asia, spreading in gardens and lawns in the n.e.)

Deutzia scabra Thunb., Wyoming County (*William N. Grafton* s.n.) November 16, 1972. (Introduced from Eastern Asia, spreading in thickets and roadsides.)

Kalmia angustifolia L., Tucker County (*John A. Gibson* s.n.) Summer 1979. (Mainly a coastal plain species but it does occur in mountains and elsewhere where similar soil conditions exist; see Core, Castanea in press 1980.)

Veronica officinalis L. Var. *tournefortii* (Vill.) Richenb., Randolph County (*Eugene Hutton* s.n.) June 1-20, 1979. (Introduced from Europe, found in wet areas of the n.e.)

County additions and corrections here reported are:

Cypripedium reginae Walt. Removed from county records Lincoln County (*Helen Paulich* s.n.) April 1938 which has been determined to be *C. pubescens* Willd. and add (*Eugene Hutton* s.n.) Tucker County June 16, 1979.

Cleistes divaricata (L.) Ames. Add Raleigh County (*William N. Grafton, Raymond Arnold* and *Raymond Husson* s.n.) October 5, 1970; (*Osbra L. Eye* s.n.) July 7, 1971 and Barbour County (*Eleanor Bush* s.n.) June 1979.

Betula papyrifera Marsh. Berkeley County (*E. S. Elliot* s.n.) December 1954 has been found to have been incorrectly identified. This specimen is *Betula nigra* L. This removes the county record.

Free Phage and Plaque Morphology Responses to Low Frequency Vibration in *E. coli* CR 34λ/(λ)

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Abstract

A strain of *E. coli* CR 34λ/(λ), in liquid culture, was exposed to seven sweeps of low frequency vibration (50 to 10,000 hz) for a four minute exposure at a force of 2G. Various plaque morphologies were shown to be especially sensitive to unique vibration sweeps. Also, of the specific segments of the vibration spectrum examined, several were found to produce either greater or lesser amounts of free phage (as compared to non-vibrated controls).

Introduction

The effects of low frequency sound (infrasound) and mechanical vibrations on living organisms came to the forefront of scientific attention with the dawn of the spaceage. This came about primarily as a result of the high levels of vibration experienced during the launching and reentry of spacecraft and the concern for the safety of the astronauts. Hence, increased efforts were made to determine the biological effects of these forces, which were being produced by the engines, aerodynamics, and acceleration aspects of the rockets. Levels of sound generated by aircraft engines, the breaking of the sound barrier, rock concerts, and city and industrial noise have come under scrutiny for harmful effects. But, the fact that sound must travel through air, whose impedance is a mismatch with our body[6], greatly reduces the harmful physiological and genetic effects to low frequency (0-110Hz) and/or to very high amplitudes[6]. Annoyance, a psychological/neurological phenomena linked

to noise, may occur more commonly, as was evident by the refusal of Concorde engineers to work in offices close to the engine testbed[4]. Mechanical vibration, however, is transferred more directly, because the human body is often coupled with the source of vibration through contact, as in the case of a jackhammer, or through solids, such as the vibrations of a compressor attached to a floor. So, in a mechanically vibrated system more energy is transmitted, hence the dangers to humans are greater. Like the effects of sound waves, mechanical vibration exhibits its most profound biological effects at lower frequencies, close to the resonance frequencies of the body and its organs[22]. Also, since most environmental sources such as trains, earthmovers, and other modes of transportation produce vibrations in the 0-100 Hz range, hence the majority of the work done in studying vibration effects are between those frequencies. However, vibration frequencies from 1 Hz to 100,000 Hz are also capable of producing undesirable effects in humans[22], therefore, investigations into frequencies above 100 Hz may also prove useful to our understanding of vibration effects on living organisms.

In these studies, sinusoidal vibration (vibration with a regular oscillating movement) is of interest mainly because it allows for the examination of the effect of frequency. Random vibration, or non-periodic vibration, occurs at irregular intervals and so would not allow one to experimentally observe response to frequency. Other aspects of sinusoidal vibration include: velocity, acceleration, displacement, and duration. Of these terms, frequency, displacement, and acceleration are probably of greatest interest[5] and frequency seems to be the most significant factor with respect to physiological effects[5]. Since frequency is directly related to acceleration[10], it must also be considered.

Displacement and duration may have major effects on protein and/or the DNA of a cell, in that shear forces increase with more displacement and genetic changes may require significant amounts of time for effects to be expressed. The effects of vibration on the physiological systems of humans and animals include changes in: body temperature[20], respiration[19], blood chemistry[18], hormonal levels[3], neural functions[7], and muscle activity[8]. Genetic changes as a result of vibration treatment include: chromosomal rearrangement[17], altered exopolysaccaride levels[3], increased mutagenic activity[16], altered enzyme activity[15], and altered sex ratios[14]. It is at the genetic level that the interest of this paper is focused, especially with regard to the speculation of events which may occur at the molecular level. For the examination of this aspect of research, the induction of a viral prophage from a well defined and thoroughly investigated genetic system was used, viz., the *Escherichia coli* bacterophage lambda (λ) lysogenic system. Induction, which results when the repressor coded for the lambda immunity area is inactivated[11] results in viral reproduction which is phenotypically expressed by plaques, or areas of lysis, on a bacterial "lawn" of susceptible *E. coli* cells. By using five plaque morphology phenotypes, induction frequency and the relationship of frequency to plaque morphology was examined.

Methods

The lysogenic strain CR 34λ/(λ) was used for these experiments. This strain was chosen because it has been shown to be a host-range mutant[11] which alters the tail structure of lambda resulting in the failure of the virus to attach or to be adsorbed by the bacterium. This system allows for the measurement of only total infectious "free" phage for the subsequent estimates of induction.

Seven frequency sweep treatments of coupled mechanical vibration were used with 16 culture tubes of bacteria, viz: 0-100 Hz, 100-1000 Hz, 1000-2800 Hz, 2800-4600 Hz, 4600-6400 Hz, 6400-8200 Hz, and 8200-10,000 Hz; at 2G force for time durations of 4 minutes on vertically mounted tubes coupled to a voice coil shaker (Goodman C-47 vibrator). Control tubes of the lysogenic bacteria culture were hung (with string and rubber band interfaces) from the ceiling directly above the vibrating apparatus so as to receive sonic vibrations from the machine, but were not directly coupled to the vibrator. The first part of the experiment (on growth) confirmed the results reported by Fradkin and Keller[9] on the induction of lambda with respect to vibration exposure.

In these experiments, two replicates were used for each of the seven sweeps and controls. Eight sub-replicate plates were made and counted for each major replicate. From a single cell isolate (previous day) divided equally into 16 culture tubes, lysogenic strain CR 34λ/(λ) was grown overnight @37°C to the late logarithmic phase of growth before being subjected to vibration. After undergoing one of the eight different treatments (or control), the cultures were allowed to grow an additional one and one-quarter hours @37°C to allow for at least one "generation" of phage growth. The experiment was constructed to estimate all infectuous free phage particles as detected by the sensitive indicator strain (*E. coli* K-40). The second part of this experiment was designed to differentiate the types of plaques generated by the experimental treatments on the basis of size and appearance of the plaque margin. The five types of plaques scored were: large and medium smooth margin plaques, irregular margin plaques, small plaques (margin not discernible), and bullseye shaped plaques. Classification on a phenotypic basis (plaque morphology) was done in an attempt to show differential effects of mechanical vibration on the different classes of plaques.

Results

I. *Experiment on Growth.*

The results of this aspect of the experiment confirmed the earlier results reported by Fradkin and Keller[9] on induction with respect to the exposure of lysogenic bacteria to mechanical vibration. Although the phage densities were generally not significantly different from the control, only the phage density of the 2,800-4,600 frequency treatment showed significantly higher phage production (via a Chi-square test) than that found in the control. A graph of the response of phage density vs. frequency treatment can be seen in Figure 1.

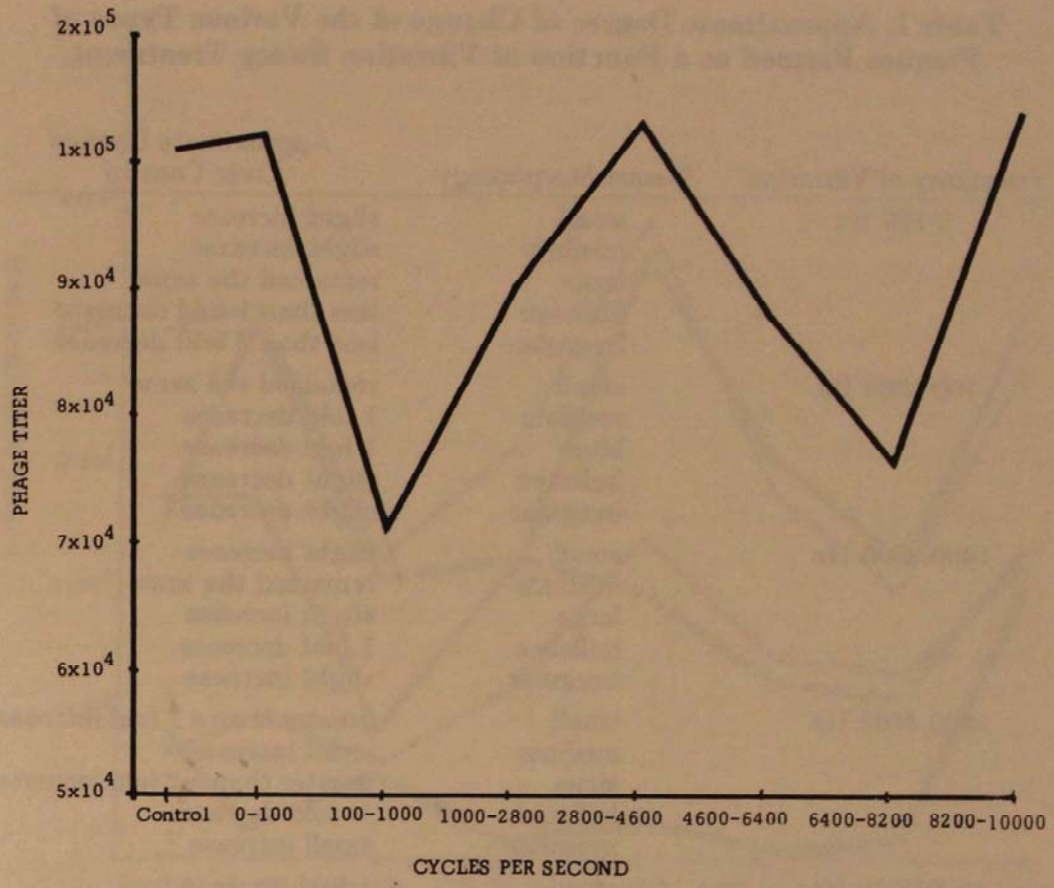

FIGURE 1. Results of Vibration Exposure of CR 34λ/(λ) on Phage Titer as a Function of Frequency Treatment.

II. *Plaque Morphology Assessment.*

Analysis of the five different plaque morphologies with respect to frequency of vibration treatment and the change in phage density allowed for groupings with respect to similar responses as can be seen in Table 1 and Figure 2. These results indicate that: 1) the bullseye plaque responses had decreased levels at all frequencies except the 8,200-10,000 Hz treatment, 2) the patterns of the irregular and medium sized plaque responses were quite similar (except for the 2,800-4,600 Hz treatment), especially at the three highest frequency sweeps, 3) the large and small phenotypes exhibited quite similar response patterns, and 4) all plaque types exhibited a decreased level of production as, compared with their respective controls (except for the small plaque class) at the 6,400-8,200 Hz treatment, and 5) all plaque types increased in frequency (over the controls) except for the bullseye and irregular plaque types at the 2,800-4,600 Hz treatment.

Discussion

Plaque morphology was among the earliest attempts to define the genetic structure of the bacteriophage lambda. Several plaque phenotypes that were isolated on the basis of size, turbidity, and margin

Table 1. Approximate Degree of Change of the Various Types of Plaques Formed as a Function of Vibration Sweep Treatment

Frequency of Vibration	Plaque Morphology	Approximate Change Over Control
0-100 Hz	small	slight increase
	medium	slight increase
	large	remained the same
	bullseye	less than 1 fold decrease
	irregular	less than 2 fold decrease
100-1000 Hz	small	remained the same
	medium	1 fold decrease
	large	1 fold decrease
	bullseye	slight decrease
	irregular	slight decrease
1000-2800 Hz	small	slight increase
	medium	remained the same
	large	slight increase
	bullseye	1 fold decrease
	irregular	slight increase
2800-4600 Hz	small	greater than a 2 fold increase
	medium	small increase
	large	greater than a 2 fold increase
	bullseye	½ fold decrease
	irregular	small increase
4600-6400 Hz	small	1 fold increase
	medium	greater than a 1 fold decrease
	large	slight increase
	bullseye	greater than a 1 fold decrease
	irregular	greater than a 1 fold decrease
6400-8200 Hz	small	slight increase
	medium	greater than a 1 fold decrease
	large	slight decrease
	bullseye	less than a 1 fold decrease
	irregular	greater than a 1 fold decrease
8200-10,000 Hz	small	1½ fold increase
	medium	remained the same
	large	1½ fold increase
	bullseye	1½ fold increase
	irregular	remained the same

from large, turbid plaques by Jacob and Wollman[12] showed not only phenotypic variation, but also exhibited genetically mapable mutations responsible for each type of plaque morphology[12]. Genetic characterization of these plaque morphologies through 3 point mapping revealed three different clear plaque mutations, and one mutation which resulted in a fuzzy plaque margin. Also, the three point mapping method gave the order and approximations of map distance among the various mutants. When a copy of the Jacob and Wollman's morphology map is contrasted with biochemically well defined lambda mutations, inferences can be

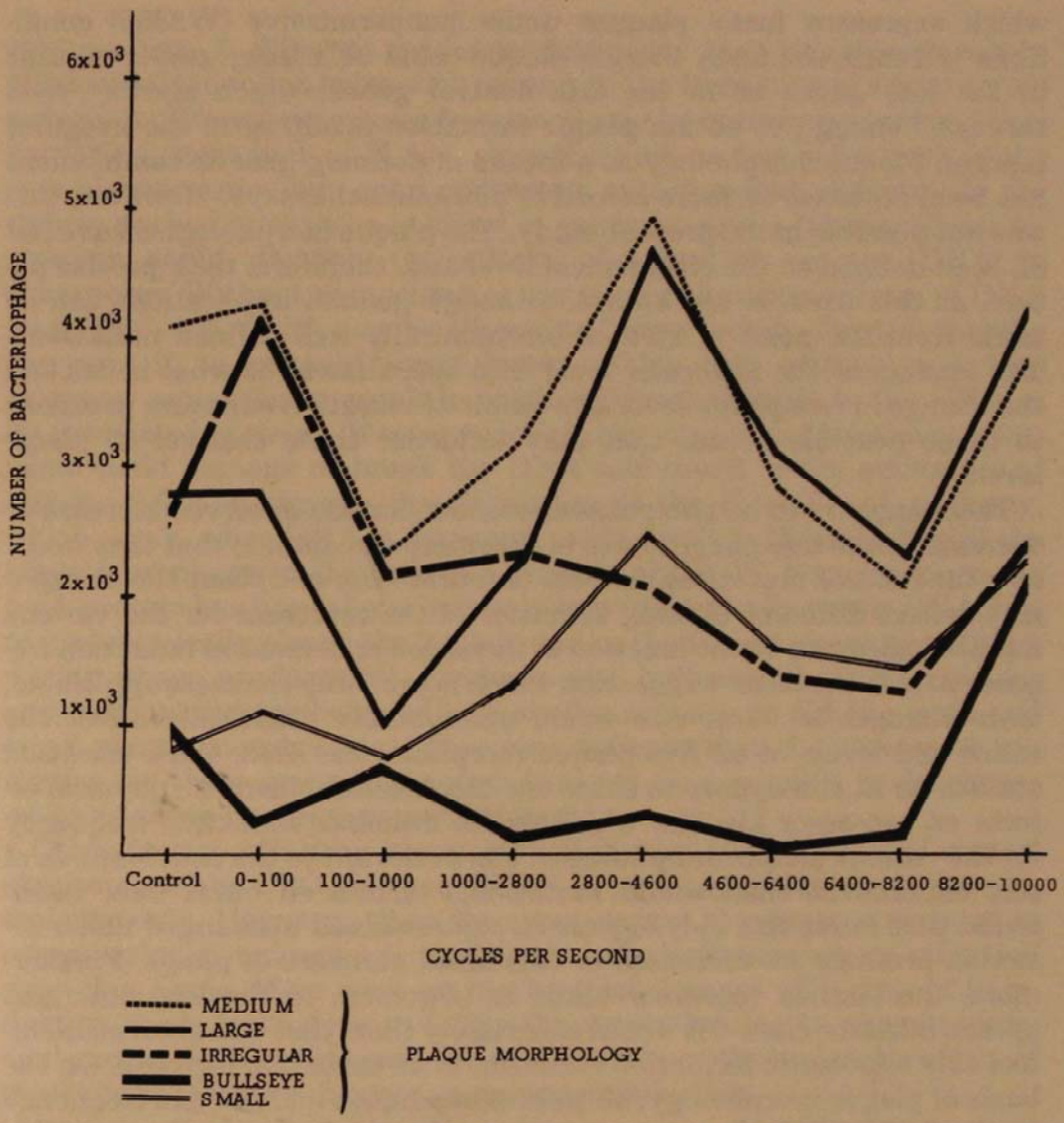

FIGURE 2. Results of Vibration Exposure to CR 34λ/(λ). Phage Morphology vs. Specified Frequency Treatment.

made which may explain the different genetically defined plaque morphologies. For example, the small plaques characterized in these vibration experiments resemble the λB221 deletion mutant plaques, which were examined in earlier studies on λB221 C_{I}, CI^{857} BIO Q phage bouyant density work. The λB221 phage contains a deletion of approximately 22% of its DNA[11] and maps in the left transcribed operon at a position similar to that of the small plaque mutants of Jacob and Wollman[12]. Kaiser[13], found that the "cocarde" mutants of Jacob and Wollman which were clear plaque mutants actually occurred in the CII and CIII genes. Finally, the fuzzy plaque mutants of Jacob and Wollman[12], which are similar to the irregular plaque margin phenotypes scored here, appear to map in the right transcribed operon near the "late" genes. One such fuzzy plaque margin mutant is a "leaky" suppressor-A mutant phage,

which expresses fuzzy plaques under nonpermissive (W3350) conditions[11]. Hence, the fuzzy margin plaque could be a leaky amber mutant in the late genes or in the late control genes, which allows "read through" enough to obtain plaque formation resulting in the irregular margin. Plaque morphology as a means of defining genetic complement has been replaced by more sensitive biochemical assays. However, this was not possible in the present study. The plaque morphologies have not all been defined at the biochemical level and, therefore, their precise nature, at this time, is not known, although general implications can be made from the point of view of biochemically well defined mutations. The concern at the molecular level is to speculate as to what is causing the change in free phage level as a result of vibration exposure in regard to those possible events that may influence these changes in phage levels.

There appears to be two possible reasons for the observed increase or decrease in the free phage levels in these experiments: 1) that they occur as a function of mutational effects on burst size, or 2) that the changes may reflect different binding affinities of the repressor for the various morphologies as a direct function of increased or decreased induction frequency. It is the latter suggestion which is probably the more applicable, since changes in burst size would undoubtedly drastically affect the ratios and levels of all five plaque morphologies. Also, since vibration studies on *E. coli* appear to show few biochemical changes[2], physical effects on repressor kinetics which would influence induction frequency for the various plaque morphologies more relevant to the observations of this experiment than would mutational effects on burst size. Beall[1] found that burst size in lysogenic *E. coli* remained unchanged under selection pressure for increased or decreased numbers of phage. Furthermore, the lambda repressor binds in oligomers to the left and right operon initiator sites[11], it would seem likely then, that vibration could affect this oligomeric formation resulting in an induction increase. On the basis of plaque morphology, all classes of plaques increased in frequency at the 2,800-4,600 Hz treatment except for the bullseye plaques. This may be explained at the molecular level by hypothesizing that the CI area, which codes for the repressor, may be different in the case of the bullseye plaque. This logically follows since lambda has been found to contain variants in repressor protein such as I^{434} which has a molecular weight 26,000 as compared to the "wild type" lambda CI repressor which has a molecular weight of 27,000[11]. The difference in size and structure may well impare differential denaturation or conformational changes of these proteins with respect to the frequency of vibration to which they are exposed. Further evidence of the genetic difference of the bullseye plaque is that this plaque morphology showed a slight decrease for all frequency treatments except the 8,200-10,000 Hz treatment, where its expression increased over 1½ fold. Another morphological class which may be different at the molecular level is the small plaque, which did not show the characteristic decrease in induction at the 100-1000 Hz and 6400-8200 Hz treatments as did the other plaque types. If this small plaque producing phage is similar to the B_2 or B_{221} deletion, as mentioned earlier, it may be possible that this deletion affects repressor affinity by changing the resonance frequency of the *E. coli*

chromosome. A different resonance frequency may therefore result in differential induction rates with respect to the frequency of vibration exposure. A different resonance frequency may be quite important in a prokaryotic system such as *E. coli,* since there are no organelles such as the endoplasmic reticulum, golgi apparatus, mitochondria, or especially the tightly packed nucleus as is found in eukaryotic cells. These cellular inclusions could dampen the effects of vibration on the DNA in eukaryotes. Without dampening or restricting the circular form of DNA found in *E. coli,* which may be allowed to "whip" when vibrated, thereby exposing it to unusual shear forces, which may release or entrap repressor molecules or result in conformational changes in the DNA or its associated proteins. If severe enough, the vibrational frequency treatment could damage or break the DNA and result in the activation of cellular S.O.S. pathways. An activation of the *E. coli* recA pathway, which occurs when DNA is damaged, could result in the induction of the lambda prophage in the case of a lambda or the P_{22} lysogen, since the recA protein has been shown not only to mutagenically repair DNA, but to proteolytically cleave the lambda and/or the P_{22} repressor, thereby inducing phage production[21]. Evidence also indicates that the irregular and medium classes behaved in a similar manner as did the large and small plaque morphologies. This may indicate that the repressors are similar for these groups, although it is not now possible to determine which of these two groups are different.

Other factors affecting phage induction may be the levels of control elements such as CRO, CII, and CIII[11], or possibly mutations to the control elements. However, since the exact nature of repressor removal or derepression is unknown it is difficult to hypothesize where vibration may play a role. More work on biochemical changes with respect to induction needs to be done to define the events leading to phage expression and to thereby delineate the exact nature of the molecular effect of mechanical vibration frequency on phage induction.

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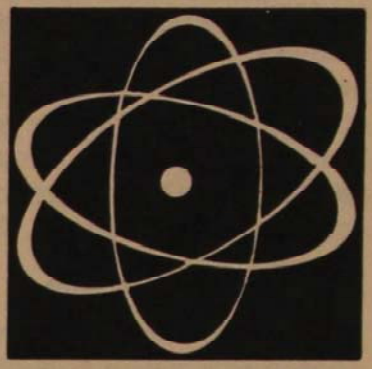

The Solid State Isomerization of Tetraphenylarsonium Trans-S,S(Dithiocyanato)Bis(Dimethylglyoximato) Cobaltate(III) to the N,N Isomer

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Abstract

Differential Thermal Analysis of the S,S Isomer of $[As(C_6H_5)_4]$ $[Co(DMGH)_2(SCN)_2]$ indicated a broad endotherm at about 137°C. IR and UV spectra demonstrated that Isomerization to the N,N isomer occurs in the solid state in the region of this temperature. The data also suggests that counter-ion size is a factor in controlling the isomerization.

The study of linkage isomerization has received the attention of inorganic chemists in recent years since a knowledge of the bonding mechanisms involved would add significantly to our understanding of bonding in coordinated complexes and the factors influencing it. The characterization of the linkage isomer pair, however, presents many difficulties and has been the source of considerable disagreement in the field(8). The reporting of a new isomerization is always, therefore, undertaken with some trepidation.

Although the ambidentate nature of the thiocyanate ligand is well established with a large number of linkage isomer pairs known (3,9), the same cannot be said for the cyanate ligand. Virtually all known cyanate complexes are N bonded(2,5) with the possible exception of a rhodium compound reported by Norbury and Anderson(1).

For some time the work at West Virginia State College has centered on attempting to produce an O-bonded isomer primarily in Cr(III) and

Co(III) complexes. Recently some evidence for the formation of both isomers of trans-bis(cyanato) bis(ethylenediamine)chromium(III) has been reported (6). It was our intention to study a well established cobalt(III) thiocyanate isomer system and then attempt parallel reactions with cyanate. We would like to report the solid state transformation of tetraphenylarsonium *trans*-S,S(dithiocyanato)bis(diglyoximato) cobaltate(III) to the N,N-isomer.

Experimental Section

The electronic spectra were obtained on a Varian 634 spectrophotometer using N,N-dimethyl-formamide as the solvent. The infrared spectra were recorded on a Perkin-Elmer 137 Infracord Spectrometer and a Perkin-Elmer 599 Spectrometer. All Spectra were taken in 1% KBr disks. Differential thermal analysis was performed on a Fisher 360 Differential Thermalanalyzer.

Materials: All chemicals used were of AR grade.

Preparation: $[As(C_6H_5)_4]$ $[Co(DMGH)_2$ $(SCN)_2]$ and $[As(C_6H_5)_4]$ $[Co$ $(DMGH)_2$ $(NCS)_2]$ were prepared as described by Epps and Marzilli (7). (Where $DMGH_2$ is the abbreviation for dimethylglyoxime).

Results and Discussions

The tetraphenylarsonium salts of the S,S, and N,N isomers were satisfactorily prepared and characterized by their IR spectra. As reported by Epps and Marzilli, the spectra were quite similar with the exception of a peak which appears at 11.9 microns (835 cm^{-1}) in the N,N isomer and is absent in the S,S isomer. Additionally, the S,S, isomer was slightly more soluble in ethanol than was the N,N isomer.

Electronic spectra of the two isomers are similar, except that the d-d transition band have shifted (492 nm to 480 nm) to a lower wavelength in the N-N isomer, as expected from a lower ligand field of S-thiocyanates. The results are given in Table 1.

This, coupled with previous work done on the system by Epps and Marzilli, suggested that we could use the IR peak at 11.9 microns as diagnostic for the N,N isomer.

A differential thermal analysis of the tetraphenylarsonium salt of the S,S, isomer showed a broad endotherm at about 137°C with decomposition starting around 230°C. Since energy was being absorbed by the system this raised the possibility that a rearrangement of some sort was occurring.

Weighed amounts of the S,S, isomer was isothermally heated for one hour in a thermostated oven at 140°, 160°, 200°, 220°C. As can be seen in Figure 1, a peak appeared in the IR at 11.9 microns at the first three temperatures. The IR at 220°C showed that decomposition was occurring. It therefore seems apparent that the 137°C endotherm represents the isomerization of the S,S isomer to the N,N form.

The potassium salt of the S,S isomer was also heated in the same manner but no change in the IR spectra was observed. This suggests that a counter-ion effect is present in the solid state isomerization process.

At least two other solid state isomerizations are known in

Table 1. Electronic Spectra of Tetraphenylarsonium Trans-(Dithiocyanato)bis(dimethylglyoximato)cobaltate(III) Isomers.

1.029×10^{-3} and 1.029×10^{-5} M solution in dimethylformamide solution. Molar absorptivity, $\in$, $mole^{-1}\ cm^{-1}$ liter.

Registry No.	λ max(nm)	$\in$ ($mol^{-1}\ cm^{-1}$ liter)
S-S isomer 39494-93-4	492	5.2×10^2
	338	4.9×10^4
N-N isomer 39494-95-6	480	4.2×10^2
	326	2.2×10^4

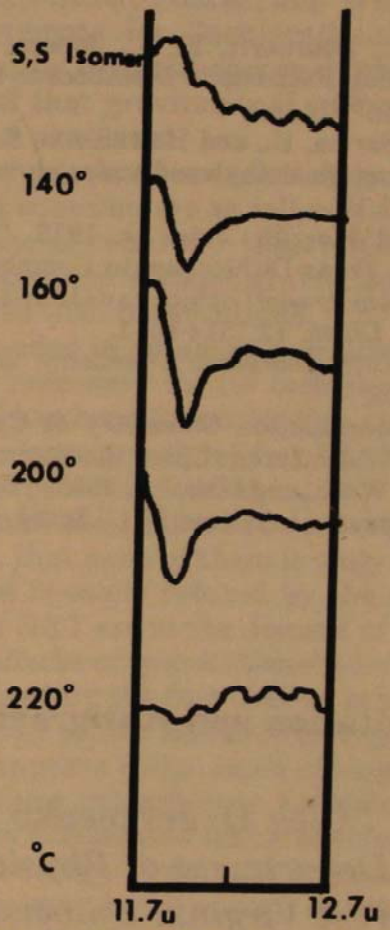

FIGURE 1. IR Spectra in the region of 11.9 microns for the tetraphenylarsonium salt of the S,S isomer after isothermal heating at various temperatures.

cobalt(III)-thiocyanate systems. $K_3[Co(CN)_5NCS]$ converts to the S isomer when heated to 150°C for 6 hours or at room temperature in about four months.(9) *Trans* $[Co(acac)_2(SCN)(py)]$ converts to the N isomer at 68°C with a $t_{1/2}$ of about 12 hours(4). (Where acac is the abbreviation used for acetylacetone and py the abbreviation for pyridine.) Both of these conversions suggest kinetic control with the application of heat speeding up the kinetics. The S,S, and the N,N isomers of $[As(C_6H_5)_4]$ $[Co(DMGH)_2(CNS)_2]$ show no tendency to isomerization at room temperature, even after one year.

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Gravitation and Antigravitation

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Abstract

The localizability of gravitational energy is re-examined. It is concluded that there is no unequivocal justification for its exclusion as a source term in Einstein's field equation. Semiclassical calculations are used to determine how the results of the general relativity theory should be corrected if gravitational energy is localizable and is itself a source of gravitation.

Introduction

A not well-known peculiarity of the presently available solutions for Einstein's gravitational field equation

$$R_{ij} - \frac{1}{2} g_{ij} R = - \frac{8\pi k}{c^4} T_{ij}$$

is that they all are obtained by assuming that the sources of gravitation are all types of mass densities and all types of energy densities (electric, magnetic, thermal, etc.), except for the energy density of the gravitational field itself. The reason for such discriminatory treatment of gravitational energy has never been made very clear. In works on general relativity (see, for example, Misner, Thorne, and Wheeler, 1973, p. 467) one finds plausibility arguments for "nonlocalizability" of gravitational energy and for its exclusion from the energy-momentum tensor T_{ij}. However, no definitive proof that gravitational energy density must not appear in T_{ij} has ever been presented.

The three strongest arguments for excluding gravitational energy as a source term in the field equation are as follows:

(1) Predictions of general relativity theory (GRT) obtained with the aid of Einstein's field equation without gravitational energy as a source have been found to agree with observations.

(2) One has not succeeded in expressing gravitational energy density in a tensor form, as is necessary for its inclusion in the field equation (only a "pseudotensor" has been found for this energy).

(3) Einstein's "equivalence principle" forbids the appearance of gravitational energy as a source in the field equation.

A careful examination of these (as well as other presently known arguments) shows, however, that none of them is truly convincing or compelling. The first argument is easily refuted by the fact that all presently verifiable predictions of GRT are in the domain of weak fields, where, as it is shown below, the effects of gravitational energy are negligible. The second argument is refuted by the fact that no proof of the nonexistence of the gravitational energy tensor has ever been presented.

The third argument appears to be much stronger than the first two. What it means is that since, according to Einstein, a gravitational field is equivalent to a certain accelerated frame of reference, and since there apparently is no special energy in the space defined by the accelerated frame of reference, there may be no energy in the space containing the gravitational field, either. An analysis of this argument shows, however, that it is based on an unprovable premise and that it can be refuted by reversing it. Indeed, let us suppose that a gravitational field is a carrier of gravitational energy. The equivalence principle demands then that a certain energy density would appear in the space defined by the equivalent reference frame. But how will this energy manifest itself? The only presently known way in which it could be detected is by its gravitational effects. However, since the equivalent reference frame is flat and boundless, the "equivalent" energy density as seen in this frame must be uniform and must occupy all space. But, as is well known, a uniformly distributed mass (energy) occupying all space produces no gravitational

effects. Hence the "equivalent" energy is not detectable, or, as an observer in this reference frame would say, is "absent." Thus the absence of space energy in an accelerated reference frame does not prove the nonexistence or nonlocalizability of gravitational energy, and hence the equivalence principle does not forbid its appearance as a source term in Einstein's gravitational field equation.

On the basis of the above considerations it appears that the exclusion of the gravitational energy density as a source term in Einstein's field equation is merely a matter of practical necessity (since no tensor has been found for it). Hence all presently known results of GRT based on Einstein's field equation may be more or less inaccurate. It is therefore desirable to investigate how such results will be modified if the energy density of the gravitational field is included as a source of gravitation. This can be done by means of semiclassical calculations presented below.

Theory

The classical gravitational theory (Newtonian theory) can be formulated in terms of the two field laws

$$\nabla \times \mathbf{G} = 0 \quad (1), \qquad \nabla \cdot \mathbf{G} = -4\pi k\varrho \quad (2)$$

and the energy law

$$U = -\frac{1}{8\pi k}\int_{\text{All space}} G^2 dv \quad (3) \quad \text{or} \quad U_v = -\frac{G^2}{8\pi k}, \quad (4)$$

where $\mathbf{G} = d\mathbf{F}/dm$ is the gravitational field vector, $\varrho = dm/dv$ is mass density, k is the universal constant of gravitation, U_v is the energy of the gravitational field. According to Eq. (2), the sources of the gravitational field are the mass elements $dm = \varrho dv$. However, according to the mass-energy relation

$$U = mc^2, \quad (5)$$

any energy has a mass given by $m = U/c^2$, where c is the velocity of light. Hence we may conclude that the gravitational energy density given by Eq. (4) has a mass density

$$\varrho_g = -\frac{G^2}{8\pi kc^2}. \quad (6)$$

But then the sources of the gravitational field must be $dm_{\text{total}} = (\varrho + \varrho_g)dv$, and Eq. (2) must be rewritten as $\nabla \cdot \mathbf{G} = -4\pi k(\varrho + \varrho_g)$. As a result, the field laws, Eqs. (1) and (2), now become

$$\nabla \times \mathbf{G} = 0 \quad (7) \quad \text{and} \quad \nabla \cdot \mathbf{G} = -4\pi k\varrho + \frac{G^2}{2c^2}. \quad (8)$$

We shall take the last two equations as the basic field laws for a semi-classical gravitational theory. Observe that the mass density of the field itself, ϱ_g, is negative. Thus Eq. (8) indicates that there may exist not only ordinary attractive gravitational fields but also repulsive, or anti-gravitational, fields. It also indicates that the field outside a spherical mass depends not only on its magnitude but also on its structure (internal field), so that the mass can not be replaced by an equal point mass at the center, as is done in the Newtonian theory.

The basic field equations of the classical theory, Eqs. (1) and (2), are usually solved indirectly by means of the gravitational potential ϕ, defined by

$$\mathbf{G} = -\nabla\phi. \tag{9}$$

By combining Eqs. (9) and (2) one obtains

$$\nabla^2\phi = 4\pi k\varrho, \tag{10}$$

which, subject to appropriate boundary conditions, can be solved for a variety of mass distributions. The field G can then be found from ϕ by means of Eq. (9). Sometimes one uses integral methods for solving Eqs. (1), (2), and (10). Any of the following expressions can be employed for this purpose ($\mathbf{r}_u$ denotes the radial unit vector)

$$\mathbf{G} = -k \int \frac{\mathbf{r}_u}{r^2}\, dm, \tag{11}$$

$$\mathbf{G} = k \int \frac{\nabla\varrho}{r}\, dv \tag{12}$$

and

$$\phi = -k \int \frac{dm}{r}. \tag{13}$$

Unfortunately, none of the above techniques can be used for solving Eqs. (7) and (8), since Eq. (8) is nonlinear in G. Thus, on this theory, one cannot in general find the gravitational field G from a given mass distribution ϱ. There is, however, a way out of this difficulty: one can postulate a certain field G satisfying Eq. (7) and then from Eq. (8) find the mass distribution

$$\varrho = -\frac{\nabla\cdot\mathbf{G}}{4\pi k} + \frac{G^2}{8\pi k c^2} \tag{14}$$

producing this field. Several examples of such fields and the corresponding mass distributions are given below. All fields used in these examples are spherically symmetric and hence satisfy Eq. (7) automatically. Of course, even if a field satisfies Eqs. (7) and (8), it still may be physically meaningless. We shall, therefore, restrict the solutions of Eqs. (7) and (8) to those that satisfy the following validity conditions: (a) the energy of

the field must be finite, (b) the field must be finite at $r = 0$, (c) the matter mass density ϱ must be either positive or zero, and (d) the field must be everywhere continuous.

Examples of Gravitational Fields

Example 1. Find the mass distribution producing the field

$$G = -\frac{kmr}{a^3} \quad \text{for} \quad r \leq a \tag{15}$$

and

$$G = -\frac{km}{r^2}\mathbf{r}_u \quad \text{for} \quad r > a, \tag{16}$$

where the symbols are the same as before. Note that in the classical theory this field is produced by a spherical mass m of radius a and uniform density $\varrho = 3m/4\pi a^3$.

Substituting Eqs. (15) and (16) into Eq. (14) and differentiating, we obtain

$$\varrho = \frac{m}{4\pi a^3}\left(3 + \frac{kmr^2}{2c^2a^3}\right) \quad \text{for} \quad r \leq a \tag{17}$$

and

$$\varrho = \frac{km^2}{8\pi c^2 r^4} \quad \text{for} \quad r > a. \tag{18}$$

The most interesting aspect of this solution is that, according to the present theory, a $1/r^2$ field is produced not by a mass distribution confined to a spherical volume, but rather by a mass distribution extending all the way to infinity. Another interesting aspect is that m in Eqs. (15) and (16) is now not the mass of the central body. The latter mass, as obtained by integrating Eq. (17), is

$$m_o = m\left(1 + \frac{km}{10c^2a}\right), \tag{19}$$

so that

$$m = \frac{5c^2a}{k}\left[\left(1 + \frac{2m_ok}{5c^2a}\right)^{1/2} - 1\right] < m_o. \tag{20}$$

Example 2. Find the mass distribution for the field given by Eq. (15) for $r < a$ and by

$$G = -\frac{2c^2km'}{2c^2r^2 - km'r}\,r_u \qquad \text{for} \qquad r > a, \tag{21}$$

where $m' = m(1 + km/2c^2a)^{-1}$. Note that this value for m' makes G continuous at $r = a$.

According to Example 1, ϱ for $r \leq a$ is given by Eq. (17). Substituting Eq. (21) into Eq. (14), we obtain

$$\varrho = 0 \qquad \text{for} \qquad r > a. \tag{22}$$

Thus, according to the present theory, the field in an empty space outside a spherical mass is given by Eq. (21) rather than by Eq. (16) (Newtonian field). Furthermore, m' of Eq. (21) represents not the mass m_o of the central body, but an "effective" mass smaller than m_o.

If in Eq. (21) $km'/2c^2r << 1$, the equation can be rewritten as

$$G = -\frac{km'r_u}{(1 - km'/2c^2r)r^2} \approx -\frac{km'(1 + km'/2c^2r)r_u}{r^2}$$

or

$$G \approx -\frac{km'}{r^2}\,r_u - \frac{k^2m'^2}{2c^2r^3}\,r_u\,. \tag{23}$$

As is known (see for example, Goldstein, 1951) the second term on the right of Eq. (23) causes a secular perturbation of the orbits of bodies moving in the field given by Eq. (23). Specifically, it causes the major axis of an orbit to precess in the direction of motion of the orbiting body. In the solar system this term would cause a precession of the perihelion of a planet. In the case of Mercury, for example, the precession would be 3.6″ per century.

Example 3. Find the mass distribution producing the field

$$G = -\frac{km}{a^2}(2e^{1-r/a} - 1)r_u \qquad \text{for} \qquad a \leq r \leq 2a. \tag{24}$$

Note that this field becomes *antigravitational* for $r \geq (\ln 2+1)a$.

Proceeding as before, we obtain

$$\varrho = \frac{m}{4\pi a^3}\left[2\left(-\frac{r}{a}-1\right)e^{1-r/a} + \frac{2a}{r}\left(2e^{1-r/a}-1\right) + \frac{km}{2c^2a}\left(2e^{1-r/a}-1\right)^2\right]. \tag{25}$$

Example 4. Find the mass distribution producing the field

$$G = \frac{2km(1-2e^{-1})}{ar}\mathbf{r}_u \quad \text{for} \quad r \geq 2a. \tag{26}$$

Note that this field is purely *antigravitational.**

Substituting Eq. (26) into Eq. (14), we obtain

$$\varrho = \frac{m(1-2e^{-1})}{2\pi ar^2}\left[1 - \frac{km(1-2e^{-1})}{c^2a}\right]. \tag{27}$$

Observe that $\varrho = 0$ if

$$m = \frac{ac^2}{k}\left(1-\frac{2}{e}\right)^{-1}. \tag{28}$$

This means that the field given by Eq. (26) can exist in a mass-free space, provided that Eq. (28) is satisfied.

Conditions for Antigravity and Properties of Fields in Mass-Free Space

The most interesting aspect of the present theory is perhaps the fact that it indicates the possibility of antigravitational mass distributions. Naturally, if such mass distributions are to be stable under gravitational forces alone, the internal field of the distributions must be attractive at all points of the distributions. The question arises therefore: can there exist a mass distribution producing an attractive field at all points within itself, but a repulsive field outside?

To answer this question we shall consider the most general expression for a spherically symmetric field

$$G = Af(r)\mathbf{r}_u, \tag{29}$$

*It should be pointed out that the energy of this field as calculated by using Eq. (3) is infinite, so that the field violates Condition (a). However, it will be shown in the next section that a minor modification of Eq. (26) will produce an acceptable field.

where A is a constant and f(r) is any function of r, and shall determine f(r) for $\varrho = 0$.

Substituting Eq. (29) into Eq. (14) and setting $\varrho = 0$, we have

$$0 = -\frac{\nabla \cdot G}{4\pi k} + \frac{G^2}{8\pi k c^2} = \frac{1}{4\pi k}\left[-A\nabla \cdot f(r)\mathbf{r}_u + \frac{A^2 f^2}{2c^2}\right],$$

which upon differentiation and simplification gives

$$f' + \frac{2f}{r} - \frac{A}{2c^2} f^2 = 0, \tag{30}$$

where f' is the derivative of f(r) with respect to r. The general solution of Eq. (30) is

$$f(r) = \frac{2c^2}{Ar + 2c^2 Br^2}, \tag{31}$$

where B is an arbitrary constant.

Thus, by Eqs. (29) and (30), the most general expression for a spherical gravitational field in the region of $\varrho = 0$ is

$$G = \frac{2c^2 A}{Ar + 2c^2 Br^2}\,\mathbf{r}_u, \tag{32}$$

where A and B are to be determined from boundary conditions (Condition (d) of the "Theory" section). For this field to be repulsive (positive) outside some radius r_c, and attractive (negative) within r_c, we must have $G = 0$ at $r = r_c$. But then we must have

$$A + 2c^2 B r_c = \infty, \tag{33}$$

which is impossible for a finite r_c. Hence there can be no spherical antigravitational field outside a mass distribution if the field within the distribution is everywhere attractive. Consequently, an antigravitational body must be held together by some nongravitational forces in addition to the gravitational ones.

Several other remarkable conclusions concerning fields in a mass-free space can be made from Eq. (32). First of all we note that for $r \to \infty$, Eq. (32) reduces to

$$G = \frac{Ar_u}{Br^2} = \pm \frac{km'}{r^2}\,\mathbf{r}_u\,. \tag{34}$$

where we have set $A/B = \pm km'$. Therefore in the asymptotic limit the field of a spherical mass m_0, according to the present theory, is just the Newtonian field of an "effective" mass m' (m' must be determined from the boundary conditions at the surface of m_0).

Another notable conclusion can be made by considering the sign of the arbitrary constants in Eq. (32). Let us rewrite Eq. (32) as

$$G = \frac{2c^2}{r + 2c^2B'r^2} r_u, \tag{35}$$

where we have set $B' = B/A$. Let us assume that at some distance $r = r_0$, the field must satisfy the boundary condition $G = G_0$. In this case we must have

$$G_0 = \frac{2c^2}{r_0 + 2c^2B'r_0^2}, \tag{36}$$

or

$$B' = \frac{2c^2 - G_0r_0}{2G_0c^2r_0^2}. \tag{37}$$

This means that

$$B' > 0 \quad \text{if} \quad G_0r_0 < 2c^2, \tag{38}$$

$$B' < 0 \quad \text{if} \quad G_0r_0 > 2c^2, \tag{39}$$

and

$$B' = 0 \quad \text{if} \quad G_0r_0 = 2c^2. \tag{40}$$

It can be easily seen that $B' = 0$ is generally not allowed if Condition (a) is to be satisfied. Indeed, substituting Eq. (35) with $B' = 0$ into Eq. (3) and integrating over all space, we obtain $U = \infty$. Thus $B' = 0$ must be discarded unless the range of validity of Eq. (35) is limited to a finite region of space, such as a cavity within a mass distribution. Consequently, except in a cavity, we must have $G_0r_0 \neq 2c^2$.

It is, however, the case of $B' < 0$ that is particularly interesting, for it leads to field configurations analogous to "black holes" of the general relativity theory. Indeed, if $B' < 0$, there exists a certain distance

$$r_c = -\frac{1}{2B'c^2} \tag{41}$$

for which Eq. (35) becomes $G = \infty$. Such a field could be called a "black bubble," as its effect on the surrounding matter would be essentially the same as that of a black hole. The radius r_c of the bubble can vary from r_o to ∞, depending on how much $G_o r_o$ exceeds $2c^2$. Although on first examination there appears to be nothing wrong with such an object, further analysis shows that it cannot exist. Indeed, if Eq. (35) with $B' < 0$ is substituted in Eq. (3) in order to find the energy of the field contained in a space of radius r_c or larger, an improper integral results. The integral does not converge. Hence, by Condition (a), $B' < 0$ is not allowed except, of course, in a cavity whose outer radius is $r < r_c$.

Thus we conclude that at the surface of an unconfined spherical mass the relation

$$G_o r_o < 2c^2 \tag{42}$$

must always be satisfied. This imposes a restriction on the smallest radius of such a mass. For example, for a mass whose internal field is given by Eq. (15) the radius of the mass $a = r_o$ is always

$$a > \frac{mk}{2c^2}. \tag{43}$$

Observe, however, that m in this equation is an effective mass rather than the "true" mass m_o. For the true mass we have

$$a > \frac{5m_o k}{12c^2}, \tag{44}$$

which is obtained by substituting Eq. (20) into Eq. (43).

An interesting consequence of Eq. (44) is that a "gravitational collapse," at least for a spherical body, is impossible. This conclusion will be further supported by the results of the next section.

Antigravitational Mass Distribution

Using the results of the preceding sections we can now construct a mass distribution producing an antigravitational field. Let the field be

$$G = -\frac{kmr}{a^3} \quad \text{for} \quad 0 \le r \le a, \tag{45}$$

$$G = -\frac{km}{a^2}(2e^{1-r/a} - 1)r_u \quad \text{for} \quad a \le r \le 2a - \alpha, \tag{46}$$

and

$$G = \frac{8akm(e-2)^2}{e[4a^2(e-2) + \alpha(e+2)r]r}\, r_u \quad \text{for} \quad r > 2a - \alpha, \quad (47)$$

where α is a distance satisfying the relation $\alpha << a$, and where a satisfies the relation

$$m = \frac{ac^2}{k}\left(1 - \frac{2}{e}\right)^{-1} = 3.78\,\frac{ac^2}{k}. \quad (48)$$

The field given by these equations is continuous at all points and hence satisfies Condition (d). It also satisfies Eq. (8), provided that the mass distribution for the three regions under consideration is given by Eqs. (17), (25), and $\varrho = 0$, respectively. Note that Eq. (47) is the same as Eq. (26) except for the term $\alpha(e + 2)r$ in the denominator. The inclusion of this term is sufficient to make the energy of the field finite, thus satisfying Condition (a).

A graphical representation of this field and of the corresponding mass distribution is given in Fig. 1. Starting at infinity and proceeding toward the origin, we find that from $r = \infty$ to $r = 1.69a$ the field is purely antigravitational (repulsive) with a maximum (point of maximum repulsion) at $r = 2a - \alpha$. At $r = 1.69a$ the field becomes zero. From there on the field is an ordinary gravitational (attractive) field with a minimum (point of maximum attraction) at $r = a$ and diminishing to zero at $r = 0$. It is important to note that by imposing Eq. (48) upon the central mass m we not only made $\varrho = 0$ for $r > 2a - \alpha$, but also fixed the radius of the central mass to

$$a = 0.26\,\frac{km}{c^2} \quad (49)$$

and the radius of the entire mass to

$$r_o = 2a - \alpha \approx 0.52\,\frac{km}{c^2}. \quad (50)$$

Had we assumed that the mass distribution did not extend beyond $r = 1.69a = 0.44\,\frac{km}{c^2}$, the external field would be zero from the surface of the mass to infinity. Thus, a body with such a mass distribution would appear from the outside as having no mass at all.

Discussion

A number of interesting consequences can be drawn from the above calculations. Some of these consequences are summarized below.

1. It appears that antigravitational bodies can exist in the universe.
2. It appears that the mass of the universe, of a galaxy, or of a stellar

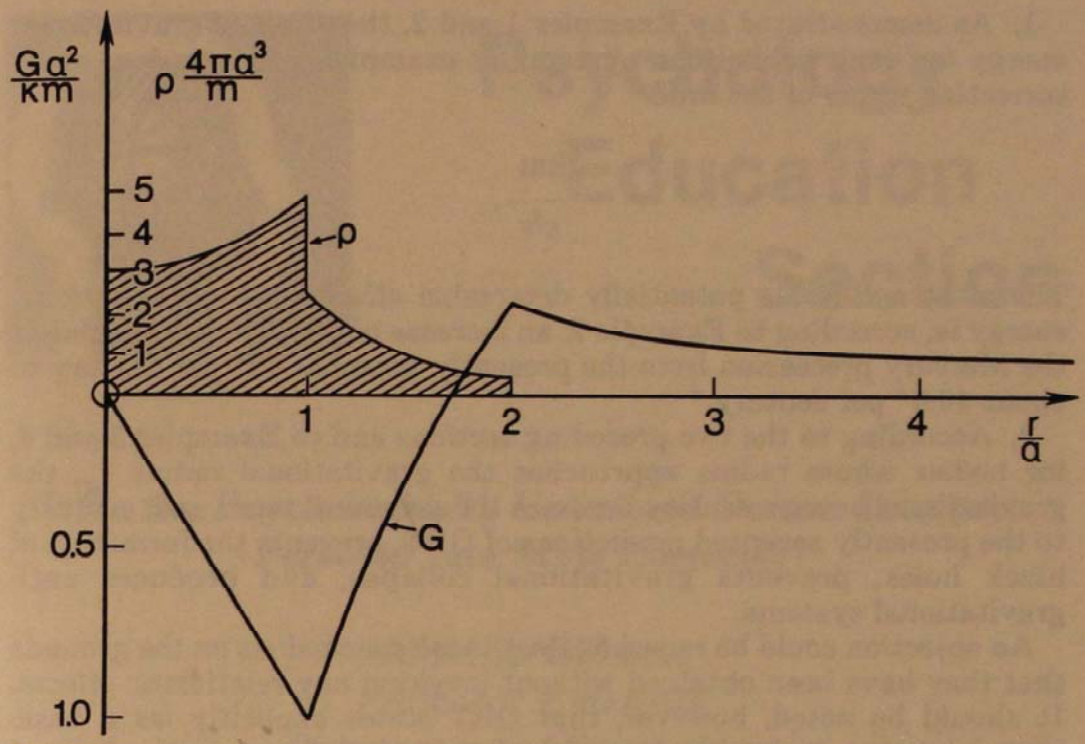

FIGURE 1. A mass distribution ϱ and the corresponding field G for an antigravitational system. The scale above the horizontal axis is for ϱ. The scale below the horizontal axis is for G. It is assumed that α in Eqs. (46) and (47) is negligible compared to a. Therefore α does not appear in the drawing.

object can be much larger than the present astrophysical measurements indicate, since there can exist objects of negative or of zero apparent mass. The latter objects would constitute "hidden" masses as they do not produce gravitation effects.

3. It appears that there exists a lower limit for the radius of a mass at which the mass becomes unstable and begins to eject particles from its surface. Thus a gravitational collapse appears to be impossible.

4. The existence of black holes appears to be questionable. Indeed, according to Eq. (49), the radius of the central mass of the distribution shown in Fig. 1 is *smaller* than the "gravitational radius" (black hole radius)

$$r_g = \frac{2km}{c^2}. \tag{51}$$

Yet the gravitational field near this radius is zero rather than immensely strong as is required for black holes. Furthermore, as has been shown above, black holes of a finite radius violate the requirement of finite energy of a gravitational system.

Finally, as far as the exclusion of the gravitational energy as a source in GRT is concerned, one can make the following conclusions:

1. As demonstrated by Examples 1 and 2, the effect of gravitational energy for weak fields (solar system, for example) is to introduce small correction terms of the order

$$\frac{km}{c^2 r}. \tag{52}$$

The most noticeable potentially detectable effect of the gravitational energy is, according to Example 2, an increase of the theoretical value of the Mercury precession from the presently accepted 43″ per century to about 46.6″ per century.*

2. According to the two preceding sections and to Examples 3 and 4, for bodies whose radius approaches the gravitational radius r_g, the gravitational energy density becomes the dominant term, and, contrary to the presently accepted predictions of GRT, prevents the formation of black holes, prevents gravitational collapse, and produces anti-gravitational systems.

An objection could be raised against these conclusions on the grounds that they have been obtained without invoking any relativistic effects. It should be noted, however, that GRT states explicitly (as a basic postulate) that it should agree with the classical theory in the limit of weak fields and small velocities. Since the systems discussed here did not necessarily involve high velocities or strong fields, (for instance, the mass distribution in Fig. 1 has a zero field at $r = 0.44 \frac{km}{c^2}$ and a weak repulsive field thereon) it is clear that the present conclusions cannot be criticized on the basis of GRT anymore than they can be criticized on the basis of the Newtonian theory. It appears therefore quite obvious that unless a definitive proof for nonlocalizability of gravitational energy is produced, the presently accepted predictions of GRT for systems whose dimensions approach r_g must be regarded as highly questionable.

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*It is interesting to note that if one uses the Brans-Dicke theoretical value for the precession (Brans and Dicke, 1961), then the corrected theoretical value becomes approximately 43″, which is the same as the GRT value, and is very nearly equal to the observed value. Therefore, the agreement between the observed and the GRT value for the Mercury precession cannot be considered as a reliable proof of GRT, whereas the disagreement between the observed and Brans-Dicke value for the Mercury precession cannot be considered as a disproof of the Brans-Dicke theory.

Psychology Education Section

Does the Psychologically Untutored Person Interpret Personal Life Style Correctly?

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Abstract

The authors hypothesized that readers of a structured diary can grasp the author's life style intuitively. Sixteen college students were assigned to write passages in their anonymous "structured" diaries, patterned on themes of life style explained to the students beforehand. The students described from memory one or more recent situations that had provoked a particular motivational theme designated by the researchers. The descriptions were made in terms of "What I did and/or said;" "What I felt;" "What I thought;" "What I decided to do"; and "Conflicts, if any, I experienced."

When the diaries were completed, the students were told to synthesize intuitively the different themes to portrayals of their life style. The anonymous diaries were randomly interchanged, and students interpreted the diaries of fellow students. Thus, each student's diary was not only interpreted by its author, but also by fellow students.

A correlation of +.588 was found between the content categories of life styles gathered intuitively by a student from his diary and the content categories of life

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style derived likewise intuitively from the same diary by a randomly chosen fellow student. It appears then that psychologically untrained persons who have an opportunity to observe another person's life style in a systematic manner as afforded by "structured diaries," agree on mutual life styles fairly closely.

Introduction

In our time, most people sense the style of persons, of their activities and creations. The public have become very style-conscious of almost everything: prose and poetry, music, architecture and furnishings, fashions, sports and entertainment. Even growing old and facing death is a matter of style of life. The concept "personal style of life" was coined by Alfred Adler (1930, 1935), although the term can be traced back 200 years to the French naturalist and writer, Louis de Buffon (1707-1788), whose famous statement "The style is the man himself" (*Le style est l'homme même*) is often cited.

What constitutes the life style of individuals? According to Alfred Adler (1930, 1935), it is the individual himself. At the age of four or five, the child, placed in a world of grown-ups, comes to sense inevitably some inferiority of his, some bodily or mental defect, some real or imagined mistreatment, conferred upon it in the family, or by others, or in many other ways.

In growing up, he will try to assert himself by compensating or over-compensating for what he feels to be a weakness in his existence. He may do this genuinely or self-deceptively. In any case, he adopts a plan of life, a style of life, spelling superiority instead of inferiority.

This choice may be problem-solving, even creative; or it may be self-deceptive, threat-oriented, denying the inferiority or retreating from it. The problem-solving attitude will render him mature, the threat-oriented, neurotic.

Ingenious as Adler's theory of life style is, it is one-sided, monothematic, deriving life style from a single motivation: self-assertion. Adler has this monothematic one-sidedness in common with Freud, who interprets personality by the sex-instinct.

Allport (1937, 1961) and Wolff (1943) argue that personal life style is the overall consistent way in which a person carries on his life. Murray (1938) sees a "need-integrate" in man. An individual's needs focus on objects satisyfing the needs, and setting off behavior patterns, instrumental in obtaining the objects. Thus, "need-integrates" are thematic dispositions constituting an individual's life style. Coleman (1964) realized that consistent ways of perceiving, thinking, and acting lead to characteristic *modus operandi* of life style. Ruch (1967) in his introductory psychology textbook recognized the fundamental importance of life style as a particularity of personality.

Gilbert has studied life style theoretically and practically over a long period (1950, 1960, 1979). As early as 1950, he pioneered with a "structured diary" (Figure 1) as an instrument for the appraisal of personal life style.

Diaries have been used as gates to patients' and to normal peoples'

psyche (Gilbert, 1950, 1960, 1979). The supposition is that the diary keeper is less inhibited in revealing himself in a private diary than he would be in personal communication with others.

Diaries as media of patients' disclosures have been used by several psychotherapists. In his preface to the *Diary of a Young Girl*, Freud regards the diary as a key to the patient's psyche. Jung required his patients to keep dream logs. In Morita therapy, the patient is instructed to keep a journal in which he reports on past traumas as well as on his behavior and feeling during the day. In Cognitive Therapy, patients are asked to write down their thoughts about their morbid sadness and depression.

Allport (1961) emphasized the diagnostic value of the diary, saying that the diary is normally less constrained from the autobiography, letters or interviews; and that there are few errors of memory.

The hypothesis of our investigation was that psychologically untrained persons can grasp each other's life style intuitively by reading and synthesizing each other's "structured diary." This amounts to being closely exposed to another person.

Materials and Methods

Sixteen West Virginia Wesleyan College students, enrolled in a course, "Describing your own life style," and admitted to the course from any college department, met every day in class. Each received a "structured diary" in which to report every day about one particular "theme" constituting life style as explained to them in class. Each time students were dismissed with the assignment to record from memory situations and the "behavior" in them in the manner prescribed in a standard form.

Date _____ Description of Situation _____
Behavior reactions in the situation _____
What I did and/or said:
What I thought:
What I felt:
What I decided to do:
Conflicts I experienced:

FIGURE 1. Standard Form for Recording a Situation.

The set of themes of life style used in our investigations was adopted from the phenomenological view of themes common to human beings (Lersch, 1966). Here is a brief synopsis of the themes of life style.

Like subhuman creatures, *Homo sapiens* is governed by the theme of preserving life. But then, *Homo sapiens* evolves the theme of becoming, maintaining and unfolding a self. This involves self-seeking, mastering others and mastering things; and entails self-esteem if successful.

Transcending these self-centered themes is the theme of seeking companionship, friendship and love. Self-transcending are also the themes of acquiring knowledge for its own sake, and of embracing ideas and ideals; and the theme of accomplishing work. Another self-transcending theme is conforming with conventions and abiding by the law. Gilbert (1950)

found in phenomenological view that the life style of man, especially of the highly mature man, contains also the theme of self-cultivation, i.e., of addressing oneself to one's own style with the view to possibly refashioning it. Finally, the enjoyment of beauty, the reflection on the meaning of the world, and the sensing of divinity turn man's gaze above and beyond himself. These themes commonly form the life style of humanity, and uniquely compose the life style of every individual.

The subjects were told to describe "from memory" situations of specific thematic character. In following this instruction, the subjects had to concentrate on each theme of the life style one at a time writing in a special section of the diary. Subjects were released from their inhibitions and repressions by the anonymity of the diaries. Thus, the subjects were instructed to report "from memory" critical situations, looming large in their mind, situations that had stirred up their ego, unpleasantly or pleasantly. They were also enjoined to mention bodily ailments as well as mental disturbances. Some of them noted confrontations or clashes with fellow beings.

The standard form indicates that the subject noted after each situation what he did, said, thought, felt, decided to do, and conflicts he may have experienced. Daily routines were not recorded singly, but a general statement was required. The performance of, and the psychological reaction to routine is a significant aspect of life style.

Since the keeping of "structured diaries" is based on the special arrangement of the entries, the question poses itself: can one rely on subjects' completing the sections of the standard form in the prescribed way?

We found that subjects often did not adhere precisely to the captions of the form. We did not insist that they do so. What mattered to us was to induce them to report about the situation and their behavioral aspects as uniformly and comprehensibly as possible, which the sections of the "structured diary" help to achieve.

After all themes involved in our style concept have been accounted for by situation-behavior descriptions in the diary form, the diary keeper is ready to interpret his own life style from his records in the diary. He is told first to peruse these sections uninterruptedly. Then he is to integrate intuitively by empathy the situation-behavior complexes put down in the diary under the different themes of life style to a rounded portrayal of his life style. No psychological training was given, nor was it desirable for this self-interpretation; nor could it be expected from our group of subjects. In this way, the style of their doing, thinking, feeling, etc., could be gathered.

After the self-interpretations of life style were finished, they were turned in separately to the research team. Its concern then was to ascertain whether a statistically randomly chosen student of the group, who does not happen to recognize the identity of the diary assigned to him, would concur with the diarist's interpretation of his life style.

For this purpose, the subjects exchanged their anonymous diaries in a randomized manner. The aim of this procedure was to examine our hypothesis that psychologically untrained persons can grasp one

another's life style intuitively and by empathy, by associating with one another over a long period of close observation, or in our project, by reading their "structured diaries."

Although most class members did not know one another, it was possible that despite anonymity of the diaries the identity of one or another diarist could be guessed by the student to whom another student's diary had been randomly assigned.

If in this interchange of diaries a subject happened to recognize the identity of "the other,"—which he was supposed to report us—or if he would have seen from remarks in his interpretation that he/she had guessed the identity of the diary assigned to him, we would have assigned to him/her another diary, making sure that he does not guess the identity of the author. No such case occurred in our project.

The crucial implication of the original hypothesis states that the self-interpretations of life style and the respective interpretations by others should correlate. This hypothesis was examined by comparative content analysis between "self-interpretation" scores and the scores of "interpretations by others." In his early use of "structured diaries," Gilbert (1950) applied the traditional method of "diagnosing" life style intuitively and by empathy. Tristine Rainer, in her notable book, *The New Diary* (1978) points out that prominent psychotherapists, using "diary-devices" for the interpretation of life style, do so even in our scientific era intuitively, empathically and clinically.

In place of intuitive diagnosing of life style from diaries Gilbert (1950) used content analysis for the interpretation of "structured diaries," originated by him. Thus, when a passage read, "I want to be accepted," it received a score of *1-f*, *f* meaning "fellowship with others," and *1* being the highest of a 3-scale scoring of intensity—*2* being a medium, and *3*, the lowest intensity grading.

The frequency of equivalent content-intensity scores aids in elaborating the synthesis of a content analysis. Themes carrying the highest frequency are dominant characteristics of life style.

Results

Individual correlations for each of 16 subjects between "self-interpretation scores" and the scores of "interpretations by others" were computed. Each correlation was transformed (using Fischer's method) to a normal variable (Z), and this variable was in turn standardized (ZO). Thus the significance of each correlation was evaluated by determining the significance of the standardized Z value. At the five percent level twelve of the sixteen correlations indicated a meaningful relationship between "self-interpretation" and "other-interpretation" of "structured diaries."

We then took the weighted average of the Z values, thereby obtaining a composite normal variable for all 16 subjects. We denoted this variable by ZO. The computed value for ZO was .675, which transforms to a pooled correlation coefficient (via the inverse Fisher transform) of .588. This ZO converts to a standard normal value of 10.709, which is significant at the .1 percent level. Thus, the occurrence of twelve significant

correlations in a random sample of sixteen correlations yielded a highly significant pooled correlation of .588.

Discussion

Our assumption was that everybody has an inherent ability to judge intuitively the life style of another person confronting him. We supposed further that a person, lacking the opportunity to continual contact with another, could explore his life style effectively by having him keep a "structured diary."

We believe that a "structured diary" is better for grasping another person's life style than are chance meetings with new acquaintances, conveying first impressions which are corrected by frequent meetings in the future.

Another argument for diaries as a source of life style is that on account of their situation-behavior arrangement, "structured diaries" compel their authors to make more comprehensive and precise depictions of their life than they would do in regular, continuous entries.

In our project, the life style of persons was explored for lack of time only by short versions of the "structured diary." In this version, used in the present project, the subject illustrates by situation-behavior descriptions how each theme of the life style structure works out for him.

If more time is available, a long version of the "structured diary" can be written in which subjects just record ego-stirring situations as they occur over a long period continually. The written material is then content-analyzed, with the themes of life style as viewpoints.

The use of the long version raises an intriguing possibility. In the future, people might keep "structured diaries" continually, and submit them to specialists, who would appraise their life style by content analysis, and counsel on life style modifications.

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Social Science Section

Attendance Taking as a Means of Developing Academic Commitment

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Abstract

This paper reports the results of an experiment designed to explore different classroom reward contingencies and find the one most efficacious in encouraging class attendance and thus, academic commitment. In addition, reward contingencies are compared in terms of perceived satisfaction by students, and the relationship between class attendance and final course grade is examined. Reward contingencies based on giving students bonus points for their attendance are shown to be superior to those deducting penalty points for absence or not involving course grading points at all.

Introduction

The literature on teaching techniques in social sciences, regardless of disciple, tends to concentrate on the in-class presentation of concepts, but fails to address problems of class organization arising as a result of the current trend to open enrollment policies. Students admitted under

these policies are, in most cases, capable of matriculating but lack a background that would give them college work habits. Instructors find themselves faced with the seemingly irreconcilable tasks of maintaining both class enrollments and standards of teaching at a high level. What are we to do in these circumstances?

This paper is an effort to address the issues of class organization raised by the dilemma of retaining enrollment and keeping standards high. We will attempt to answer three questions as a means of suggesting a way to resolve the predicament stemming from contemporary open enrollment policies:

1. What set of reward contingencies will be the most successful in encouraging students to make the basic academic commitment of attending class?
2. Beyond encouraging their presence in the classroom, what set of reward contingencies will be perceived most favorably by students, thus increasing their positive commitment to academic work?
3. Is there a relationship between class attendance and understanding material (as represented by final grade) that would make our efforts to encourage attendance a worthwhile enterprise rather than an empty exercise in behavior control?

Nine classes in introductory sociology, psychology, and geography were divided into three groups. One group was given bonus points for attending class. A second group had penalty points deducted for absence. In the third (control) group, attendance was taken, but no points were involved. Roll was called in one-third of the class periods on a random basis. Evidence indicates that, while absenteeism occurred in all groups, the "gradient of increasing absence" during the term was significantly less of the Bonus Point group than for the other two conditions and that students thought more favorably of receiving bonus points. Additionally, a negative relationship between absence and final grade indicates that coming to class does make a difference. Should these results hold over several semesters, then clearly the possibility of bonus points for attendance serves as a possible answer for resolving our dilemma of keeping up enrollment without lowering teaching standards.

Literature Review

The teaching journals of sociology, psychology, and geography contain many interesting and ingenious ideas for the presentation of substantive concepts. Although there is no substitute for good teaching, students may well respond to the reward contingencies associated with their grades more reliably than to in-class presentations and activities. After all, they have been taught throughout their schooling that grades are the medium of exchange, their "earnings" for the class. Additionally, reward contingencies associated with grades can be put into operation from the first day of class, whereas, quality teaching may require time (and students' attendance) before its effects can be felt.

We must turn, for help in our dilemma, to the literature of teaching itself. A review of this literature has revealed some interesting perspectives regarding the relationship between reward contingencies and class

attendance. A study undertaken by Lloyd, Garlington, Lowry, Burgess, Euler, and Knowlton (1972) found that the use of weekly quizzes increased attendance. However, the attendance was above 90 percent on quiz days, but dropped to a mean of 46 percent and 38 percent respectively, on days that were designated nontest, or on days when no information pertaining to testing was being discussed.

A parallel study by Williams (1975) nearly replicates the data. Attendance was higher for quiz meetings than for optional class meetings where specific test material was not covered. The material presented in these two studies indicates that exam scores, or the presentation of material likely to be used on examinations will increase attendance. Conversely, students will be less likely to present themselves for class if there are not grade related contingencies.

Hovell, Williams, and Semb (1979) conducted a systematic replication of the Lloyd et al. study. The researchers found, "In general, high attendance seems to be a function of grade related contingencies. . . . Further, attendance was uniformly higher for test meetings as compared with nontest meetings for each class." The researchers also noted an "interesting contrast" for meetings which were designated nontest. They state:

> During the latter part of the semester, a much smaller proportion of students from the quiz groups attended class on nontest meetings than from the no-quiz group. In fact, the magnitude of change from the first part of the semester to the latter part of the semester was greater than a 50 percent decrease for the quiz groups, while less than a 20 percent decrease to the no-quiz group. For the quiz classes these percentages translate to as few as three or four students attending class for some nontest meetings.

The authors, Hovell, Semb, and Williams, reached two conclusions from their study:

> . . . first, frequent grade related contingencies (e.g., frequent testing) can maintain high attendance when in effect; secondly, frequent grade related contingencies may lower attendance at optional class meetings relative to infrequent contingencies when they are not in effect. Thus, where high regular attendance at all meetings is deemed necessary, contingent course credit probably should be provided for attendance at all class meetings.

A piece of literature in this area relevant to question 2 is by Donald R. Street (1975) who asserted that state supported universities cannot afford the luxury of noncompulsory attendance. Although he argues very effectively in defense of his assertion, Street closes his treatise by admitting that an "attitude of rebellion" might be fostered among students if compulsory attendance were required, and this, "would be counterproductive to any benefits anticipated," from a change to compulsory attendance from noncompulsory attendance.

Conceivably, this problem might arise. However, a study conducted by Baum and Youngblood (1975) indicates that the likelihood of this happening is not great. The initial purpose of the Baum and Youngblood

study was not directed toward the issue raised by Street, *per se*, but was an attempt to analyze absenteeism and organizational effectiveness. Beyond this endeavor, they also concerned themselves with the problem of legal compliance and the impact it might have on employee satisfaction. To analyze their conceptions, a research project was conducted at Purdue University, utilizing undergraduates who were enrolled in intermediate accounting courses. Using a single control policy (i.e., a single set of reward contingencies), compulsory attendance with negative sanctions for non-attendance, Baum and Youngblood concluded, "... that a single control policy had an impact on not only absenteeism (lowered) but also performance increased. Furthermore, the legalistic control policy did not result in reduced satisfaction with the instructor or the course." Their findings suggest that compulsory attendance will not result in student rebellion and be counterproductive.

Hershel H. Nelson (1973) examined the literature pertaining to question 3, whether or not classroom attendance had a direct relationship to grades. He concluded from his view of the relevant research that, "... for the most part, systematic studies conducted ... indicate no significant difference between the performance of students who attended regularly (usually three times a week) and those who studied independently with fewer contact hours or no contact at all except for examinations." In spite of these findings, Nelson still postulated that significant differences do exist between students who attend class regularly and those who do not. According to Nelson, this difference could be measured by employing the chi-square statistical technique. Using that statistical technique in a study he conducted at Polk Community College, Nelson found that more failures occurred in what he termed the "irregular attendance" category than in the "regular attendance" category.

The present study expands upon the research cited above and carries it further by using a greater variety of contingencies, thus allowing more specific discrimination of the mechanisms in operation.

Method

Nine classes in courses fulfilling the social science general studies requirement constituted the experimental population for the study. The nine included four sections of Introductory Sociology, three sections of Introductory Geography, and two sections of Introductory Psychology. Three experimental groups were formed of three classes each. Two groups were treatment groups. In the "Bonus Point" group, students received extra points if they were present when roll was taken in the class, equal to a maximum of 10 percent of the total number of points for the class. In the "Penalty Point" group, students had points deducted if they were absent when roll was taken, again equal to 10 percent of the value of total class points. In the control group, roll was taken as in the treatment groups, but no points were added or subtracted.[1] Roll was

1. Class sizes for the experimental conditions were as follows: "Bonus Point" group (three class sections): 67, 63, 67 (=197); "Penalty Point" group (three class sections): 68, 45, 32 (=145); Control group (three class sections): 67, 73, 51 (=191).

called in one-third of the meetings in each class. The dates for taking attendance were selected independently for each class by a random draw method.[2]

Four faculty members participated in the experiment. Each participant taught classes in two of the experimental groups. Thus, each acted as his/her own control for teaching differences between groups. Each also taught classes on both the Monday-Wednesday-Friday and the Tuesday-Thursday class schedule, acting as their own controls for difference between days of the week.

At the end of the term, students in the classes completed an "Attendance Policy Student Questionnaire." This instrument provided information on the success of the experimental manipulation in terms of students' awareness of the different attendance policies among course sections and that they were participating in an experiment. The survey also asked for students' assessment of the "fairness" of the attendance policy in their class and whether they thought the attendance policy was a "good idea" and had helped them to get a better grade. Upon completion of the survey, students were given a one-page explanation sheet as a debriefing for the experiment. No student expressed any resentment at being an involuntary participant in the experiment.

Results: Reward Contingencies and Class Attendance

Figure 1 and Table 1 present the results of the experiment with respect to question 1. It is easily seen that the Bonus Point condition classes maintained the best attendance throughout the term. After the first quarter of the term, the average for absence in the Bonus Point classes as a proportion of absence reported in the Penalty Point and Control conditions is .55.

Linear regression analysis indicates that the "gradient of increasing absence" during the term is far smaller in the Bonus Point condition. The regression equations for the three conditions are as follows:

$$\text{Bonus Point: } Y = 7.962 + .070\,X$$
$$\text{Penalty Point: } Y = 6.752 + .239\,X$$
$$\text{Control: } Y = 6.157 + .290\,X$$

The T-values for the differences between the Bonus Point regression line and the Penalty Point and Control regression lines are 4.53 and 5.9 respectively, both significant at .0001.

An examination of the zero-level correlation coefficients for the three conditions further clarifies the nature of the relationship between reward contingencies and class attendance. The values of r equal: Control, $r = .698$; Penalty Points, $r = .451$; and Bonus Points, $r = .277$. For the Con-

2. At the beginning of the term, the dates on which each class would meet were put in a receptacle and one-third were drawn without replacement. In a few instances, roll was not called on the prescribed date because of the unexpected absence of the instructor. Roll was taken on the next date available.

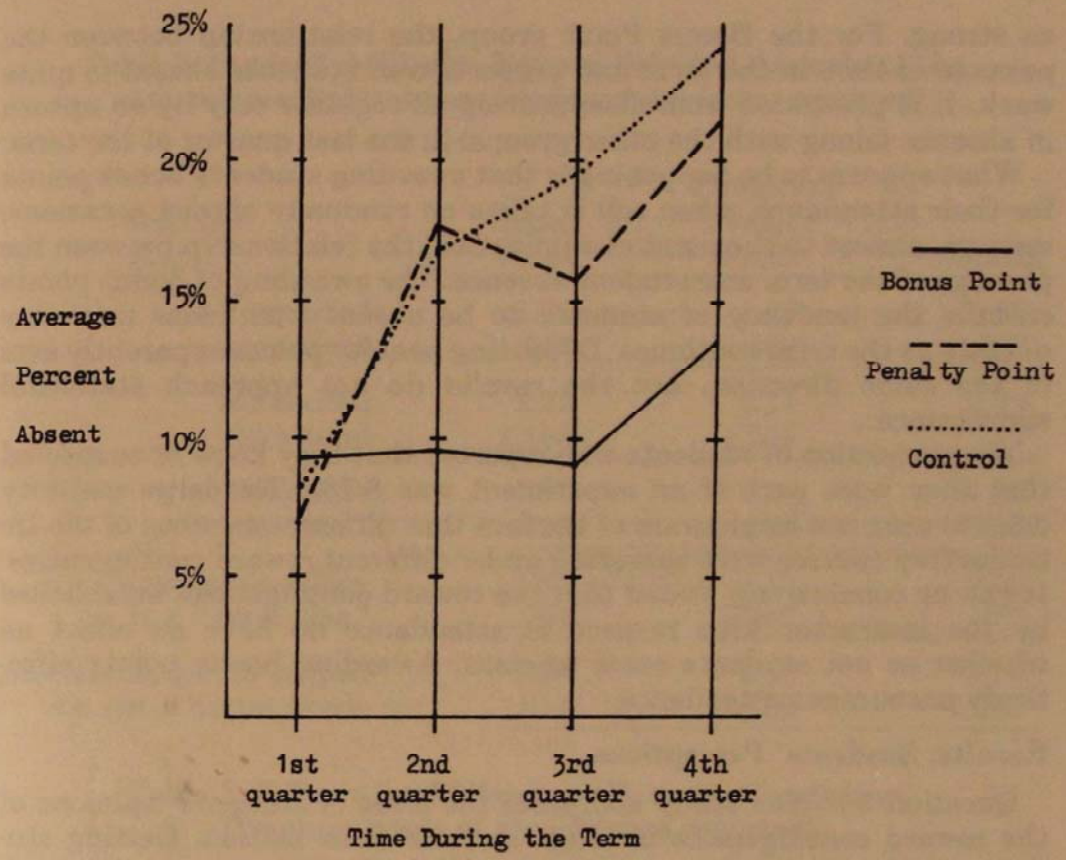

FIGURE 1. Average percent absent by experimental condition and time.

Table 1. Average Percent Absent by Experimental Condition and Time.

Experimental Condition	*Time* 1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Bonus Point	9.40	9.65	9.12	13.50
Penalty Point	6.68	17.76	15.78	22.49
Control	8.24	16.90	19.66	24.05
$\frac{\text{Bonus Point}}{(\text{Penalty Point} + \text{Control})(\frac{1}{2})}$	1.26	.56	.51	.58

trol group, there is a strong linear, direct relationship between how far along in the term the class is and the percentage of students absent. Every week of the term adds about one more percent to student absences. For the Penalty Point group, the direct, linear relationship is not

as strong. For the Bonus Point group, the relationship between the passage of time in the term and proportion of students absent is quite weak. It is prevented from disappearing all together only by an upturn in absence (along with the other groups) in the last quarter of the term.

What appears to be happening is that awarding students bonus points for their attendance, when roll is taken on randomly chosen occasions, reduces, almost to the point of elimination, the relationship between the passage of the term and student absence. The awarding of bonus points curtails the tendency of students to be absent from class more frequently as the term continues. Deducting penalty points apparently acts in the same direction, but the results do not approach statistical significance.

The proportion of students who reported that they knew or suspected that they were part of an experiment was 8.7%. The large majority (89.2%) were not even aware of the fact that different sections of the Introductory courses were operating under different reward contingencies. It can be conclusively stated that the reward contingencies established by the instructor with respect to attendance do have an effect on whether or not students come to class. Awarding bonus points effectively encourages attendance.

Results: Students' Perceptions

Question 2 in this study addresses the issue of students' opinions of the reward contingencies in effect in their class section. Getting students to attend class is not the entire story. The literature on the possibility of counter-productive student rebellion is not conclusive. And, in that light, given a choice, it seems sensible to select reward contingencies that are not only effective in getting students to attend class, but are also seen by them in favorable way.

Tables 2 and 3 present the results relevant to discussing students' satisfaction with different reward contingencies. Means are calculated based on four-fold discrete choices, except for self-reported attendance, which offered six choices.

The tables indicate that the Bonus Point condition is reacted to much more positively by students than either the Penalty Point or Control condition. T-tests show a highly significant difference between the Bonus Point condition and both the Penalty Point and Control conditions, but no difference between the less favored conditions, with respect to "fairness," "being a good idea," or "helping you to get a better grade."

With respect to self-reported attendance, or "being influenced to attend class," the results are somewhat different. Again, there is a significant difference betweens students in the Bonus Point and Control conditions. But, this time, the difference between the Bonus Point and Penalty Point conditions is not significant. The difference between the Penalty Point and Control conditions is significant in the matter of influencing students to attend class.

Student responses to the questionnaire confirm the efficacy of grade related contingencies in influencing students to come to class as com-

Table 2. Student Attitudes Toward Selected Aspects of the Attendance Policy (mean/standard deviation reported)

Selected Aspect	*Condition* Bonus Point	Penalty Point	Control
Self-reported attendance	1.75 .602	1.88 .683	2.02 .658
Influenced to attend	2.22 1.185	2.11 1.205	2.49 1.147
Attendance policy is "fair"	1.62 .837	2.09 1.000	1.95 .922
Attendance policy is a "good idea"	1.57 .794	2.17 .947	2.09 .977
Attendance policy helped you get a better grade	1.90 .814	2.52 1.056	2.74 1.048

Table 3. T-Tests for Differences Between Conditions. (T-values/levels of significance reported)

Selected Aspect	*Differences* BP -vs- PP	BP -vs- C	PP -vs- C
Self-reported attendance	−1.77 ns	−3.92 p<.001	−1.73 ns
Influenced to attend	0.79 ns	−2.19 p<.03	−2.82 p=.005
Attendance policy is "fair"	−4.43 p<.001	−3.40 p=.001	1.30 ns
Attendance policy is a "good idea"	−6.02 p<.001	−5.49 p<.001	0.71 ns
Attendance policy helped you get a better grade	−5.75 p<.001	−8.31 p<.001	−1.77 ns

pared to the no-reward case. However, students evidence far more satisfaction with the grade related contingencies when they are applied positively, as a bonus, rather than negatively, as a penalty.

Results: Class Attendance and Grades

The final question that we investigated in this study involved the relationship between class attendance and the grade earned by the student. Table 4 presents the results.

Table 4. Relationship Between Absences and Grade. (correlation coefficient/level of significance reported)

Condition/ Section	*Correlation Coefficient*	*Significance*	*Class Size*
Bonus Point	−.395	p<.001	197
2	−.384	p<.005	67
4	−.203	ns	63
8	−.535	p<.001	67
Penalty Point	−.380	p<.001	145
5	−.537	p<.001	68
7	−.467	p<.001	45
9	−.527	p<.005	32
Control	−.464	p<.001	191
1	−.584	p<.001	67
3	−.453	p<.001	73
6	.114	ns	51

Generally, there does seem to be a negative correlation between absence from class and the grade received by the student. The more absences, the lower the grade. This effect might be expected in the grade related reward conditions, but it holds true for the Control condition sections also.

Although the attendance—grade relationship exists generally, however, it does not exist universally for all the sections. The relationship between class attendance and grade may be mediated by the style of the instructor, a heavy reliance on readings as opposed to lecture, for instance. Our results support Nelson's findings, but suggest the relationship may be more complex and situation-dependent than students merely being present in the classroom.

Conclusion

The present research involves the replication and extension of a number of studies investigating various aspects of class organization at the college and university level. It goes beyond previous research in that we have been able to discriminate among three sets of reward contingencies, both in terms of their efficacy in influencing students to attend class, and actually getting them into the classroom throughout the entire term, and in terms of the students' response to the reward contingencies they find operating in their classroom.

Our results need to be confirmed over a greater number of school semesters with additional numbers of classes. Indications at this point, however, strongly suggest the awarding students bonus points for attending class (when roll is taken on randomly selected occasions) will increase their attendance, be perceived by them in a favorable light, and thus improve their understanding of presented material, as indicated by

higher grades. Awarding bonus points appears to be a long step in resolving the dilemma of maintaining both high enrollments and high standards of teaching.

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Special Publication Section

The Null Hypothesis of Science*

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This paper is concerned with how scientists view their enterprise, and with how this view affects their interactions with nonscientists. A wise appraisal of the status of scientific knowledge should promote constructive interaction.

Does science have a distinctive monopoly on at least certain kinds of truth? Are there at least some claims that science can make with absolute confidence? Most science textbooks certainly do convey the impression that they are describing nature as it really is. They may refer to unresolved controversies between alternative theories, but in that very act it is often implied that other claims are universally accepted as true. Often this actually does reflect the consensus within the scientific community. It is not rare that one hears that "evolution is a fact." V. F. Weisskopf (1977) identified the "external" frontiers of science as in the realms of the very large and the very small—cosmology and particle physics. "Internal" frontiers remain only because of the complexity of the atomic realm. But

> . . . there is today a general belief that the basic principles of the atomic world are known and no additional law or principle is necessary in order to explain the phenomena of the atomic realm, including the existence and the development of life.

*This paper was presented under the title "Is Scientific Knowledge Relative?". In preparation for publication it has been reorganized. The present title refers to my concluding metaphor, which summarizes my argument.

Bertrand Russell (1945) said, "Whatever can be known, can be known by means of science. . . ."

Confidence in the correctness of current scientific theory is understandable because it does indeed explain much of our human experience, it correctly predicts much that would otherwise not have been anticipated, and it enables us to control our environment in multitudinous ways.

Nevertheless, it is sobering that these same statements could have been made, and were made, about Ptolemaic astronomy and Newtonian physics, both of which were so good that they still find abundant practical use today, but both of which are now regarded as terribly erroneous descriptions of the universe. Equally sobering have been the findings of cultural anthropology, which showed us that notions that seemed self-evident in one culture were not even regarded as true in another. S. J. Gould (1978, 1980) has recently written some fascinating papers showing how today's racial prejudice and ethnocentrism was yesterday's scientific objectivity.

But the most fundamental reason for skepticism is that every assertion either is itself an assumption or is derived by reasoning based on assumptions. This is equally true in all systems of thought. Every line of reasoning must begin somewhere. Conversely, to any assertion one can always respond, "Why is that so?" or, "What is your basis for making that claim?"

Does Science Approach the Truth?

Let us assume, with K. R. Popper (1962), that a true assertion is one that corresponds with facts. Popper insists on distinguishing the *meaning* of truth from the *criteria* for determining whether a particular assertion is true. He asserts that we all understand the meaning of truth, at least approximately, but that there is no general criterion of truth. Therefore, while many of the claims of science may be true, we cannot be certain of the truth of any particular claim. Theories cannot be *verified.* Nevertheless, the concept of truth remains important as the goal of inquiry, and Popper is convinced that this goal can be approached by the method of making refutable conjectures and attempting to refute them (1962, 1965). Popper says the truth is approached by a process of elimination when theories are *falsified.*

Popper is one of the two men who have had the greatest impact on the philosophy of science in the current half century. The other is T. S. Kuhn. Kuhn, in *The Structure of Scientific Revolutions* (1962; 2nd ed., 1970a), distinguished between *normal science* and *extraordinary science.* Normal science consists of the solving of *puzzles* according to the example and standards of the *paradigm* currently accepted in the discipline. Experiences are anomalies if they generate puzzles that persistently resist solution. Anomalies may provoke a period of *crisis* during which the fundamental assumptions of the existing paradigm are brought into question. The extraordinary science of such a period may produce a new paradigm which, if accepted by the members of the discipline, provides

the new standards of a new period of normal science. In this event, a *scientific revolution* has occurred.

Kuhn claims that when the scientific community thus shifts its allegiance from one paradigm to another, there is no definable logic that forces it to do so. Paradigm shifts are mass *conversions* which are influenced, but not dictated, by new evidence. Reasoning in terms of evidence cannot dictate acceptance of a paradigm because the selection, weighting, and application of various standards of evaluation is ultimately a matter of private judgment. Furthermore, a paradigm is more than a set of standards; it is a unique way of *seeing* evidence. Devotees of different paradigms have difficulty communicating with one another because, even if they use the same words, these words refer to different constellations of meaning. There is no evidence likely to convert someone sufficiently committed to seeing all evidence only in terms of his preexisting paradigm. In short, while paradigms cannot be verified, neither can they be falsified. Kuhn sees the debates that characterize extraordinary science as conclusive only in the sense that one paradigm is accepted and the other rejected. In normal science, says Kuhn, the paradigm itself is not brought into question at all. In fact, when a scientist fails to solve a puzzle, it is he that is judged deficient, not the paradigm.

Kuhn is thus led to question whether science can be regarded as approaching the truth, or whether it is even meaningful to ask whether theories are true. He says there is "no theory-independent way to reconstruct phrases like 'really there'. . . ." However, Kuhn does see progress in science toward greater accuracy of prediction, a greater diversity of problems solved, and the like.

Is Scientific Knowledge Relative?

Popper (1970) is distressed by what he calls Kuhn's relativism. Popper (1962) defines relativism as

> . . . the theory that the choice between competing theories is arbitrary; since either there is no such thing as objective truth; or no such thing as a theory which is . . . nearer to the truth than another theory; or, if there are two or more theories, no ways or means of deciding whether one of them is better than another.

He sees it as "the main philosophical malady of our time" because he thinks it promotes moral relativism, nihilism, intellectual despair (1962) and irrationalism (1970). Popper (1970) correctly attributes to Kuhn the belief

> . . . that the rationality of science presupposes the acceptance of a common framework . . . that rationality *depends* upon something like a common language and a common set of assumptions . . . that rational discussion, and rational criticism, is only possible if we have agreed on fundamentals.

This "thesis of relativism" Popper calls "The Myth of the Framework." He allows that critical discourse is easier within a framework than be-

tween frameworks, but insists that "a critical discussion and a comparison of the various frameworks is always possible."

My own view of all this is that the points of difference between Popper and Kuhn are far less significant than their points of agreement: that systems of thought (paradigms, frameworks) exist, that these systems are based on assumptions, that there can be no ultimate criteria of validity, that certainty regarding the truth of particular assertions, even if meaningful, is unjustifiable, but that inquiry is a worthwhile enterprise nevertheless.

Kuhn (1970b), I think rightly, accuses Popper of underestimating the barriers to understanding that often separate systems of thought. Popper (1970) rightly insists that open minds can to some extent break out of the confines of their accepted systems of thought. Kuhn (1970b) seems to agree. Popper's insistence on the approachability of truth matches what I perceive to be the view of most scientists, even though, as Kuhn suggests, it is a concept that may lead to a philosophical morass.

Can any specific assertion justifiably be regarded as true? Assertions may be true relative to, and by the standards of, the public or private system of thought that produced them, as in a theorem of Euclidean geometry, or even directly, by assuming them to be true. Even Popper agrees that absolute certainty that an assertion is true, with respect to a reality outside the system of thought that produced it, is never totally justified. (There is always the solipsist alternative.) Popper (1962) even admits that absolutists might be inclined to call *him* a relativist.

Is scientific knowledge relative? It seems to me that it has to be considered relative to the assumptions of science. If there be danger in relativism, I think the security of society depends on the fact that almost everyone is in fact willing to admit that some specific things are right and others are wrong. There is much disagreement as to what those things are. But with or without relativism, the only way to deal with those disagreements is by persuasion. The kind of relativism that I feel compelled to accept, and with which both Popper and Kuhn seem to agree, is the kind that does not despair of the possibility of reaching intelligent conclusions, even though different intelligent people will reach different conclusions. Such a relativism, I contend, is a bulwark of the freedom, tolerance, compromise, and problem-solving that must characterize a well-ordered pluralistic society.

Science and Religion

The "establishment clause" of the First Amendment ("Congress shall make no law respecting an establishment of religion . . .") has been cited by courts in striking down legislation banning the teaching of evolution or mandating equal time for fundamentalist creationism in public school curricula. However, some fundamentalists assert that the clause is violated when only evolution is taught in public schools because this tends to "establish" nontheistic and theistic religions that accept evolution, at the expense of theistic religions that do not (Bird 1979). They also assert that there is scientific evidence that discredits evolution and supports a

recent creation, and that can be considered and taught along with evolution without reference to any specific religion. This they call "scientific creationism" (Morris 1974).

If the fundamentalists' proposal for equal time were implemented and upheld by the courts, I think that it would lead to a gross misrepresentation of science. However, it does have some attractive features. First, I find it encouraging that spokesmen for groups that once sought to suppress the teaching of evolution now advocate an open clash of ideas—whether or not they were driven to this position by failure of their earlier efforts. In fact, they now sometimes succeed in making scientists look like narrow-minded dogmatists—perhaps because such people do exist in every group. Second, when scientists assert that "evolution is a fact," when they teach the theory of evolution in a manner that suggests that it is unnecessary to make a case for it, or when they suggest that all evidence points unequivocally to evolution, they, too, are misrepresenting science. Third, there clearly is something wrong with making students listen to, and then regurgitate, ideas which they regard as evil, as well as false, without some effort to put the exercise in reasonable perspective.

W. A. Moyer, Executive Director of the National Association of Biology Teachers, recently had this to say (1980):

> . . . science and creationism are based on different logical frameworks. One attempts to comprehend natural laws that are assumed to be immutable (deliberately disregarding the question of deity); the other attempts to comprehend the relationship between humans and their deity.

This illustrates my own thesis, to be developed below. But Moyer continues:

> As my old philosophy professor at Syracuse University used to say, science and religion have no more reason to come into conflict than the traffic on Route 15 and New York Central's trains.
>
> The answer of course, is to keep theology out of science curricula; to do otherwise is to create dangerous confusion in the public mind over the nature of science. . . .

Perhaps it is fitting that the traffic metaphor conjures up visions of grade-crossing accidents. Science and religion do not conflict so long as they are regarded as completely distinct, nonoverlapping enterprises. But many scientists and many Christians are not merely concerned with playing their particular game by its own rules; rather they view themselves as describing what the one and only universe is really like. Most people, including most scientists and most fundamentalists, would agree that they are asking the same question when they ask how old the earth is. They would also agree that if the earth is 4.6 billion years old, it is not in some other sense only 6 to 10 thousand years old, and vice versa. Likewise, mankind either does or does not have ancestors drastically different from itself. Like it or not, "theology," even if silent, may very well

be in the science classroom—unless students with religiously grounded doubts about science are evicted.

In a guest editorial in the March 1980 issue of *BioScience,* Moyer calls for organization of "Committees of Correspondence on Evolution, composed of people willing to communicate the meaning and wonder of evolution to the public." I regard this as an excellent idea, provided that it is not taken as a declaration of war on fundamentalists. In fact, I advocate that the committees go part of the way in meeting the understandable concerns of fundamentalist parents by promoting the following thesis.

Public Systems of Thought

It is my thesis that, to minimize the "dangerous confusion in the public mind over the nature of science"—or of a religion or of any other public system of thought—schools should do much more to examine the general properties of all public systems of thought, and to identify the distinguishing features of particular systems.

A public system of thought is a group enterprise. The group has founders, subsequent generations of leaders (in old groups), and followers who undergo appropriate indoctrination or training. Members of the group share a set of assumptions. Assumptions I define broadly as the starting points or foundation in any attempt to show the structure of the system. Assumptions include meanings assigned to words (including their emotional baggage), fundamental assertions using those words, the rules according to which the system allows these entities to be manipulated, other rules of behavior, examples of proper behavior, standards of evaluation, and the goals of the enterprise. Meanings, assertions, rules, examples, standards, and goals may be explicit or implicit. These assumptions largely determine the scope of the enterprise, what it can and cannot do. Every public system of thought has its own "logic." It has been exposed to, and in conflict with, other systems of thought with overlapping concerns. Its practitioners have found ways to resolve challenges to their own satisfaction. It is conservative; its practitioners deal with its scope of concern by its own rules, not those of a different system. The commitment of its practitioners to abide by its rules assures that the potential of the system for dealing with problems in the domain it claims will be explored. The system has ways of controlling unacceptable internal dissent or deviation. When it does not, splintering results. Systems of thought arise and may in time evolve, be changed drastically by revolution, or be abandoned.

A metaphor suggests itself: the biological species concept. According to this a species is defined as an actually or potentially interbreeding population. It retains its identity by severely curtailed interspecific hybridization, coupled with adequate intraspecific genetic interchange. Subspecies may exist, and if gene flow among them ceases, speciation may result. I leave it to the reader to develop this metaphor further, to flesh out the analagous conditions in systems of thought, and to ponder implications for epistemology.

For now it will suffice to stress that, to maintain their identity,

systems of thought, like biological species, must impose constraints that define the group membership and keep it integral. Some systems of thought demand full-time commitment from their adherents; sanctions may be imposed when slippage is detected. Other systems of thought require only that their assumptions be accepted tentatively, as working hypotheses, while the practitioner is active in that system. Until I realized that this is true of science, I had difficulty understanding how some scientists could insist on scientific standards in their work and then adopt religious beliefs based on a different set of standards (Fezer 1971).

Whatever constraints are imposed by a system of thought on the external behavior of its practitioners, these constraints need not necessarily limit what goes on in their private inner sancta.

Private Beliefs

Since all systems of thought are based on potentially controversial assumptions, their conclusions must also be recognized as potentially controversial. Thus anyone, confronted in his private world with the conflicting but separately credible claims of different public systems of thought, is free to judge which system has the more credible or acceptable assumptions and conclusions. To question the claims of a system one need only identify and question its assumptions. (This is precisely how fundamentalists dispose of evolutionists' arguments to their own satisfaction, and vice versa.) Arguments are usually thought of as strengthened if it can be shown that their assumptions are widely accepted as true. But even universally accepted assumptions, if there are such things, are subject to the possibility of challenge.

Assumptions, of course, can be accepted tentatively, for the sake of argument only, without admitting their validity, and therefore without admitting the ultimate validity of the conclusions validly derived from them.

Students who understand why every system of thought is vulnerable to accusations of error should be better able to defend their most cherished beliefs in their own minds, even when forced to learn conflicting concepts.

How is Science Unique?

Resemblance between my thesis and Kuhn's is not coincidental, since I have merely taken his thesis about systems of thought in science and generalized it to all systems of thought. Indeed, both Popper and Kuhn, while especially concerned with the nature of progress in science, are clearly concerned about human knowledge in general. Many systems of thought claim knowledge. But worldwide, science has a unique reputation for its ability to deliver what is regarded as knowledge. Why is this so? From Kuhn's account of scientific revolutions it is not clear why science should be unique.

Whatever the answer, the Principle of Parsimony (Occam's Razor) does seem to have guided the selection, retention, and alteration of the assumptions of science, not at every moment in history, but in the long run. The assumptions of science, at any given time in its history, may

simply have been those that were individually least controversial, and yet were able, collectively, to lead to some degree of understanding. Most other systems of thought do not reject the assumptions of science. They do insist on making some additional assumptions of their own. If a scientist rejects a religion, it is because he judges its additional assumptions unnecessary and therefore unjustified. If a religion finds its conclusions in conflict with those of science, it is usually not because it rejects the assumptions of science, but because it judges them inadequate. Thus, if we compare the assumptions of uniformitarianism and catastrophism, which constitute the foundations of the theory of evolution and of fundamentalist creationism, respectively, we find that catastrophism logically includes uniformitarianism, but not vice versa. That is, catastrophism adds assumptions to those of uniformitarianism. Uniformitarianism asserts that nature is regular (i.e., lawful). Catastrophism asserts that nature is also sometimes irregular.

The Null Hypothesis of Science

I suggest, as a metaphor for the epistemological status of science, the familiar table that lists possible outcomes when a null hypothesis (H_o) is tested statistically.

		Decision	
		Accept H_o	Reject H_o
Unknown Reality	H_o is true	Correct decision.	Type I error. Probability of making this type of error chosen by decision-maker.
	H_o is false	Type II error. Probability of making this type of error depends on reality and on probability chosen for Type I error.	Correct decision.

The null hypothesis of science is that its assumptions, and the explanatory principles that have been or will be derived by reliance on them, are adequate to explain any explainable phenomenon. It is the hypothesis of no difference between the assumptions of science and the set of assumptions needed to explain the phenomenon. Additional assumptions are unjustified. If there are phenomena inadequately explained by scientific principles, they must remain unexplained. Scientists, while they are functioning as scientists, must accept this null hypothesis, i.e., they must set the probability of Type I error equal to zero. The probability of making a Type II error is 1 when the null hypothesis is in fact false and when Type I error is set equal to zero. By accepting the null hypothesis, the practising scientist exposes himself to the certainty of making a Type II error if the assumptions and principles of science really are inadequate to explain the phenomenon.

If we apply Kuhn's terminology to this situation, we might say that a person engaged in normal science has accepted the null hypothesis of science, whereas a person engaged in extraordinary science is questioning it. Fundamentalist creationists do not want the assumptions of science changed, but they do want them augmented. This is not likely to happen so long as the scientific community as a whole is content with the explanatory potential of its basic assumptions and skeptical of the validity of additional assumptions. And just as the Lutheran community is the right entity to determine what Lutheranism is, so the scientific community is the right entity to determine what science is. "Scientific creationism" is not science, but is rather a different system of thought with its own augmented set of assumptions. Scientific creationists, of course, are free to attempt to convert the scientific community to redefining itself.

Meanwhile, scientists should keep in mind that it is not irrational to conclude that scientific assumptions are not adequate for all explanatory purposes, even if they themselves have judged them to be adequate. Where you and I stand can only be a matter of our own private judgments.

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WEST VIRGINIA ACADEMY OF SCIENCE
ANNUAL TREASURER'S REPORT
FISCAL YEAR 1979 - 1980

April 10, 1980
WVAS Annual Meeting
West Virginia State College
Institute, WV

January 1, 1979 to December 31, 1979

CASH RECEIPTS

Balance on hand January 1, 1979		$ 9,922.07
Dues	$ 2,420.00	
Institutional Membership	600.00	
Proceedings	1,560.00	
Pro Forma Page Charges	333.50	
Contributions	20.00	
Talent Search	32.00	
Annual Meeting (1979)	612.00	
Interest on Savings	462.18	
TOTAL RECEIPTS FOR YEAR	$6,039.68	
TOTAL RECEIPTS & BALANCE ON HAND		$ 15,961.75

CASH DISBURSEMENTS

Printing	$4,540.53	
Contributions	27.70	
Annual Meeting (1979)	623.18	
Talent Search	175.00	
Junior Academy	750.00	
Supplies	27.22	
Secretary Help	137.00	
Postage	28.87	
Miscellaneous	91.75	
TOTAL DISBURSEMENTS	$6,401.25	
RECEIPTS LESS DISBURSEMENTS	(361.57)	
CASH ON HAND December 31, 1979		$9,560.50

(Savings - $1,643.18)
(Checking - $1,917.32)
(Certificate of Deposit - $6,000.00)

Respectfully submitted,

Th K. Pauley

Thomas K. Pauley, Treasurer, WVAS

Annual Business Meeting
West Virginia Academy of Science
Room 122, Wallace Hall
West Virginia State College
Institute, West Virginia 25112
April 11, 1980 1:00 p.m.

The meeting was called to order by President Warner.

The minutes of the 1979 annual meeting were read by Dr. Phillips. Dr. Keller moved, seconded by Dr. Fezer, to accept the minutes. Motion passed.

Dr. Glencoe gave the treasurer's report (copy enclosed). Dr. Das Sarma moved, seconded by Dr. Keller, to accept the treasurer's report. Motion passed.

Dr. Glencoe presented the following list of nominees from the Nominating Committee:

President-Elect - Dr. Robert Nunley
University of Charleston

Treasurer - Dr. Thomas Pauley
Salem College

Dr. Keller moved, seconded by Dr. Phillips, that the nominations be closed. Motion passed. Dr. Keller moved, seconded by Dr. Fezer, to accept the nomination of Dr. Nunley as the President-Elect. Motion passed. Dr. Phillips moved, seconded by Dr. Das Sarma, to accept the nomination of Dr. Pauley as Treasurer. Motion passed.

Professor Gould reported on his accomplishments during the last five years as Editor of the Proceedings. He announced that Volume 50 is at the printers.

Dr. Fezer moved, seconded by Dr. Tarter, to give Professor Gould a vote of appreciation for the work he did as Proceedings Editor. Motion passed.

Dr. Kaegan discussed the possibility of securing money for publications from various sources.

Dr. Hurlbutt presented the Editors report. Page proofs of Volume 51, No. 2 of the Proceedings have been sent to the authors. Volume 51, No. 3 will be a symposium on strip mining, and No. 4 will be an author index.

Dr. Fezer presented a request from Linda Butler, President of the West Virginia Entomological Society, to affiliate the Society with the Academy. Dr. Fezer made a motion, seconded by Dr. Nunley to affiliate the Entomological Society. Motion passed. After some discussion, the Society representative was informed that the Entomological Society must petition the Academy to become affiliated.

Dr. Warner reported that $750.00 would be given to the Junior Academy of Science for their 1980 expenses.

Miss Bartholomew explained the cost to the Academy of returned mail from members whose addresses were unknown.

Dr. Kaegan discussed the problems of the anti-science attitude which is is spreading through various school systems in this country. He suggested that the Executive Committee address the State Board of Education on how science is involved in our highly technological society. Dr. Kaegan moved, seconded by Miss Bartholomew, that the Executive Committee compose a statement on the anti-science attitude. Motion passed.

Miss Bartholomew gave the necrology report. Harry Friedley and John Burke died recently.

Dr. Clarkson announced that the 1981 annual meeting will be held in Morgantown on Saturday, April 11, in Percival Hall. The Executive Committee will meet Friday, April 10. Professor Gould moved, seconded by Dr. Phillips, to hold the meeting according to Dr. Clarkson's announcement. Motion passed.

The meeting was adjourned by Dr. Warner.