A COMPARATIVE STUDY OF BENTHIC MACROFAUNAL PRODUCTION BY STANDING CROP IN A STREAM AFFECTED BY ACID MINE DRAINAGE

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ABSTRACT

A COMPARATIVE STUDY OF BENTHIC
MACROFAUNAL PRODUCTION BY STANDING CROP
IN A STREAM AFFECTED BY ACID MINE DRAINAGE

BY

ROGER GRIFFITH

This study investigated the benthic macrofaunal production of a stream severely damaged by acid mine drainage and a comparison with a similar stream with minimal damage from acid mine drainage. Production in riffle and pool conditions in both streams were compared.

Under normal low flow conditions, biomass relationships in alkaline and acid portions of the stream tend to be quite similar. The acid riffle community seems less flexible and tends to be unstable in the face of rapidly changing conditions such as increased flows. Excessively high flow conditions tend to reduce the biomass to a universal minimum level throughout all portions of the stream.

Fish populations and the resultant cropping on the benthic biomass may have had a significant effect on the relationships discussed.

Further studies are suggested.

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By

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INTRODUCTION

The following description of the study area is based on an article by James D. Sisler (1961) in the BITUMINOUS COALFIELDS OF PENNSYLVANIA:

Approximately 45 square miles of land in Conemaugh, Young, and Armstrong Townships of Indiana County and South Bend Township of Armstrong County, Pennsylvania are drained by Blacklegs Creek and its tributaries. With the exception of some small portions of the upper and middle reaches, the drainage area is composed of marginal farm land with large tracts of second growth, mixed forest interspersed with brush covered fields and some open fields. Some open farm land which is currently active, is found along the upper reaches of the water shed and the middle portions of the mainstream. The small town of Clarksburg has some septic tank drainage into the middle portions of the mainstream as well.

Much of the marginal area has been heavily mined, both deep and strip, and several of the tributaries are influenced by acid drainage. Two tributaries of Blacklegs Creek show a significant effect on Blacklegs Creek itself. Whiskey Run, above Clarksburg, destroys the alkalinity for a short distance. Blacklegs Creek quickly recovers and maintains its alkaline and biological integrity until it receives Big Run. From this point on the stream is acid.

Whiskey Run is acid from headwaters to mouth. Big Run is turned acid by a major discharge approximately half way to the mouth.

Much of the mining has been on the Pittsburgh (No. 8) seam, which averages 6 feet in depth at this point with an average sulfur content of 1.5%. The overburden is generally shallow even on deep mines. The immediate overburden usually consists of neutral or slightly acid sandstone (Pittsburgh).

Since Big Run is affected by one major discharge, it was chosen for this study. It has a drainage area of 8.8 square miles in Young, Conemaugh Townships and South Bend Township in Armstrong County. Above the major source of pollution, it is relatively unpolluted with no active mining. No strip mining exists on the main-stream. Active mining is minimal and restricted to tributaries entering the stream at or below the major discharge. The geology is typical of the Blacklegs Creek watershed. The floor of the stream, as is generally true of the Blacklegs basin, is shale. The Pittsburgh limestone lies beneath the shale at a depth of 8 feet. The boney coal in the seam is 15 inches at this point creating a potential for high acidity. The cover is strictly marginal with extensive second growth forest.

Streams in this area are characteristically low in productivity with moderate diversity. Under normal conditions the number and type of organisms are determined by their ability to adapt to stream conditions and interact. The balance is upset by any type of pollution. The severity of the pollution determines the composition of the biological community.

Numerous studies beginning with Lackey (1938) have attempted to define the organisms surviving in acid mine drainage polluted waters. However, until the studies of Lind and Parsons (1965, 1968) little attempt had been made to quantify the amount or productivity of the organisms existing in acid mine drainage polluted aquatic environment. The study of Tom's Run in Clarion County, Pennsylvania by Dinsmore (1968) was the first comprehensive study, including productivity, conducted on a stream affected by acid mine drainage. However, Tom's Run is not a stream severely damaged by acid mine drainage.

The current study is designed to investigate the benthic macrofaunal production of a stream severely damaged by acid mine drainage and compare it to a similar stream with minimal damage from acid mine drainage.

Big Run is an ideal selection for this purpose.

One major discharge destroys the stream. Only deep mining of the shallow slope type is involved with only one coal seam. The upper reaches are relatively unpolluted.

The study involves a comparison of riffles and pools in acid and alkaline conditions. The purpose of the study is to determine whether a reduction in macrofauna production (as measured by a series of standing crops) occurs in a grossly acid-mine-drainage polluted situation when a reduction in variety occurs. It is also of interest to determine if the acid mine drainage causes a masking of production differences in distinct habitats (i.e., riffle and pool).

SAMPLING LOCATIONS

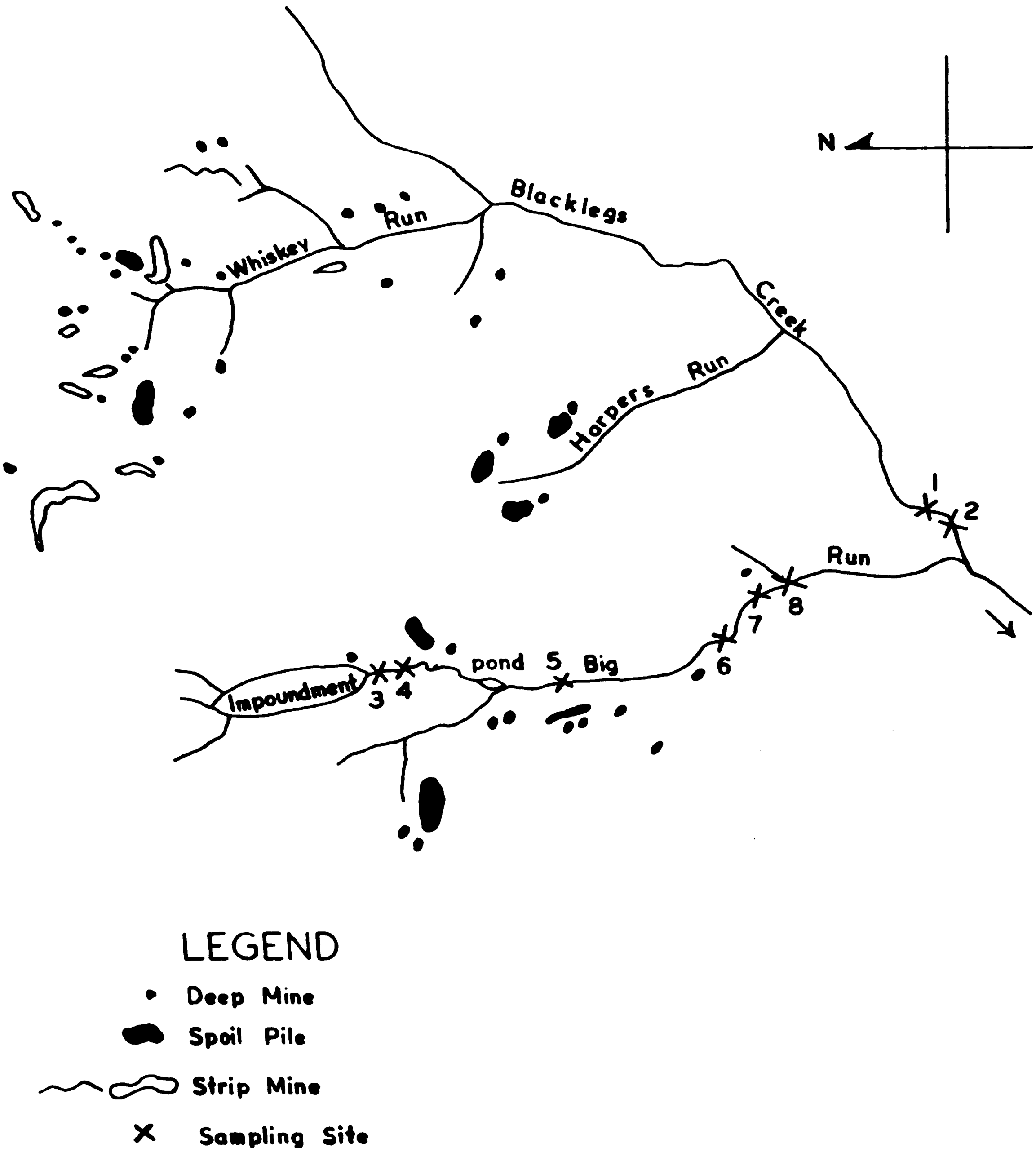
Eight sites which include two alkaline riffles, two acid riffles, two alkaline pools, two acid pools were selected. Initially three stations were placed at each site, (left bank, right bank, and middle) making a total of 24 stations. However, replacement of "lost" stations gave us four stations at certain sites, during given sampling runs.

It was initially planned to have all eight sites on Big Run. The considerations of similar flow conditions, cover, etc. precluded this. The four acid sites are located on Big Run. Only two alkaline sites are located on Big Run due to the rapidly changing conditions of flow and cover as the headwaters are approached.

Two alkaline stations were placed on Blacklegs Creek immediately above the confluence with Big Run. The flow and cover at this point on Blacklegs Creek is comparable to the lower reaches of Big Run. Using Blacklegs Creek for two stations (one pool and one riffle) has the added advantage of providing a dual control on the acid stations.

Five chemical sampling stations were used for the eight sites (Figure 1).

Figure 1. Map of study area.


N
Blacklegs
Creek
Whiskey
Run
Harpers
Run
Run
Big
pond
Impoundment
1
2
3
4
5
6
7
8
LEGEND
Deep Mine
Spoil Pile
Strip Mine
Sampling Site

PHYSICAL AND CHEMICAL METHODS

Stream flows were gaged using the standard method of tag line and float, measuring speed and depth periodically across the width of the stream.

At certain sampling times the flow rates at various sites could not be measured. Estimated flow rates were obtained in such situations by taking the average flow rate at the site and the average flow rate at another site which was gaged on the dates in question and setting up an algebraic proportion ($a/b=x/c$) where a is the average flow of the site in question, b is the average flow of the site selected for comparison, c is the flow of the site selected for comparison during the particular sampling time, and x is the estimated flow of the site in question. All estimated flows are so marked in the tables.

Temperature was measured by a standard mercury thermometer. Conductivity was measured by portable Beckman Conductivity Meter. Dissolved Oxygen was measured by Delta Scientific D. O. Meter. Air calibration was normally used due to the time factor. Chemical analyses were conducted in accordance with the 1964 edition of Standard Methods.

The pH, total alkalinity, total acidity, hardness, manganese, and arsenic were run strictly according to the procedures described in Standard Methods, 1964 edition. The analyses for sulfates, ferrous iron and ferric iron were modified to utilize the packaged dry reagents of Hach Chemical Company.

BIOLOGICAL METHODS

Benthic sampling for macrofauna in a uniform manner is a persistent problem. Use of artifical substrates suggested by Mason (1967 & 1968), Britt (1955) and others can provide a uniform means of sampling but these have little relation to the natural substrate.

In this situation it was desirable to have a uniform substrate which corresponded as nearly as possible to the natural conditions. Since the base of the stream bottom is composed primarily of sandstone, it was decided that a rock substrate using inert sandstone would be ideal for the study. The substrates should be as uniform as possible for all stations, and they should be set in the stream bottom in such a manner as to endure the exact conditions to which the natural substrate is subject.

To meet the above criteria the substrates were designed as follows: Rectangular plastic dishpans were cut to form trays with a depth of 2½ inches and an average surface area of one square foot and filled with a uniform mixture of ½ to 2 inch inert sandstone. The substrates were placed flush with the stream bottom except where bedrock made this impossible.

All material, mud, debris, etc., collected on the substrate during the sampling period was processed. The substrates were washed in a dishpan with a soft toothbrush in the manner described by Mason (1967) and reset. The material in the dishpan was concentrated in the standard manner with a #30 mesh sieve and initially preserved in approximately 5-7% formalin. Within 96 hours the preservative in the samples was changed to 70% alcohol, 5% glycerin and Rose-Bengal stain added in the manner described by Mason (1967).

The original sampling schedule called for bimonthly samples. However, weather conditions, stream conditions, and time considerations forced the schedule to be altered to trimonthly or seasonal.

At convenience, the samples were sorted using a clear plastic tray with a combination of over- and under-lighting and a three-inch magnifying glass. The sorted organisms were keyed to family with an American Optical Dissection scope.

After identifying the organisms, they were weighed on a Mettler balance. The total weights for each station were recorded. The data from all sites were subjected to statistical comparison and a diversity index was used to compare acid and clean stations.

On the final sampling run, Surber samples were collected at pool and riffle sites in both alkaline and acid portions of the stream for comparison with the substrate samples. When using the Surber sampler in pool areas, an artificial current was created with the use of a large dissection pan. Preservation, sorting and keying followed the procedures discussed above.

Fish in the alkaline portions of the stream were collected by electric shocker and seine. The species and numbers collected were recorded. An unsuccessful attempt was made to determine fish population by mark and recapture method. The second collection of fish was preserved in alcohol and keyed to species, measured and weighed.

An unsuccessful attempt was made to measure periphyton production by the chlorophyll method. Slides were mounted in stryrofoam holders and attached to the substrate. On each run they were collected and frozen. At a convenient date, they were analyzed following the procedure of Richards (1952). Due to sample loss in the stream and various equipment failures, data from this portion of the study is unusable.

RESULTS AND DISCUSSION

Physical and Chemical

The natural stream conditions varied considerably throughout the year. On all runs, several substrates were lost, apparently due to flow fluctuations. The stream flow characteristics (Table 1, Appendix Table A1) also made it difficult to locate some of the substrates. As a result, some of the substrates were presumed lost but were recovered at a later sampling period.

All substrates at some sites were lost on occasion due to the high stream flows. At site 1, for instance, they were lost completely in the winter and spring sampling runs; site 5 also had a considerable problem with loss.

In the case of site 1, an effort was made to recover some of the data by the use of Surber sampler results. The Surber samples were collected during the final sampling run.

Little significant difference between the Surber samples and substrates was observed. The substrate yields ranging from 1.23 gm/square foot to less than 0.01 gm/square foot, and the Surber samples ranged from 0.27 gm/square foot to 0.01 gm/square foot (Tables 2 and 3)

Table 1. Summary of flow, alkalinity, acidity, iron, dissolved oxygen data.

	Sites 1 & 2	Sites 3 & 4	Site 5	Site 6	Sites 7 & 8
Flows (cfs)					
Maximum	82.87(est.)	25.73	36.81	59.12(est.)	71.00(est.)
5/19/68	($\pm$ 20.41)			($\pm$ 22.07)	($\pm$ 0.25)
Minimum	4.91	0.22	1.75	3.86	5.52
8/17/68					
Average	25.87	7.87	15.45	20.06	22.86
Total Acidity (mg)					
Maximum	13.0	60.0	460.0	537.0	462.0
Date	5/19/68	5/19/68	9/17/67	9/9/67	8/17/68
Minimum	0	3.12	55.0	116.5	85.5
Date	8/67,11/67,8/68	11/14/67	5/19/68	5/19/68	5/19/68
Average	4.0	26.6	197.5	287.0	271.5
Total Alkalinity (mg)					
Maximum	109.0	54.0	0	0	0
Date	8/17/68	5/19/68			
Minimum	11.0	13.0	0	0	0
Date	5/19/68	9/17/68			
Average	56.5	31.3	0	0	0

Table 1--Continued.

	Sites 1 & 2	Sites 3 & 4	Site 5	Site 6	Sites 7 & 8
Total Iron (mg)					
Maximum	1.6	1.5	9.0	17.4	16.8
Date	5/19/68	5/19/68	9/17/67	8/17/68	8/17/68
Minimum	<0.1	<0.1	2.6	7.0	2.0
Date	11/67,5/5/68,8/68	9/17/67	5/19/68	9/9/67	9/9/67
Average	0.2	0.4	5.6	11.1	9.3
5/19/68	1.6	1.5	2.6	8.7	7.5
Dissolved Oxygen (mg)					
Maximum	12.3	12.0	13.6	12.6	12.9
Date	11/17/67	11/18/67	11/18/67	11/18/67	11/18/67
Minimum	9.3	7.6	10.4	10.2	9.4
Average	10.8	10.3	11.7	11.4	11.3
5/19/68	11.2	11.4	11.2	11.3	11.7

Table 2. Average weight (ranges in parentheses) of benthic organisms by date and site, including crayfish.

Artificial Substrate Summary	8 & 9/67		2/68		8/68	
Site	Number of Stations Retrieved	Average Weight	Number of Stations Retrieved	Average Weight	Number of Stations Retrieved	Average Weight
		g		g		g
1 Alkaline Pool	3	2.11 (1.51-2.54)	0	-	0	-
2 Alkaline Riffle	3	1.85 (0.27-3.74)	3	2.26 (1.06-1.55)	3	0.13 (0.09-0.21)
3 Alkaline Riffle	4	0.67 (0.07-1.16)	4	1.25 (1.12-1.82)	3	0.60 (0.27-1.23)
4 Alkaline Pool	3	0.31 (0.05-0.82)	3	2.84 (1.12-4.46)	3	0.07 (<.01-0.184)
5 Acid Riffle	3	0.56 (0.24-1.20)	0	-	2	0.03
6 Acid Pool	3	0.94 (0.48-1.74)	2	0.83 (0.73-0.92)	4	0.20 (<0.01-0.68)
7 Acid Riffle	3	1.07 (0.75-1.39)	3	0.04 (0.01-0.08)	2	<0.01 (<0.01-<0.01)
8 Acid Pool	3	0.90 (0.38-1.20)	2	0.57 (0.54-0.57)	3	0.10 (0.04-0.15)

Table 2--Continued.

Artificial Substrate Summary	8 & 9/67		2/68		8/68	
Site	Number of Stations Retrieved	Average Weight	Number of Stations Retrieved	Average Weight	Number of Stations Retrieved	Average Weight
		g		g		g
Surber Samples						
1					3	0.01 (<0.01-0.27)
2					2	0.05 (<0.01-0.10)
3					-	-
4					3	<0.01 (0-<0.01)
5					-	-
6					2	0.01 (<0.01-0.02)
7					2	<0.01 (<0.01-<0.01)
8					-	-

Table 3. Average weight (ranges in parentheses) of benthic organisms by date and site, excluding crayfish.

Artificial Substrate	8 & 9/67		2/68		6/68	
Site	Number of Stations Retrieved	Average Weight	Number of Stations Retrieved	Average Weight	Number of Stations Retrieved	Average Weight
		g		g		g
1 Alkaline Pool	3	0.35 (0.12-0.53)	0	-	0	-
2 Alkaline Riffle	3	0.40 (0.27-1.53)	3	1.52 (1.06-2.34)	3	0.13 (0.27-1.23)
3 Alkaline Riffle	4	0.47 (0.07-1.04)	4	1.25 (.12-1.82)	3	0.60 (0.27-1.23)
4 Alkaline Pool	3	0.06 (0.05-0.06)	3	2.80 (1.12-4.36)	3	0.06 (<0.01-0.18)
5 Acid Riffle	3	0.56 (0.24-1.20)	0	-	2	0.03 (<0.01-0.05)
6 Acid Pool	3	0.94 (0.48-1.74)	2	0.83 (0.73-0.92)	4	0.20 (<0.01-0.68)
7 Acid Riffle	3	1.07 (0.75-1.39)	3	0.04 (0.01-0.08)	2	<0.01 (<0.01-<0.01)
8 Acid Pool	3	0.90 (0.38-1.20)	2	0.57 (0.54-0.57)	3	0.10 (0.04-0.14)

Table 3--Continued.

Artificial Substrate	8 & 9/67		2/68		6/68	
Site	Number of Stations Retrieved	Average Weight	Number of Stations Retrieved	Average Weight	Number of Stations Retrieved	Average Weight
		g		g		g
Surber Samples						
1					3	0.08 (<0.01-0.22)
2					2	0.05 (<0.01-0.10)
3					-	-
4					3	<0.01 (0.-<0.01)
5					-	-
6					2	.01 (<0.01-0.02)
7					2	<.01 (<0.01-<0.01)
8					-	-

and (Appendix Tables A2-A4). The substrates showed a higher yield; however, the wide range of both substrates and Surber samples would preclude the assumption of any significant differences without a more intensive sampling by both methods.

Extremely high flows occurred just prior to the final (spring, 1968) sampling run. As a result, scouring appears to have had a significant effect on the results of the sampling run, masking the normal differences between sampling stations and sites (see Tables 1, 2 and 3). Due to the high flows, the substrates were not lifted until about three weeks after the planned termination point.

Efforts to measure the effects of emergence were also stymied by the high flows. The high flows occurred during the prime emergence periods in April and May and precluded any quantitative measurement of emergence.

Qualitatively, observations suggest that emergence may have little effect on the production ratios between acid and clean areas. However, it would require an additional study of the emergence period under considerably less stringent conditions to gain a clear picture of the effects of emergence on this type of study.

The flow data shown in Table 1 for the May, 1968 period are not indicative of the highest flows reached during this period. They are representative only of the flows at a period when it was physically possible with a degree of safety to measure them. Observations of the stream indicated that flows attained considerably higher values than the ones recorded.

Chemical data from the stream areas studied were consistent throughout the study as shown in Table 1.

It is interesting to note that even in extremely high flows, the acid stations maintained an amazing consistency of quality. The pH never rose above 3.0 and the total acidity never decreased below 150 ppm. The shallow drift mines with their fractured roofs and floors are likely responsible for this.

As shown in Figure 1, numerous mines are found in the drainage area. Only a few consistently discharge into the stream. However, all mines may be assumed to be constantly oxidizing pyrites to form sulfuric acid. With increased surface run off and drainage, the "dormant" mines began discharging acid water via surface and subsurface drainage into the stream. Thus, the normal dilution effect of increased flows is minimized by the additional acid load.

This appears to be true for the highest flows observed in the spring of 1968.

Another interesting observation, in relation to the acid portions, is the consistently high D. O. (Dissolved Oxygen). The fact that much of the material is already oxidized, as indicated by the small residuals of ferrous iron (shown in Appendix, Table A1), would be a reasonable explanation for the phenomenon. This is especially true when one takes into account the additional oxidative and aeration capabilities of the numerous riffles found in this section of stream.

The alkaline portions of the stream follow a much more normal sequence of chemistry in relation to flows. Decreased alkalinity tends to occur with increased flows due to surface runoff (Table 1). The D. O. was within normal range for this type of stream. Little D. O. sag was observed during either high or low flow.

At some of the alkaline sites during high flows, the total acidity exceeded the total alkalinity. However, it was not free acidity and the stream remained alkaline in nature. The pH remained between 6.0 and 7.0. It seems reasonable to assume that the free alkalinity and basic water were unchanged by the bound acidity.

It is the writer's view that this part of the experiment is worth pursuing if someone can devise a sampling device capable of withstanding the rigors of this type of situation.

Benthic Fauna

Acid mine drainage pollution is toxic. The type of community which exists in the acid situation is composed of organisms which have the most tolerance to the toxic conditions prevalent in the water chemistry. Typically, the diversity of a natural aquatic community is drastically reduced, often decimated, with the introduction of a severe toxicant into the water. If sufficient food, etc. are available, the organisms present in the community may develop large populations with the fauna operating on a highly simplified predator-prey relationship. The phenomena is well documented in the pollution literature with Dinsmore (1968), Lackey (1939), and others amply demonstrating it for the acid mine drainage situation.

The diversity index concept was used by Dinsmore (1968) to aid in the clarification of the phenomena discussed above. The index is useful in clarifying the community-organism population relationships in the acid situation.

Unlike some toxic conditions the acid mine drainage condition has a two fold action. Organisms may be removed from the community due to the direct toxic effects or they may be removed by the elimination of water quality parameters necessary for their existence. For instance, the large amount of free sulfuric acid available in the acid mine drainage environment effectively removes calcium from some types of usage by organism of the community, i.e., protective coverings. Thus, organisms such as snails, clams, and crayfish may be effectively removed by the absence of available calcium for their special needs rather than any direct toxicity.

Parson (1968) found the number of benthic species in continuously polluted areas was small in comparison with the total number of individuals. Portions of the stream sporadically affected by acid mine drainage had a community composition similar to the surrounding streams according to Parsons. The data he presented showed five genera from three families composing the benthic community in continuously polluted areas; 10 benthic genera from 6 families existing in one sporadically polluted area; a benthic community of 16 genera from 9 families present in the "normal" unaffected area.

The chemical data presented by Parsons (1968) suggests that the degree of acid mine drainage pollution in the stream he studied is similar to the degree of pollution in Big Run. In Big Run 3 to 4 families were generally found in the acid portion of the stream and from 8 to 12 families in "clean" portions of the stream (Tables 4 - 6).

Dinsmore's (1968) study of Tom's Run includes estimates of biomass and diversity indices. His study shows a decrease in the diversity index figure with increasing acidity. The data for biomass is somewhat more variable. However, his data generally suggest a similar biomass production rate for both acid and alkaline streams. According to Dinsmore's discussion, the variability of the biomass in the polluted sections of the stream is likely due to unstable substrate. In addition to acid mine drainage, Tom's Run is influenced

Table 4. Organisms collected, September, 1967.

Group	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
DIPTERA								
Chironomidae	X	X	X	X	X	X	X	X
Empedidae		X						
Helpidae		X	X	X			X	X
Tipulidae		X	X					
TRICHOPTERA								
Hydropsychidae	X	X	X	X				
Phryganeidae			X			X	X	X
Psychomyiidae	X	X						
Rhycophilidae		X						
EPHEMEROPTERA								
Baetidae		X						
Heptageneiidae	X					X		
ODONATA								
Agrionidae		X						
Gomphidae	X							
MEGALOPTERA								
Corydalidae		X						
Sialidae	X	X	X	X	X	X	X	X
COLEOPTERA								
Dytiscidae					X		X	
Elmidae	X	X						
LEPIDOPTERA								
Pyralididae					X			
CRUSTACEA								
Astacidae	X	X	X					
Copepoda		X						
Daphnia							X	
Ostracoda			X					
OLIGOCHAETA	X	X	X	X				

Table 4--Continued.

Group	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
NEMATODA	X	X	X	X				
PELYCYPODA								
Sphaeridae			X	X				
GASTROPODA								
Pulmonata		X						
PLATYHELMINTHES		X	X					
Salamander (redbacked)	X	X						
Unknown			X					

Table 5. Organisms collected, February, 1968.

Group	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
DIPTERA								
Chironomidae		X	X	X		X	X	X
Empedidae		X						
Heleidae		X	X	X				
Tabanidae		X		X				
Tipulidae		X	X	X				
TRICHOPTERA								
Hydropsychidae		X	X	X				
Psychomyiidae		X						
Phryganeidae			X	X				
PLECOPTERA								
Perlodidae		X		X				
EPHEMEROPTERA								
Baetidae		X						
Ephemeridae			X					
Heptageneiidae		X		X				
ODONATA								
Agrionidae				X				
MEGALOPTERA								
Corydalidae		X						
Sialidae		X		X		X	X	X
COLEOPTERA								
Dyliscidae			X					
Elmidae		X						
LEPIDOPTERA								
Pyralididae				X			X	
CRUSTACEA								
Ascellidae		X						
Astacidae		X		X				
Hydrocarira		X						
Unknown			X					

Table 5--Continued.

Group	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
OLIGOCHAETA		X	X	X				
NEMATODA		X						
PELYCYPODA								
Sphaeridae			X	X				
PLATYHELMINTHES			X					

Table 6. Organisms collected, June, 1968.

Group	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
DIPTERA								
Chironomidae	X	X	X	X	X	X	X	X
Heleidae	X	X	X	X		X		
Tabanidae		X	X					
Tipulidae		X	X	X				
Unknown		X				X		X
TRICHOPTERA								
Hydropsychidae	X	X	X	X		X		
Phryganeidae		X						
PLECOPTERA								
Perlodidae		X	X					
EPHEMEROPTERA								
Baetidae	X	X	X					
ODONATA								
Gomphidae	X							
MEGALOPTERA								
Corydalidae		X						
Sialidae	X	X	X	X	X	X	X	X
COLEOPTERA								
Dytiscidae					X	X		
Elmidae	X	X	X					
Psephenidae	X							
LEPIDOPTERA								
Pyralididae			X			X		X
CRUSTACEA								
Ascellidae		X						
Astacidae	X			X				
OLIGOCHAETA	X	X		X				

Table 6--Continued.

Group	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
NEMATODA		X		X				
PELECYPODA								
Sphaeridae			X	X				
Unknown								X

by brines and other types of drainage from old gas and oil wells. These added sources of pollution are likely to change the characteristics of the biota in comparison with a stream such as Big Run, affected solely by acid mine drainage. The degradation caused by acid mine drainage in Dinsmore's study of Tom's Run is not as severe as the degradation of Big Run in the current study. Only one station (21) in the Tom's Run study approaches the water quality of the acid section of Big Run.

Even with the differences discussed above, Dinsmore's data tend to support the findings of this study. Tables (2 to 6) and Appendix Tables (A2 and A5) show that the initial production and diversity in the fall of 1967 is similar to that described by Dinsmore. The diversity also closely follows the descriptive studies of Parsons (1968).

The winter sampling of this study shows a significant increase in standing crop in the "clean" portion of the stream while a decrease in production is found in the "acid" portions of the stream. Field observations suggested that periods of relatively high flows occurred during this period.

It appears that the "yellow bouy", a flocculent composition of ferric hydroxide and sulfate, described by Dinsmore (1968) had created an extremely unstable shifting substrate, has the same effect in Big Run. The riffle areas tend to be stained with a yellowish-red crust with little sediment, while the pools tend to have leaves and debris, normal silt, and a mixture of the "yellow bouy" type flocculant material. As Tables 2 and 3 and Appendix Tables A2-A4 indicate, biomass in the pool areas is considerably more stable than the riffle areas of the acid section. The riffle populations were almost annihilated, apparently by the scouring effect. Pools, on the other hand, tend to have a relatively constant standing crop during the winter season. Since the population is composed primarily of Chironomidae with Sialidae as predators, it seems reasonable to expect the riffle areas to be decimated in high flows. Both groups of organisms are well adapted to pool conditions and poorly adapted to survive the extreme velocity fluctuations that riffles of a small stream like Big Run tend to have during late fall, winter, and early spring in this area.

Since they seem to be the most tolerant to acid mine drainage, the Chiromidae and Sialidae will tend to inhabit all available habitats open to them. Those habitats for which they are least adapted leave them extremely vulnerable to the physical and other changes which normally occur.

The "clean" areas, on the other hand, tended to show a greater production than the acid areas. Populations in the clean areas also tend to change character. In general, it seems that the clean areas have population structures well adapted to the task of maintaining stability in face of fluctuating conditions. The "clean" communities tend to be highly stable and require extremely adverse conditions to decimate them.

Data from the spring of 1968 (Tables 1 - 4 and 7) shows what happens in the face of extremely adverse conditions. As discussed above, the spring of 1968 had exceptionally severe and prolonged condition of high water. This condition caused severe reduction in all populations, both acid and alkaline, within the stream. The differences in production between riffle or pool, acid or alkaline, can not be discerned statistically. An interesting feature of the phenomenon is that while the populations of the pools in the acid section were reduced to sparse levels by the high flows, the populations of the riffles were not reduced to a significantly higher degree than in the winter sampling period. Another interesting feature is that the "clean" riffles and pools tended to be uniform in population and of levels comparable to the acid sections. This phenomenon suggests that under conditions of extreme flows there is a base level of population density which is not reduced regardless of other limiting factors. This seems to be a good subject for additional study.

The differences in diversity between "acid" and "clean" or alkaline stations were also reduced by high flows. Thus, the exceptional conditions of the high flows masked the real differences between acid and alkaline areas of the stream.

Surber sampling conducted during this period reflected the same pattern, suggesting a similar standing crop for the natural substrate under these conditions.

This tends to confirm the effectiveness of the artificial substrate as compared with the Surber for a sampling device for measuring the real benthic standing crop under conditions of this study.

The sampling in the fall of 1967 suggested that under conditions of low flow the biomass in the acid and alkaline portions of the stream tends to be similar. The riffle areas in the "acid" portions stream are unable to maintain a stable biomass under fluctuating conditions while the riffle of "clean" alkaline portions of the stream may actually increase biomass. Biomass in the acid pools remained constant under fluctuating conditions while biomass in alkaline pools is apparently increasing according to the winter 1968 sampling. Since the loss of one site in an alkaline pool occurred during this period, it is not felt that enough data exist to make a definite conclusion in this regard.

The exceptionally high flows of the June 1968 sampling run mask the differences between acid and alkaline portions of the stream found earlier in the sampling run and seem to reduce all portions of the stream to a common denominator.

Some variation from the expected norm of high biomass in riffle areas and low biomass in pools occurred during the study. These differences seemed minor and may be due to the expected anomolies in field situations. It is possible with very small streams of this type that the pool riffle distinction is not as clear-cut as in much larger streams.

Fish studies on the alkaline sections of the study area were conducted at the conclusion of the study. An effort, which was unsuccessful, was made to estimate population by the mark and recapture method. The species, number, size and weight of the fish collected are shown in Appendix Tables A12-A15. At sites 1 and 2, the first collection which was marked but not kept, contained a great many suckers and the second collection contained a large number of largemouth bass. Stonerollers and darters were the other main fish collected. The composition of the fish population suggests that the benthic biomass may be cropped to a large degree by the fish in the stream. It seems reasonable that cropping by fish may have a significant influence on the apparent relationships discussed in this paper and should be investigated further.

CONCLUSIONS AND RECOMMENDATIONS

Under normal low flow conditions, biomass relationships in alkaline and acid portions of the stream tend to be quite similar. The acid riffle community seems less flexible and tends to be unstable in the face of rapidly changing conditions such as increased flows. Excessively high flow conditions tend to reduce the biomass to a universal minimum level throughout all portions of the stream, although additional studies are required for verification.

Fish populations and the resultant cropping on the benthic biomass may have had a significant effect on the relationships discussed in this paper. Additional studies are required to draw definitive conclusions regarding fish and their effects.

An additional relationship which should be looked into further is the biomass relationship between pool and riffle in a small stream such as those discussed in this paper.

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APPENDIX

Table A1. Summary of chemical and physical data by station.

Flow and Chemistry Data Summarized	Sites 1 & 2	Sites 3 & 4	Site 5	Site 6	Sites 7 & 8
Flow (cfs)					
Maximum	83.87 est. ± 20.41	25.73	36.81	59.12 est. ± 22.07	71.00 est. ± .25
Date	5/19/68	5/19/68	5/19/68	5/19/68	5/19/68
Minimum	4.91	.22	1.75	3.86	5.52
Date	8/17/68	8/17/68	8/17/68	8/17/68	8/17/68
Average	25.78	7.87	15.45	20.06	22.86
pH					
Maximum	7.6	7.0	3.6	3.3	3.2
Date	11/11/67	11/14/67	11/11/67	11/11/67	11/11/67
Minimum	7.4	6.3	2.7	2.5	2.4
Date	8/27/67 & 5/5/68	8/17/68	8/17/68	5/19/68	5/19/68
Average	7.5	6.6	3.14	2.9	2.8 (4)
Conductivity (Mho)					
Maximum	900	440	1500	1650	1600
Date	8/27/67	8/17/68	9/17/67	9/9/67	9/9/67
Minimum	280	220	280	580	540
Date	5/19/68	5/19/68	5/19/68	5/19/68	5/19/68
Average	555	339 (340)	946 (950)	1196 (1200)	1191 (1200)

Table A1--Continued.

Flow and Chemistry Data Summarized	Sites 1 & 2	Sites 3 & 4	Site 5	Site 6	Sites 7 & 8
D. O. (ppm)					
Maximum	12.3	12.0	13.6	12.6	12.9
Date	11/17/67	11/18/67	11/18/67	11/18/67	11/18/67
Minimum	9.3	7.6	10.4	10.2	9.4
Date	8/17/68	8/17/68	8/17/68	8/17/68	8/17/68
Average	10.8	10.3	11.7	11.4	11.3
Hardness (ppm)					
Maximum	446	274	635	660	655
Date	8/17/68	8/17/68	8/17/68	8/17/68	8/17/68
Minimum	274	122	192	210	164
Date	5/5/68	5/19/68	5/19/68	5/19/68	5/19/68
Average	369.75 (370)	199.6 (200)	449.6 (450)	468.4 (468)	460.6 (461)
Cold Acidity (mg)					
Maximum			189.0	372.0	353.0
Date			8/17/68	8/17/68	8/17/68
Minimum			16.0	35.5	27.0
Date			5/19/68	5/19/68	5/19/68
Average			96.84 (.8)	171.7	176
Total Acidity (mg)					
Maximum	13	60	460.0	537	462
Date	5/19/68	5/19/68	9/17/67	9/9/67	8/17/68
Minimum	0	3.12	55.0	116.5	85.5
Date	8/67, 11/67, & 8/68	11/14/67	5/19/68	5/19/68	5/19/68
Average	4.0	26.6	197.5	287.0	271.5

Table A1--Continued.

Flow and Chemistry Data Summarized	Sites 1 & 2	Sites 3 & 4	Site 5	Site 6	Sites 7 & 8
Total Alkalinity (mg)					
Maximum	109.0	54.0	0	0	0
Date	8/17/68	5/19/68			
Minimum	11.0	13.0	0	0	0
Date	5/19/68	9/17/68			
Average	56.5	31.3	0	0	0
Sulfates (mg)					
Maximum	330	191	650.0	725	633
Date	8/27/67	11/14/67	9/17/67	9/9/67	9/9/67
Minimum	205	16.8	92.5	150.0	114
Date	5/8/68	5/19/68	5/19/68	5/19/68	5/19/68
Average	269.2	112.0	328.1	404	387.9
Manganese (mg)					
Maximum	0.8	1.20	2.7	2.8	4.0
Date	5/8/68	5/19/68	5/5/68	8/17/68	8/17/68
Minimum	0.4	.13	0.6	.75	.4
Date	8/17/68	5/19/68	5/19/68	5/19/68	5/19/68
Average	0.6	.52	1.76	1.74	1.90

Table A1--Continued.

Flow and Chemistry Data Summarized	Sites 1 & 2	Sites 3 & 4	Site 5	Site 6	Sites 7 & 8
Total Iron (mg)					
Maximum	1.6	1.53	9.0	17.4	16.8
Date	5/19/68	5/19/68	9/17/67	8/17/68	8/17/68
Minimum	<0.1	<0.1	2.63	7.0	2.0
Date	11/67, 5/5/68 & 8/68	9/17/67	5/19/68	9/9/67	9/9/67
Average	0.2	.4	5.6	11.1	9.3
Ferrous Iron (mg)					
Maximum	0	.2	.82	5.3	2.72
Date		5/19/68	8/17/68	8/17/68	5/5/68
Minimum	0	0	<.1	.5	0
Date		8/17/68 11/14/67 9/17/68	11/11/67 5/5/68 5/19/68	9/9/67	9/9/67
Average	0	.05	.26	2.2	1.50

Table A1--<u>Continued</u>.

Temperature (^oC)	Sites 1 & 2	Sites 3 & 4	Site 5	Site 6	Sites 7 & 8
Dates					
8/27/67	26				
9/9/67				23	23
9/17/67		(20)	(14.5)		
11/11/67	9	8.2	10.5	11	11
11/14/67					
2/6/68	4				
2/10/68			4	4	4
2/24/68		2			
5/5/68	10.5	11	10.5	9.5	9.5
5/19/68		11	10.5	10.0	10
8/17/68	24.5	24	16	15.5	17
Average	14.8	12.9	11	12.2	12.4

Table A2. September, 1967 Macrofaunal weights (Mg/sq. ft.).

Site No.		No. Values	Mean	D^2 Var.	Std. Dev. D	Coef. Var.	Std. Error
1	With Crayfish	3.000	2.109	0.285	0.533	0.252	0.307
	Without Crayfish	3.000	0.347	0.045	0.212	0.610	0.122
2	With Crayfish	3.000	1.847	3.090	1.757	0.951	1.014
	Without Crayfish	3.000	0.395	0.027	0.164	0.414	0.094
3	With Crayfish	4.000	0.668	0.200	0.447	0.669	0.223
	Without Crayfish	4.000	0.472	0.256	0.505	1.069	0.252
4	With Crayfish	3.000	0.306	0.197	0.443	1.447	0.225
	Without Crayfish	3.000	0.055	0.000	0.000	0.000	0.000
5		3.000	0.564	0.301	0.548	0.971	0.316
6		3.000	0.936	0.489	0.699	0.746	0.403
7		3.000	1.071	0.101	0.317	0.295	0.183
8		3.000	0.904	0.205	0.452	0.500	0.260

Table A3. February, 1968 Macrofaunal weights (Mg/sq. ft.).

Site No.	No. Values	Mean	D^2 Var.	Std. Dev. D	Coef. Var.	Std. Error
1						
2	3.000	2.257	3.939	1.984	0.879	1.145
3	4.000	1.253	0.875	0.935	0.746	0.467
4	3.000	2.842	2.785	1.668	0.586	0.936
5						
6	2.000	0.829	0.017	0.310	0.156	0.091
7	3.000	0.043	0.001	0.031	0.720	0.017
8	2.000	0.557	0.000	0.000	0.000	0.000

Table A4. June, 1968 Macrofaunal weights (Mg/sq. ft.).

Site No.		No. Values	Mean	D^2 Var.	Std. Dev. D	Coef. Var.	Std. Error
1							
2		3.000	0.129	0.004	0.063	0.488	0.036
3		3.000	0.597	0.303	0.550	0.921	0.317
4		3.000	0.071	0.009	0.094	1.323	0.054
5		2.000	0.027	0.001	0.031	1.148	0.021
6	W/O 17A	3.000	0.063	-0.001	0.031	0.492	0.017
	With 17A	4.000	0.051	0.000	0.000	0.000	0.000
7		2.000	0.007	0.007	0.007	2.000	0.007
8		3.000	0.095	0.002	0.044	0.463	0.025

Diversity Index

The Diversity Index is one adapted from Wilhm (1967) and used by the Federal Environmental Protection Agency, Wheeling Office. The Index is

$$d_2 = S\text{-}1/\ln\ (\#)$$

where S is the total number of groups and ln (#) is the natural log of the total number of individuals.

On the tables dealing with Diversity Index several symbolic designations are found:

$\overline{N}$ is the average number of individuals per group;

σ^2 is the variance of individuals per group;

σ is the standard deviation of individuals per group.

In the average Diversity Index per site the following terms are used:

Mean is the mean average index/site;

Var. is the variance of the mean average index;

S.D. is the standard deviation of the mean average index.

Table A5. Artificial substrate diversity index for 9/67.

	Station Number	Date	$\bar{N}$	σ^2	σ	d_2
Site 1	1	9/67	10.875	520.125	22.806	1.567
	2	9/67	12.000	735.250	27.116	1.709
	3	9/67	6.667	209.250	14.465	1.954
Site 2	4	9/67	66.000	10810.250	103.972	1.253
	5	9/67	8.214	398.335	19.958	2.740
	6	9/67	24.091	3355.291	57.925	1.792
Site 3	7A	9/67	50.000	20420.000	142.899	1.309
	7B	9/67	50.000	10273.000	101.356	0.724
	8	9/67	3.250	13.929	3.732	2.148
	9	9/67	3.250	9.357	3.059	2.148
Site 4	10	9/67	3.250	14.917	3.862	1.170
	11	9/67	3.333	11.467	3.386	1.669
	12	9/67	3.000	5.000	2.236	1.971
Site 5	13	9/67	491.333	675232.35	821.725	0.741
	14	9/67	139.000	47407.000	217.732	0.332
	15	9/67	130.333	37509.333	193.673	0.335
Site 6	16	9/67	64.250	7615.583	87.267	0.541
	17	9/67	167.000	23762.000	154.149	0.172
	18	9/67	38.667	3817.353	61.784	0.421

Table A5--Continued.

	Station Number	Date	$\bar{N}$	σ^2	σ	d_2
Site 7	19	9/67	356.000	475394.01	689.488	0.413
	20	9/67	372.333	378981.3	615.618	0.290
	21	9/67	353.000	349957.0	591.572	0.287
Site 8	22	9/67	55.667	2970.33	54.501	0.390
	23	9/67	316.333	247632.3	497.623	0.292
	24	9/67	110.000	19984.0	141.365	0.345

Table A6. Artificial substrate diversity index for 2/68.

	Station Number	Date	$\overline{N}$	σ^2	σ	d_2
Site 2	4	4/68	8.923	172.910	13.150	2.524
	5	2/68	29.583	2269.356	47.638	1.873
	6	2/68	23.500	1320.091	36.333	1.950
Site 3	7A	2/68	6.375	89.125	9.441	1.780
	7B	2/68	25.571	2237.952	47.455	1.157
	8	2/68	3.333	5.467	2.338	1.669
	9	2/68	22.250	1644.917	40.558	0.656
Site 4	10	2/68	4.300	24.456	4.945	2.393
	11	2/68	10.545	246.073	15.687	2.104
	12	2/68	8.875	155.839	12.484	1.642
Site 6	16	2/68	89.000	288.000	16.970	0.193
	18	2/68	43.000	800.000	28.284	0.225
Site 7	19	2/68	6.500	24.500	4.950	0.390
	20	2/68	15.000	200.000	14.142	0.294
	21	2/68	30.000	1152.000	33.941	0.244
Site 8	22	2/68	88.500	5304.500	72.832	0.193
	23	2/68	31.000	679.000	26.058	0.441

Table A7. Artificial substrate diversity index for 6/68.

	Station Number	Date	$\overline{N}$	σ^2	σ	d_2
Site 2	4	6/68	18.667	2082.000	45.629	1.561
	5	6/68	10.667	284.250	16.860	1.752
	6	6/68	141.928	11.913		1.755
Site 3	7A	6/68	9.286	406.571	20.164	1.437
	7B	6/68	6.833	72.167	8.495	1.346
	8	6/68	12.833	585.367	24.194	1.511
Site 4	10	6/68				
	11	6/68	4.000	35.200	5.933	1.573
	12	6/68				
Site 5	14	6/68	3.500	12.500	3.536	0.514
	15	6/68	2.667	4.333	2.082	0.962
Site 6	16	6/68	7.333	72.333	8.505	0.647
	17A	6/68	0.000	0.000	0.000	0.000
	17	6/68	3.800	17.700	4.207	1.358
	18	6/68	4.250	34.250	5.852	1.059
Site 7	20	6/68	0.000	0.000	0.000	0.000
	21	6/68	5.000	18.000	4.243	0.434

Table A7--Continued.

	Station Number	Date	$\overline{N}$	σ^2	σ	d_2
Site 8	22	6/68	3.833	15.367	3.920	1.595
	23	6/68	7.000	8.000	2.828	0.379
	24	6/68	3.500	0.500	0.707	0.514

Table A8. Surber sampler diversity index for 6/68.

	Station Number	Date	$\bar{N}$	σ^2	σ	d_2
Site 1	1	6/68	0	0	0	0
	2	6/68	2.200	2.700	1.643	1.668
	3	6/68	2.333	5.250	2.291	2.628
Site 2	4	6/68	7.000	139.143	11.796	1.739
	6	6/68	4.000	8.000	2.828	0.481
Site 4	10	6/68	0.000	0.000	0.000	0.000
	11	6/68	0.000	0.000	0.000	0.000
	12	6/68	0.000	0.000	0.000	0.000
Site 6	16	6/68	0.000	0.000	0.000	0.000
	17	6/68	2.667	4.333	2.082	0.962
Site 7	19	6/68	0.000	0.000	0.000	0.000
	21	6/68	0.000	0.000	0.000	0.000

Table A9. Artificial substrate average diversity index/site for 9/67.

	Site Number	Date	Mean d_2	Var.	S.D.
Sta. 1,2,3	1	9/67	1.743	0.0382	0.196
Sta. 4,5,6	2	9/67	1.928	0.567	0.752
Sta. 7A,7B,8,9	3	9/67	1.583	0.484	0.696
Sta. 10,11,12	4	9/67	1.603	0.164	0.405
Sta. 13,14,15	5	9/67	0.313	0.001	0.034
Sta. 16,17,18	6	9/67	0.378	0.035	0.188
Sta. 19,20,21	7	9/67	0.328	0.005	0.073
Sta. 22,23,24	8	9/67	0.342	0.002	0.050

Table A10. Artificial substrate average diversity index/site for 2/68.

	Site Number	Date	Mean d_2	Var.	S.D.
	2	2/68	2.116	0.127	0.356
Sta. 4,5,6					
	2	2/68	1.912	0.003	0.054
Sta. 5,6					
	3	2/68	1.316	0.267	0.517
Sta. 7A,7B,8,9					
	4	2/68	2.046	0.143	0.379
Sta. 10,11,12					
	5				
Sta. 13,14,15					
	6	2/68	0.209	0.000	0.022
Sta. 16,18					
	7	2/68	0.303	0.004	0.063
Sta. 19,20,21					
	8	2/68	0.317	0.031	0.175
Sta. 22,23					

Table A11. Artificial substrate average diversity index/site for 6/68.

	Site Number	Date	Mean d_2	Var.	S.D.
	2	6/68	1.690	0.012	0.111
Sta. 4,5,6					
	3	6/68	1.432	0.007	0.0823
Sta. 7A,7B,8					
	4	6/68	1.573	-	-
Sta. 11					
	6	6/68	0.766	0.346	0.588
Sta. 16,17A,17,18					
	6		1.021	0.128	0.351
Sta. 16,17,18					
	7		0.217	0.094	0.307
Sta. 20,21					
	8		0.829	0.444	0.666
Sta. 22,23,24					

Table A12. Surber average diversity index/site for 6/68.

	Site Number	Date	Mean d_2	Var.	S.D.
	1	6/68	1.456	1.78	1.337
Surber 1,2,3					
	2	6/68	1.110	0.791	0.890
Surber 4,6					
	4	6/68	0.000	0.000	0.000
Surber 10,11,12					
	6	6/68	0.481	0.462	0.680
Surber 16,17					

Table A13. Sites 1 and 2 fish collections 7/20/68.

Species	Number	cm Size	gm wt.	Number Clipped	wt-gm Clipped
Largemouth Bass	1	12	18.96	0	-
Micropterus salmoides	1	10	12.90	0	-
	1	9	7.81	0	-
Bluegill	1	6	2.55	0	-
Lepomis macrochirus					
Common sucker	1	12	20.34	0	-
Catastomus commersoni	1	9	9.15	0	-
	1	8	5.9	0	-
Stoneroller	2	10	25.60	2	25.60
Capostoma anomalum	1	9	8.13	1	8.13
	3	8	17.01	2	11.53
	6	7	28.00	3	14.55
	3	6	9.53	0	-
Creek Chub	1	8	6.57	0	-
Semotilus atromaculatus	1	7	4.22	0	-
Redside dace	2	6	3.45	0	-
Phoximus elongatus	2	5	2.54	0	-
Bluntnose minnow	2	5	3.26	0	-
Pimephales notatus					
Fantail darter	1	5	1.46	1	1.46
Etheostoma flabellare	1	4	0.78	1	0.78

Table A14. Sites 1 and 2 fish collections 7/27/68.

Species	Number	cm size	gm wt.
Largemouth bass	1	14	30.55
Micropterus salmoides	1	13	23.45
	1	12	22.45
	1	11	16.08
	3	10	29.51
	1	9	7.94
Bluegill			
Lepomis macrochirus	1	5	2.15
Common sucker			
Catastomus commersoni	2	21	171.00
	1	20	85.61
	1	18	70.65
	3	14	80.72
	4	13	78.27
	1	11	12.42
	4	10	42.72
	1	8	5.04
Stoneroller	1	12	24.69
Capostoma anomalum	1	10	10.25
	1	9	8.38
	4	8	26.45
	8	7	35.20
	4	6	11.95
Creek chub			
Semotilus atromaculatus	1	7	4.05
	1	<2.5	0.15

Table A14--Continued.

Species	Number	cm size	gm wt.
Fantail darter *E. flabellare*	1	6	1.89

Table A15. Sites 3 and 4 fish collections 7/27/68.

Species	Number	cm size	gm wt.
Bluegill	5	2	3.43
L. macrochirus			
Spotted sucker	1	8	4.88
Minytrema melanops			
Creek chub	1	11	16.31
S. atromaculatus	1	9	8.85
	1	7	3.12
	1	6	2.70
Fish Collection 7/20/68			
Bluegill	1	4	1.21
L. macrochirus			
Common sucker	1	10	11.80
C. commersoni	1	8	5.32
	1	3	0.26
Creek chub	1	7.0	5.11
S. atromaculatus	2	<2.5	0.27