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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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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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your patience and understanding during a time in my life when it was needed most.

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 small drainage basin (14.61 km) 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, Flatfoot Creek was investigated for water quality, benthic macroinvertebrates, fish populations and the feeding requirements of the fishes.

A physio-chemical analysis was made of Flatfoot Creek. With the exception of five parameters, the creek met guidelines set by State and Federal agencies. The most important limiting factors of the tailwaters were low dissolved oxygen (1.0 mg/l) and high total solids (652 mg/l).

The benthic populations ranged from a low species diversity (d = 0.36) at the tailwaters to the highest value (d = 3.04) at the headwaters. Dipteran larvae and aquatic oligochaetes inhabited the lower reaches while ephemeropterans, plecopterans, and trichopterans inhabited the upper reaches. No rare, threatened or endangered species of benthic macroinvertebrate was found in the study area.

The fishes of Flatfoot Creek were dominated by forage species (e.g. Emerald Shiner, Striped Shiner and Creek Chub). The rough fishes 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.

Stomach analysis showed a large portion of the fish populations to be dependent upon benthic organisms, to the extent that fishes would not inhabit the area unless sufficient benthic populations were present.

Recommendations were made to the U. S. Army Corps of Engineers for disposal of dredge material from the canal they propose to construct. The author feels uniform disposal over the bottomlands of Flatfoot Creek with the stream re-channeled will have the least detrimental effect on the environment. Ecological requirements such as pool and riffle habitats with proper substrate material will allow benthic and fish populations to populate the man-made portion of the stream.

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CHAPTER I

INTRODUCTION

The Gallipolis Locks and Dam project is located on the Ohio River at Mile 279.2 near Apple Grove, West Virginia. Constructed as a navigational structure, the project became operational in 1937. The main purpose of this non-navigable 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 has caused costly time delays and accidents during its operation.

Under the Water Resources Development Act of 1976, a series of studies investigated how the navigation problem at the Gallipolis Locks and Dam could be eleviated. Several plans have been developed for the structures modification and/or replacement. The location of Flatfoot Creek is such that construction in the area of the project will have an adverse effect upon this small drainage basin.

The objectives of this study were directed primarily toward the effects upon Flatfoot Creek. Careful review of the plans as proposed by the U. S. Army Corps of Engineers in conjunction with additional data collected outside of this investigation allowed the author to suggest the disposal plan with the least detrimental effects. Data from a tributary of Mud Run were, in particular, necessary in the evaluations.

The five objectives of this study were: (1) to sample and identify the populations of fishes and benthic macroinvertebrates within the Flatfoot Creek drainage basin, (2) to analyze the physical and chemical aspects of the stream for habitat suitability, (3) to identify stomach contents of the fishes in order to evaluate the level of dependence upon aquatic insects as a necessary link in a food chain, (4) to document species composition and relative abundance for baseline data in post-canal comparisons, and (5) to suggest mitigations for possible reduction of impact upon the environment.

CHAPTER II

REVIEW OF THE LITERATURE

When one reviews the literature in aquatic ecology, it can be seen that environmental surveys are evolving from an ecological movement. In the past, little or no regards were given to wildlife and conservation. However, at the same time studies (taxonomical, ecological, physiological) were establishing the roots upon which current environmental assessments are being made.

Taxonomical investigations of fish within West Virginia have been conducted for many years (e.g. Goldsborough, 1908; Raney, 1947). Today the need for these surveys is just as great in assessing the environment prior to and following man's intervention in nature (e.g. pre-impoundment investigation of Twelvepole Creek; Tarter, 1972; post-impoundment of Twelvepole Creek; Goodno, 1974). Authors, including Trautman (1957), Carlander (1969) and Pflieger (1975), are including the ecology and physical tolerances of individual species with their taxonomic works.

Investigators in various fields (e.g. phytoplankton, zooplankton, benthic macroinvertebrates, vegetation, chemistry) have realized that no one area of study can accurately sum up the quality and productivity of the stream biota. The combined effort of many disciplines are required to assess the environment in its present form and especially to predict the impact of stress upon an ecosystem. Predictions of ecological adjustments to extraneous habitat modifications aids to minimize detrimental effects upon the sytem. When modification of nature in the form of construction is required, usually for economic reasons, the environmental impact can be reduced if proper precautions vital to the ecology of the study area are taken.

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. The existing structure, a high-lift, non-navigable dam, was constructed in 1937 as a unit in the Ohio River navigation system. The dam establishes a navigational pool for 41.7 miles (67.1 km) up the Ohio River and 31.1 miles (50.0 km) up the Kanawha River. The project has two parallel locking chambers. The main chamber is 600 feet (183 m) long and 110 feet (33.5 m) wide, the auxillary chamber with the same width is 360 feet (109.8 m) long. The primary purpose of the Gallipolis project was to aid in the transport of bulk materials along the Ohio River by barge. The structure does not serve for any flood control prevention.

Forty-two years after its completion the project has become obsolete and inadequate for todays' demands. Modern tows, although varying in size, often require 1200-foot chambers in order to pass without dividing the barges. The Gallipolis structure is the only navigation project in about 900 miles of the Ohio River which does not have at least one 1200-foot chamber. To compound the problem, the structure was built in a bend in the river. Approaching tows maneuvering toward the lock chambers block the approach of the auxillary chamber. Simultaneous lockages are practically impossible and single lockages are difficult, time consuming and somewhat dangerous during moderate to high water conditions. Consequently, the average waiting time for passage is three hours and another hour for lockage. For this reason, the Gallipolis Locks and Dam has become a bottleneck to barge traffic on the Ohio River.

The Water Resources Development Act of 1976 authorized design studies for modification of the Gallipolis project. Four principal alternatives are being evaluated: (1) a single 1200-foot lock in a canal; (2) double 1200-foot locks in a canal; (3) staged development with an initial 1200-foot canal and provisions for a second; and (4) making necessary repairs on the existing project.

The fourth alternative is the least likely due to the cost-benefits and necessity for improved conditions. An estimated $64 million would be required to rehabilitate the dam and existing lock chambers to provide an extended project life. The existing structure can physically handle 50-63 million tons annually. Short-range forecasts indicate a traffic level of approximately 55-60 million tons annually by 1985. The structure would therefore be over capacitated in seven to eight years.

The other three plans include the digging of a bypass canal. The canal would be about 1.7 miles (2.7 km) long and would essentially straighten the bend in the river. The canal would vary in width from about 200 feet (61.0 m) to 500 feet (152.5 m) depending upon the number of chambers required. Projections indicate that any of the three plans will allow for increased river traffic over the 50-year project life. Costs will range from 170 to 213 million dollars.

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.

In the event any of these plans are chosen, devastating effects upon the environment will occur as is normally expected with projects of this scale. Due to increased barge traffic, impacts on the Ohio River are currently being assessed. This thesis is a part of environmental field studies conducted on Flatfoot Creek and Mud Run in the hopes that through planning a better environment can be maintained.

CHAPTER III

DESCRIPTION OF THE STUDY AREA

Gallipolis Locks and Dam

The Gallipolis Locks and Dam is located on the Ohio River at Mile 279.2 below Pittsburgh. Constructed as a navigational structure, 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 construction of the Gallipolis Dam eliminated locks and dams numbers 24, 25 and 26 on the Ohio River and numbers 9, 10 and 11 on the Kanawha River. The structure was built in a bend of the river so that access to both chambers is restricted by the pathway of maneuvering barges. In addition, the short lock chambers delay the passage of tows so that the Gallipolis area is heavily congested with river boat traffic. 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

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

(Figure 1). Flatfoot Creek is approximately 8.2 miles (13.2 km) in length and drains 5.64 square miles (14.61 km). The lower 2.5 miles (4.0 km) transects the Ohio Floodplain, much of which is used for agriculture and pasture land.

Geology

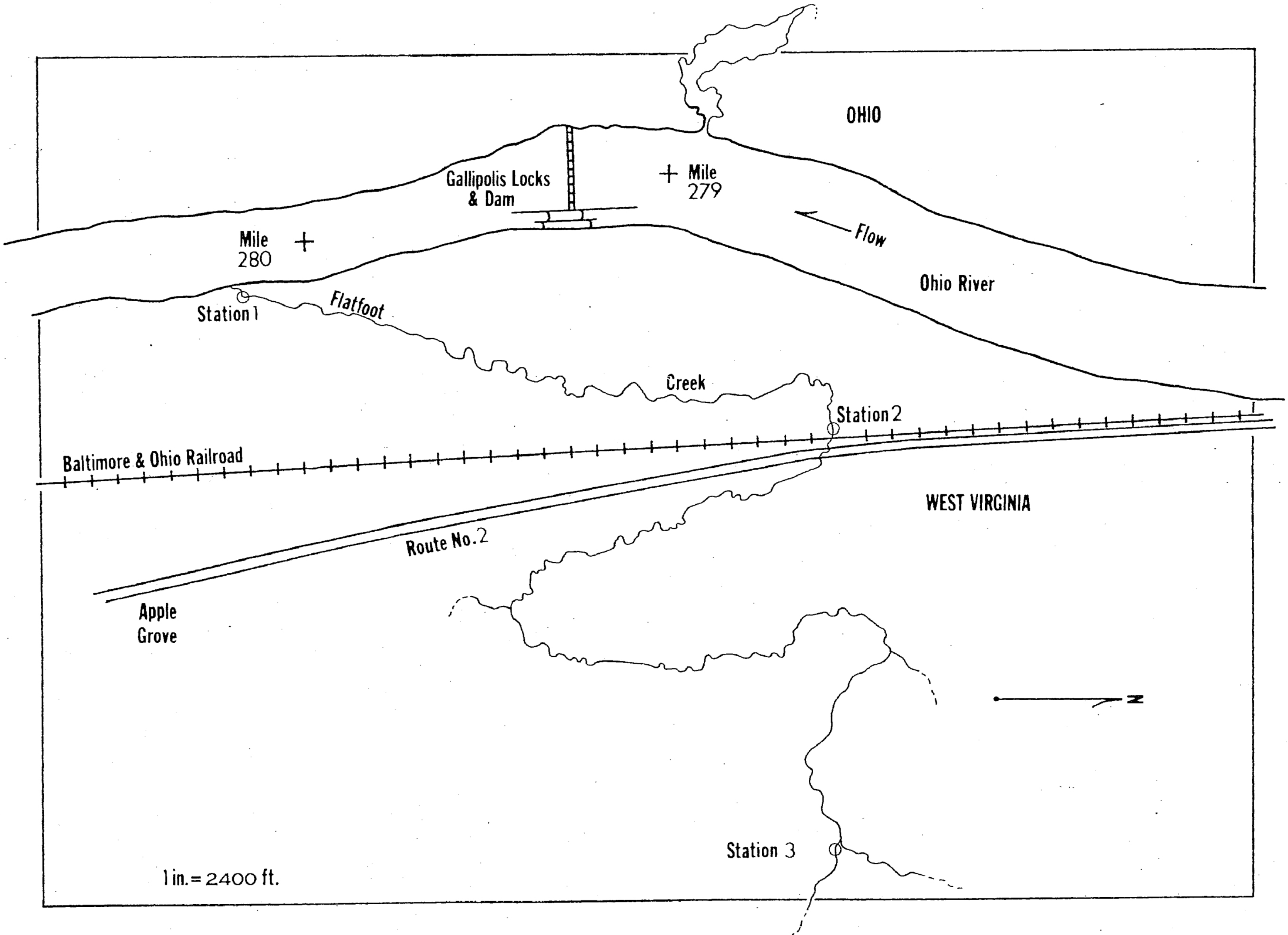
Flatfoot Creek flows into the Ohio River where stream currents become less swift. Geologically speaking, the Ohio River is not cutting a downward channel as rapidly as in the past but has increased erosion laterally widening the valley. The load of sediment once carried in swifter water settled out forming floodplains. Over these plains the river takes a meandering course, cutting in one bank and filling on the other. Broad flat bottoms 30 (9 m) to 40 (12 m) feet above the river were termed "first terrace" by Dr. I. C. White in 1878 (Krebs, 1911). The Gallipolis Locks and Dam was built on one of these terraces.

The original study for the Corps of Engineers established six stations on Flatfoot Creek. Three stations were shosen to typify the various habitats.

Station 1

Station 1 is located at the confluence of Flatfoot Creek with the Ohio River (Figure 1). In the environmental report for the U. S. Army Corps, this station is identified as 1GAL10001. The map coordinates are 82° 11' 07" West Longitude and 38° 40' 07" North Latitude. The banks are steep and tree

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


OHIO
Gallipolis Locks & Dam
Mile 279
Flow
Mile 280
Ohio River
Station 1
Flatfoot
Creek
Station 2
Baltimore & Ohio Railroad
WEST VIRGINIA
Route No. 2
Apple Grove
N
Station 3
1 in. = 2400 ft.

cover is dense. The riparian vegetation is *Acer saccharinum* L. (silver maple), *Celtis occidentalis* L. (hackberry), *Fraxinus pennsylvanica* Marsh. (green ash) and *Juglans nigra* L. (black walnut) (Evans, 1977). Due to seasonal variation in pool levels (normal pool elevation 515 feet msl, Greenup Locks and Dam), this station is subject to frequent inundations. The substrate subject to change from heavy sedimentation, is composed of deep mud, high in sand and silt.

Station 2

Station 2 is located 1.5 miles (2.4 km) above the mouth and 100 yards below the Baltimore and Ohio railroad trestle (Figure 1). In the environmental report for the U. S. Army Corps, (Tarter, 1977), the station identification number is 1GAL10006. 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 riparian vegetation, in order of decreasing abundance, consists of *Platanus occidentalis* L. (sycamore), *Ulmus rubra* Muhl. (slippery elm), *Robinia pseudo-acacia* L. (black locust) and *Acer saccharinum* L. (silver maple). The substrate is composed of loam soil, silt and small gravel.

Station 3

Station 3 is located 4.5 miles above the mouth of the creek and 1 mile east of State Route 2 (Figure 1). The station identification number is 1GAL10005 in the environmental report for the U. S. Army Corps. Map coordinates are 82° 09' 22" West Longitude and 38° 41' 30" North Latitude. The riparian vegetation is composed of *Quercus alba* L. (white oak) and

Roninia pseudo-acacia L. (black locust). This headwater station has a substrate composed of sand, gravel and rocks on a stone bedrock. A large portion of the stream is covered with riffle areas. An old strip mine is located above this area but no adverse effects were noted during the study period.

CHAPTER IV

MATERIALS AND METHODS

Physio-Chemical Methods

Field Collections. Thirty-eight physio-chemical parameters were measured at seven sampling stations by the Water Quality Section of the U. S. Army Corps of Engineers, Huntington District. Seasonal samples were taken on March 7, 18 and 21 (winter), April 28 and 29 (spring), August 20 (summer) and November 3 (fall). Samples for summer and fall consisted only of temperature, dissolved oxygen, pH and specific conductance. An evaluation of all parameters and stations is not made in this study. However, three data sets were used which coincide with the stations selected. In addition to the four parameters already mentioned, total alkalinity (mg/l), calcium (mg/l), magnesium (mg/l), sodium (mg/l), potassium (mg/l), chloride (mg/l), sulfate (mg/l), total, suspended and dissolved solids (mg/l), nitrogen (nitrite-nitrates, Kjeldahl, ammonia) (mg/l), total and dissolved phosphorous (mg/l) and turbidity (Nephelometric Turbidity Units = NTU) were available for analysis.

Insitu Measurements. Temperature, dissolved oxygen, pH and specific conductance were measured on site using a Hydrolab Surveyer (Hydrolab, Austin, Texas). The temperature was recorded in degrees centigrade, dissolved oxygen in milligrams per liter and specific conductance in micro-mhos per square centimeter. Instruments were calibrated prior to field determinations.

Laboratory Analysis. Grab samples were taken at each of the stations and stored in Cubitainers and 400 ml plastic bottles. Samples tested for calcium, magnesium, sodium and potassium were preserved with 10 ml of nitric acid to 1 liter of water. Samples tested for chloride, sulfate, nitrogen (NO_2, NO_3, Kjeldahl, NH_3OH), and total phosphorous were preserved with 5 ml of mercuric chloride to 1 liter of water. The 200 ml samples taken were filtered and preserved with 0.5 ml of mercuric chloride for dissolved phosphorus. Unpreserved samples were taken for total alkalinity, total solids, suspended solids, dissolved solids and turbidity. Laboratory analysis of the chemical parameters was performed by the Reservoir Control Center, Water Quality Section, Ohio River Division Laboratory, U. S. Army Corps of Engineers, Cincinnati, Ohio. Analytical procedures followed are those described in Standard Methods (APHA, 1965). Turbidity samples were analyzed on a Hach 2100A Turbidimeter.

Biological 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.

Samples were rinsed and placed in white enamel pans and salt solution added to aid in the flotation of small insects. They were examined under fluorescent magnifier lamps. Benthic macroinvertebrates were separated from rock and leaf debris by hand picking. Rocks were checked for trichopteran cases and other invertebrates and discarded. Following sorting, each square-foot sample was blotted dried and weighed on a Bosch S-2000 electric, single-pan balance. The animals were preserved in 70 percent ethanol and labeled by station, sub-sample and date until further identification.

Identification of the macroinvertebrates was made under a Bausch and Lomb binocular dissecting microscope and an Olympus compound microscope. Dipteran larvae were mounted on glass slides in euparol. Identification was made at the lowest possible taxon using the following taxonomic keys: Bryce and Hobart (1972), Burks (1953), Edmondson (1959), Flint (1962), Frison (1935), Hissom (1975), Hitchcock (1974), Holsinger (1972), Johannsen (1937), Lewis (1974), Mason (1973), Needham and Needham (1938), Needham and Westfall (1955), Olson (1972), Pennak (1953), Ross (1937, 1944), Tarter (1976) and Usinger (1971). Collections were stored in the West Virginia Benthological Survey at Marshall University.

Statistical Tools. Because each station is environmentally different, the composition of macroinvertebrates will vary in the samples. In order to compare stations, one stream to another or stress upon a population when the composition of fauna is diverse, a method of rating this diversity is necessary. A Shannon-Weaver index of diversity was calculated for each station at each season for comparison. Due to the tremendous number of chironomid larvae, the family level was used in the index of diversity. In order that this group might be properly represented, certain genera were mentioned in the study. In the event of an unfavorable environment, species diversity for some populations are drastically reduced. The species diversity consists of two components (USEPA, 1973; Margalef, 1957): (1) richness of species, and (2) distribution of individuals among the species. The mean diversity ($\bar{d}$), of the Shannon-Weaver function was presented by Lloyd et al. (1968):

$$\bar{d} = \frac{C}{N} (N \log_{10} N - n_i \log_{10} n_i)$$

where C = 3.321928 (conversion factor to base 2); N = total number of individuals; and n_i = total number of individuals in the i^{th} species (see table in their publications). Mean diversity may range from zero to 3.321928 log N. A value generally between 3 and 4 is an unpolluted stream and less than 1, polluted (Wilhm, 1970).

Equitability is a comparison of the number of taxa in a sample (s) with the number of taxa expected (s'). The term "equitability" was coined by Lloyd and Ghelardi (1964) and compared the mean diversity with a maximum. This comparison is based on the distribution from the broken stick model of MacArthur (1957). According to MacArthur's model the distribution will range from few relatively abundant species to increasing numbers of species containing only a few individuals. A table was composed by Lloyd and Ghelardi (1964) which gives equitability values (e) from a population which conforms to the MacArthur model.

$$e = \frac{s'}{s}$$

Provided a large enough sample is taken (usually 100 or more specimens) equitability will range from 0 - 1. This reduced scale is sensitive to slight levels of degradation. Good water quality for example, will usually have an equitability value of between 0.6 - 0.8.

Fishes. With the exception of station 1 in the winter collection, the ichthyofauna was sampled at all the stations for all seasons. High water prevented the collection of a winter sample at station 1. A nylon seine (4 X 15 feet) of ¼-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. The following taxonomic keys were used: Clay (1975), Eddy (1969), Pflieger (1975) and Trautman (1957). Nomenclature follows that of the American Fisheries Society (1970). The fishes were blotted dry, weighed on a Bosch S-2000 electric, single-pan balance and enumerated. Collections were stored in the N. Bayard Green Zoology Museum at Marshall University.

Food Web. Fish specimens from the winter and spring collections were examined for dependence of the fish population upon the benthic macroinvertebrates. When possible, 8 specimens from each taxon were dissected and stomachs removed. The stomach contents were removed using micro-dissecting scissors and examined under a Bausch and Lomb dissecting microscope. The contents were identified to the lowest possible taxon using the previously mentioned taxonomic keys and reference specimens obtained from the benthic collections.

CHAPTER V

RESULTS AND DISCUSSION

Physical Data

Temperature

The mean temperature for the study area over the four seasons was 14.6 C. Station 1 showed the least amount of fluctuation. While the mean temperature at station 1 was 16.1 C, the variance from this was only 5.8 C (range = 11.0 - 21.9 C). Stations 2 and 3 showed more variability with 15.1 and 21.9 C difference from the maximum temperature on 20 August and minimum temperature on 7 March.

Stations 2 and 3 exhibited a more regular pattern in seasonal fluctuations. Station 1 was influenced by the backwaters of the Ohio River on 7 March when the other stations reached their minimum. The water temperature of the Ohio River at the Gallipolis Locks and Dam on that date was 10.0 C.

Turbidity

The highest turbidity, 155 NTUs, occurred at station 3 on 7 March. The minimum was 6.8 NTUs at stations 2 and 3. Station 1 had a mean turbidity of 68.7 (39 - 115) NTUs. Turbidity was measured at stations 2 and 3 on 7 & 21 March. The mean values were 35.9 and 80.9 NTUs for stations 2 and 3, respectively. However, these data are from one season only.

Care must be taken in analyzing these data because of the irregular sampling and varying importance placed on this parameter. Turbidity when measured as transmittance of light is a rather crude evaluation (Stern, 1978). It may include plankton and inorganic matter (total solids) suspended in water. Such solids will decrease the depth of light penetration reducing the depth of the photic zone and reducing primary production. In some cases and at some levels, however, it may stimulate primary production through the addition of nutrients. High levels of turbidity may cause upper surface waters to become heated and inhibit mixing (USEPA, 1976). In such cases, dissolved oxygen is not dispersed and nutrients are less plentiful due to complex interactions (Stern, 1978). Recommendations by the National Academy of Science committee are that the photic zone should not be affected by more than 10 percent of its depth (NAS, 1974).

Chemical Data

Dissolved Oxygen

The highest dissolved oxygen was sampled at station 3, $\bar{x}$ = 10.8 (7.6 - 12.0) mg/l. Station 2 had the next highest value but the minimum value was considerably lower than the headwater station ($\bar{x}$ = 8.4; 1.7 - 12.1 mg/l). Station 1 had the lowest value, $\bar{x}$ = 4.9 (1.0 - 6.9) mg/l.

Dissolved oxygen values at station 1 were not influenced by the Ohio River on 3 November as was the temperature. The minimum for the study period at station 1 was reached on that date, 1.0 mg/l. However, the Ohio River had a much higher value of 9.7 mg/l. Other parameters associated with low dissolved oxygen were recorded for this date: high turbidity, high total, dissolved and suspended solids and high levels of many heavy metals. The West Virginia water quality criteria Section 12.02 sets the minimum dissolved oxygen values at 5.0 mg/l (DNR, 1977). The Environmental Protection Agency defines for the lowest protection level, a minimum 4.6 mg/l (USEPA, 1973). Therefore, stations 1 and 2 on Flatfoot Creek are presently below desired guidelines.

Hydrogen Ion Concentration (pH)

The pH values at all stations were acceptable to state and federal regulations (DNR, 1977; USEPA, 1973). Station 1 had a mean value ($\bar{x}$) of 6.7 (6.2 - 7.2); station 2, $\bar{x}$ = 7.1 (6.8 - 7.5); and station 3, $\bar{x}$ = 7.4 (6.9 - 7.9).

Specific Conductivity

Conductivity values did not vary greatly from station to station. However, there was a steady increase of salinity from the headwaters downstream. Starting with station 3 and ending with station 1, the means and ranges (micromhos per centimeter) were as follows: $\bar{x}$ = 209, 84 - 315; $\bar{x}$ = 235, 173 - 300; and $\bar{x}$ = 314, 268 - 354.

Ionic Strength and Buffering Capacity Factors

Total Alkalinity. The mean value for Flatfoot Creek of the total alkalinity (58.7 mg/l as $CaCO_3$) was safely above the water quality criteria set forth by the USEPA (1976) with a minimum of 20.0 mg/l as $CaCO_3$. The National Academy of Science (1974) regulates stream conditions so that the naturally existing levels shall not be reduced by more than 25 percent.

Total Hardness. The entire drainage basin of the area consists of moderately hard water by water quality standards (USEPA, 1973, 1976). The minimum value obtained was 81.0 mg/l $CaCO_3$ from the headwater station 3.

Other Factors. Calcium, magnesium, sodium and sulfate were all within acceptable values by USEPA (1973) guidelines. Potassium values were below the recommended levels established by USEPA (1973) (6 - 85 mg/l) at station 1 ($\bar{x}$ = 5.04 mg/l), station 2 ($\bar{x}$ = 2.30 mg/l) and station 3 ($\bar{x}$ = 1.57 mg/l). Chloride levels met EPA standards at the lower end of the range (3 - 170 mg/l) and satsified West Virginia standards for less than 100 mg/l (DNR, 1977).

Nutrients

Nitrogen. The nitrate-nitrite levels were much below the maximum 45 mg/l set by DNR (1977). The mean values for stations 1, 2 and 3 were 0.46 mg/l, 0.37 mg/l and 0.23 mg/l, respectively.

The maximum level of Kjeldahl nitrogen occurred at station 1 with 0.74 mg/l.

Un-ionized ammonia is quite toxic and the amount of total ammonia which becomes toxic is dependent upon pH, temperature and ionic strength. The maximum total ammonia value was 0.50 mg/l. At the time this occurred, the maximum total ammonia would have to have been 5.1 mg/l before the critical 0.02 mg/l of un-ionized ammonia would have been reached (USEPA, 1974, 1976).

Phosphorus. Total phosphorus levels ranged from $\bar{x}$ = 33.3 ug/l at station 3 to $\bar{x}$ = 197.0 ug/l at station 1. Similarly, the dissolved phosphorus levels were lowest at station 3 ($\bar{x}$ = 10.0 ug/l) and highest at station 1 ($\bar{x}$ = 31.0 ug/l). Lower levels of total and dissolved phosphorus at stations 2 and 3 may be erroneous. Samples were not collected for all seasons at these stations.

Phosphorus is generally considered a limiting nutrient since it normally occurs in the lowest concentrations and is required for freshwater plants. In lake situations, an overabundance (30^{+}ug/l) will cause eutrophication (USEPA, 1976). In a stream situation, it is recommended that phosphorus remain under 100 ug/l (USEPA, 1976). Eutrophication is no longer the main concern but bioaccumulation may present a problem.

Solids

Total Solids. Total solids ranged from 148 to 652 mg/l. Station 1 had a mean of 347.5 mg/l, while stations 2 and 3 showed a mean of 220 and 190.3 mg/l, respectively.

Suspended Solids. Suspended solids ranged from 5 to 372 mg/l. The highest values were at station 1 ($\bar{x}$ = 127, 55 - 372 mg/l).

Dissolved Solids. The only recorded values for stations 2 and 3 were 147 and 120 mg/l, respectively.

The level of protection from the amount of total and suspended solids was low (81 - 400 mg/l) (USEPA, 1973). On occasion greater amounts occurred at station 1. The USEPA (1976) recommends that a stream should not have its compensation point for photosynthetic activity reduced by 10 percent through modifications to the stream.

Biological Data

Benthic Macroinvertebrates

A total of 7085 benthic macroinvertebrates were collected representing 15 orders, 37 families, 59 genera and approximately 65 species (Tables 1-4). With the exception of station 1, samples were taken representing four seasons. Due to high water on 7 March and several weeks thereafter, no winter sample could be collected at the tailwater station.

Station 1. In spring (28-29 April) 181 invertebrates from 6 Taxa were found (Table 2). The aquatic oligochaetes (Naididae) occupied the greatest percent frequency (84.5) ($N = 153$, $\bar{x} = 51.0/ft^2$). Another oligochaete (Enchytraeidae) made up 7.7 percent ($N = 14$) of the total. Chironomid larvae ranked third with 3.3 percent ($N = 6$). The species diversity and equitability values were low, 0.95 and 0.32, respectively. The mean biomass of the sample was 0.2977 grams.

In summer (20 August), 752 invertebrates from 14 taxa were collected (Table 3) in the samples. Aquatic oligochaetes (Naididae) dominated the sample (93.9%, $N = 706$). The remaining taxa contained so relatively few numbers ($x = 3.5$/taxon) that they had little effect on the species diversity ($\bar{d} = 0.52$) and equitability values ($e = 0.21$). The mean biomass was 0.5546 grams.

In fall (5 November), only 8 taxa ($N = 484$) were identified (Table 4) from the samples. Once again, aquatic

Table 1. Linear abundance and distribution of the macro-invertebrates in Flatfoot Creek, Mason County, West Virginia. Values are the total numbers collected on 7-8 March 1977 (Winter). Data represents information from three Surber square-foot samples at each station. Due to high water, no samples were taken at Station 1.

TAXA	Station 2 Total	Station 2 $\bar{X}$	Station 3 Total	Station 3 $\bar{X}$
PLATYHELMINTHES				
Turbellaria				
Phagocata sp.	-	-	6	2.0
ANNELIDA				
Oligochaeta				
Naididae	143	47.7	-	-
ARTHROPODA				
Crustacea				
Amphipoda				
Crangonyx sp.	2	0.7	-	-
Isopoda				
Asellus sp.	1	0.3	-	-
Lirceus sp.	13	4.9	-	-
Decapoda				
Cambaridae	5	1.7	-	-
Insecta				
Ephemeroptera				
Ameletus sp.	-	-	16	5.3
Caenis sp.	7	2.3	2	0.7
Leptophlebia sp.	1	0.3	-	-
Stenonema tripunctatum	-	-	5	1.7
Plecoptera				
Allocapnia vivipara	13	4.9	11	3.7
Diploperla robusta	-	-	7	2.3
Isoperla transmarina	3	1.0	-	-
Trichoptera				
Cheumatopsyche sp.	-	-	47	15.7
Diplectrona sp.	-	-	1	0.3
Ptilostomis sp.	1	0.3	-	-
Rhyacophila torva	1	0.3	2	0.7
Coleoptera				
Stenelmis crenata (Adults)	2	0.7	7	2.3
S. crenata (larvae)	2	0.7	-	-
Hemiptera				
Belostoma sp.	1	0.3	-	-

Table 1 concluded.

TAXA	Station 2 Total	Station 2 $\bar{X}$	Station 3 Total	Station 3 $\bar{X}$
Diptera				
Chironomidae (larvae)	663	221.0	-	-
Chironomidae (pupae)	44	14.7	1	0.3
Ceratopogonidae				
Palpomyia sp.	1	0.3	-	-
Tabanidae	1	0.3	-	-
Chrysops sp.	3	0.3	2	0.7
Tipulidae				
Hexatoma sp.	1	0.3	-	-
Pseudolimnophila sp.	12	4.0	-	-
Tipula sp.	2	0.7	-	-
MOLLUSCA				
Pelecypoda				
Sphaerium sp.	211	70.3	-	-
Gastropoda				
Physa sp.	-	-	1	0.3
Total	1150	383.7	111	37.0
TOTAL NUMBER OF TAXA	23		14	
SHANNON-WEAVER INDEX	2.01		2.83	
EQUITABILITY	0.23		0.71	

Table 2. Linear abundance and distribution of the macroinvertebrates in Flatfoot Creek, Mason County, West Virginia. Values are the total numbers collected on 28-29 April 1977 (Spring). Data represents information from three Surber square-foot samples at each station.

	Station 1		Station 2		Station 3	
TAXA	Total	$\bar{X}$	Total	$\bar{X}$	Total	$\bar{X}$
ASCHELMINTHES						
Nematoda	-	-	1	0.3	-	-
ANNELIDA						
Oligochaeta						
Enchytraeidae	14	4.7	-	-	-	-
Lumbricidae	-	-	15	5.0	-	-
Naididae	153	51.0	176	58.7	1	0.3
Tubificidae						
Branchiura sowerbyi	3	1.0	20	6.7	-	-
ARTHROPODA						
Crustacea						
Amphipoda						
Crangonyx sp.	-	-	56	18.7	1	0.3
Gammarus sp.	4	1.3	-	-	-	-
Isopoda						
Asellus sp.	-	-	380	126.7	-	-
Lirceus sp.	-	-	23	7.7	1	0.3
Decapoda						
Cambaridae	-	-	16	5.3	3	1.0
Insecta						
Ephemeroptera						
Baetis sp.	-	-	3	1.0	-	-
Caenis sp.	-	-	5	1.7	1	0.3
Heptagenia sp.	-	-	171	57.0	215	71.7
Paraleptophlebia sp.	-	-	13	4.3	1	0.3
Pseudocloeon sp.	-	-	16	5.3	19	6.3
Plecoptera						
Amphinemura delosa	-	-	5	1.7	72	24.0
Diploperla robusta	-	-	-	-	13	4.3
Isoperla transmarina	-	-	-	-	81	27.0
Leuctridae	-	-	-	-	4	1.3
Trichoptera						
Cheumatopsyche sp. (Larvae)	-	-	2	0.7	9	3.0
Cheumatopsyche sp. (Pupae)	-	-	-	-	1	0.3
Rhyacophila ledra (Larvae)	-	-	-	-	3	1.0
R. ledra (Pupae)	-	-	-	-	2	0.7
R. torva (Pupae)	-	-	-	-	7	2.3
Wormaldia sp. (Larvae)	-	-	-	-	9	3.0

Table 2 concluded.

TAXA	Station 1 Total	$\bar{X}$	Station 2 Total	$\bar{X}$	Station 3 Total	$\bar{X}$
Coleoptera						
Stenelmis crenata (Larvae)	-	-	-	-	145	48.3
S. crenata (Adults)	-	-	-	-	49	16.3
Diptera						
Chironomidae (Larvae)	6	2.0	562	187.3	67	22.3
Chironomidae (Pupae)	-	-	174	58.0	2	0.7
Ceratopogonidae						
Simuliidae	-	-	11	3.7	-	-
Tabanidae	-	-	-	-	-	-
Chrysops sp.	-	-	4	1.3	1	0.3
Tipulidae	-	-	-	-	-	-
Tipula sp.	-	-	-	-	4	1.3
MOLLUSCA						
Pelecypoda						
Sphaerium sp.	-	-	125	41.7	-	-
Gastropoda						
Lymnaea sp.	1	0.3	-	-	-	-
Physa sp.	-	-	1	0.7	-	-
Total	181	60.3	1780	593.5	711	236.6
TOTAL NUMBER OF TAXA	6		21		24	
SHANNON-WEAVER INDEX	0.95		2.95		3.04	
EQUITABILITY	0.32		0.52		0.46	

Table 3. Linear abundance and distribution of the mcaro-invertebrates in Flatfoot Creek, Mason County, West Virginia. Values are the total numbers collected on 20 August 1977 (Summer). Data represents information from three Surber square-foot samples at each station.

	Station 1		Station 2		Station 3	
TAXA	Total	$\bar{X}$	Total	$\bar{X}$	Total	$\bar{X}$
ANNELIDA						
Oligochaeta						
Naididae	706	235.3	231	77.0	9	3.0
Tubificidae						
Branchiura sowerbyi	4	1.3	15	5.0	-	-
ARTHROPODA						
Crustacea						
Amphipoda						
Crangonyx	1	0.3	2	0.7	-	-
Isopoda						
Asellus	-	-	2	0.7	-	-
Lirceus	-	-	2	0.7	-	-
Decapoda						
Orconectes	-	-	2	0.7	-	-
Insecta						
Ephemeroptera						
Stenonema tripunctatum	-	-	-	-	1	0.3
Caenis	-	-	-	-	14	4.7
Trichoptera						
Cheumatopsyche	1	0.3	-	-	-	-
Coleoptera						
Hydroporus						
Laccophilus	-	-	6	2.0	-	-
Stenelmis	-	-	2	0.7	5	1.6
Hydrophilidae	2	0.7	-	-	-	-
Hemiptera						
Sigara	-	-	2	0.7	-	-
Megaloptera						
Chauliodes pectinicornis	1	0.3	-	-	-	-
Diptera						
Chironomidae	4	1.3	128	42.7	13	4.3
Culicidae	1	0.3	-	-	-	-
Ceratopogonidae						
Palpomyia	-	-	1	0.3	-	-
Simuliidae						
Stratiomyidae	1	0.3	-	-	-	-
Euparyphus	-	-	3	1.0	-	-
Odontomyia	-	-	-	-	4	1.3
Tabanidae						
Chrysops	-	-	6	2.0	3	1.0
Tipulidae						
Erioptera	-	-	1	0.3	6	2.0
Unidentified	18	6.0	12	4.0	19	6.3

Table 3 concluded.

TAXA	Station 1 Total	Station 1 $\bar{X}$	Station 2 Total	Station 2 $\bar{X}$	Station 3 Total	Station 3 $\bar{X}$
MOLLUSCA						
Pelecypoda						
Sphaerium	5	1.7	102	34.0	-	-
Gastropoda						
Lymnaea	2	0.7	-	-	-	-
Physa	5	1.7	5	1.7	2	0.7
Pyrgulopsis	1	0.3	-	-	-	-
Total	752		522		76	
Taxa	14		17		10	
SHANNON-WEAVER INDEX	0.52		2.00		2.03	
EQUITABILITY	0.21		0.59		0.92	

Table 4. Linear abundance and distribution of the macroinvertebrates in Flatfoot Creek, Mason County, West Virginia. Values are the total numbers collected on 5 November 1977 (Fall). Data represents information from three Surber square-foot samples at each station.

TAXA	Station 1 Total	Station 1 $\bar{X}$	Station 2 Total	Station 2 $\bar{X}$	Station 3 Total	Station 3 $\bar{X}$
ASCHELMINTHES						
Nematoda	-	-	1	0.3	-	-
ANNELIDA						
Oligochaeta						
Lumbriculidae	-	-	7	2.3	-	-
Naididae	462	154.0	241	80.3	17	5.7
Tubificidae						
Branchiura sowerbyi	4	1.3	17	5.7	-	-
ARTHROPODA						
Crustacea						
Amphipoda						
Crangonyx	-	-	5	1.7	-	-
Isopoda						
Asellus	-	-	10	3.3	-	-
Lirceus	-	-	22	7.3	-	-
Decapoda						
Cambarus	-	-	1	0.3	-	-
Insecta						
Ephemeroptera						
Stenonema tripunctatum	-	-	-	-	6	2.0
Caenis	-	-	-	-	15	5.0
Trichoptera						
Cheumatopsyche	1	0.3	-	-	25	8.3
Hydropsyche	-	-	-	-	6	2.0
Ptilostomis	-	-	2	0.7	1	0.3
Pycnopsyche	-	-	-	-	1	0.3
Coleoptera						
Agabus	-	-	4	1.3	-	-
Hydroporus	1	0.3	-	-	-	-
Stenelmis	-	-	-	-	2	0.7
Hemiptera						
Sigara	-	-	10	3.3	-	-
Diptera						
Chironomidae	10	3.3	699	231.3	11	3.7
Culicidae	-	-	-	-	1	0.3
Ceratopogonidae						
Palpomyia	-	-	3	1.0	-	-
Psychodidae						
Simuliidae	-	-	-	-	1	0.3
Euparyphus	-	-	-	-	1	0.3

Table 4 concluded.

TAXA	Station 1 Total	$\bar{X}$	Station 2 Total	$\bar{X}$	Station 3 Total	$\bar{X}$
Tabanidae						
Chrysops	-	-	2	0.7	2	0.7
Tipulidae						
Tipula	-	-	-	-	4	1.3
Unidentified	1	0.3	-	-	-	-
MOLLUSCA						
Pelecypoda						
Sphaerium	5	1.7	163	54.3	-	-
Gastropoda						
Helisoma	-	-	1	0.3	-	-
Lymnaea	-	-	-	-	1	0.3
Physa	1	0.3	2	8.0	11	3.7
Total	484		1213		105	
TOTAL NUMBER OF TAXA	8		17		16	
SHANNON-WEAVER INDEX	0.36		1.93		2.47	
EQUITABILITY	0.31		0.42		0.84	

oligochaetes dominated with 95.4 percent Naididae (N = 462, $\bar{x}$ = 154/ft^2). The species diversity (0.36) and equitability values (0.21) were the lowest for all stations and seasons. The mean biomass was 0.2585 grams.

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

Station 2. In winter, 23 taxa (N = 1150) were identified from the samples (Table 1). Chironomid larvae dominated the samples with a frequency of 57.6 percent (N = 663, $\bar{x}$ = 221.0/ft^2). Dominant genera were *Trissocladius*, *Strictochironomus*, *Cricotopus* and *Eukiefferiella*. Sphaeriid clams ranked second in abundance with 18.3 percent (N = 211, $\bar{x}$ = 70.3/ft^2). The index of diversity and equitability value were 2.01 and 0.23, respectively; the mean biomass was 2.3504 grams.

In spring, 21 taxa (N = 1780) were recorded from the samples (Table 2). This was the largest number of individuals collected for this station. Chironomid larvae were in the greatest numbers (562) but many pupae were also taken (174). Together their dominance was 41.2 percent of the total (x = 245.3/ft^2). Isopods (*Asellus*) ranked second in percentage frequency (21.3%, N = 380, $\bar{x}$ = 126.7/ft^2). 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. The mean biomass, 6.8431 grams, was the highest of any station during the study period.

In summer, 17 taxa (N = 1213) were identified from the samples (Table 3). Naidid worms dominated the sample with 44.2 percent of the total (N = 231, $\bar{x} = 77.0/ft^2$). The next two most abundant taxa were chironomid larvae (24.5%, N = 128, $\bar{x} = 42.7/ft^2$) and sphaeriid clams (19.5%, N = 102, $\bar{x} = 34.0/ft^2$). The remaining fourteen taxa contained relatively few numbers. The species diversity was 2.0 and the equitability value, 0.59. The mean biomass was 0.6235 grams.

In fall, 17 taxa (N = 1213) were recorded at this station (Table 4). Chironomid larvae (57.2%) ranked first in percent frequency (N = 694, $\bar{x} = 231.3/ft^2$) and sphaeriid clams (13.4%, N = 163, $\bar{x} = 54.3/ft^2$) ranked second and third in abundance. The remaining 14 taxa contained relatively few individuals. The index of diversity was 1.93 and the equitability value, 0.42. The mean biomass of the sample was 3.4704 grams.

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 (Table 5).

Station 3. In winter, 14 taxa (N = 111) were identified in the sample (Table 1). _Cheumatopsyche_ sp. ranked first in percentage frequency and numbers (42.3%, N = 47, $\bar{x} = 15.7/ft^2$). The mayfly genus _Ameletus_ ranked

Table 5. Classification, location and tolerance of benthic macroinvertebrates to decomposable organic wastes from Flatfoot Creek, Mason County, West Virginia. T = Tolerant, F = Facultative, and I = Intolerant (USEPA, 1973).

PLATYHELMINTHES (Flatworms)
  Turbellaria (F) (Planarians)
      Phagocata sp.

ASCHELMINTHES (Round Worms)
  Nematoda (F) (2)

ANNELIDA (Segmented Worms)
  Oligochaeta (Aquatic Earthworms)
    Enchytraeidae
    Lumbricidae
    Lumbriculidae (T) (2)
    Naididae (F) (1) (2) (3)
    Tubificidae
      Branchiura sowerbyi (T) (1) (2)

ARTHROPODA
  Crustacea
   Amphipoda (Scuds)
      Crangonyx sp.
      Gammarus sp. (F) (1)
   Isopoda (Sow Bugs)
      Asellus sp. (T,F,I) (2)
      Lirceus sp. (F) (2) (3)
   Decapoda (Crayfish)
    Cambaridae
  Insecta
   Ephemeroptera (Mayflies)
    Siphlonuridae
      Ameletus sp.
    Baetidae
      Baetis sp.
      Pseudocloeon sp.
    Heptageniidae
      Heptagenia sp.
      Stenonema tripunctatum (I) (3)
    Leptophlebiidae
      Leptophlebia sp.
      Paraleptophlebia sp.
    Caenidae
      Caenis sp. (F,I) (2) (3)
   Plecoptera (Stoneflies)
    Nemouridae
      Amphinemura delosa
    Capniidae
      Allocapnia vivipara (F) (2) (3)

Table 5 continued.

- Leuctridae
- Perlodidae
  - *Isoperla transmarina*
- Trichoptera (Caddisflies)
  - Rhyacophilidae (I)
    - *Rhyacophila ledra* (3)
    - *R. torva* (2) (3)
  - Philopotamidae
    - *Wormaldia* sp.
  - Hydropsychidae
    - *Cheumatopsyche* sp. (F) (1) (2) (3)
    - *Diplectrona* sp.
  - Phryganeidae
    - *Ptilostomis* sp.
- Coleoptera (Beetles)
  - Dytiscidae
    - *Hydroporus* sp.
    - *Laccophilus*
  - Elmidae
    - *Stenelmis crenata* (I) (2) (3)
- Hemiptera (True Bugs)
  - Belostomatidae
    - *Belostoma* sp. (T) (2)
- Megaloptera (Megalopterans)
  - Sialidae
    - *Sialis aequalis*
- Diptera (True Flies)
  - Chironomidae (Midge Flies)
    - Tanypodinae
      - *Procladius* sp. (T,F)
      - *Trissopelopia* sp.
    - Chironominae
      - *Dicrotendipes* sp.
      - *Microtendipes* sp. (I)
      - *Stictochironomus* sp.
      - *Tanytarsus* sp.
    - Orthocladiinae
      - *Cricotopus* sp. (I) (2)
      - *Diplocladius* sp.
      - *Eukiefferiella* sp.
      - *Orthocladius* sp. (F,I)
      - *Parakiefferiella* sp.
      - *Psectrocladius* sp. (I)
      - *Trichocladius* sp.
      - *Trissocladius* sp.

Table 5 concluded.

Ceratopogonidae (Biting Midges)
Palpomyia sp. (2)
Simulidae (Black Flies) (T,F,I) (2) (3)
Tabanidae (Horseflies)
Chrysops sp.
Tipulidae (Crane Flies)
Hexatoma sp. (2)
Pseudolimnophila sp.
Tipula sp.
Stratiomyidae (T) (1)
Culicidae (T) (1) (3)
MOLLUSCA
Pelecypoda (Clams)
Sphaerium sp. (f) (1) (2)
Gastropoda (Snails)
Helisoma sp. (T) (2)
Lymnaea sp. (T,F) (1)
Physa sp. (T) (1) (2)
Pyrgulopsis sp.

second (14.5%, N = 16, $\bar{x}$ = 5.3/ft^2) and the stonefly Allocapnia vivipara (9.9%, N = 11, $\bar{x}$ = 3.7/ft^2) ranked third. The index of diversity was 2.83 and the equitability value, 0.71. The mean biomass was 2.6160 grams, the lowest of any winter sample.

In spring, the taxa increased to 24 (N = 711) (Table 2). The mayfly genus Heptagenia was the most abundant (30.2%, N = 215, $\bar{x}$ = 71.7/ft^2) taxon. The beetle Stenelmis crenata (larvae and adults) ranked second (27.0%, N = 194, x = 64.6/ft^2). The species diversity was the highest with 3.04 and the equitability value was 0.46. The mean biomass was 3.9747 grams.

In summer, 10 taxa (N = 76) were found in the collection (Table 3). Of the identifiable specimens, the mayfly genus Caenis ranked the most abundant with 18.4 percent of the total (N = 14, $\bar{x}$ = 4.7/ft^2). Chironomid larvae ranked second (17.1%, N = 13, $\bar{x}$ = 4.3/ft^2). However, the highest percentage (23.7%) were unidentified dipteran larvae. The species diversity was 2.03 and the equitability, 0.92, a relatively high value. The mean biomass was a low 0.1876 grams.

In fall, 16 taxa (N = 105) were recorded for this station (Table 4). The most abundant taxon was the caddisfly genus Cheumatopsyche (23.8%, N = 25, $\bar{x}$ = 8.3/ft^2). Naidid worms ranked second (16.2%, N = 17, $\bar{x}$ = 5.7/ft^2) and Caenis naiads third (14.3%, N = 15, $\bar{x}$ = 5.0/ft^2). The index of diversity was 1.93 and the equitability value, 0.42. The mean biomass was 0.5060 grams.

Station 3 has 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 were collected from four seasons (Tables 6-9). All fishes were grouped into the following three categories; game, forage and rough fishes (Tables 10-13). Game fishes were represented by the families Centrarchidae and Scianidae. The forage fishes include Cyprinidae, Percidae, and Clupeidae. Catostomidae and Ictaluridae comprised the rough fishes (Table 14).

High water prevented the winter collection of station 1 which was inundated by the Ohio River for several weeks.

Station 1. In spring, forage fishes comprised 95.0 and 58.2 percent of the numbers (N = 147) and weights, respectively (Table 11). The sample was dominated by the Emerald Shiner *Notropis atherinoides* (80.0%, N = 112). The second most abundant species, another cyprinid, was the Sand Shiner *N. stramineus* (7.1%). The remaining 5 species comprised no more than 5.7 percent for any one taxon (Table 7). Game fishes, primarily Bluegill, composed 5 percent of the collection.

Table 6. Relative abundance and distribution of the fishes in Flatfoot Creek, Mason County, West Virginia, during winter, 1977. Due to high water, no sample was taken at station 1.

Common Name	Station 2		Station 3	
	No.	% of Tot.	No.	% of Tot.
Green Sunfish	2	4.3	4	2.7
Longear Sunfish	-	-	3	2.0
Spotted Bass	-	-	1	0.6
Stoneroller	-	-	6	4.1
Emerald Shiner	1	2.1	-	-
Striped Shiner	6	12.7	32	22.3
Spotfin Shiner	15	31.9	-	-
Redbelly Dace	-	-	5	3.4
Bluntnose Minnow	23	48.9	26	18.1
Blacknose Dace	-	-	1	0.6
Creek Chub	-	-	40	27.9
Johnny Darter	-	-	17	11.8
White Sucker	-	-	8	5.5
TOTAL	47		143	

GRAND TOTAL
(Stations 2 and 3) 190

Table 7. Relative abundance and distribution of the fishes in Flatfoot Creek, Mason County, West Virginia, during spring, 1977.

Common Name	Station 1		Station 2		Station 3	
	No.	% of Tot.	No.	% of Tot.	No.	% of Tot.
Green Sunfish	-	-	1	0.4	2	1.7
Pumpkinseed	1	0.7	-	-	-	-
Bluegill	5	3.5	-	-	-	-
Longear Sunfish	1	0.7	-	-	-	-
Spotted Bass	-	-	-	-	1	0.7
Stoneroller	-	-	-	-	7	5.9
Emerald Shiner	112	80.0	57	22.9	-	-
River Shiner	3	2.1	9	3.6	-	-
Striped Shiner	-	-	3	1.2	49	41.5
Spotfin Shiner	-	-	8	3.2	-	-
Sand Shiner	10	7.1	99	39.8	-	-
Southern Red-belly Dace	-	-	-	-	10	8.5
Bluntnose Minnow	8	5.7	39	15.7	8	6.8
Creek Chub	-	-	22	8.8	28	23.7
Johnny Darter	-	-	2	0.8	9	7.6
White Sucker	-	-	9	3.6	4	3.4
TOTAL	140		249		118	
GRAND TOTAL	507					

Table 8. Relative abundance and distribution of the fishes in Flatfoot Creek, Mason County, West Virginia, during summer, 1977.

Common Name	Station 1		Station 2		Station 3	
	No.	% of Tot.	No.	% of Tot.	No.	% of Tot.
Bluegill	7	14.9	-	-	-	-
Longear Sunfish	-	-	-	-	1	1.9
Spotted Bass	-	-	1	1.1	1	1.9
Black Crappie	1	2.1	-	-	-	-
White Crappie	2	4.2	-	-	-	-
Drum	1	2.1	-	-	-	-
Stoneroller	-	-	1	1.1	8	15.4
Carp	1	2.1	-	-	-	-
Emerald Shiner	32	68.1	-	-	-	-
River Shiner	1	2.1	-	-	-	-
Striped Shiner	-	-	22	24.2	9	17.3
Spotfin Shiner	-	-	1	1.1	-	-
Bluntnose Minnow	2	4.2	6	6.6	12	23.1
Creek Chub	-	-	55	60.4	6	13.9
Johnny Darter	-	-	-	-	8	15.4
Gizzard Shad	-	-	1	1.1	-	-
White Sucker	-	-	1	1.1	7	13.5
Black Bullhead	-	-	3	3.3	-	-
TOTAL	47		91		52	
GRAND TOTAL	190					

Table 9. Relative abundance and distribution of the fishes in Flatfoot Creek, Mason County, West Virginia, during fall, 1977.

Common Name	Station 1		Station 2		Station 3	
	No.	% of Tot.	No.	% of Tot.	No.	% of Tot.
Green Sunfish	-	-	2	3.2	1	1.0
Bluegill	27	19.7	-	-	-	-
Longear Sunfish	6	4.4	-	-	-	-
Spotted Bass	-	-	1	1.6	-	-
Black Crappie	45	32.8	-	-	-	-
White Crappie	2	1.4	-	-	-	-
Stoneroller	-	-	5	8.1	13	13.4
Carp	1	0.7	-	-	-	-
Emerald Shiner	48	35.0	-	-	-	-
River Shiner	1	0.7	-	-	-	-
Striped Shiner	1	0.7	21	33.9	31	32.0
Mimic Shiner	3	2.2	-	-	-	-
Southern Red-belly Dace	-	-	-	-	4	4.1
Bluntnose Minnow	2	1.4	1	1.6	21	21.6
Creek Chub	-	-	30	48.4	18	18.6
Johnny Darter	-	-	-	-	7	7.2
White Sucker	-	-	2	3.2	2	2.1
Yellow Bullhead	1	0.7	-	-	-	-
TOTAL	137		62		97	
GRAND TOTAL	296					

Table 10. Percentage frequency of total numbers and weight of game, forage and rough fishes collected from Flatfoot Creek, Mason County, West Virginia, in winter (7-8 March 1977). N = total numbers. Due to high water, no sample was collected at station 1.

Station	Percentage Frequency (Numbers) Game	Forage	Rough	Percentage Frequency (Weight) Game	Forage	Rough
Station 2	4.3	95.7	0.0	3.9	96.1	0.0
Station 3	5.6	88.8	5.6	24.3	66.7	9.0
Total Stations 2&3	5.3	90.5	4.2	-	-	-
N		190				

Table 11. Percentage frequency of total numbers and weight of game, forage and rough fishes collected from Flatfoot Creek, Mason County, West Virginia, in spring (28-29 April 1977). N = total numbers.

Station	Percentage Frequency (Numbers) Game	Forage	Rough	Percentage Frequency (Weight) Game	Forage	Rough
Station 1	5.0	95.0	0.0	41.8	58.2	0.0
Station 2	0.4	96.0	3.6	0.2	71.9	27.9
Station 3	2.5	94.1	3.4	3.5	93.6	2.9
Total Stations 1-3	2.2	95.2	2.6	-	-	-
N		507				

Table 12. Percentage frequency of total numbers and weight of game, forage and rough fishes collected from Flatfoot Creek, Mason County, West Virginia, in summer (20 August 19777). N = total numbers.

Station	Percentage Frequency (Numbers)			Percentage Frequency (Weight)		
	Game	Forage	Rough	Game	Forage	Rough
Station 1	23.4	76.6	0.0	26.7	73.3	0.0
Station 2	1.1	94.5	4.4	1.7	94.4	3.9
Station 3	3.8	82.7	13.5	21.1	44.8	34.1
Total Stations 1-3	7.4	86.8	5.8	-	-	-
N		190				

Table 13. Percentage frequency of total numbers and weight of game, forage and rough fishes collected from Flatfoot Creek, Mason County, West Virginia, in fall (5 November 1977). N = total numbers.

Station	Percentage Frequency (Numbers)			Percentage Frequency (Weight)		
	Game	Forage	Rough	Game	Forage	Rough
Station 1	58.4	40.8	0.7	75.4	21.1	3.5
Station 2	4.8	91.9	3.2	5.4	85.5	9.1
Station 3	1.0	96.0	2.0	0.5	96.1	0.3
Total Stations 1-3	28.4	69.9	1.7	-	-	-
N		296				

Table 14. List of fishes collected from Flatfoot Creek, Mason County, West Virginia.

GAME 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 Sciaenidae - 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

In summer, forage fishes composed 76.6 and 73.3 percent of the numbers (N = 47) and weights, respectively (Table 12). The dominating species was the Emerald Shiner (N = 32) with 68.1 percent of the total numbers (Table 8). Game fishes, primarily Bluegill, comprised 23.3 percent of the collection.

In fall, game fishes comprised 58.4 and 75.4 percent of the numbers and weights, respectively (Table 13). Again, the Emerald Shiner was the most abundant fish (35.0%, N = 48) but *Pomoxis nigromaculatus* (Black Crappie) was nearly as numerous (32.8%, N = 35) in the total numbers (N = 137) (Table 9).

Station 2. Forage fishes showed the highest numerical percentages for the study period in winter (95.7%) and spring (96.0%) (Tables 10,11). Of the 47 fish collected in winter, 23 (48.9%) were the Bluntnose Minnow *Pimephales notatus.* Of the 249 fish collected for spring, 99 (39.8%) were the Sand Shiner. Second to the Sand Shiner was the Emerald Shiner (22.9%, N = 57) (Tables 6,7). In percent frequency by weight, the rough fishes (9 white suckers) ranked second to the forage fishes (27.9%).

In summer and fall, forage fishes again showed the highest numerical percentages, 94.5 and 85.5, respectively (Tables 8,9). This time the Creek Chub *Semotilus atromaculatus* was the most abundant species in summer and fall with 60.4 and 48.4 percent, respectively. Ninety-one and 62 specimens were taken in summer and fall, respectively.

Station 3. In winter, 143 fishes were collected. Forage fishes dominated the numerical abundance with 88.8

percent (Table 10). Semotilus atromaculatus and Notropis chrysocephalus (Striped Shiner) ranked first (27.9%) and second, respectively in numerical percentage frequency (Table 6). Game fishes, primarily Green and Longear Sunfishes, ranked second to forage fishes in percent frequency by weight (24.3%).

In spring, 118 fishes were collected. Forage fishes dominated the numerical percentage with 94.1% (Table 11). The Striped Shiner made up 41.5 percent of the numerical abundance. Game fishes were a poor second to forage fishes with 3.5 percent of the percent frequency by weight.

Forage fishes dominated the numerical percentage in summer (82.7%) and fall (96.0%) (Tables 12,13). During both seasons, the Creek Chub and Striped Shiner ranked first and second in numerical percent frequency (Tables 8,9). In frequency by weight, the forage fishes comprised 44.8 and 96.1 percent in summer and fall, respectively.

Food Web

From winter and spring, 227 fishes from 16 species were examined for stomach contents. Fish diets were checked for dependence upon the benthic macroinvertebrates. Stomachs of benthic insects were not examined. Figures 2 and 3 represent a complex food web from the winter and spring collections.

Station 1. Forage fishes dominated the population at this station. The Emerald Shiner which comprised 80.0 percent of the fishes in the spring was found to consume the

Figure 2. Feeding relationships of fishes from winter collection.

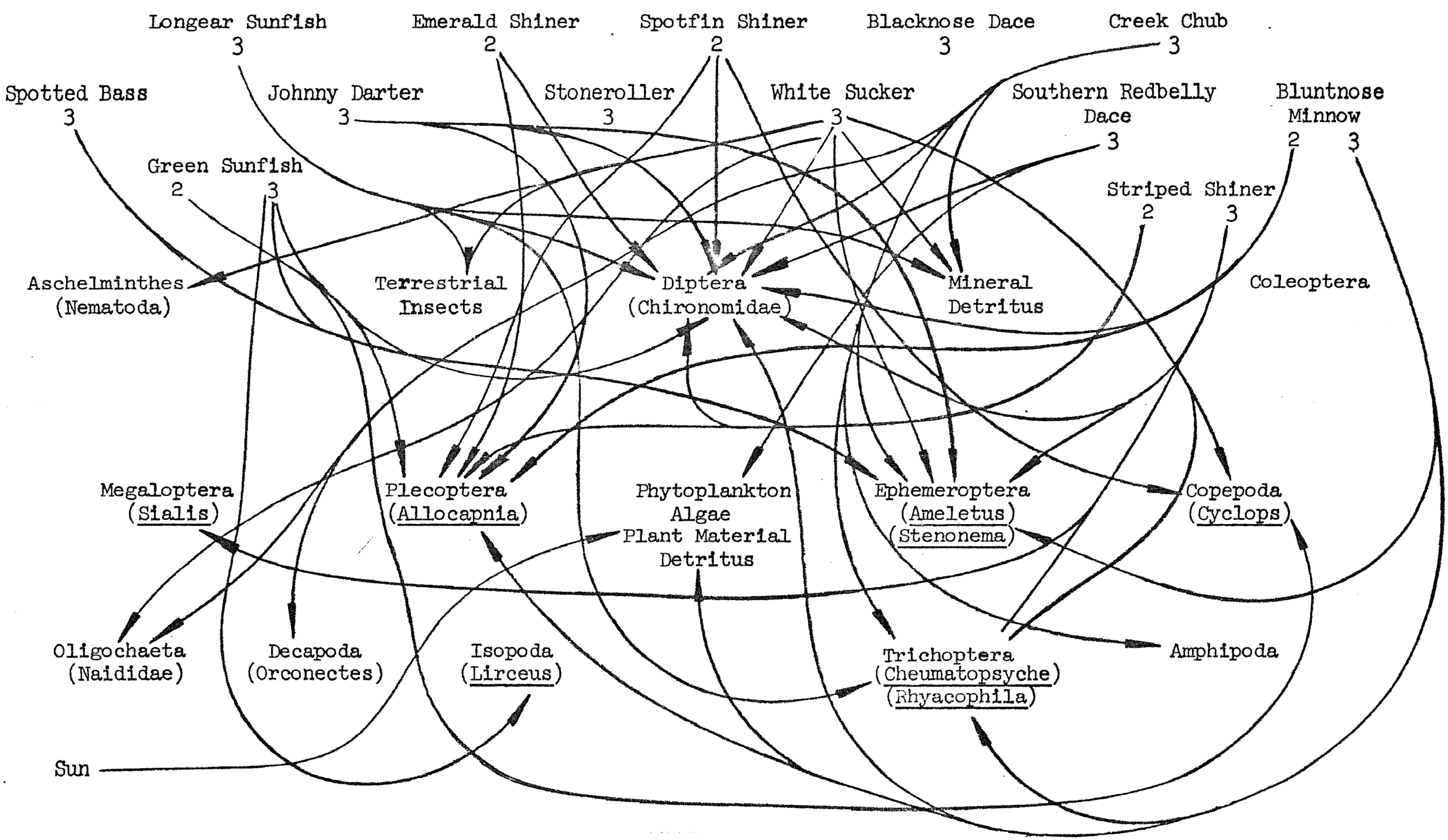
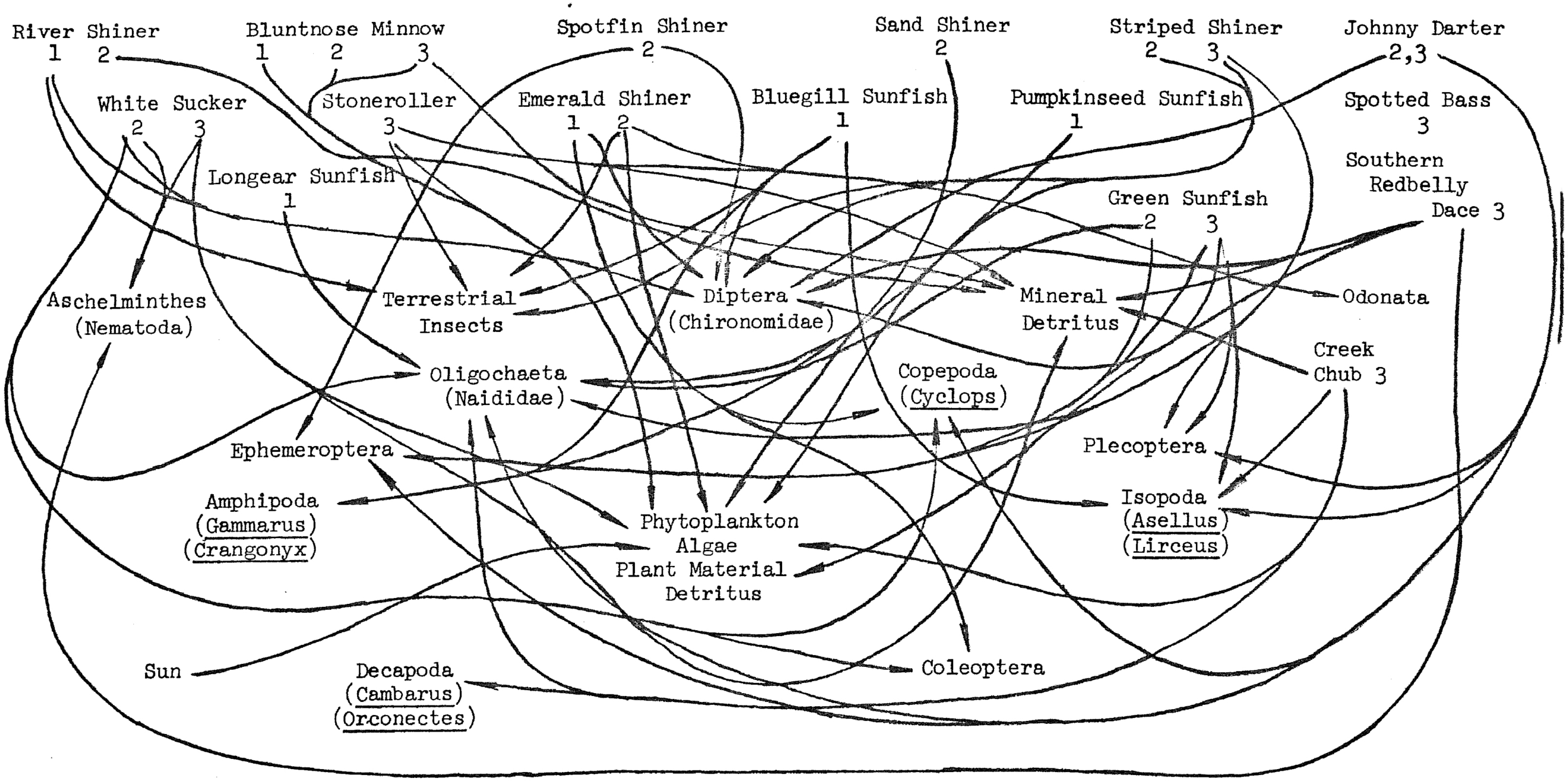

Longear Sunfish
3
Emerald Shiner
2
Spotfin Shiner
2
Blacknose Dace
3
Creek Chub
3
Spotted Bass
3
Johnny Darter
3
Stoneroller
3
White Sucker
3
Southern Redbelly Dace
3
Bluntnose Minnow
2 3
Green Sunfish
2 3
Striped Shiner
2 3
Aschelminthes
(Nematoda)
Terrestrial Insects
Diptera
(Chironomidae)
Mineral Detritus
Coleoptera
Megaloptera
(Sialis)
Plecoptera
(Allocapnia)
Phytoplankton
Algae
Plant Material
Detritus
Ephemeroptera
(Ameletus)
(Stenonema)
Copepoda
(Cyclops)
Oligochaeta
(Naididae)
Decapoda
(Orconectes)
Isopoda
(Lirceus)
Trichoptera
(Cheumatopsyche)
(Rhyacophila)
Amphipoda
Sun

Figure 3. Feeding relationships of fishes from spring collection.



River Shiner
1 2
Bluntnose Minnow
1 2 3
Spotfin Shiner
2
Sand Shiner
2
Striped Shiner
2 3
Johnny Darter
2,3
White Sucker
2 3
Stoneroller
3
Emerald Shiner
1 2
Bluegill Sunfish
1
Pumpkinseed Sunfish
1
Spotted Bass
3
Longear Sunfish
1
Southern
Redbelly
Dace 3
Green Sunfish
2 3
Aschelminthes
(Nematoda)
Terrestrial
Insects
Diptera
(Chironomidae)
Mineral
Detritus
Odonata
Creek
Chub 3
Oligochaeta
(Naididae)
Copepoda
(Cyclops)
Ephemeroptera
Plecoptera
Amphipoda
(Gammarus)
(Crangonyx)
Phytoplankton
Algae
Plant Material
Detritus
Isopoda
(Asellus)
(Lirceus)
Sun
Decapoda
(Cambarus)
(Orconectes)
Coleoptera

following items: terrestrial insects (i.e. lepidopteran larvae, Arachnids), dipteran larvae, coleopteran larvae and adults (*Stenelmis crenata*) and copepods. Second to the forage fishes by weight were the game fishes, primarily the Bluegill Sunfish *Lepomis macrochirus*. Bluegill were found to consume the following items; lepidopteran larvae, dipteran larvae, amphipods, isopods, and copepods. Phleiger (1975) stated that food habits often change with age and growth. Therefore, the composition of diet is seldom found in any one fish.

The benthic invertebrates preyed upon were occasionally few in number or absent from benthic collections. Ivlev (1961) explained that the size of the predator ration depends on average concentration and degree of patchiness of distribution of the prey. Often times collections by the Surber sampler alone may not accurately represent actual populations (USEPA, 1977).

Station 2. Of the dominating forage fishes, the Bluntnose Minnow, Sand Shiner and Creek Chub were the most numerous. The Bluntnose Minnow was found to consume plant material, detritus and algae. According to Phleiger (1975) and Ewers (1935), cladocerans and bottom organisms were missing from its diet. The Sand Shiner was found to consume solely plant material and detritus. The Creek Chub was found to ingest a large variety of items; plant and mineral detritus, isopods, ephemeropterans, aquatic oligochaetes, terrestrial insects, arachnids, coleopterans and decapods. The Creek

Chub is considered an active carnivore and small amounts of plant material are usually accidentally ingested (Phleiger, 1975).

The White Sucker, an important rough fish, was found to consume the following items: dipterans, nematodes, coleopterans, oligochaetes, and copepods.

Station 3. The important forage fishes are the Creek Chub and the Striped Shiner. The Creek Chub fed on the same invertebrates as at station 2. The Striped Shiner fed on plant material, detritus, algae, plecopterans, ephemeropterans, dipterans, oligochaetes and terrestrial insects. Phleiger (1975) described a generalized feeding habit for it. An important game fish was the Green Sunfish. It was found to ingest plecopterans, ephemeropterans, isopods and dipterans.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Physio-Chemical

The water quality of Flatfoot Creek has no unusual characteristics. With the exception of five parameters, this creek meets the guidelines set forth by the United States Environmental Protection Agency (EPA, 1973, 1976) and the West Virginia water quality criteria (DNR, 1977).

Probably the most important limiting factor to aquatic life at stations 1 and 2 is the low dissolved oxygen. While the headwater station 3 maintained a minimum dissolved oxygen of 7.5 mg/l, stations 1 and 2 were depleted to 1.0 and 1.7 mg/l, respectively. The suggested minimum level for aquatic life is 5.0 mg/l (DNR, 1977).

The second most important factor and associated with the dissolved oxygen is the level of total, suspended and dissolved solids. Although stations 2 and 3 did not differ by more than 124 mg/l total solids, station 1 surpassed the maximum by 380 mg/l. High levels reduce photic zones which decreases primary production. Stations 1 and 2 only supported 9 and 8 taxa of phytoplankton, respectively, while station 3 supported 15 taxa. The winter values of density (cells/liter) at station 3 were almost twice that of stations 1 and 2 (Weaks, 1977). Heating of surface waters from turbidity inhibits

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Potassium and chloride levels were slightly lower than the accepted standards. The potassium values were low at all stations but never more than 8.6 mg/l from the suggested mean. Chloride levels were only occasionally below the accepted range at station 3 but stations 2 and 3 were consistently below suggested mean values.

At station 1, phosphorus levels surpassed the suggested 100 mg/l level with a mean of 197 ug/l. The maximum value was 540 ug/l. The range at station 2 and 3 were within suggested values.

Benthos

Generally the number of taxa and the species diversity decreased from the headwaters to the tailwaters of Flatfoot Creek. All seasons combined, stations 1, 2 and 3 contained 16, 41 and 34 taxa, respectively. No one order comprised more than 29.4 percent at station 3 but station 2 was comprised of 50.0 percent dipterans and station 1, 95.0 percent annelid worms.

At station 3, the specimens were predominantly mayflies (29.4%), stoneflies (18.7%) and caddisflies (11.4%). The mayfly *Heptagenia* made up 21.4 percent of the benthos.

Station 2 was predominantly fly larvae (50.0%) and aquatic worms (18.5%). Larva and pupa of Chironomidae made up 48.7 percent of the sample. Dominant genera were *Trissocladius*, *Strictochironomus*, *Cricotopus* and *Eukiefferiella*.

Oligochaetes in the family Naididae composed 17.0 percent.

Station 1 was predominantly aquatic worms (95.0%). The family Naididae made up the majority of the benthos (93.2%) from this station.

For all seasons, the highest indices of diversity were calculated for station 3. The lowest index of diversity (0.36) was recorded at the tailwater station 1. The lack of rocky substrate and frequent inundations by the Ohio River may be partially responsible for the fewer number of taxa and lower indices of diversity.

The use of organisms as indicators of water quality is an increasing practice. It is known that some species have higher tolerances to environmental conditions than others (USEPA, 1973).

Table 5 includes a list of taxa from station 1 which have been classified according to tolerances to decomposable organic wastes as established by the U. S. Environmental Protection Agency (1973). No taxa were found at station 1 which were less than facultative to organic wastes.

From station 2, five taxa were found which were less than facultative to organic wastes (Table 5). Four of these classified as intolerant were found only in winter. Chemical data taken at the same time showed the water quality to be at its best (e.g. total & suspended solids-lowest, turbidity-lowest, dissolved oxygen-good, eight other high detrimental parameters-lowest). The fifth indicator species was classified as facultative-intolerant and disappeared from the samples after two seasons. Fifteen other taxa were rated tolerant-facultative.

From station 3, five taxa were found which were less than facultative to decomposable organic wastes. Four classified as intolerant were found on at least three occasions. The fifth (Caenis sp.) is classified as facultative-intolerant and was found on all occasions.

No rare, threatened, or endangered species of benthic macroinvertebrate was found in the study area. However, the caddisfly Rhyacophila ledra Ross had only been reported from Wayne County, West Virginia prior to this study. Also, R. torva Hagen had only been reported from Randolph and Fayette Counties. The stonefly Perlesta placida Hagen is a new county record from West Virginia.

Fishes

The fishes of Flatfoot Creek are dominated by forage species.

With all stations combined, the 324 fishes of station 1 were composed of forage fishes (69.4%), game fishes (30.2%) and rough fishes (0.3%). The Emerald Shiner made up 85.3 percent of the forage fishes. The game fishes were the Black Crappie (46.9%) and the Bluegill (39.8%). The only rough fish was the Yellow Bullhead.

With all seasons combined, the 449 fishes of station 2 were composed of forage fishes (95.1%), rough fishes (3.3%) and game fishes (1.6%). The forage fishes were composed of several species, none of which dominated by more than 25.0 percent. Important species were the Creek Chub (25.0%), Sand

Shiner (23.2%), Bluntnose Minnow (16.2%) and Emerald Shiner 13.6%). The rough fishes were the White Sucker (80.0%) and Black Bullhead (20.0%). The predominant game fish was the Green Sunfish (71.4%).

With all seasons combined, the 410 fishes of station 3 were composed of forage fishes (91.5%), rough fishes (5.1%) and game fishes (3.4%). Important species of the forage fishes were Striped Shiner (32.3%), Creek Chub (24.5%), Bluntnose Minnow (17.9%), Johnny Darter (10.9%) and the Stoneroller (1.9%). The White Sucker was the only rough fish taken in the sample. The game fishes were made up of the Green Sunfish (50.0%), Longear Sunfish (28.6%) and Spotted Bass (21.4%).

The Southern Redbelly Dace *Phoxinus* (= *Chrosomus*) *erythrogaster* and the River Shiner *Notropis blennius* are listed as fishes of scientific interest on the tentative list of rare animal species for West Virginia. The remainder of the population is common and widespread.

Stomach Analysis

Of the fishes examined for stomach contents, a majority were carnivorous. From the winter collection, 58.3, 33.3 and 8.3 percent were carnivores, omnivores, and herbivores, respectively. From the spring sample, 62.5, 18.8 and 18.5 percent were carnivores, herbivores and omnivores, respectively. The 227 fish examined fed upon 15 food source categories from algae and plant detritus to crayfish. The major prey was dipteran larvae. An assortment of aquatic insects made up a large part of the remaining food sources.

Summary of Plans: Locks and Dam Replacement

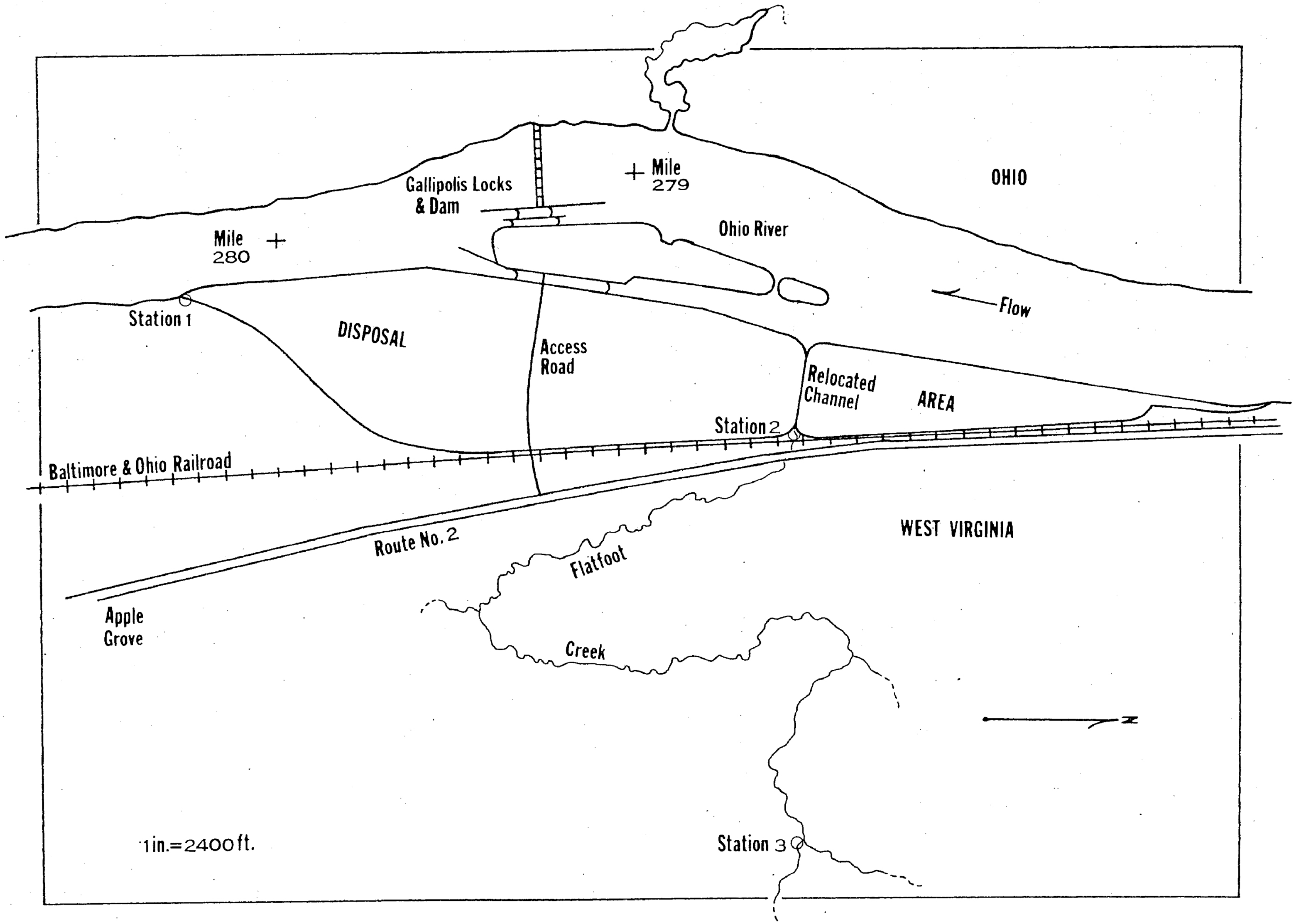
In order to handle an increased amount of river traffic efficiently and economically, the Gallipolis Locks and Dam will be replaced or modernized to eliminate this bottle-neck from the Ohio River system. Modernization of the existing locks alone will physically allow only 50-63 million tons passage annually. Based on short-range forecasts which indicate traffic levels of 55-60 million tons by 1985, it is highly likely that an alternate canal plan will be initiated.

If a canal is necessary, the United States Army Corps of Engineers have developed three disposal plans for dredged material. If plan 1 is implemented, dredged material will be uniformly disposed over the bottomlands adjacent to the canal stretching over 1.7 miles (2.7 km) of Flatfoot Creek and rechanneling the stream (Figure 4). If plan 2 is adopted, the material will be placed in mounds 70-100 feet (23-31 m) in height along either side of Flatfoot Creek. If plan 3 is adopted, the material will be transported 3 miles (4.8 km) away to an area in the Mud Run drainage basin. Mud Run is a small stream similar to Flatfoot Creek but is a tributary of Crab Creek of the Ohio River. The heavy construction proposed for the canal will have detrimental effects upon the environment during its construction. With the proper planning, environmental effects following the construction may be minimized.

Assessment

Extensive environmental studies of Flatfoot Creek and

Figure 4. Proposed plan of development of Gallipolis Locks and Dam displaying uniform disposal over bottomlands and channel relocation.


OHIO
Mile
279
Gallipolis Locks
& Dam
Ohio River
Mile
280
Flow
Station 1
DISPOSAL
Access
Road
Relocated
Channel
AREA
Station 2
Baltimore & Ohio Railroad
WEST VIRGINIA
Route No. 2
Flatfoot
Creek
Apple
Grove
N
1 in.=2400 ft.
Station 3

the Mud Run tributary have been conducted by many individuals from various disciplines: phytoplankton and non-vascular plants, Thomas E. Weaks, Ph.D.; fishes, benthos and zooplankton, Donald C. Tarter, Ph.D.; vegetation and flora, Dan K. Evans, Ph.D.; mammals, amphibians and reptiles, Ralph W. Taylor, Ph.D.; birds, Henri C. Seibert and Richard Yahner.

Based on these data in this thesis and data from Mud Run with emphasis on benthic macroinvertebrates and fishes, I believe that Plan 1 (uniform disposal over the bottomlands adjacent to the canal) will have the least environmental impact.

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 these 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 for West Virginia.

Recommendations

Fishes

Ten of the following taxa will be eliminated from the stream (stations 1 & 2) but the majority will repopulate the new channel from the Ohio River: Game Fishes (Pumpkinseed Sunfish, Black and White Crappies, Drum) and Forage Fishes (Carp, Emerald Shiner, River Shiner, Spotfin Shiner, Mimic Shiner, Gizzard Shad).

Four species of game fish will be eliminated; Pumpkinseed Sunfish, Black and White Crappies and Drum. Other game fishes found in the channel area include Spotted Bass, Bluegill Sunfish, Longear Sunfish, and Green Sunfish. The Green Sunfish's tolerance to turbidity, fluctuation in temperature and decreased dissolved oxygen concentration will probably allow this species to populate the relocated channel first.

Of the forage fishes, the following six species will be eliminated from stations 1 and 2; Emerald Shiner, River Shiner, Spotfin Shiner, Mimic Shiner, Carp and Gizzard Shad. Other forage fishes include the Stoneroller, Striped Shiner, Sand Shiner, Bluntnose Minnow, Creek Chub and Johnny Darter.

The only rough fish from stations 1 and 2 was the White Sucker.

If proper ecological requirements are met in the relocated channel, most of the populations will re-inhabit the area.

(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 (if possible) to allow colonization by zoobenthic populations to provide fish food. The food web showed the importance of benthic organisms as producers.

(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.

Benthos

Thirty-eight taxa of benthic macroinvertebrates will be destroyed at stations 1 and 2. Only 8 taxa, however, 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.

Since the benthic populations are fish food type organisms, many of the recommendations for benthic organisms have already been 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 developes, leaf detritus will probably be in inadequate supply despite what may wash downstream.

Although having an immediate detrimental effect, I 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 run-off. If proper ecological requirements are met, a relocated channel for Flatfoot Creek should repopulate to the larger extent within a couple of years.

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