The Black River:

A Comprehensive Study of Physical and Chemical Characteristics and their Potential Management Implications

By

James D. Chitty
Paul M. Gugg
Steven J. Steinberg
Stephen G. Townsend
Jeoff A. Urioste

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University of Michigan
Biological Station

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Abstract

An analysis of the Black River's biological and physiochemical characteristics was conducted for comparison to the model proposed by the river continuum theory . The theory specifies that the biological fauna, physical characteristics and chemical composition observed, are reflected in river order changes in terms of the presence, absence, or density of producer and consumer communities. The study reflected consistencies between the model and observed physical parameters and chemical attributes, but biological indicators were less corroborating. Physical characteristics such as temperature, depth, width, velocity, discharge, and suspended sediments increased with river mile and trends in the data became apparent. Chemical factors such as nitrates, dissolved oxygen, pH, alkalinity, and hardness, though not as clearly conclusive, show a gradient associated with river order transition. Biological indicators were not as conclusive in supporting the river continuum theory since there was no representation of shredders in the headwaters and predatory species were found at most sites. Management issues of the Black River address the control of soil erosion, species composition, and sedimentation as well as maintaining water temperature.

Introduction

The river continuum concept as it applies to the Black River specifically proposes that river dynamics are inter-connected and dependent upon each other in terms of biological, chemical, and physical characteristics in such a way that predisposes the success of a river's productivity only if there can be some balance between these criteria (Vannote et al., 1980). These guidelines provide insight for evaluating predictable and observable biological characteristics for river complexes and how they relate to the physical environment. The purpose of our study, in part, was to critically evaluate the Black River for each of these criteria and to make recommendations for possible management strategies for this river which has been designated as wild and scenic. Moreover, observation of a baseline species inventory is useful in creating management plans for the river. It was also considered critical that each team member acquire experience in the rigors of field data collection for a team designed project. That each member received all or some of the skills required for stream data analysis was in itself a goal for the study. It is hoped that our data and observations will be of some use to the Black River watershed managers.

Evaluation of the river under the continuum processes included biological sampling of each of seven sites for fish and benthic species, as well as observing any other outstanding organisms found (e.g., bivalves at site seven). Live organisms are an indication of the continuum theory in action. If our biological samples support the theory, then there should be a continuous change along the river in terms of both biota and associated chemical and physical attributes. Test procedures involving chemical analyses for alkalinity, hardness, total phosphorus, and nitrates were performed in the laboratory using appropriate techniques. Determinations of pH, dissolved oxygen, and conductivity were performed at each site. Physical characteristics were evaluated using Habitat Suitability Index standards for bottom composition. Velocity, channel depth and width, and temperatures were measured using various test equipment with sufficient accuracy to satisfy the needs of the experiment.

Headwaters of the Black River originate a few miles north of Johannesburg, Michigan, Otsego County. This river flows for approximately 60 river miles northward where it eventually empties into the Cheboygan River three miles south of the City of Cheboygan. As the Black flows through each river order change, certain characteristics consistent with the river continuum concept change noticeably as outlined by our analysis. Generally, as the river changes from a first order river through successive order changes to a fourth order river, biotic, chemical, and physical features change in response to the varying available nutrients relative to micro-habitats. Stream flow and water clarity conditions for the river at the observed sites were relatively slow, shallow, clear waters for sites 1, 2, 3, and 6, but faster clear water at sites 4 and 5, with turbid slow waters for site 7 (see map, Figure 1). Bottom consistency was mainly sand and silt with various patches of gravel and cobble throughout the sites, though sites 4 and 5 were mainly cobble due in large part to the swiftness of the waters. Characteristics of the riparian vegetation on the banks include a gradual change in fauna from cedar swamp at site 1, to lily pads and cattails at site 7. From sites 2 to 6, there were various vegetative species including but not limited to river alder, beech trees, white cedar, grass, sedges, cotton wood, and aspens.

Historical Background

The headwaters for the Black River stem from the Green Swamp area near the Cheboygan /Montgomery County border at T. 31 N., R.1 W., Sections 8, 9, 16, 17, 20, 25, 26, 27, 28, 29. Temporal derivation of the river originates form the last glacial period from which a series of moraines and outwash terraces were created leaving enormous amounts of surface sand and gravel. Specifically, the Port Huron moraine forms an east-west crest traversing the Black River drainage basin. This moraine was deposited by the Port Huron ice sheet approximately 13,000 years ago (Bright et al., 1991). While considered less stable than the Sturgeon and Pigeon Rivers which originate nearby, the highly permeable soils allow ground water to move relatively unrestricted into the river. This constant influx creates a stable flow and depth profile and consequently sustains the river at a relatively constant annual temperature desirable for salmonid species which proliferate within the river. Furthermore, because of the constancy of the river flow, bank erosion and flash flooding are not major conditions of the Black River's dynamics (Wiley, 1992). According to the US Geological Survey of 1968, maximum variation in this river is approximately two feet.

The three trout species found in the Black River include brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and rainbow trout (*Salmo gairdneri*) Trout populations as well as the native grayling (*Thymallus spp.,*) have been altered significantly over the last century either as a result of natural succession or as a response to human impacts. From the early 1800's to 1850, grayling had been dominant in the Black River. Prior to the logging operations on the Black River in the late 1800's, a slow progression of brook trout, which had been introduced in 1884 in the Au Sable and Manistique Rivers, began to take over the native grayling. Both brown (introduced in 1883) and rainbow (introduced in 1875) trout are exotic species valued by sport fisher persons, but have also impacted natural populations. By the early 1900's, grayling had been almost completely replaced by brook trout and the last known grayling was caught on the Manistique River in 1912. The Black River was the last known river in Michigan to hold any appreciable numbers of grayling (Wiley, 1992). Michigan continues to maintain laws against possessing any grayling that may be caught on the Black (Michigan Fishing Guide, 1992). In the early 1900's, brook trout became the dominant species. In the Black River brook trout have not been suppressed by the competitively superior brown trout as they have been in many other northern Michigan streams. Rainbow trout have had some success surviving in the Black but remain elusive to sport fisher persons.

Logging peaked in the 1890's which accelerated the demise of the grayling, but enhanced the populations of invading brook trout. Log jams and splash dam dynamiting practices widened the banks and added huge quantities of sand and silt into an already delicate river, choking off much of the spawning grounds required by the few remaining grayling. By the 1930's, brook trout were on the decline and brown trout began to move to the fore front. Although known to be present, rainbow trout have been sparse at best and do not seem to be numerous in sampled sections.

Human-made dams have created obstacles for indigenous species by acting as both sand and silt collection points as well as interference for access to much desired spawning grounds. These dams also slow the waters and elevate the temperature of the waters. Elevated water temperatures create serious consequences for a brook trout fishery but the Tower Dam has minimal impact in raising the water temperature of the upper Black. It would create serious consequences for the brook trout fishery if temperature was raised. The Black River has been designated a wild and scenic river until it reaches the backwaters of the Tower Dam north of Route 68 in Tower Township. These upper reaches remain essentially free of the pollution created by municipal and industrial complexes, but probably acquire minimal effluents from the few cabins found on the banks. Principally owned by the state, this pristine area remains protected from future development, but the future for the lower stretches is in jeopardy of being over exploited (US Geological Survey, 1991). The Tower Dam is the first location on the Black River where any water regulatory device exists. Hydroelectric power is the sole reason for the dam site. Klieber Dam , built for the same reason as Tower Dam, is located south of Black Lake in the town of Klieber and also raises the temperature and interferes with spawning efforts. Annual average flow through the dam is 272 cubic feet per second, but reached a record high of 1860 cubic feet per second on 7 April 1960. An all time low of 50 cubic feet per second was reached during dam repairs in November of 1949 (US Geological Survey, 1991). These conditions may elicit unnatural cyclic responses from both benthic and fish populations if extremes persisted long enough or effects occurred frequently.

Some natural damming performed by beaver communities has been historically linked to human intervention on the Black River. With the settlement of the river, more food trees for the beaver became available and consequently resulted in a population explosion which ultimately concluded in heavy damming of the Black River. Without some method to control the beaver population, the Black River is subjected to heavy beaver impact. Beaver dams create pools which slow the water flow and causes a general increase in annual temperature. Current measures, such as dynamiting beaver dams and trapping and removing beavers, are being taken to remove existing dams and beavers on a regular basis in an effort to enhance the river for brook trout (Wiley, 1992).

Sufficient high quality habitat able to sustain brook trout populations is a critical management issue (Wiley, 1992). Sand and silt, through natural or disruptive addition, continually threatens much of the prime spawning grounds and seems to be favoring the brown trout species. Brown trout are a predatory species that reduce the numbers of fry and fingerlings of all other salmonid species. Brown trout also have a competitive advantage in that they spawn in the early fall whereas brook trout spawn in the late fall. By the time brook trout hatch, the brown trout fingerlings are large enough to prey upon the brook trout fry. Black River trout management has sought to favor brook trout populations through physical removal of brown trout, sediment management and thermal control through beaver dam removal (Fenske, 1992).

Outlook

Though sometimes difficult to traverse, the Black River remains a delicately balanced ecosystem that provides recreational value (wilderness, canoeing, and trout fishing) to the general public on a regular basis. The popularity of the lower Black for boating and canoeing is becoming increasingly evident from the number of users seeking waters requiring no portages. On the other hand, a large scale livery operation may not occur due to the numerous rocky shoals that would cause excessive boat damage (US Geological Survey Reconnaissance, 1968). Increasing public demand on the river dictates that updated information and management strategies such as special fishing regulations be implemented to counteract this increased pressure. Sections of the river have been rated by many fisher persons as some of the best in the northern regions of the southern peninsula of Michigan. These areas of the Black require management to sustain habitat for water quality, fishes, and wildlife utilizing the river, as well as continued efforts to maintain the reputation of this wild and scenic river. Overall value of the Black River is solely dependent on characteristics of flow, water quality, river bed, and banks (US Geological Survey, 1991) and management thereof.

Materials

The following is a list of materials and equipment used in physical, chemical and biological sampling:

pH pen - Cole Parmer, Chicago, IL.

Conductivity pen - Cole Parmer, Chicago, IL.
Mercury Thermometer
30 meter Open Reel Tape
Meter Stick
14 foot Straight Seine
Kick Screen
2 Viewing Pails
12 125 ml Poly Sample Bottles
12 1 liter Poly Sample Bottles
2 Stryofoam coolers
#625 Pygmy Current Meter - Teledyne Gurley, Troy, NY.
Hydrolab 4000 Series - Hydrolab Environmental Data Systems, Austin, TX.
YSI Model 57 Oxygen Meter
Backpack Electro-Shocker Model BP-4 Coffelt Electronics Company Inc.
2 pair Rubber Gloves

Methods

River Selection Process

Four rivers were proposed as possible study sites for our project. Our group worked in conjunction with the Black River Management Study Group (Tansey et al., 1992) on the river selection process. Rivers considered included the Maple, Sturgeon, Black, and Jordan. Selection of the river for study was done by ranking each river for five criteria. Since our ability to study the sites was limited by travel expenses and time constraints, the estimated travel distance to the rivers was a primary concern. Rivers which were closer to the University of Michigan Biological Station (UMBS) were ranked as more desirable than those which were further away. The length of the river was also important to our study since a longer river would provide more order changes at which samples would be taken hence longer rivers were considered more desirable than shorter rivers. Access to each of the rivers (e.g.

road crossings, boat launches, state land, parks, camp-grounds, and bridges) was also of interest since the number of study sites were limited by access to the river. Rivers which provided ample amounts of public access were rated more desirable than rivers with limited access.

The last two criteria used to rank the rivers were of greater interest to the management aspect of our project. Since some of the management survey was to be done by canoeing, the rivers were ranked on the length and safety of the navigable water available on each. Rivers with longer and safer stretches of water were ranked above those rivers with swifter, shorter stretches of navigable water.

The final consideration in the selection process was the amount of state or federal owned land along each of the rivers. Rivers with ample state or federal ownership were more desirable than rivers which lacked such land since government owned lands are more easily accessible. The differentiation between government owned and privately held lands was also important because a management plan could be more easily implemented on government lands than on private lands.

When all five of the factors were considered by the two project groups the possible choices were reduced to the Black and Sturgeon Rivers. Site visits of these two were conducted and the Black River was selected as the project site due to its reasonable distance from the UMBS, length and changes in magnitude, plentiful road access, amount and relative safety of its navigable water, and primarily state and federal ownership along the river.

Site Selection

Once the Black River was selected, seven sampling sites were identified along the river. Three criteria were used in the selection of the sampling sites. First, study sites were desired a short distance downstream from where the order (size) of the river increased in magnitude. River order was determined by using topographic maps to locate points at which major tributaries entered the Black River. The first available access point downstream of the tributary was then located as a sample site. Where stream order did not increase over a long distance additional sample points were sited as access made possible.

Sampling sites were also desired downstream of obstacles to the river's natural course such as dams or lakes which would alter the chemical or physical characteristics of the river. The final consideration in locating sampling sites was the accessibility of those sites by car and foot. When sites were located in close proximity to bridges, the exact sampling site was located some distance upstream from the bridge to avoid bias due to the bridge such as runoff or constriction of the river channel in the sample area. The exact location of each of the seven sampling sites as shown on the Black River map (Figure 1) are as follows:

Site:	Location:
1	NW 1/4 NW 1/4 sec. 27, T. 31 N., R. 1 W., Otsego Co., MI (Upstream of culvert under Route F-44 north of Johnson's Crossing)
2	NE 1/4 NE 1/4 sec. 34, T. 32 N., R. 1 W., Otsego Co., MI (Upstream of culvert under Tin Shanty Bridge Road)
3	NE 1/4 NE 1/4 sec. 29, T. 33 N., R. 1 E., Cheboygan Co., MI (Upstream of bridge on Clark Bridge Road)
4	NE 1/4 SE 1/4 sec. 11, T. 33 N., R. 1 E., Cheboygan Co., MI (Upstream of bridge on Black River Road near Dixon Highway)
5	SW 1/4 NE 1/4 sec. 29, T. 35 N., R. 1 E., Cheboygan Co., MI (Below dam on Klieber Twin School Road)
6	NE 1/4 NW 1/4 sec. 34, T. 36 N., R. 1 E., Cheboygan Co., MI (Upstream of bridge on Black River Road south of Zolner Road)
7	SW 1/4 SW 1/4 sec. 8, T. 36 N., R. 1 E., Cheboygan Co., MI (Upstream of bridge on Black River Road north of South River Road)

Water Quality Tests

A number of tests were used to quantify the water quality of the Black River. Tests were chosen that would be efficient in the field while also providing information useful to management of the river for recreational activities. Water quality is determined in relation to a number of factors including: dissolved solids and gases; suspended sediments; and physical properties of the river. Those measures of particular interest in recreational uses include dissolved oxygen and nutrients such as nitrates and phosphates. Physical characteristics including temperature, pH, and conductivity are also important to recreational use of the river (US Geological Survey Reconnaissance, 1968).

A brief description of the tests and methods used in data collection at each of the sampling sites and how these relate to water quality follows. Measures made on site were repeated between two and four times and an average was then taken when appropriate.

Temperature

Temperature is an important requirement in a trout stream such as the Black River. If temperatures become too high in the stream, its value as brook trout habitat will decline rapidly.

The temperature of the water at each location was determined using the Hydrolab in the temperature measurement mode. When this equipment was not on site a hand-held mercury thermometer was used to measure temperature. The temperature was taken slightly below the surface of the water at the center of the transect since the current of the river prevented any stratification of the water column.

Dissolved Oxygen

A second important characteristic of recreational rivers is the level of dissolved oxygen. Dissolved oxygen is very important to both the habitat and aesthetic qualities of the river. Low oxygen can lead to buildup of decomposing organic material which is both unsightly and may create an unpleasant odor (US Geological Survey Reconnaissance, 1968). Except for aquatic bacteria, most aquatic life requires high levels of dissolved oxygen to survive. Turbulence, rooted aquatic plants and microscopic algae all contribute to the level of dissolved oxygen. If levels fall extremely low, below four ppm, fish life will be stressed (Baughman et al., 1991).

Dissolved oxygen measurements were determined using a YSI oxygen meter and a Hydrolab. The measurements were taken in the flow at half of the water's depth at the center of the transect.

pH

The pH of an aquatic system impacts both the chemical and biological makeup of the water (Baughman et al., 1991). The value of the pH represents the concentration of hydrogen ions in the system and indicates the level of acidity or alkalinity of the water (US Geological Survey Reconnaissance, 1968).

Measurement of pH is on a logarithmic scale. The value is the reciprocal of the hydrogen ion concentration on a log scale of 1 to 14. A pH of seven is neutral, higher pH indicates alkaline or basic waters and lower pH indicates acidic waters. Each one point increase in pH represents a ten-fold decrease in the hydrogen ion concentration (Baughman et al., 1991).

The pH of the water at the sample sites was determined by using a Hydrolab configured to measure pH or through the use of a hand held electronic pH pen. The pH of the water was measured in the same location as the dissolved oxygen.

Conductivity

Conductivity acts as a direct measure of dissolved ions in the water based on its ability to transfer an electric current. As the level of dissolved ions increases, conductivity increases. Though conductivity itself is rarely a water quality problem, increases over time can be an indicator of increasing human effects. Conductivity may be noticeably increased by such inputs as septic system effluent, fertilizer runoff and storm-water influx. (Baughman et al., 1991).

Conductivity is measured in units called mhos. The conductance measured is between two electrodes of one centimeter square placed one centimeter apart. Values are reported in µmhos per square centimeter (one µmho equals one-millionth of a mho) (Baughman et al., 1991).

Conductivity at the sample sites was measured using the Hydrolab configured to measure conductivity or through the use of a hand held conductivity pen. Conductivity was measured in the same location as dissolved oxygen.

Alkalinity

Alkalinity is a measure of compounds present in the water which provide acid neutralizing ability. The level of alkalinity is based on the amount of dissolved carbonate and bicarbonate material present. In northern Michigan much of this carbonate material comes from surface water flowing through soils and glacial deposits and over limestone bedrock, dissolving out carbonate material. A high buffering capacity as measured by alkalinity, represent the ability to maintain water acidity at levels tolerable to aquatic life (Baughman et al., 1991).

Samples of water (100 ml) were collected on each field day at each sample site and analyzed in the lab. The samples were tested for total alkalinity. The samples were tested individually and the results of the tests from each day were averaged to determine an average result for each sample site.

Once the samples were in the lab, 25 ml were transferred into Erlenmeyer flasks containing stir bars for analysis. To determine total alkalinity, several drops of brom-cresol green methyl red indicator were added to the samples to produce a blue/green color. The sample was titrated with 0.2N sulfuric acid until the solution turned pink/orange in color. The amount of titrant used to achieve the color change was recorded. The above procedure was repeated on each of the samples. The total alkalinity was calculated with the following formula:

Total alkalinity as mg $CaCO_3$ per liter = B * 10

where: B = ml total titration from start to pH 4.5 (methyl orange end point)

The final values for each site were then determined by averaging the results of the three samples (Lind, 1979).

Hardness

Hardness is expressed as a characteristic of water based on the concentration of calcium and magnesium ions. Normally hardness is not considered a harmful characteristic for humans and the ions involved are necessary for aquatic plants as nutrients. Hard water may, however, decrease the tolerance of fish to toxic metals in the water (Lind, 1979).

A 25 ml sample was collected from each sample site and brought back to the laboratory for analysis. Each sample was diluted to 50 ml in an Erlenmeyer flask using deionized water. The pH was normalized to pH 10.00 for all samples using a water hardness buffering solution. Several drops of an indicator solution, Eriochrome Black T dye, were then added to the diluted sample. The sample was placed on a white piece of paper and titrated with EDTA until the red color of the dye was removed. The hardness of the sample was then calculated in the following formula: (Lind, 1979)

EDTA hardness as mg $CaCO_3$ per liter = A * 40

where: A = ml titration

Nitrogen and Phosphorus

Nitrates and phosphates are important nutrients in aquatic systems. If the levels of these nutrients are too high, vegetation can become so abundant that the stream will be choked and dissolved oxygen can become depleted (US Geological Survey Reconnaissance, 1968). Nitrate is the nitrogen form most useful to aquatic plants and the form most commonly tested for. Similarly, only a small portion of the total phosphates are available directly to plants, in the form of ortho-phosphates. Phosphate is often a limiting nutrient and often regulates the growth of algae making it an important nutrient influencing water quality (Baughman et al., 1991).

Water samples for nitrate and phosphate testing were taken in the field. Sample bottles of 125 ml were washed in a 10% solution of sulfuric acid (H_2SO_4) for 30 minutes. Each bottle was rinsed on site in river water before the actual sample was taken. The bottles were filled at approximately 1/2 the depth of the river in the center of the transect. Each bottle was then capped while under water.

Numbered bottles were submitted to the lab at UMBS for testing. Bottles in the first sample set were numbered consecutively one through seven according to the site they were collected at. As a control the second sample set was coded with random numbers -- a blind test in which no expectations influenced by the original data would be present on the part of the lab personnel.

Tests procedures used by the UMBS lab were from Franson, (1981). Nitrates were tested by "automated cadmium reduction method" (#418F). Total phosphorus was tested using the "preliminary digestion steps for total phosphorus" (#424C) followed by "automated ascorbic acid reduction method" (#424G).

Stream Velocity

Stream velocity has several impacts on the recreational potential of the Black River system. The Michigan Department of Conservation has set out some general guidelines for recreational potential of rivers in the state. In streams where there is a high drought flow, summer water temperatures are maintained at levels tolerable to cold water species such as trout. However, if flows are too high, excessive erosion may occur. Variable velocities also make rivers more interesting to fisher persons so long as flow is not so fast that it is dangerous for wading.

Canoeing or kayaking also requires sufficient flow. The length of the season is dependent on how soon spring floods end and the degree of summer drought. Velocity changes along the river increases interest to canoeists and kayakers. Other uses such as camping or cabin based recreation on rivers are correlated with fishing and boating potential (US Geological Survey Reconnaissance, 1968).

Calculating discharge was a particular problem for this research group and several methods were utilized to obtain flow values. The most reliable method found was the use of the spheroidal organic velocity instrument (an orange) which was floated on the river over a measured distance. The travel time over the known distance was recorded for several runs. Depths were then measured along the transect to obtain an average for the river. This data, in conjunction with a correction factor of 0.8 for cobble substrate and 0.9 for sand substrate, provided a calculated estimate of flow for each site (Needham and Needham, 1962).

The second method used incorporated an electronic current meter. and a depth profile constructed from three points on segments less than 10 meters width and five points on segments over 10 meters wide. The instrument worked well in areas where flow was substantial, but in areas of low flow, especially near the edges, the meter failed to operate properly. The minimum flow required to register on the velocity meter was determined to correct for sample points that did not have sufficient flow. Where usable data was obtained it was recorded for comparison with readings from the spheroidal organic velocity instrument.

At sites 6 and 7, depth presented a particular problem. Neither of the above methods was possible, thus makeshift estimates were made by measuring depth with a weighted tape suspended from the bridge crossing and timing objects floating under the bridge. The width of the bridge was recorded as the distance of travel. This provided some idea of stream flow at these sites, though the reliability of these methods is questionable. Comparison with data from the US Geological Survey shows values obtained for flow were of the same order of magnitude (US Geological Survey Reconnaissance, 1968; US Geological Survey Water Resources Data, 1991).

Suspended Sediment Load

The suspended sediment load, or amount of particulates in suspension at each sampling site were determined by filtering a sample of water through 0.45 μm filter paper of known weight. A specified quantity of water was then filtered from each sample site. After the water sample had been filtered, the filter paper was placed into a drying oven to evaporate excess water from the sample. After drying for 24 hours in the oven at 100° C, the filter paper was weighed and the weight of the paper prior to filtering was subtracted so that the amount of suspended particulates could be calculated. The suspended sediment load for each of the sample sites was determined by multiplying the average suspended sediment in grams per liter by discharge. Thus, the amount of suspended sediment passing each sampling site in grams per second could be calculated and compared between sites (Lind, 1979).

Bottom Characteristics

Visual estimations of river bottom character were made at each sample site. River substrate and cover are important characteristics in determining the quality of the site habitat for trout. Classifications of bottom character include (from smallest to largest) silt, sand, gravel, and cobble. The amount of in-stream cover was also noted at the sites, including in-stream or overhanging vegetation, under-cut banks and the amount of in-stream logs. Quantity and quality of pools related to depth, size and visual obscurance was also noted.

Fish Sampling

Fish species were collected using two different methods. A 14 foot long seine was worked at the sample sites. Researchers worked downstream towards the seine to force fish into the net making a special effort to stir up fish in deep pools with abundant cover. A number of small non-salmonid fish were found using this method.

Electro-fishing was a more successful method of fish sampling. Data were collected at sites 1 through 3 using a backpack electro-fishing unit. The remaining sites were not electro-fished due to difficulty in getting the equipment into those sites or depths being too great to use the backpack unit. However, seines were used at sites 4 and 5 in leu of electro-fishing. Electro-fishing was the only method successful in capture of salmonids. Trout and other large fish were apparently easily spooked or are better able to swim upstream against the current in which the seine was deployed. The sixth and seventh sample sites were too deep to use either method of fish sampling.

Benthic Sampling

Benthic invertebrate samples were collected using kick-screens and seines. A screen or seine was placed downstream from researchers who stirred up bottom sediments upstream and moved down towards the seine or screen to displace benthic organisms. Organisms were then captured as they flowed downstream.

Once collected, organisms were identified, logged and released.

Sampling of the benthic invertebrates was done to look for indicator species and to gather data on species present. Sample sites 1 through 5 were seined and kick-screened several times. Sites 6 and 7 were too deep to allow sampling of this type. No attempt to quantify invertebrate populations was made in this study.

HSI for Brook Trout

The Habitat Suitability Index (HSI) for brook trout is a series of river characteristics that give an estimation of a river's quality as habitat. Optimal brook trout habitat is characterized by cold, clear spring-fed rivers. Rocky substrate without siltation in riffle areas and areas of slow, deep water, numerous deep pools and ample in-stream cover are also important. Stable, well vegetated banks and consistent water flow and temperature are necessary as well (Raleigh, 1982).

This study did not include complete HSI analysis of sample sites except site 2 which was evaluated during an all class exercise on 26 July 1992. Rather, some visual estimation of stream quality combined with the measured chemical and physical data allowed estimation of the quality of the Black River as brook trout habitat. The collected data was viewed in light of several HSI model components and where HSI data was available for the Black River, this was included in the analysis of the results.

Results

Refer to Table 1 for a summary of all the data collected on the Black River.

The substrate at site 1 was predominantly sand with many downed cedar trees and undercut banks. Sand was also the major component of the substrate at site 2 upstream of the Tin Shanty Road crossing. There was a large amount of silt deposited along the sides of the river. Substrate composition changed to gravel and cobble downstream of the road crossing. The substrate at site 3 was composed mostly of sand with a few downed trees along the banks. The substrate of site 4 consisted of gravel and cobble, with the only cover provided by overhanging vegetation. The substrate at site 5 was mostly cobble with some gravel deposited along the sides of the stream. Site 6 was mostly sand with some silt deposits. There were large masses of aquatic plants in some of the slower moving parts of the river. The substrate at site 7 was mostly silt with some sand. There were large numbers of aquatic macrophytes along the edges of the river. There was also a large amount of marl on the substrate due to the precipitation of calcium carbonate.

Temperatures on the Upper Black River ranged from 12.5° C at the headwaters (site 1) to 23.5° C downstream from Black Lake (site 7). The mean temperature at each site generally increased along the entire course of the river (Figure 2).

pH remained relatively constant, with a low of 7.0 recorded at site 1 and a high of 8.5 recorded at site 3 (Figure 3). pH was lowest overall for the entire course of the river on 12 July 1992, possibly due to the input of precipitation that had been occurring on the two previous days. The mean pH across sample sites did not show any significant trends and remained nearly constant (Figure 3).

Conductivity generally decreased along the course of the river (Figure 4). The mean conductivity measured at the headwaters of the Black River was approximately 377 µmhos. The lowest mean conductivity (235 µmhos) was recorded at site 7, as the river exited Black Lake.

A decrease in the amount of dissolved nitrates was discovered (Figure 5). No nitrate was detected at site 7 since nitrate could not be detected at concentrations less than .005 ppm. The overall levels of nitrate were low.

There was no noticeable trend in the amount of total phosphorus along the course of the river (Figure 6), although the level of total phosphorus was conspicuously higher (23.4 ppb) at site 3 on the 22nd of July. Otherwise, the level of total phosphorus remained fairly constant.

Both alkalinity and hardness decreased along the course of the river (Figure 7). Alkalinity ranged from a high of 239 mg $CaCO_3$/L at site 1 to a low of 143.5 mg $CaCO_3$/L at site 7. Hardness dropped from 248 mg $CaCO_3$/L at site 1 to 148 mg $CaCO_3$/L at site 7.

Dissolved oxygen concentration remained fairly constant at all of the sample sites (Figure 8), although an unusually high reading of 19.4 mg/L was recorded at site 2 on 5 August. Dissolved oxygen was expected to decrease as stream order increased.

Discharge increased considerably as stream order increased (Figure 9). Discharge was lowest at site 1 and increased nearly 61 times by site 7, as the river exited Black Lake. The discharge measured at site 5, located just downstream from Klieber dam on 22 July, was close to the discharge measured by the US Geological Survey in 1991 (6.956 vs. 7.702 cubic meters per second). This helped confirm the accuracy of our discharge calculations.

Suspended sediment load increased along with the increase in discharge along the course of the Black River (Figure 10). As stream volume and velocity increased, the amount of suspended particles in the water increased (although the amount of suspended sediment per liter did not necessarily increase downstream from the first sample site).

Data on species diversity in the Black River was only obtained at sample sites 1 through 5. A total of 10 fish species and five insect orders were identified at the sample sites (Table 2 and 3). Two classes of mollusks and two orders of crustaceans were also located and identified (Table 3).

Discussion of Field Observations

According to the stream continuum concept proposed by Vannote et. al, our study of the Black River should have identified , "... a continuous gradient of conditions [along the river's course] including width, depth, velocity, flow volume, and temperature" (Vannote et al., 1980). Such a continual gradient in the physical aspects of the Black river was identified.

Physical Data

The width of the stream increased from a minimum of 6.2 m at the site most near the headwaters, site 1, to a maximum of 59.8 m at site 7, the final sampling site (Table 4). The change in the river's width would be expected to have had an impact on the conditions within the river. At the upper sampling sites, 1 and 2, the surrounding terrestrial vegetation, through the shading of the river, would of had a limiting effect on the amount of photosynthesis which could have occurred. As the river widened to greater than 15m in width, all remaining sites, the shading effect of the surrounding terrestrial vegetation was minimal, and photosynthesis could provide some autochthonous inputs into the river. Evidence to support this conclusion includes the lack of grazing animals, those that feed on algae, at sites 1 and 2; and their appearance beginning in site 4.

Related to the increase in the river's width was an increase in temperature along the river's course (Figure 2). The river's mean water temperature was lowest at site 1 (13.9°C) and steadily increased to its highest value at site 7 (20.6°C). The increase in temperature was probably related to the amount of solar energy reaching the water and the greater time the water was in contact with ambient temperature air. The smaller the width of the river and the more shaded it was by terrestrial plants, the less solar energy reached it resulting in a lower temperature. In areas of the river which were wider, more of the water was exposed to solar radiation and ambient temperature air and the water is warmer. The trend between river width and temperature is shown by Figure 11.

Dissolved oxygen (DO) levels were lowest at site 1, increased to their highest value at site 2, and then slowly decreased towards the end of the sampling sites (Figure 8). Oxygen levels were expected to be highest in the headwaters and decrease downstream. The decreasing trend of DO levels down the river's course was expected since the solubility of O_2 in water decreases as temperature increases. This exception from the oxygen level expected at site 1 may be explained by some degree of decay occurring in the cedar wetlands.

The maximum depth of the river, measured at the study sites, indicates a trend towards increasing depth along the course of the river (Table 4). Likewise, a trend of increasing velocity was also identified along the river's course (Table 4). Since width, velocity, and maximum depth were increasing along the sample sites, it follows that discharge increased also. Figure 9 records the change in discharge along the sampling sites. The large increase in discharge between sites 6 and 7 was a function of the increase in the river's width and depth, from 29.7 to 59.8 m and from .89 to 2.35 m respectively. The presence of Black Lake and its associated tributaries between sites 6 and 7 would also contribute to the increase in discharge identified between those sites.

Suspended sediment loads increased dramatically along the river's course (Figure 10). Measurements were lowest in the headwaters (site 1) and increased to the final sampling site. Consecutive increases in the suspended sediment load were recorded at each site except site 5, which was below a dam. The dam was probably acting as a sediment trap which would account for the slight decrease in suspended sediment loads at site 5. Large size particles, those readily visible to the naked eye, were abundant in the filtered samples of sites 1-3, while they were absent from the filtered samples of sites 4-7. The observation of large size particles in the headwater areas of the river supported the river continuum's assertion that coarse particulate matter should be dominant in headwaters while fine particulate matter would be dominant in downstream areas.

Chemical Data

Trends in the measurement of chemical data were also noted between the study sites. The change in conductivity along the river is illustrated by Figure 4. The conductivity of the water was highest in the headwaters (377 μmhos) where the stream was dependent on allochthonous inputs and lowest at the final study site (210 μmhos). Baughman et al. (1991) described a similar drop in conductivity in their study of the Black River. Our range for conductivity is similar to the range considered by the United States Geological Survey (1991) as being characteristic of non-polluted waters, which range between 255 μmhos to 399 μmhos. The high conductivity levels at the headwaters of the river are probably due to the large amount of terrestrial inputs into the water and the addition of ions to the water from the river bottom and banks. The inputs of those ions would be magnified by the relatively small amount of water that was receiving them. Further downstream, the decrease in conductivity could be due to the precipitation of $CaCO_3$, which is related to the decrease in both alkalinity and hardness along the river's course. The observation of marl deposits starting at site 5 would support this theory.

Average nitrate values steadily decreased downstream from site 1. The highest value recorded 0.03 ppm (site 1) was ten times greater than the nitrate values recorded at the final study site, 0.003 ppm. Nitrate levels were possibly highest in the upper reaches of the river (lowest site numbers) due to the large amounts of nitrogen entering the river from gypsy moth fecal matter and decaying vegetation. The decrease in nitrate levels along the course of the river was probably due to an increase in organisms such as, bacteria and blue green algae, which could consume the nitrates (Wetzel, 1983). Since nitrate levels did not increase in sites 4-7, where the surrounding watershed started to change from forest to agricultural and residential uses, additions of nitrate from fertilizers and other artificial sources did not seem to be significant. The trend in nitrate levels is illustrated by Figure 5.

Total phosphorus levels remained fairly constant throughout the sampling sites. The mean total phosphorus level varied between a low of 12.85 ppb at site 6 and a high of 16.6 ppb at site 3. A possible explanation for the highest total phosphorous level being identified at site 3 was the land use patterns above the site. Located directly upstream from site 3 are the Black River Ranch and the Blue Lakes Club, which could be responsible for the elevated total phosphorous levels. No trend was apparent between the increasing size of the river and the level of total phosphorus (Figure 6). Since the solubility of phosphate is dependent on the pH of the water, the nearly constant levels of pH in the stream would support the lack of a trend in the total phosphorus findings. Total phosphorus levels would only be expected to increase if pH changes occurred, which would alter the solubility of phosphorus. As with nitrate levels, no significant increases in total phosphorus were noted along sites 4-7 where the watershed type changed from forested to agricultural and residential uses. Changes in total phosphorus levels, had they occurred due to artificial inputs from sewage and fertilizers, would have had a localized effect due to their quick uptake by algae and the influence of pH on their solubility. Those changes in total phosphorus, had they occurred, would have only been detected if sampling took place directly downstream of the source pollution (Grant, 1992).

pH readings taken at each of the seven sampling sites did not demonstrate an increasing or decreasing trend, but were fairly constant. Mean values ranged from a low of 7.7 to a high of 8.2 (Figure 3). The nearly constant pH readings along the course of the river suggest that a buffering action was taking place. High alkalinity measurements in the river indicate large amounts of HCO_3^- and CO_3^-, which act as buffers and would be expected to be plentiful due to the calcareous soil and carbonate rich rock formations in the area (Hough, 1958). Levels of CO_2 in the river could also help explain the suspected buffering action taking place. If the river system had been CO_2 limited, fluctuations in pH would have been expected. Since those fluctuations were not encountered, CO_2 was not limiting in the Black River. The buffering capacity of the river was maintained by the constant equilibrium of Equation 1. If CO_2 subscript concentrations were not in equilibrium, fluctuations in OH^- concentrations would alter the pH along the river's course. The plentiful amounts of CO2 which had to be in the river to explain the trends in pH, alkalinity, and hardness, would force Equation 1 to the right.

[1] $$HCO_3^- + OH^- = CO_3^{-2} + H_2O$$

Both alkalinity and hardness levels decreased along the sampling sites (Figure 7). Alkalinity decreased from a mean of 239 to 144.5 mg $CaCO_3$/L. A US Geological Survey (1991) of the Black River obtained similar results with bicarbonates, a component of hardness, ranging from 150 to 254 (HCO_3) mg /L. Similarly, hardness measurements decreased from 246 mg $CaCO_3$/ L at site 1, to 154 mg $CaCO_3$/ L at site 7. The decreasing trends in both alkalinity and hardness appeared to be related (Grant, 1992).

At the headwaters of the river (Figure 7) the highest levels of both alkalinity and hardness were observed. High values for those measurements in the headwaters were due to the high inputs of $CaCO_3$ from the surrounding calcareous soils and bedrock (Hough, 1958). CO_2 levels were expected to be high in the upper reaches of the stream due to a lack of CO_2 uptake through photosynthesis because of the shading of the river from terrestrial vegetation. CO_2 levels would also be expected to be highest in the colder areas of the river because the solubility of CO_2

decreases inversely to temperature.

As the river's size increases, photosynthesis becomes more prominent resulting in the increased uptake of CO_2 along the river's course. According to Equation 2, the uptake of CO_2 due to photosynthesis would shift the equation to the right, resulting in the removal of both Ca^{2+} (a component of water hardness) and HCO_3^- (a component of alkalinity). As conditions in the river improved to favor photosynthesis, increased levels of CO_2 would be utilized and larger levels of Ca^{2+} and HCO_3^- would be removed, further reducing hardness and alkalinity values. Temperature gradients would also play a role in the removal of CO_2 from the water. As noted previously, the solubility of CO_2 decreases as temperature increases, thus levels of CO_2 would not only be reduced down stream by photosynthesis but also by decreased solubility levels as the river warmed.

[2] $$Ca^{2+} + 2\,HCO_3^- = CaCO_3 \text{ (precipitates)} + H_2O + 1\,CO_2$$

Biological Data

Information on both the aquatic insects and fish species present were collected at most study sites. According to the river continuum concept, the relative abundance of aquatic insects utilizing different energy sources should change downstream (Vannote et al., 1980). Insects identified as shredders would be expected to be dominant in the headwaters, followed by collectors and grazers in the mid reaches of the river, and then predators in the lower stretches.

Our data did not support the predicted succession of insects along the river's course. It should be noted that insect sampling occurred only at sites 1 through 5. Sites 6 and 7 were not sampled due to their depths. Predatory insects, mainly Megaloptera and Odonata, were found at each site except site 2. Grazing insects, Trichoptera, were noted at sites 1 and 2 while the only collector species Ephemeroptera, was recorded at site 5. No apparent trend was recognized between the insects' energy source and their location in the river. Table 3 lists the invertebrates found in the Black River. It should be noted that searches for aquatic insects were not conducted vigorously and not all survey crew members were experienced in identifying aquatic insects. Other studies have identified orders of insects not encountered in our survey, such as Diptera and Coleoptera, inhabiting the Black River (Bright et al., 1991).

Fish sampling efforts resulted in the identification of 10 species recorded in Table 2. A Michigan Department of Natural Resources study found a greater diversities of fish species in the river with 16 species being identified at one location near Town Corner Lake (Fenske, 1992). It is probable that more species of fish would have been collected by our study group if a generator powered fish shocker were used instead of a battery operated shocker.

Discussion of Management Relevance

Overview

Studies such as this are an essential step in the preliminary planning stages for prudent management undertakings. Their primary purpose being to provide baseline information. These studies provide an inventory of aquatic organisms and document habitat conditions at a particular point in time, such as before and/or after proposed projects. The parameters measured in this study can be affected as much by management and manipulative measures as by geology, geography and natural events such as drought or rainfall. The construction of a dam for instance, can change the character of not only the backwaters, but of the adjoining systems below the dam. Similarly, management actions such as sand traps and erosion control measures can have effects in terms of target species habitat improvement for miles down river. The generalized effects of management actions will, on occasion, be predictable; but the dynamic nature of rivers and the interactions within riparian communities can cause long chain repercussions with final results contrary to those intended. To avoid undesirable consequences, it is essential that managers be aware of river ecology and dynamics and that they keep abreast of case studies and the latest research efforts.

The characteristics presently requiring management action for the Black River are maintaining a favorable water temperature for brook trout, and the control of sedimentation and erosion. Managers of the Black River have taken steps to eliminate beaver dams as a means of controlling temperature. Evidence of habitat improvement structures (flow diverters) were noted near site 2, but no sand traps were encountered near any of our sample sites. Erosion control measures were noted near road crossings and heavily used areas such as Clark Bridge Road. In 1991, the Michigan Department of Natural Resources conducted extensive electro-fishing and removed an average of 1.1 pounds of brown trout per acre from the Black River (Fenske, 1992). Efforts to control salmonid species composition are more a policy decision than a requirement of stream habitat maintenance. Habitat enhancement for brook trout has been undertaken, but in many regards it is an all salmonid species improvement regime.

Water chemistry, particularly the presence of phosphates and nitrate, are at acceptable (low) levels now, but should be monitored for possible trends towards quality degradation.

Exactly what is within the manager's control varies from watershed to watershed and depends largely on ownership and use of adjacent lands. In the case of the Black River, it is fortunate that the majority of the reach above the first crossing with Black River Road (site 4) flows through the Pigeon River Country State Forest (PRCSF). Restrictions on logging operations near the river and buffer zones for oil exploration and production have helped minimize the impact of those commercial activities on the forest's watersheds. The section of river above state owned land is primarily undeveloped cedar wetlands, hence residential and agricultural runoffs are not problematic. Roads do not run directly along any section of the upper river and road crossings are quite infrequent. Consequently, highway pollutants such as hydrocarbons and road salts are not significant.

One piece of data from our field investigations that should catch the managers attention is likely related to land ownership and use. Site 3 is immediately downstream of private land holdings, including the Black River Ranch and Blue Lake Club. On 22 July, the total phosphorus level sampled at that point was the highest in our study (includes both phosphorus sampling days) and was 1.6 times higher than the average for the 52 mile segment we sampled (23.4 vs. 14.3 ppb). This sample alone, even if totally free of sampling or analysis error, does not warrant immediate action. The total phosphorus level down stream at site 4, taken 1 hour later, was about average (16.3 ppb) indicating rapid assimilation precipitation and/or dilution. Additionally, the sample taken at site 3 on August 5, 1992 was below average for the river (9.8 ppb). This abnormality in the data does however, draw attention to the possibility that the elevated level observed was due to activities on private land and warrant some further monitoring.

Recognizing that the Black River is the major source of water for the 80 billion gallon Black Lake, authors of the 1991 Black Lake Watershed Nonpoint Source Management Plan looked at primarily the same parameters as this study to investigate and quantitatively describe the lake's "high water quality." Inputs from the Black River give Black Lake a theoretical turn over or flushing rate of once every 5 months (Northeast Michigan Council of Governments, Tip of the Mitt Watershed Council). Clearly, any water quality changes resulting from management actions along the Black River will have an impact on Black Lake and to a lesser degree, the remainder of the Cheboygan River Watershed.

River Uses

If one of the manager's objectives is to provide an optimal combination of user outputs, in addition to the physically measurable parameters, the manager must be cognizant of the aesthetic qualities of the river and its suitability for desired recreation activities. The manager must also be aware of the systems most basic characteristics such as velocity and flashiness. The Black River is relatively flashy, in that it responds more to rainfall events, than the Sturgeon and Pigeon Rivers which parallel it. This is likely the result of the river's greater width and the less permeable drift comprising it's drainage basin (US Geological Survey Reconnaissance, 1968).

During the period of our study—12 June to 9 August 1992—another UMBS study group investigated the upper Black River's recreation potential including camping, hunting, trapping, and canoeing opportunities on the Mainstream in the 8 mile reach between the Clark Bridge Road crossing (site 3) and the Milligan Highway crossing, 1.5 miles down river of site 4 (Tansey et al, 1992). The US Geological Survey also prepared a recreation use summary as part of their 1971 *Reconnaissance of the Black River*. The US Geological Survey report includes a safe wading curve for fisher persons. The curve and a rule of thumb stating that safe wading velocities multiplied by depth (in feet) should not exceed 10. While some stretches of the Black exceed this combination, the vast majority of the river's upper reaches are well within safe wading limits. The report addresses a variety of fishing characteristics all of which were quite favorably assessed. The desirable pH range of the river's water is likely to be sustained as it is attributable to the region's calcarious soils (Hough, 1958). The presence of trout preferred invertebrates and rough fish as well as the Habitat Suitability Index (HSI) for brook trout are addressed elsewhere in this paper. The river also scored well for camping and boating (canoeing) activities. Characteristics within the manager's control, or at least influence, such as fish species composition and density, bank steepness, erosion potential, bank vegetative, cover and navigability, will greatly influence the attractiveness of the river.

Analysis of Management Actions

On the Black River, measures such as the removal of brown trout, trout habitat enhancement structures, canoe access sites, fallen tree removal, erosion control revetment and beaver dam removal have been undertaken with some success. A report on brook trout habitat prepared by Michigan Department of Natural Resources in 1991 indicated that trout populations (in pounds per acre), although significantly below the historic average, was approximately the same in 1991 as it was in 1986, the previous inventory year (Fenske, 1992). That report also stated that in 1991 the average growth index for brook trout was 1.4 inches above Michigan's average length. Studies conducted by UMBS student groups revealed that the brook trout HSI near site 3 has improved from 1988 and 1989 averages of .15 to .46 in 1992 (Wiley, 1992).

Although a formal management plan for the river is still under development by the Michigan Department of Natural Resources, current management actions appear to be successful in protecting water quality and salmonid habitat through integration of forestry, wildlife and fisheries actions. The river provides an enjoyable combination of solitude and recreation activities. While this summer's inclement weather may have influenced our observations, the river does not appear to be heavily utilized.

Conclusions

Both our physical and chemical data supported the river continuum's theory of a continuos gradient in physical and chemical conditions along the river's course.

Biological data collected during the study did not conclusively support the river continuum's prediction of a succession of insect species along the river's course. Possible shortcomings in sampling techniques could explain this discrepancy. Important indicator species may have been present and were not collected.

Management concerns at present on the Black River include temperature regulation and the control of sedimentation and erosion. These issues will need to be addressed in the future if the water quality and trout habitat of the Black River are to be maintained. Monitoring of nitrate and total phosphorus levels should continue to help ensure that land uses within the Black River watershed do not degrade the river's quality. In order to be successful in the development and implementation of a Black River fisheries management plan, managers will need to combine skillful integration of forest, wildlife, watershed and fisheries programs with the necessary degree of flexibility and creativity to protect the quality of this unique watershed and meet the demands of a growing user base.

Research Resources

In addition to a host of texts and published works on limnology and riparian systems in general, a number of studies have been conducted on the Black River Watershed. One of the most extensive investigations was undertaken as part of regional water quality study conducted by the UMBS in 1974 (Gannon and Paddock). Additional data was compiled in investigations by Northeast Michigan Council of Governments (NEMCOG) in 1979 and 1985 (Tip of the Mitt Watershed Council, 1991).

Recent studies (Talsma, UMBS, 1991 and Tip of the Mitt, 1991) include fairly extensive water chemistry analyses from sites on the Black River and it's tributaries. A student research group at UMBS in the summer of 1991 (Bright et. al.) conducted a comparative study of the Pigeon, Black and Sturgeon Rivers. That paper includes water chemistry, fairly detailed diagrams indicating shore line vegetation types and HSI calculations for two segments of the Black.

A number of government and private agencies collect data pertaining to the Black River and its usage. The University of Michigan Biological Station has conducted a number of studies on the Black River Watershed. In addition to student researchers, the station staff, along with faculty at the Ann Arbor campus, includes a wealth of information on fisheries, aquatic systems, and related fields. The station also has a staffed laboratory capable of conducting a wide variety of chemical and physical tests.

The Department of Natural Resources is responsible for management of the watershed. The Michigan Department of Natural Resources office in the Pigeon River Country State Forest has a forester (Joe Jarecki), a fisheries biologist (Steven Swan), and a wildlife biologist (Doug Whitcomb) on staff. Michigan Department of Natural Resources reports are excellent sources of information on the River and surrounding flora and fauna. The most useful Michigan Department of Natural Resources publication for this study was a survey of brook trout prepared by an employee from the Gaylord office (Fenske, 1992).

The US Geologic Survey maintains records of stream flow volumes for the Black River from data collected at their Klieber Dam gauging station. Information regarding annual, daily and seven day mean flows, as well as historical record flows, is tabulated by US Geological Survey. The data is published annually in the *Water Resources Data for Michigan*. US Geological Survey also prepares Reconnaissance maps and reports for major rivers in the United States (including the Black River). The nearest US Geologic Survey Office is located in Grayling, Michigan. The office headed by Russ Munmerick has a full time staff of four employees.

Perhaps the most active non-governmental organization in riparian systems research in Northern Michigan is the Tip of the Mitt Watershed Council (TOMWC) located in Conway Michigan. The organization, staffed with six and a half permanent positions, is funded by donations and research grants from private, state, federal and local governments. Tip of the Mitt staff include professionals in policy, environmental law, information systems, limnology and accounting disciplines. TOMWC employees also serve on local committees and planning councils.

Other organizations which may be able to provide information on the Black River include the Northeast Michigan Council of Governments, the US Army Corps of Engineers (primarily lower reaches and Cheboygan River) and local utility companies. At least one local high school conducts field work on the Black River. TOMWC has records of their data collected since 1989.

During the course of this project, a number of faculty and staff at UMBS were consulted and visits were made to the offices of Michigan Department of Natural Resources (Pigeon and Gaylord) and Tip of the Mitt Watershed Council. Telephone interviews were conducted with personnel at US Geological Survey in Grayling. The "References" section of this paper contains a list of those interviews and meetings.

References

ApMadoc, Tudor, Reed Alexander and Milton Coulson, *A Trout Angler's Guide to the Black River*, Challenge Chapter, Trout Unlimited; 1972.

Baughman, Ann, Doug Fuller, Personal interview at Tip of the Mitt Watershed Council, Conway, MI on 5 August 1992.

Baughman, Ann, Doug Fuller, Rick Deuell and Diane Rekowski, *Black Lake Watershed Nonpoint Source Management Plan*, Tip of the Mitt Watershed Council, Conway, MI; 30 September 1991.

Bright, E., Ansara Hirst, Jon Hoekstra, Andrew Lewis, Leslie Mead and Ken Wilhelm, *Survey of the Ecology and Management of the Sturgeon, Pigeon, and Black Rivers within the Pigeon River Country State Forest.* University of Michigan Biological Station; 1991.

Dennis, Jerry and Craig Date, *Canoeing Michigan Rivers, A Comprehensive Guide to 45 Rivers*, Friede Publications, Davison, MI; 1986.

DMB Graphic Arts, "Northern Tip of Michigan," Map, Universal Map, East Lansing, MI; 1986.

Fenske, Janice L., *Survey Report of the Upper Black River System, Otsego, Montmorency, Cheboygan, and Presque Isle Counties 1991*; 11 June 1991.

Franson, Mary Ann H., ed., *Standard Methods for the Examination of Water and Wastewater (15th ed.) 1980*, American Public Health Association, Washington, D. C.; 1981.

Grant, Mike, Chemist, University of Michigan Biological Station, Personal Conversation; 10 August 1992.

Hough, Jack L. *Geology of the Great Lakes*, University of Illinois Press, Urbana, IL; 1958.

Lind, Owen T., *Handbook of Common Methods in Limnology (2nd ed.)*, C.V. Mosby Company, St. Louis, MO; 1979.

Michigan Atlas and Gazetteer (4th ed.) ,DeLorne Mapping, Freeport, ME; 1991.

Michigan Department of Natural Resources, "Red Bridge Trail, Bummer's Roost Loop - Presque Isle and Cheboygan Counties," Map, Michigan Department of Natural Resources Forest Management Division; October 1991.

Michigan Department of Natural Resources; 1992 *Michigan Fishing Guide*, Michigan Department of Natural Resources; 1992.

Nettelton, Burt, US Geological Survey, Grayling, MI, Telephone interview on 9 August 1992.

Raleigh, R. F. *Habitat Suitability Index Models: Brook Trout, US Department of the Interior, Fish and Wildlife Service*, FWS/OBS-82/10.24, 42 pp.; 1982.

Talsma, Valrie L., *An Analysis of Physical and Chemical Variance Between Sub-basins on the Upper Black River: Cheboygan, Otsego, Montmorency and Presque Isle Counties, Michigan*, University of Michigan Biological Station; 1991.

Tansey, Thomas A., Interview Notes: Personal interviews with Michigan Department of Natural Resources Fisheries Biologist Steve Swan and Michigan Department of Natural Resources Wildlife Biologist Doug Whitcomb; 22 July 1992.

Tansey, Thomas A. et al., *The Black River: A Management Plan,* University of Michigan Biological Station; 1992.

Terrell, J. W., T. E. McMahon, P. D. Inskip, R. F. Raleigh and K. L. Williamson, *Habitat Suitability Index Models: Appendix A. Guidelines for Riverine and Lacustrine Applications of Fish and HSI Models with the Habitat Evaluation Procedures,* US Department of the Interior, Fish and Wildlife Service, FWS/OBS-82/10.A. 54 pp.; 1982.

United States Department of the Interior, "Heatherton Quadrangle MI, 15 minute series, " Map, Lansing, MI; 1954.

United States Department of the Interior, "Tower Quadrangle MI - Cheboygan County, 15 minute series, " Map, Lansing, MI; 1957.

United States Geological Survey, *Surface Water Records of Michigan*: US Geological Survey Annual Report; 1991.

United States Geological Survey, *Reconnaissance of the Black River, a Cold Water River in the Northcentral Part of Michigan's Southern Peninsula,* Washington, D. C.; 1968.

Vannote, R.L., G.W. Marshall, K.W. Cummins, J.R. Sedell and C.E. Cushing, "The River Continuum Concept," *Canadian Journal of Fisheries and Aquatic Science* 37: pp. 130-137; 1980.

Wetzel, Robert G., *Limnology, 2nd ed.* Saunders College Publishing, Fort Worth, TX; 1982.

Wiley, M., Lectures delivered to the University of Michigan Biological Station students for NR 396/509 on 27 and 30 July 1992.

"1992 Michigan Canoeing Directory," Pamphlet, Recreational Canoeing Association, Indian River, MI; 1992.

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Table 1. Black River Data

	Site #1	Site #2	Site #3	Site #4	Site #5	Site #6	Site #7
Stream Order	1	2	3	3	4	4	5
Stream Width (m)	6.2	13.35	22.1	16.3	25.5	29.7	59.8
Maximum Depth (m)	0.3	0.36	0.87	0.49	0.55	0.89	2.35
Maximum Velocity (m/s)	0.33	0.45	0.51	1.38	1.18	0.5	0.17
Substrate	Sand	Sand	Sand	Cobble	Cobble	Sand	Sand/Silt
Discharge Correction Factor	0.9	0.9	0.9	0.8	0.8	0.9	0.9
7/12/92							
Temp °C	12.5	14.4	15	15.3	16.1	17.2	17.5
pH	7	7.3	8	7.4	7.3	7.4	7.9
Conductivity (µmhos)	300	370	360	370	250	340	200
Avg. Velocity (m/s)	0.33	0.43	n/a	1.38	n/a	n/a	n/a
7/22/92							
Temp °C	12.5	15.8	16.9	17.5	18.9	19.4	20
pH	8.3	8	8	8	7.9	8	8
Conductivity (µmhos)	360	350	320	330	320	320	200
Nitrate (ppm)	0.03	0.015	0.014	0.011	0.01	0.009	0.003
Total Phosphorus (ppb)	13.8	13.8	23.4	16.3	14.7	12.2	11.4
Alkalinity (mg CaCO3/L)	239	214.6	203.6	200.4	174.5	182	145.4
Hardness (mg CaCO3/L)	244	220	200	236	176	180	148
Avg. Velocity (m/s)	.19*	0.43	0.51	.63*	.73*	0.5	0.16
Avg. Depth (m)	0.198	0.259	0.438	0.427	0.364	0.591	2.35
Discharge (m^3/s)	.333*	1.338	4.44	4.397*	6.956*	7.9	20.236
Susp. Sediment Load (g/s)	0.092	0.167	1.51	1.517	1.287	1.62	7.285
7/26/92							
Temp °C	16.2	20	19.6	21.1	19.5	21.6	23.5
pH	7.9	8.2	8.5	7.9	7.6	7.7	7.8
Conductivity (µS)	470	430	260	400	250	240	310
Alkalinity (mg CaCO3/L)	239	213.3	210.1	203.6	177.8	181.6	143.5
Dissolved Oxygen (mg/L)	6	6.7	6.9	10.4	8.4	7.9	8.1
Suspended Sediment (mg/L)	3.5	0.5	4	3.7	1.3	0.9	0
8/5/92							
Temp °C	14.5	19.5	19.5	15.8	20	18.4	21.3
pH	n/a	n/a	n/a	7.7	7.9	8	8.1
Conductivity (µmhos)	n/a	n/a	n/a	400	250	280	230
Nitrate (ppm)	0.029	0.014	0.016	0.01	0.006	0.008	<.005
Total Phosphorus (ppb)	13.5	14	9.8	11.6	13.5	13.5	18.3
Hardness (mg CaCO3/L)	248	236	232	204	196	176	160
Dissolved Oxygen (mg/L)	9.5	19.4	12	9.7	8.8	8.7	8.7
Suspended Sediment (mg/L)	2	2	2.8	3.2	2.4	3.2	3.6
Avg. Velocity (m/s)	0.28	0.45	0.45	1.31	1.18	0.47	0.17
Avg. Depth (m)	0.255	0.32	0.765	n/a	n/a	n/a	n/a

* calculated w/ current meter

n/a indicates that no data were recorded in the field

Table 2. Fish Species Found on the Upper Black River

Common Name	Scientific Name
Blacknose Dace*	*Rhinichthys atratulus*
Bluntnose Dace*	*Rhinichthys notatus*
Brook Trout	*Salvelinus fontinalis*
Burbot*	*Lota lota*
Creek Chub*	*Semotilus atromaculatus*
Lamprey*	*Lampetra lamottei*
Longnose Dace*	*Rhinichthys cataractae*
Mottled Sculpin*	*Cottus bairdi*
Rainbow Darter	*Etheostoma caeroleum*
White Sucker*	*Catostomus commersoni*

* species data obtained on July 26, 1992 during a NR 396/509 class exercise

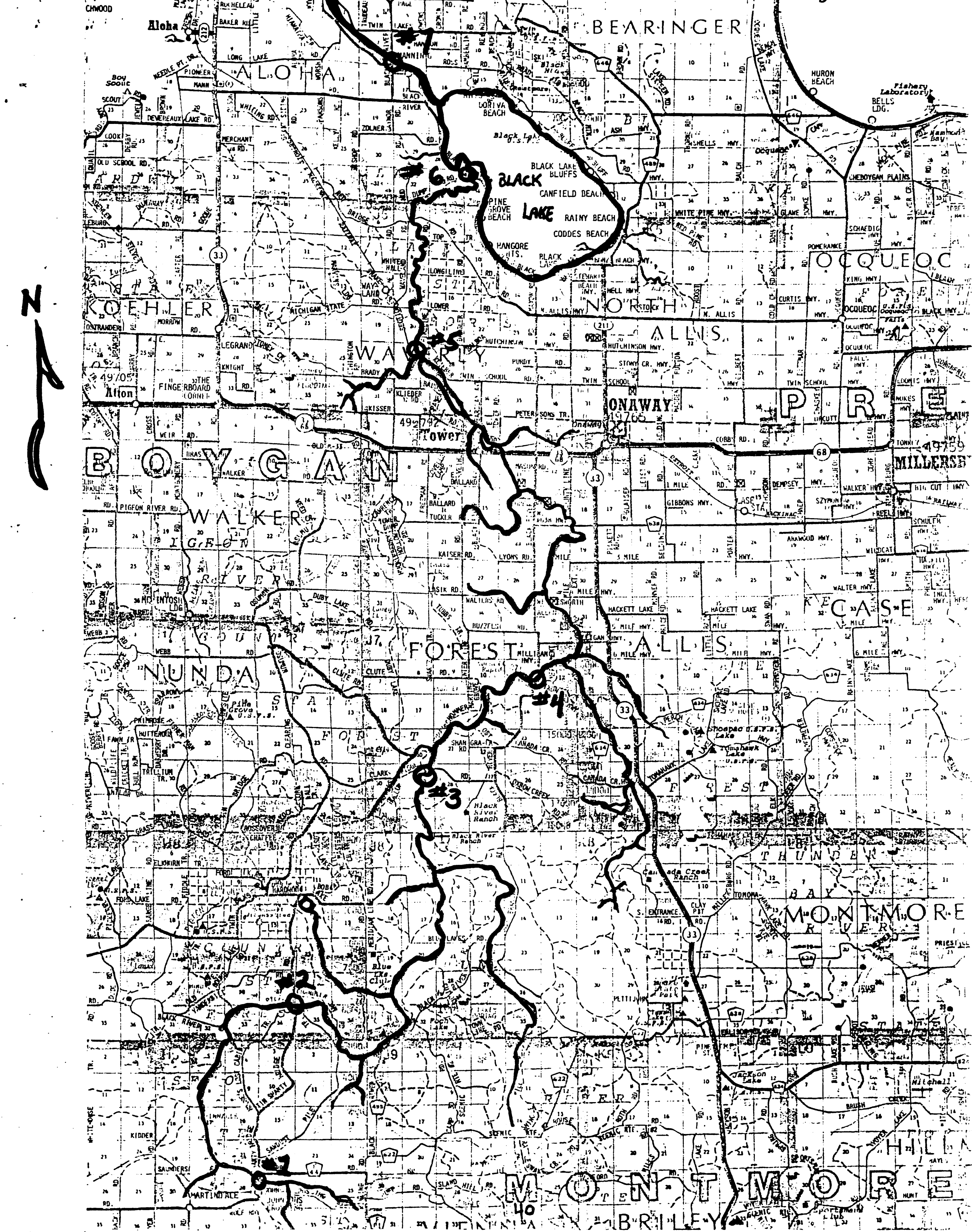
Table 3. Aquatic Invertebrates Found on the Upper Black River

Common Name	Class	Order
Fresh-water clam	Pelecypoda	
Snail	Gastropoda	
Amphipod	Crustacea	Amphipoda
Crayfish		Decapoda
Caddisfly	Insecta	Trichoptera
Dobsonfly		Megaloptera
Dragonfly		Odonata
Mayfly		Ephemeroptera
Stonefly		Plecoptera

Table 4. Physical Characteristics of the Black River

Site #	Depth (m)	Width (m)	Velocity (m/s)	Discharge (m^3/s)
1	.30	6.2	.33	.33
2	.36	13.4	.45	1.34
3	.87	22.1	.51	4.44
4	.49	16.3	1.38	4.40
5	.55	25.5	1.18	6.96
6	.89	29.7	.50	7.90
7	2.35	59.8	.17	20.24

Figure 1



N
GRANT
BEARINGER
ALOHA
Aloha
HURON BEACH
Fishery Laboratory
BELLS LDG.
BLACK LAKE
BLACK LAKE BLUFFS
CANFIELD BEACH
PINE GROVE BEACH
RAINY BEACH
CODDES BEACH
DORIVA BEACH
OCQUEOC
NORTH ALLIS
KOEHLER
WAVERLY
Tower
ONAWAY
Afton
BOYGAN
WALKER
PRESQUE ISLE
MILLERSBURG
FOREST
ALLIS
NUNDA
CASE
MONTMORE
MONTMORENCY
BRILEY
Black River Ranch
Canada Creek Ranch
Jackson Lake
#1
#2
#3
#4
#5
#6
#7
40

Figure 2. Temperature

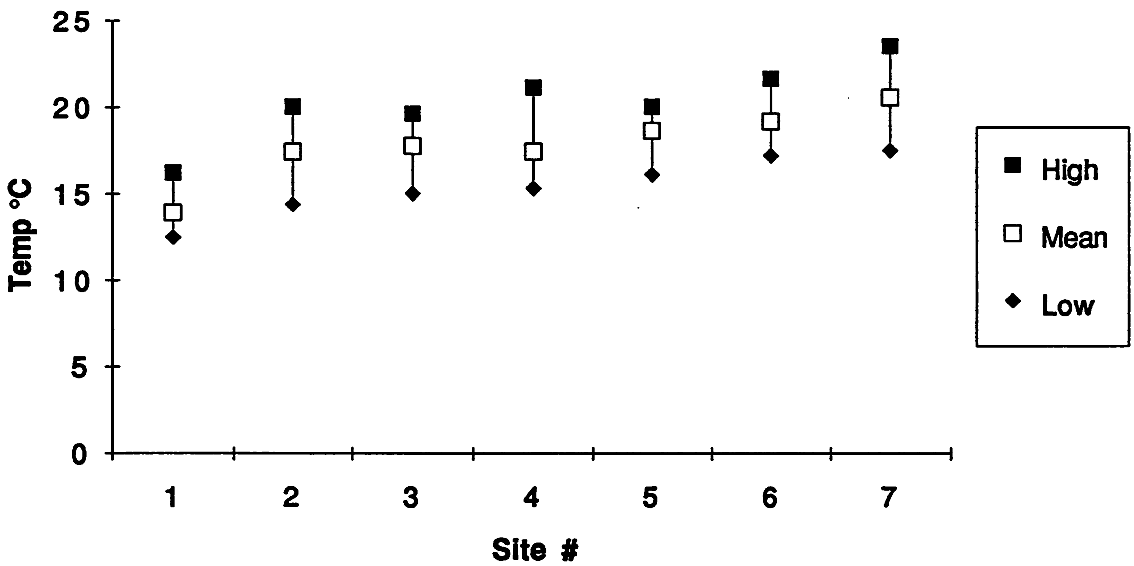


Figure 3. pH

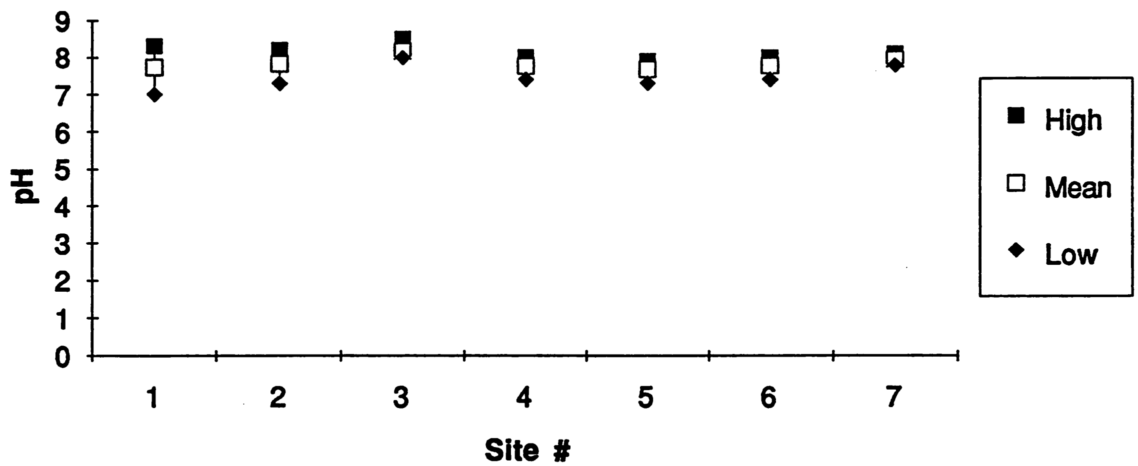


Figure 4. Conductivity

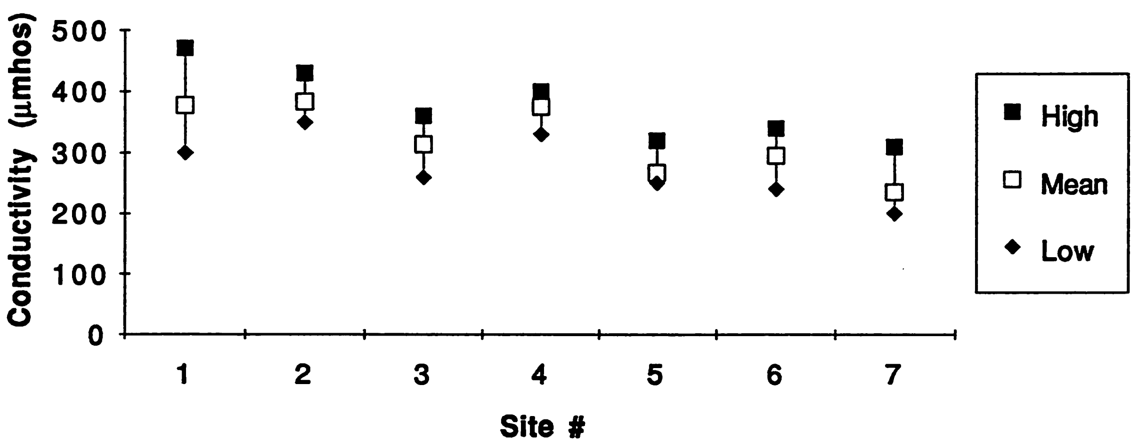


Figure 5. Average Nitrate Concentration

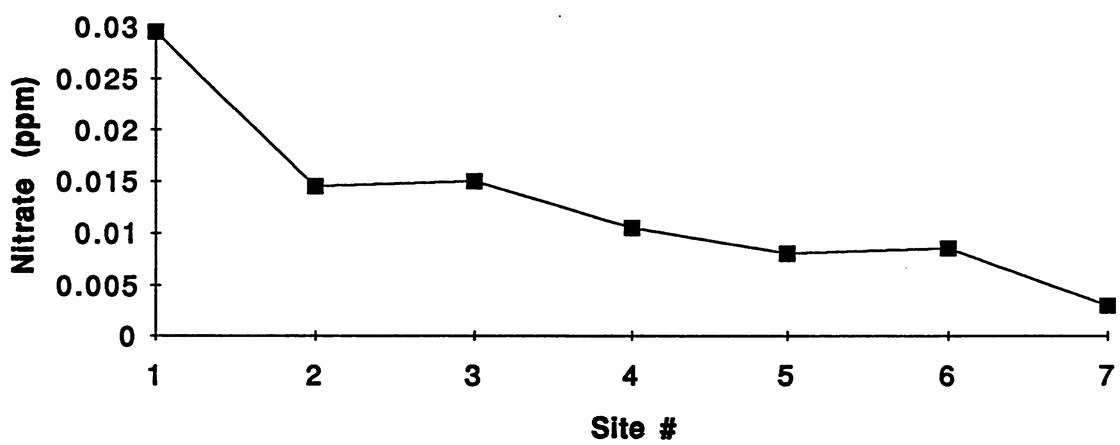


Figure 6. Average Phosphorus Concentration

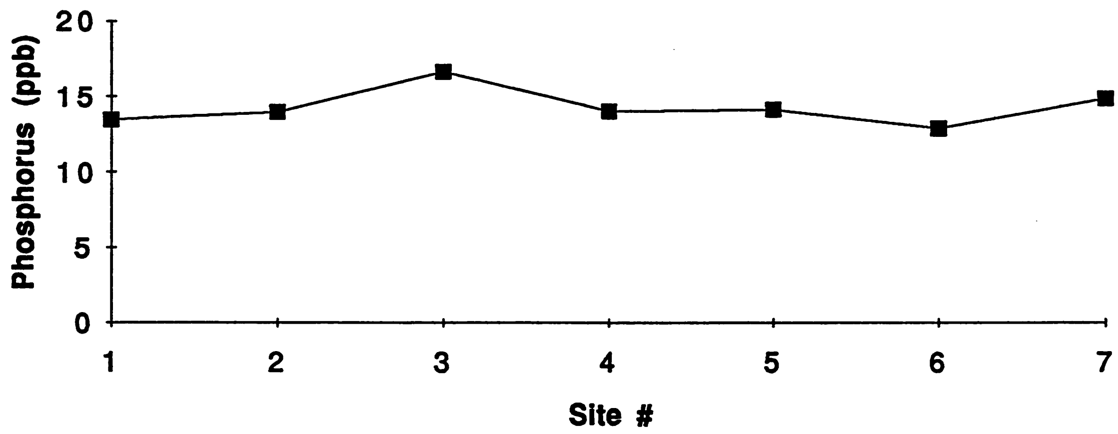


Figure 7. Average Alkalinity and Hardness

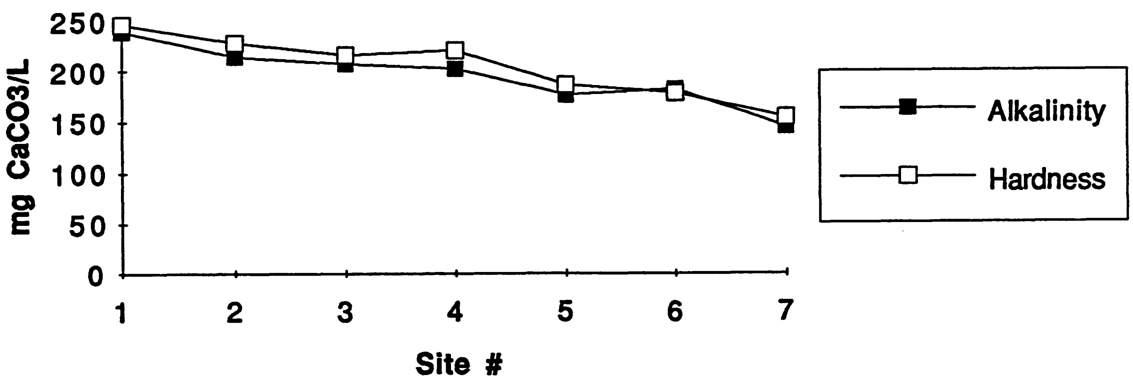


Figure 8. Dissolved Oxygen Concentration

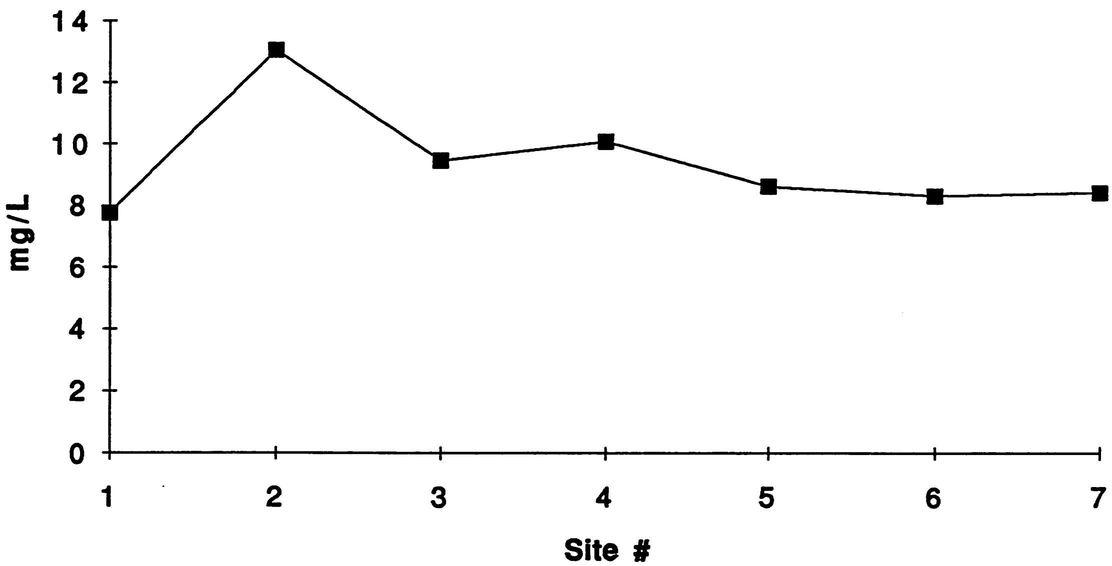


Figure 9. Discharge

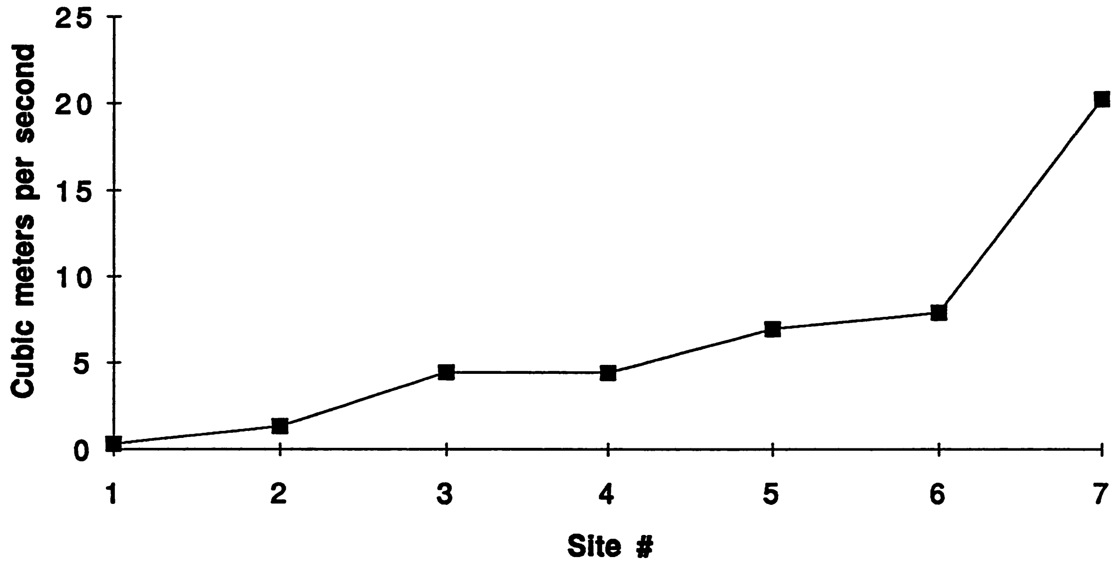


Figure 10. Suspended Sediment Load

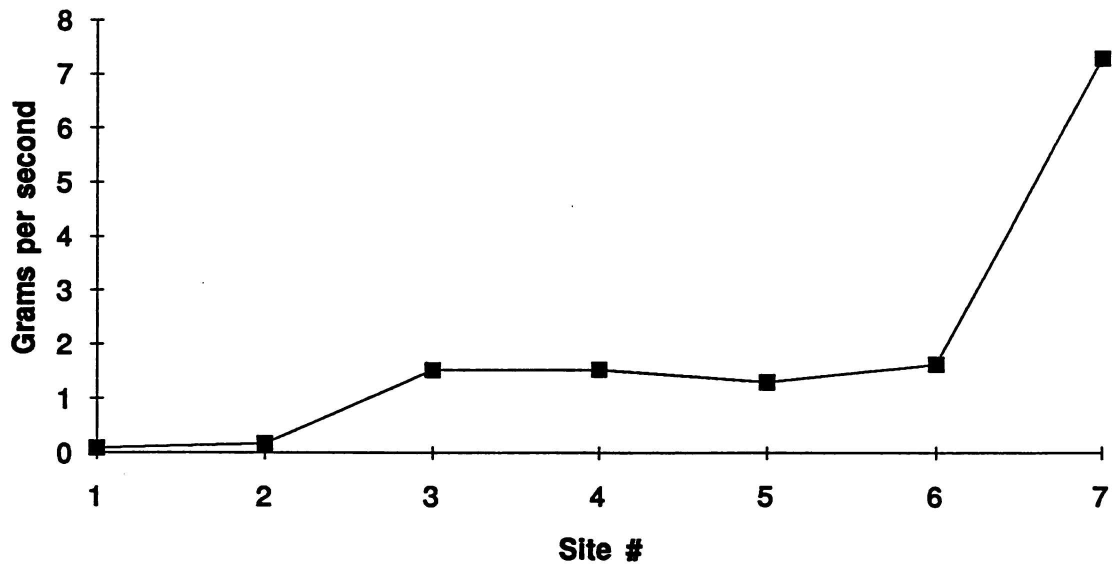


Figure 11. Temperature vs. Stream Width