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Water Quality of Fish Creek in Reference to the Endangered White Cat's Paw Pearly Mussel[1]

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ABSTRACT

Fish Creek is the last known habitat of the white cat's paw pearly mussel. The goal of this project was to contribute to maintaining viable populations of the white cat's paw pearly mussel (globally endangered) and five other mussel species. Specific sources of sedimentation and water quality problems were investigated so a detailed plan to reduce sedimentation and enhance water quality can be developed for the Fish Creek watershed. Fish Creek is a tributary to the St. Joseph and Maumee River system and is located in northeastern Indiana and northwestern Ohio. This creek, although considered one of the more pristine in the area, is impacted by agriculture and small municipalities. Beginning in an agricultural region, the creek flows near several small towns thus receiving sediment and nutrient loading. Sediment and nutrient loading introduced by these sources affects water quality and organisms, including periphyton (attached algae), macroinvertebrates (including mussels), and fish. The objectives were to provide baseline data on water quality and algal communities of Fish Creek, specifically those parameters that affect mussel populations by concentrating on degree and source of sedimentation.

Justification of work performed

Fish Creek, located in northeastern Indiana, is the last known location of the white cat's paw pearly mussel, *Epioblasma obliquata perobliqua* (U.S.

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Steward et al. 199

Fish & Wildlife Service, 1988), a state and federally listed endangered mussel species (IDNR, 1990). Anderson (1991) in his preliminary survey of the mussel fauna of Fish Creek, was not able to confirm the continued existence of the mussel, although he reported a dead specimen. Regardless of the status of the white cat's paw, Fish Creek is the home for a diverse, yet apparently deteriorated, invertebrate community including several other mussel species such as the northern riffleshell mussel (*Epioblasma torulosa rangiana*) and the clubshell mussel (*Pleurobema clava*). It has been proposed that the latter two mussel species be added to the federal list of endangered and threatened species (letter of June 24, 1992 from the Fish & Wildlife Service; Federal Register, June 18, 1992). Other species living in Fish Creek which are under review for special status are the salamander mussel, *Simpsonaias ambigua*, and the rayed bean, *Villosa fabilis* (IDNR, 1990). The presence of these species makes the protection of Fish Creek imperative.

The federally endangered white cat's paw pearly mussel (WCPPM) appears to have been extirpated throughout its range except for a short distance along Fish Creek (Watters, 1988; U.S. Fish & Wildlife, 1990). Since 1970, fresh specimens of white cat's paw have been taken only in Fish Creek. Fish Creek is a tributary to the St. Joseph and Maumee River system and is located in northeastern Indiana and northwestern Ohio. Live specimens of the species have been found above Edgerton, OH. In a recent survey (Hoggarth, 1986), the WCPPM was found in only a three mile section of Fish Creek, which makes it one of the nation's most critically endangered species (U.S. Fish & Wildlife, 1990).

Much effort has been focussed on the reduction of conventional point sources of water pollution. This effort includes the construction of municipal and industrial wastewater treatment plants. Continuing adverse effects of wastewater treatment plants and other sources of pollution on water quality include decreased organism diversity and increased numbers and biomass of pollutant tolerant species (Stewart and Robertson, 1989; Lewis, 1986; Knorr and Fairchild, 1987). However, improvements have been made in controlling these sources, and the national trend appears to be that of generally improving water quality (Smith, et al., 1987).

Erosion, siltation, sedimentation, channelization, metals, radionuclerides, pesticides, human and animal wastes, mining wastes, acid rain, and other contaminants have been implicated in reducing the numbers and kinds of freshwater mollusks (Fuller, 1974; Marking and Bills, 1980; Havlik and Marking, 1987). Problems caused by non-point (agricultural and other diffuse sources) sources of water pollution continue to cause degradation of water quality and hinder the next stage of water quality improvements in this country. Although this may prove to be the most difficult type of surface water pollution to reduce, control of pollutants from non-point sources has only recently become a national or scientific priority. More information is urgently needed about these pollutants, their mode of transport, and their action on aquatic systems and organisms (Water Pollution Control Federation, 1981).

A major source of nutrient enrichment into surface waters is from non-point sources of pollution, especially agricultural and urban runoff (Smith, 1987; Turner and Rabalais, 1991; and Gray, 1990). If national efforts to eliminate point sources of nutrient input are met, a significant source of nutrient input will remain unless non-point sources are recognized and controlled (Lamb, 1985; Smith, 1987). Disturbances such as agricultural runoff have been found to affect water quality (Golladay, 1989). Additionally, research on periphyton (attached algae) communities in disturbed versus undisturbed watersheds suggests that they are excellent indicators of water quality and are useful in showing important differences between the two areas. These differences, which have been documented (Lowe, et al., 1986), can be attributed to changes in temperature, nutrient retention, and other factors associated with water disturbance.

Knowledge of surface water quality is an integral part of any conservation effort aimed at the protection and maintenance of habitat favorable to aquatic organisms. No conservation effort or recovery plan can be attempted unless a base of which to draw upon is present. Biomonitoring in conjunction with physico-chemical analyses is now considered an essential part of any attempt at evaluating environmental quality. This is due to the broad temporal dimension that organismal analyses impart to a study, as opposed to the point-in-time measurement provided by abiotic parameters (Resh, 1979). Organismal distribution in an environment indicates their ability to tolerate the entire range of conditions to which they are subjected (Resh, 1979). Benthic macroinvertebrates and algae have gained widespread acceptance as indicator organisms due to their representative nature of the total stream biota (Kaesler and Cairns, 1971; Patrick, 1973).

Objectives

This research will fulfill step 1, as outlined in the executive summary of the recovery plan for the WCPPM (U.S. Fish & Wildlife, 1990), and involves identifying sources of water quality problems resulting from harmful land use practices. After identification, less damaging alternatives can be implemented, including management agreements and land acquisition. It is vital that a water quality study of this habitat be performed to determine water quality and identify both type and source of problems that exist in the animal's habitat. This study will help define the parameters which most likely affect the mussel's long-term viability. A management plan can then be devised for improvement of the habitat.

The overall goal for which this project will contribute is to maintain viable populations of the white cat's paw pearly mussel and five other mussel species, including the northern riffleshell, clubshell, salamander mussel, rayed bean (IDNR, 1990 [under review]), and purple lilliput by reducing sedimentation inputs and enhancing the water quality of the Fish Creek watershed. The purpose of this study is to provide background information on the biology and water chemistry of Fish Creek located in northeastern Indiana. This project had the following objectives:

1. To identify both type and source of sedimentation problems that exists in the drainage basin. This was accomplished by a conductivity/turbidity monitoring regimen to measure amount and locate the source of sedimentation problems.
2. To quantify the present water quality of Fish Creek over four seasons and during several spate events. This baseline water quality study will be utilized for comparison to future water quality to determine the effectiveness of water quality improvements after watershed management techniques have been implemented.
3. To quantify the present periphyton and macroinvertebrate community of Fish Creek by examining populations of these organisms. This is intended to serve as a baseline to compare future changes in community structure, and to further isolate areas of extensive water quality degradation.

Review of methodology used

Fish Creek is the second largest tributary of the St. Joseph River, a major stream in the Maumee River basin, and is located in northeastern Indiana and northwestern Ohio. An in-depth sampling of water quality was performed at selected stations on Fish Creek. Additional sampling occurred during or immediately after heavy rainfall spate events (at least once each season) to determine the effects of runoff on water quality. Eight stations were selected for water quality and algal monitoring (Figure 1). These stations are described as follows:

Station 1 After intersection of the west branch of Fish Creek and the branch coming from Mud Lake and gravel pits, approximately one mile east of Metz, IN on County Road 200 S.

Station 2 Prior to the intersection of the Hamilton Lake branch on route 4A, just east of Route 1.

Station 3 Hamilton Lake branch, at Route 4A just east of Route 1.

Station 4 Fish Creek at DeKalb County Road 16, approximately 2/3 mile west of Arctic, IN.

Station 5 Fish Creek at the Indiana/Ohio line as it crosses Route 1 E/Route 15 E, approximately 2/3 mile Southeast of Arctic, IN.

Station 6 Fish Creek at County Road C-50, 1.2 mile southeast of Arctic, IN, just west of the cemetery.

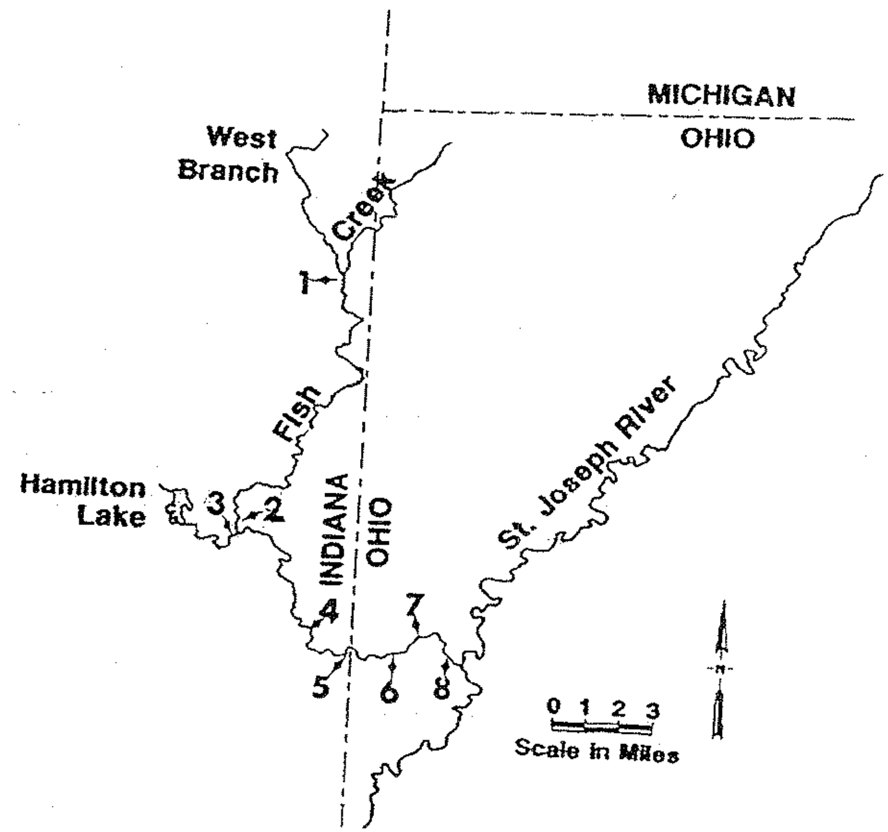

Figure 1. Map of Fish Creek area containing the eight sampling stations.

Station 7 Fish Creek at County Road which leads into Route 49, approximately 1.8 miles northwest of Edgerton, OH.

Station 8 Fish Creek at Highway 49, approximately 3/4 mile north of Edgerton, OH.

In addition to these eight stations, 48 tributaries to Fish Creek and three sites on the St. Joseph River were selected and monitored for specific conductance and turbidity (Table 1).

Water quality, nutrients, stream bed composition, flow rates, and indigenous algal and macroinvertebrate sampling were analyzed using appropriate standard methods (APHA, 1985). Actual collecting dates and parameters collected are reported (Tables 2 and 3). All samples collected were transported to the laboratory on ice, where they were either analyzed immediately or preserved appropriately for future analysis.

A one liter water sample from each station was collected in an acid-rinsed plastic bottle and returned to the laboratory on ice for chemical analysis. Analysis of several chemical and physical parameters were conducted in the field (temperature, dissolved oxygen, and pH). Other parameters, including nutrients, turbidity, and specific conductance which were analyzed in the laboratory following standard methods (APHA, 1985). Specific methodology and instrumentation follow.

- Dissolved oxygen, reported as mg/l, was measured in the field using a YSI model 57 oxygen meter, which was standardized with saturated water taken from each sampling site.
- Temperature in Celsius was determined at each site using the appropriate setting on the YSI model 57 oxygen meter. pH values were determined in the field using a model HA pH meter, manufactured by LaMotte Chemical Products Company which was standardized in the field with appropriate buffer solutions.
- Specific conductances, reported as μmhos/cm, were analyzed using the LaMotte model DA-1 conductivity meter. Preparation of the standard conductivity solutions followed procedures specified (APHA, 1985).
- Turbidity values, reported as FTU's, were obtained in the laboratory using the LaMotte model 2008 turbidity meter. A turbidity standard series was prepared by following outlined methodology (APHA, 1985).
- Total water hardness (mg/l as $CaCO_3$) was determined by titration using the LaMotte model PHT test kit and accompanying instructions.
- Total alkalinity, reported as mg/l as $CaCO_3$, was determined in the laboratory. Samples were analyzed for total alkalinity by the potentiometric titration method - standard method 403 (APHA, 1985).
- Total residues (total solids) were determined by following standard procedure 209A and are reported as g/l. Total non-filtrable residues (total suspended solids) were quantified by utilizing standard method 209C and are also reported as g/l (APHA, 1985).

Table 1. Fish Creek Site Descriptions[a]

Site	Location	Site	Location
1	200 S,.8 W Metz, IN	3f	100 yds. N 3g (Baker ditch)
1a	.5 N 1-50, P-50	3g	.1 E 775 S, 1
1b	.1 S 1-50, P-50	4	.7 W CR 16, CR 79
1c	.75 E 50 N, 950 E	4a	.05 W CR 77, 900 E
1d	.25 E 25 S, 950 E	4b	.25 W CR 77, 900 E
1d1	.7 E 40 S, 80/90	4c	.5 N CR 77, CR 4
1d2	.5 US 20, 850 E	4d	.1 S CR 77, CR 4
1e	.1 E 200 N, 700 E	4e	.3 W 4A, CR 77
1f	.25 W 100 N, Old Rt. 1	4f	.1 N CR 73, CR 8
1g	.4 N Old Rt. 1, 40 S	4g	.1 SE CR 6, 1
1h	.25 E 40 S, Old Rt. 1	4h	AT CR 12, CR 71
1i	.25 E US 20, 850 E	4i	.6 N CR 73, CR 12
1j	.3 S 850 E, US 20	4j	.2 N CR 71, CR 16
2	.1 E 4A, 1 (east branch)	5	AT W-1, C-60
2a	.75 N 850 E, 400 S	5a	.05 N CR 75, CR 18
2b	AT 850 E, 400 S	5b	.25 N CR 79, CR 12
2c	.25 W 400 S, 1000 E	5c	W AT W-1, Will. County E
2c1	.4 W 400 S, 1000 E	5d	.5 S CR 2, CR 4A
2d	.7 N 1000 E, 525 S	5e	E AT W-1, Will. County E
2e	.1 N 850 E, 500 S	5f	10 yds N site 5, (Trier ditch)
2f	.1 S 800 E, 500 S	6	.6 E C-60, CR 2
2g	.25 N 800 E, 427	6a	.05 E C-60, SR 2
2h	.5 S 700 E, 700S	7	.25 W W-3, D-50
2i	.05 W 700 S, 700 E	7a	.3 W D-50, W-3
3	.1 E 4A, 1 (west branch)	8	AT 49, CR 171
3a	.1 N 427, Wabash RR	8a	.2 S W-3, D-50
3b	.1 E Fish & Game Club Dr.	SJR1	ATE-75, 5
3c	.1 E 1, 427	SJR2	.5 E River St. (Edgerton, OH) 49
3d	.2 N 427, 1	SJR3	.1 W 6, 4-50
3e	.1 W 700 S, 550 E		

a. NOTE: An entry such as ".5 N 1-50" would read ".5 mile north on 1-50 from the intersection with P-50," to be used in conjunction with appropriate topographic maps.

Table 2. Data Collected and Sampling Dates

Parameter	1991 Sampling Dates														
	3/12	7/2	7/9	7/16	7/24	8/6	8/12	8/14	8/20	8/22	9/21	10/11	11/3	11/17	12/7
Dissolved oxygen (mg/l)	O	O		O				O	O		O		O		O
pH	O	O		O				O	O		O		O		O
Temperature (Celsius)	O	O		O				O	O		O		O		O
Specific conductance (μmhos/cm)	O	O	O	O		O	O	O	O	O	O	O	O	O	O
Conductivity (tributaries)			O				O		O		O		O	O	O
Alkalinity (mg/l as $CaCO_3$)	O	O		O				O	O		O		O		O
Hardness (mg/l as $CaCO_3$)	O	O		O				O	O		O		O		O
Turbidity (FTU)	O	O	O	O		O	O	O	O	O	O	O	O	O	O
Turbidity (tributaries)			O				O		O		O		O	O	O
Total residues (g/l)	O	O		O				O	O		O		O		O
Total nonfiltrable residues (g/l)				O				O	O		O		O		O
Ammonia (mg/l)	O			O				O	O		O		O		O
Nitrate (mg/l)	O	O		O				O	O		O		O		O
Nitrite (mg/l)	O	O		O				O	O		O		O		O
Ortho-phosphate (mg/l)		O		O				O	O		O		O		O
Substrate (% composition)					O										
Algae/diatoms					O										O
Macroinvertebrates					O										
Flow and suspended sediment						O				O		O			

Table 3. Data Collected and Sampling Dates

Parameter	1992 Sampling Dates									
	1/6	2/15	3/1	3/21	4/11	4/25	5/14	5/29	6/5	6/10
Dissolved oxygen (mg/l)	O		O			O	O			
pH	O		O			O	O			
Temperature (Celsius)	O		O			O	O			
Specific conductance (μmhos/cm)	O	O	O	O	O		O	O	O	
Conductivity (tributaries)	O	O	O	O			O			
Alkalinity (mg/l as $CaCO_3$)	O		O			O	O			
Hardness (mg/l as $CaCO_3$)	O		O			O	O			
Turbidity (FTU)	O	O	O	O	O	O	O	O	O	
Turbidity (tributaries)	O	O	O	O		O	O			
Total residues (g/l)	O		O			O	O			
Total nonfiltrable residues (g/l)	O		O			O	O			
Ammonia (mg/l)	O		O			O	O			
Nitrate (mg/l)	O		O			O	O			
Nitrite (mg/l)	O		O			O	O			
Ortho-phosphate (mg/l)	O		O			O	O			
Substrate (% composition)										
Algae/diatoms										
Macroinvertebrates									O	
Flow and suspended sediment					O			O		O

- Ammonia concentrations were determined in the laboratory following the phenate method-standard method 417C and are reported as mg/l NH_3-N (APHA, 1985). Nitrate-nitrogen (mg/l as NO_3-N) was analyzed using the LaMotte test kit following the cadmium reduction method-standard method 418C (APHA, 1985). Nitrite was analyzed by standard method 419 (APHA, 1985).
- Ortho-phosphate concentrations, mg/l as total reactive phosphorus, were determined by the ascorbic acid method-standard method 424F (APHA, 1985).
- Stream bed composition was analyzed in the summer of 1991. Samples were obtained by driving a three inch PVC pipe into the substrate at three locations along a transect at each station and compositing the material. These samples were returned to the laboratory, mixed and dried at 95°C to dryness, then dried at 105°C for 24 hours. After cooling, the cores were placed into a sieve shaker for 15 minutes. The percent mass retained by the various sieves were collected and weighed. Methods utilized were modifications of those described (Folks, 1980).
- Flow rates and stream discharge were determined six times during the project at stations 4 - 7 along the mainstem of the creek. These parameters were determined using a Model 1700 Current Meter Set from Scientific Instruments, Inc.
- Total sediment load, as g/sec, was also determined during each flow rate measurement. It is the product of total discharge at each station and total nonfiltrable residue. A representative sample of suspended sediment was collected from each of the four sample stations using the Model DH-81 suspended sediment hand sampler with operating instructions from St. Anthony Falls Hydraulic Laboratory, United States Geological Survey. The samples were then analyzed for residues using recommended filters (934-AH, radius = 4.25 cm, 1.5 micron pore size).

On July 24, 1991, three Surber samplers per station were collected at each of the eight stations (minimum number of samples as recommended by the EPA [1990]). The surber sampler is a 0.3048 m^2 grid which ensures a constant area. The sampler was placed over the substrate, and the substrate was then disturbed and organisms removed to a depth of approximate 10 cm. An attempt to sample similar substrates and depths was made at all stations. The samples were collected in one liter, wide-mouthed bottles and preserved with 70% ethyl alcohol. Macroinvertebrates were identified to genus when possible, with a strong emphasis on proper identifications. Several community parameters were employed in data analysis including the Shannon-Weaver Diversity Index (Shannon and Weaver, 1949) and a modified Hilsenhoff Biotic Index (Hilsenhoff, 1977; Plafkin, 1989).

Periphyton communities were sampled seasonally (summer, fall, and spring) in duplicate by *in situ* substrate scrapings with a large pipette.

Samples were preserved with Lugol's solution and identified by light microscope at 400X magnification. Algal communities were identified to species. From these samples, a baseline of species abundance and distribution will be assessed to be used in future comparisons after problem mitigation has had time to have an affect.

Since any definition of a spate event would be arbitrary, we define a spate event for sampling purposes as an event that was preceded by at least one-half inch of precipitation within the previous three days or at least one inch of precipitation within the previous seven days. Such precipitation data was available for Angola, IN and was obtained from the Department of Agronomy, Purdue University, West Lafayette, IN.

Fortunately, metals are not suspected to be a problem in this area. Organics, especially pesticides, may be a problem but are very expensive to monitor and are beyond the scope of this study.

Discussion of results and their significance

Water quality parameters included chemical data collected on twelve days: dissolved oxygen (mg/l), pH, specific conductance (μmohs/cm), turbidity (FTU), total alkalinity (mg/l as $CaCO_3$), total hardness (mg/l as $CaCO_3$), total residues (g/l), total non-filtrable residues (g/l), and nutrients including ammonia (mg/l), nitrates (mg/l), nitrites (mg/l), and orthophosphate (mg/l). Sample dates for these parameters were: March 12, July 2, July 16, August 14, August 20, September 21, November 3, December 7 (of 1991) and January 6, March 1, April 25 and May 14 (of 1992). See Stewart, et al. (1992) for a complete description of parameters measured.

Dissolved oxygen was measured 12 times at the eight sampling stations, and varied from 5.5 mg/l to 17.2 mg/l with a mean of 10.9 mg/l. The lowest reading was at station 1 during August of 1991, and this station had the lowest reading six out of 12 times. Station 1 also had the highest reading two out of 12 times, while station 4 had the highest reading three out of 12 times. Dissolved oxygen was significantly different between dates ($p < 0.0001$). Readings on July 2, 1991 were the lowest, averaging 6.9 mg/l for the day. Readings on January 6, 1992 were high, averaging 15.1 mg/l, and those recorded on March 1, 1992 were the highest of any date, averaging 15.9 mg/l. Dissolved oxygen concentrations were not significantly different between stations ($p = 0.9999$), although station 1 had the lowest average reading of 10.8 mg/l, and station 2 had the highest average reading of 11.5 mg/l. Never did the reading fall below 7.0 mg/l in the area suspected of harboring the WCPPM. Station 1 was the first site sampled, and all sites were sampled in numerical order.

Water temperature was measured 12 times during the course of the project, with an overall average temperature of 7.8°C. As could be expected, samples collected early in the morning tended to be the coolest. Temperature ranged from zero in the winter to nearly 23°C during July of 1991. As one would expect, temperature readings were significantly different by date ($p < 0.0001$), with January 6, 1992 having the lowest average reading of 0.33°C and July 2, 1991 having the highest average reading of 21.4°C. Temperatures were not significantly different between stations ($p = 0.9993$). Station 1 had the lowest average temperature (8.75°C) and station 7 had the highest average temperature (10.7°C).

pH was measured 12 times at the eight stations during the summer, with an overall average of 7.8 pH units. During the project period, pH varied from 7.4 to 8.1 standard units. pH at station 1 was lowest on eight of the 12 sampling dates. pH measurements were significantly different between sampling dates ($p < 0.0001$). The highest average pH (8.0) was measured on September 21, 1991. The lowest average pH (7.53) was measured on August 20, 1991. pH measurements were also significantly different ($p = 0.0370$) between stations. Station 1 had an average pH of 7.58 units, while station 2 had an average pH of 7.83 units for the year.

Total alkalinity was measured at each station 12 times during the course of the study with an overall average of 267.3 mg/l as $CaCO_3$. Values ranged from 146.3 to 418.0 mg/l as $CaCO_3$. Station 3 had the lowest alkalinity five times, followed by station 6 (four times). The highest alkalinities were recorded at station 1 (six times) and at station 2 (four times). Alkalinity measurements were significantly different by dates ($p < 0.0001$), with a low average on July 16, 1991 and a high average on September 21, 1991 of 388.3. Total alkalinity was not significantly different between stations ($p = 0.7525$). Station 8 had the lowest average alkalinity of 250.3, while station 2 had the highest average alkalinity (283.7 mg/l as $CaCO_3$).

Total hardness was measured 12 times during the course of the study with an average of 307.8 mg/l as $CaCO_3$ indicative of extremely hard water. The range for hardness was 144 to 422 mg/l as $CaCO_3$. Station 1 had the highest reading nine times, followed by station 2 which had the highest reading two times. Station 3, coming from Lake Hamilton, had the lowest reading on eight of 12 samples. Total hardness was significantly different by date ($p < 0.0001$), with the low average (189.8) on August 20, 1991 and the high average (372.8) on September 21, 1991. Total hardness was not, however, significantly different by station ($p = 0.2205$), and the lowest station had an average of 282.4, while the highest station had an average of 334.5 mg/l as $CaCO_3$.

Specific conductance was measured 11 times during the course of the study with an average of 554.4 µmhos/cm. The range for conductivity was between 293 to 770 µmhos/cm. Station 1 had the highest value on six occasions, while station 3 had the lowest value on six samplings. Specific conductance was significantly different between sampling dates ($p < 0.0001$), with the lowest average on August 20, 1991 (395.7 µmhos/cm) and the highest average on September 21, 1991 (703.8 µmhos/cm). There was no significant difference in specific conductance between stations ($p = 0.4289$). Station 1 had the highest average (591.8 µmhos/cm), with station 3 having the lowest average (509.0 µmhos/cm).

Turbidity at the eight stations was measured 11 times during the year for a mean of 88.7 FTU, and it was also measured, along with conductivity, on several additional trips. During the sampling trips, values ranged from 3.2 to 909.0 FTU. Station 1 had the highest turbidity three times, while the highest turbidity was found on seven occasions to be sampled from stations 5 through 8, encompassing the remaining habitat for the WCPPM. Turbidity was significantly different between sampling dates at the eight stations ($p < 0.0001$). The highest average turbidity (529.8 FTU) occurred on July 2, 1991, and the lowest average (6.2 FTU) on March 1, 1992. Turbidity was not significantly different between the eight stations along the main body of Fish Creek ($p = 0.9043$), with a high of 128.2 FTU as a mean for all dates and a low average of 33.0 FTU collected at station 2. Turbidity and conductivity values recorded from the tributaries are presented later in this report.

Total nonfiltrable residue (TNR) was measured 10 times during the project period at the eight sampling stations for a mean of 0.0289 g/l for all dates. The TNR range was 0.0015 to 0.2010 g/l. Eight of 10 samplings demonstrated that the lower four sites had the highest values and the lower values were found in the first three stations. Station 1 had three low samplings. TNR was significantly different by date ($p < 0.0001$); the low average (0.004 g/l) was recorded on March 1, 1992 and the high average (0.136 g/l) was recorded on August 20, 1991. Total nonfiltrable residues were not significantly different between stations ($p = 0.9621$). The average low value across all sampling dates was 0.0204 g/l at station 3 and the high value across all sampling dates was 0.0398 g/l at station 8.

Total residues were measured 12 times during the course of the study with a mean of all measurements of 0.384 g/l. Values measured ranged from 0.163 to 1.078 g/l. Station 1 had the highest value measured on 10 trips, station 3 had the lowest value on nine trips, and station 6 had the lowest value on two trips. Total residues were significantly different between dates ($p < 0.0001$), with the highest mean value collected on July 2, 1991 and recorded as 0.790 g/l. The lowest mean value (0.188 g/l) was recorded on January 6, 1992. Total residues were not, however, significantly different between sites ($p = 0.5242$). The high average (0.497 g/l) was found at station 1, and the low (0.353 g/l) at station 3.

Ammonia concentrations were measured on 11 dates during the study for a mean of all measurements of 0.1625 mg/l. Values ranged from non-detectable (<0.01 mg/l) to 1.34 mg/l. There was a great deal of variability in the values measured, both over time and at different stations on a sampling date. Interestingly, station 1 had the highest value for ammonia on four dates and the lowest value on three dates. Station 8 had the lowest and highest values on four sampling dates. Ammonia concentrations were significantly different between sampling dates ($p = 0.0031$). The lowest average value on a particular sampling date (0.015 mg/l) was recorded on January 6, 1992. Ammonia was significantly different between stations ($p = 0.9985$). Station 2 had the lowest average ammonia concentrations (0.143 mg/l) while station 1 had the highest mean ammonia levels at 0.185 mg/l.

Nitrate was measured 12 times during the course of the study for a grand mean of 1.88 mg/l. Values measured ranged from 0.25 to 5.80 mg/l. Highest values were found seven times at station 1, followed with three times at station 3 and two times at station 2. Lowest concentrations were found five times at station 3, three times at station 2 and twice at station 1. Nitrate concentrations were significantly different between dates ($p < 0.0001$). The lowest average concentration (0.656 mg/l) occurred on September 21, 1991 and the highest mean nitrate concentration (3.923 mg/l) occurred on July 2, 1991. Nitrate concentrations were not significantly different between stations ($p = 0.7655$). The lowest station average (1.60 mg/l) concentration occurred at station 2, and the highest station average concentration throughout the year (2.58 mg/l) occurred at station 1.

Low levels of nitrite were found on all sampling dates, and ranged from non-detectable to 0.410 mg/l (data for July 2, 1991 not included), for an overall average of 0.007 mg/l. Many of the levels reported were below our limits of detection. Nitrite concentrations were significantly different between sampling dates ($p = 0.0001$). Samples for July 16, September 21, and November 3 (1991) and January 6 and March 1 (1992) were below the level of detection. On July 2, 1991, the average level was 0.322 mg/l, which we consider an artifact. Nitrite levels were not significantly different between stations when all dates are examined ($p = 0.9986$). The lowest average value (0.015 mg/l) was found at station 2, and the highest (0.043 mg/l) at station 1.

Ortho-phosphate concentrations measured in Fish Creek were variable throughout the year, and had a mean across stations and dates of 0.0573 mg/l. Measured levels ranged from non-detectable (<0.01 mg/l) to 0.500 mg/l. The highest levels were found at the downstream sampling stations with eight of the 10 highest measurements collected at stations 6 through 8. The lowest measurements were generally found upstream, and station 3 had the greatest number of low readings, followed by stations 1 and 2. Ortho-phosphate concentrations were significantly different between dates ($p = 0.0001$), with a high average value of 0.398 mg/l recorded on July 2, 1991. The low values were recorded on September 21, 1991 and on January 6, 1992, were below our limits of detection. Ortho-phosphate concentrations were not significantly different between stations throughout the year ($p = 0.9666$). The low average (0.065 mg/l) was found at station 3, while the high average (0.121 mg/l) was found at station 8.

Turbidity and conductivity were measured on water chemistry sampling days at the eight main stations. In addition, turbidity and conductivity were measured at nearly all of the tributaries of the creek, the eight main sampling stations, and three sites on the St. Joseph River, above and below the entry of Fish Creek water into the St. Joseph River. These sites are further identified in Table 2. Figure 2 presents a representative turbidity sampling of the tributaries of Fish Creek. Both spate and non-spate events were sampled. A spate event is defined as a sampling event that had at least 2.54 cm of rain in the previous week, or at least 1.27 cm of rain in the previous 72 hours.

The July 9 and 10, 1991 sampling took two days to be completed; all other sampling took place in one day. During the July 9 and 10 sampling (not considered a spate event), sites with high turbidity measurements included 2b, 3f, 4d, 4j, 5d, and 5e. Measured turbidity values ranged to approximately 140 FTU. The August 12, 1991 sampling found 2i, and four sites entering the stream above station 4, to have higher turbidity values than other sites sampled on that day. Turbidity values measured at site 4a were nearly 175 FTU, and this date was considered a spate event by our criteria. Turbidity values measured on August 20, 1991 were considered to be spate samples, with turbidity values ranging up to about 450 FTU. Higher values were sampled from several sites in the upper reaches of the watershed, entering the stream above stations 1 and 2, and also in the lower reaches of the watershed above stations 4, 5, and 6. The September 21, 1991 turbidity sampling was not considered a spate event. Sites 3f, 4c, 4d, 5d, 5e, and 7a were sites of higher turbidity. Values ranged up to approximately 130 FTU. Turbidity measurements on November 3, 1991 have values which range to nearly 175 FTU with site 2f, and several sites upstream of stations 4 and 5 show elevated turbidity values. November 17, 1991 was not considered a spate event and values only go up to less than 60 FTU. Highest values on this date were from several sites above stations 4 and 5 and from site 8a. The January 6, 1992 turbidity sampling shows a similar pattern as before with several of the highest values found at several sites above station 4 and 5 and at site 8a. Turbidity data collected on February 14, 1992 had elevated values at sites 1a, 1e, 1f, 3e, and several sites above stations 4 and 5. Turbidity data collected on February 14 (Figure 3) had the high values indicative of a severe spate event, and they ranged to nearly 1000 FTU at several sites upstream of stations 4 and 5. By March 1, 1992 turbidity values had decreased, but again most of the higher values were located in the lower sections of the creek, with peaks at several sites upstream of station 4 and at site 8a. Turbidity data from March 21, 1992 clearly show that those tributaries entering Fish Creek upstream of station 4 are contributing disproportionately to turbidity levels in the creek. The April 25, 1992 turbidity sampling was considered a spate event, and results indicate that tributaries upstream of station 5 are contributing heavily to the sediment in the creek. The May 14, 1992 turbidity

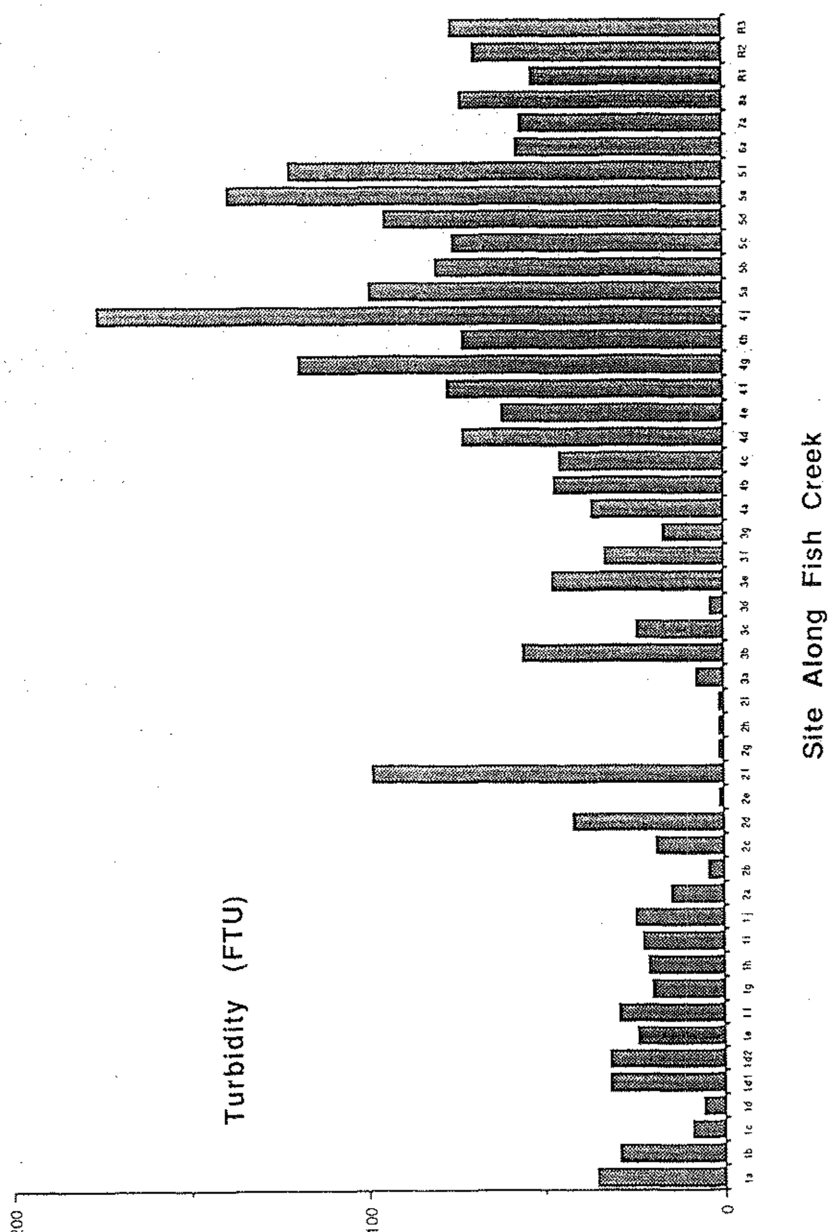

Figure 2. Turbidity along Fish Creek, November 3, 1991.

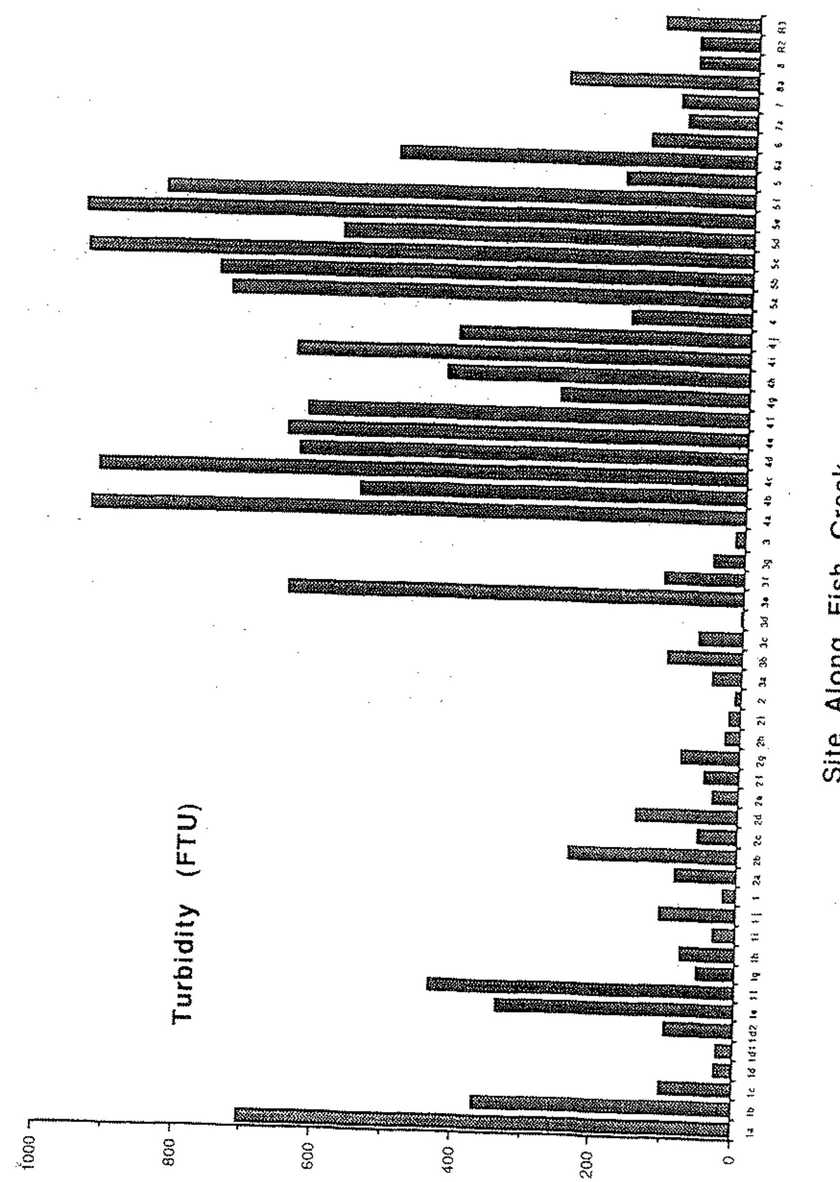

Figure 3. Turbidity along Fish Creek, February 14, 1992.

data shows several sites (2b, several sites upstream of stations 4 and 5, and sites 7a and 8a) to be of concern. May 14 was not considered a spate event. June 5, 1992 sampling, the last during this study, showed that sites 2b and 2f had elevated turbidity values.

A total of 708 turbidity samples were collected from the tributaries, the mainstem of Fish Creek, and above and below the confluence of Fish Creek into the St. Joseph River during the extended tributary turbidity and specific conductance sampling regime. The mean turbidity for all samples was 38.2 FTU. Turbidity and conductivity were weakly negatively correlated ($R^2 = -0.1059$, $p < 0.01$). Turbidity values were significantly different by date ($p < 0.0001$). The highest average values (mean value 135.7 FTU) were recorded on February 14, 1992. The lowest values were recorded on May 14, 1992 with an overall average for the sampling date of 9.51 FTU. Turbidity values from the tributaries and creek mainstem were also significantly different between stations ($p = 0.0015$). This was performed by examination of all values recorded upstream of a particular station in comparison to all values between that station and upstream of the next station. Station 8 and above only included station 8 and site 8a was the highest. This can be attributed to station 8a on several occasions having extremely high turbidity levels. The other stations that were higher than the others were station 4 with an overall mean turbidity value of 55.5 FTU and station 5 with an overall mean of 51.3 FTU. Station 3 had the lowest average turbidity value of 18.6 FTU.

Specific conductance sampled concurrently with turbidity readings at the tributaries, mainstem of Fish Creek and the St. Joseph River had a grand mean of 595.5 μmhos/cm. They were weakly correlated to turbidity as described above. Specific conductance values were significantly different by date ($p < 0.0001$). The lowest average values were collected on August 20, 1991 and were 439.5 μmhos/cm. The highest average values were collected on August 12, 1991 and were recorded at 804.9 μmhos/cm. Specific conductances were also significantly different by station ($p = 0.0286$). The lowest readings were collected at station 3 and averaged throughout the year at 533.8 μmhos/cm while the highest readings were taken at stations 1, 2, and 5 (642.6, 647.0, and 601.0 μmhos/cm respectively).

Fish Creek discharge rates are presented in Figure 4. Discharge was measured on six occasions during the course of the study with a mean of 27.15 cfs (average of all dates and the four stations measured). High water levels precluded discharge measurements from November, 1991 to March, 1992. The highest discharge measured was during April, 1992 and had a reading of nearly 70 cfs, with the lowest measured on August 6, 1991 with a reading of less then 10 cfs. The summer of 1991 was very dry, making it nearly impossible to catch spate events for sampling purposes. Discharge levels were not significantly different between stations ($p = 0.9188$). The expected downstream increase in discharge was not com-

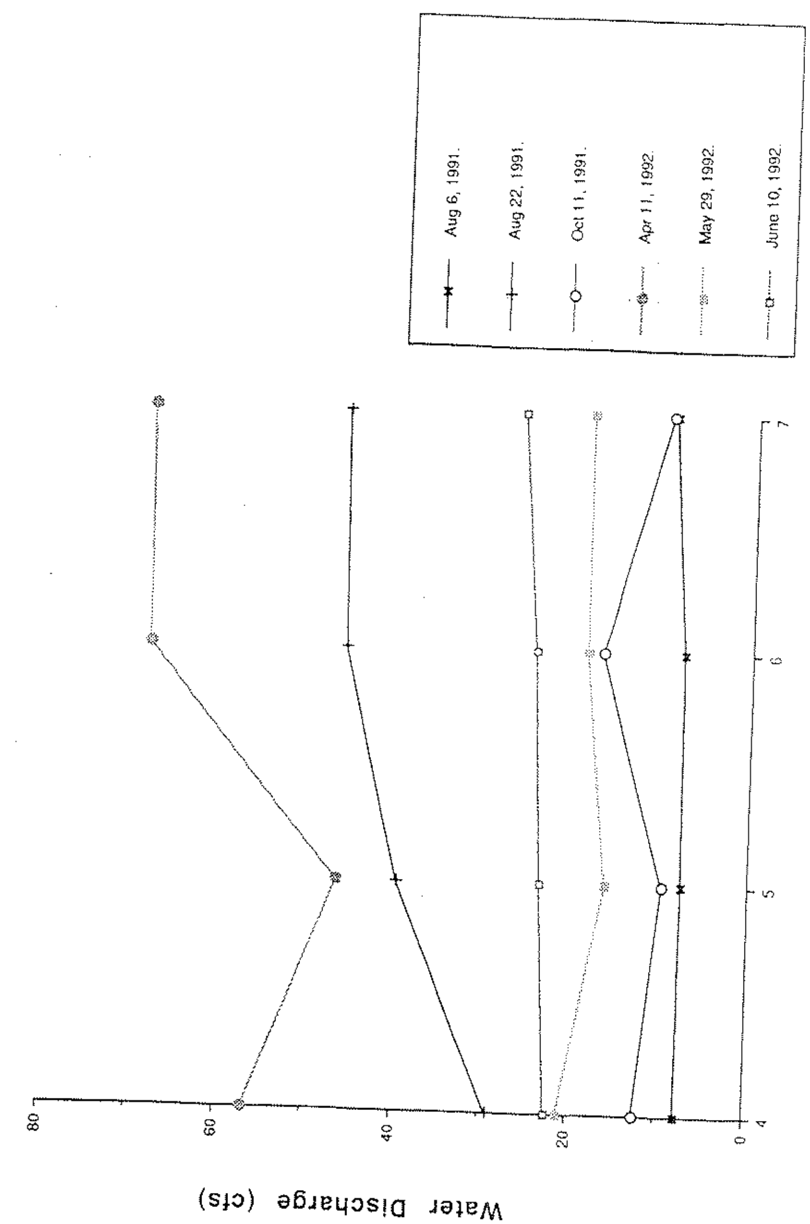

Figure 4. Fish Creek discharge rates (August 1991 to June 1992).

pletely linear, this is not unrealistic since many small streams have intermittent flow. Also the difference between stations is slight, less than one percent of total discharge between stations 6 and 7, and less than four percent between stations 4 and 5. Both of which are below a five percent margin of error. Discharge and specific conductance were negatively correlated ($R^2 = -0.7859$, $p < 0.001$).

Discharge, turbidity, specific conductance, and suspended sediment were measured on six occasions at four stations. Discharge was not significantly correlated with either turbidity or suspended solids. Turbidity and suspended sediment were significantly positively correlated ($R^2 = 0.9415$, $p < 0.001$). Most of the sample points for turbidity and suspended sediment track each other very well indicating that turbidity can be used as an indicator of suspended sediment. Interpretation of the data collected suggests that suspended sediment increases as discharge increases, as the stream gets larger. On the other hand, data collected on October 11, 1991 suggests that turbidity levels were higher in the upper reach, but settled out as the stream proceeded downstream. Turbidity values were not significantly different between stations ($p = 0.9992$), nor were suspended solids significantly different by stations ($p = 0.9648$).

Figure 5 presents results of substrate sieve analysis at the eight stations collected during the summer of 1991. Fines and clays, particles less than 0.031 mm in diameter, make up a very small proportion of the bed material. Medium-sized substrate particles (substrate items < 8.0 mm) made up a larger proportion of the bed material at stations 1, 2, 3, and 8 than at the other stations. At station 3 there was no substrate material larger than 8.0 mm. At stations 4 through 7 the bed material had a greater proportion of larger than 8 mm material, especially at stations 5, 6, and 7. At station 5, the largest size class (> 8 mm) made up nearly half of the material collected.

Macroinvertebrates were collected on July 24, 1991 at eight stations along Fish Creek. Briefly, 55 taxa were identified to the lowest practical taxon. Chironomids were dominant at station 1, and continued at a lower proportion for the remainder of the stations (Figure 6). The mayfly, *Ephoron*, appeared for the first time at station 5 and was represented at the remainder of the stations. It is a filter feeder and is considered to be an indicator of clean water.

The highest number of taxa were found at station 5, followed by station 6. Total invertebrate density was also highest at station 5 followed by station 1. At station 5 this large density was, in part, due to high densities of the filter-feeding Trichopteran, *Hydropsyche* (130 ind./m2) and the mayfly *Ephoron*. Mayflies of the genus *Stenonema* were found at all stations, but with dramatically increasing abundances at station 4. *Stenelmis* riffle beetles were relatively abundant at all stations.

Shannon-Weaver diversity of macroinvertebrates was highest at stations 2 and 3, followed by stations 5 and 6. Station 1 was dominated by

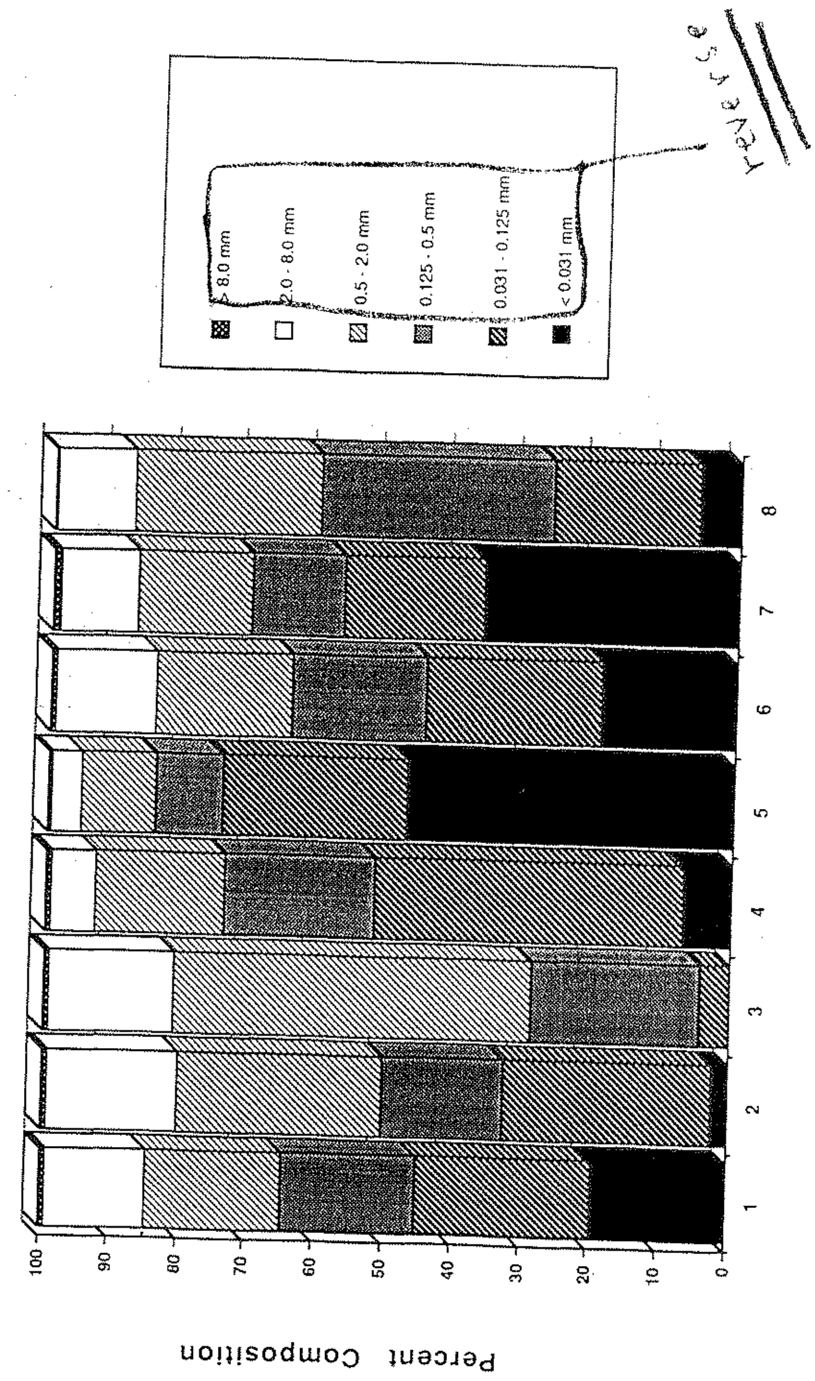

Figure 5. Fish Creek substrate seive analysis at eight sites taken during summer 1991.

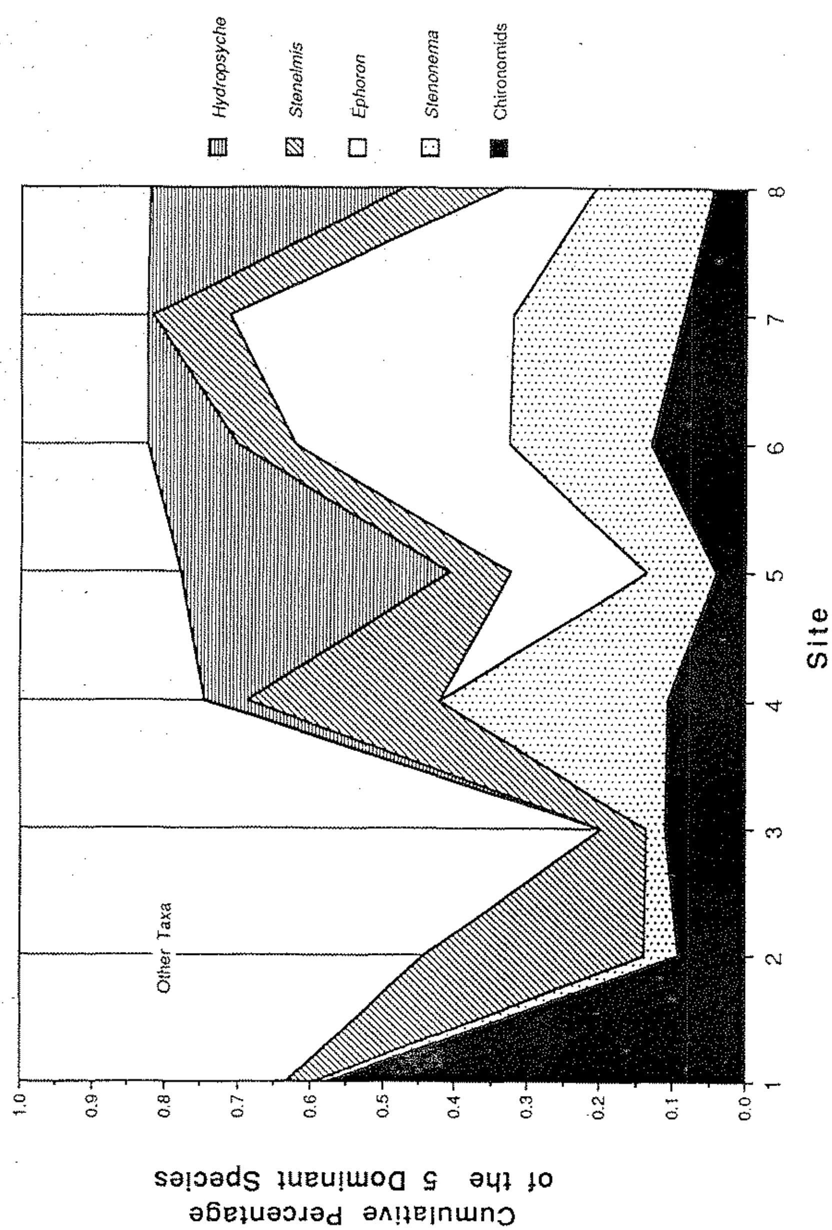

Figure 6. Fish Creek macroinvertebrate community composition.

Chironomids, which represented 57.5% of all invertebrates collected at that station. Oligochaetes, including tubificids, were also found in greatest numbers at station 1.

Interestingly, station 3 was dominated by molluscs, comprising 76.5% of all organisms found at that station. These molluscs were primarily gastropods, nutrient- tolerant scraping organisms. Their even numerical distribution amongst the taxa at stations 3 gave that station the highest diversity value.

Figure 7 presents information on functional feeding groups of macroinvertebrates. Station 1 has by far the greatest proportion of collectors. Stations 3 and 4 have the greatest proportion of scrapers, with station 1 having the least. Station 2 has the same number of scrapers as collectors. Filter feeders are very rare at stations 1 through 4, but increase to dominance from station 5 through 8.

Fall, winter, and late spring samples for algae were collected. Algal sampling revealed a heterogeneous algal community present along Fish Creek, with 80 taxa of algae identified to the genus and species level. Most evidence suggests that station 1 is somewhat different from the other stations, although not a great deal of difference can be seen among the number of species found at each sampling station on each of the three dates. Algal sampling from the summer of 1991 shows station 2 to have the lowest species richness. Stations 3, 5, 6, and 7 have the greatest species richness. The winter algal collection (sampling event 2, December, 1991), revealed that station 1 had the lowest algal species richness (one species, a *Trachelomonas sp.*), followed by station 2 with five species. Station 3 had the highest species richness, with stations 1, 4, 5, and 6 having nearly the same number of taxa. On the third algal sampling (late spring, 1992), station 1 had the lowest number of taxa, with most other stations, including station 2, having 15 to 22 algal taxa.

Examination of the dominant taxa suggests little pattern as well. At station 1, dominant species include *Spirogyra crassa* (spring), *Spirogyra micropunctata* (spring) and *Anabaena azollae* (winter). *Spirogyra micropunctata* was also dominant at station 6 in the spring sampling. *Ulothrix variabilis* was dominant at stations 4, 5, and 6 during the summer 1991 sampling.

Discussion

A baseline water chemistry inventory is presented, and much of the data suggests that station 1 is atypical. Station 3 is also somewhat atypical with regard to water chemistry, but this can be explained by water from Hamilton Lake.

A clear pattern emerges upon examination of the turbidity values sampled from the tributaries feeding into Fish Creek. Several of the sites

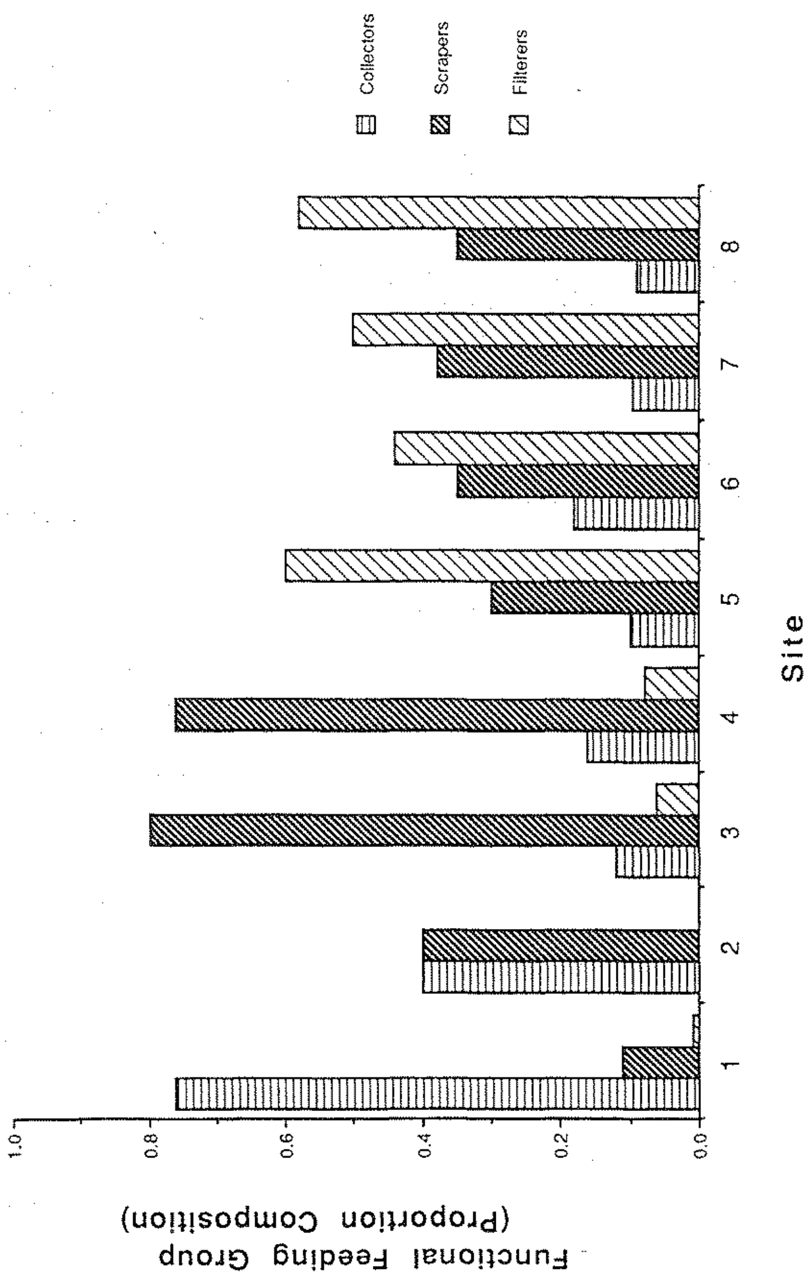

Figure 7. Proportional composition of functional feeding groups (macroinvertebrates) in Fish Creek.

tering Fish Creek upstream of station 1 had elevated values, along with some elevation in turbidity readings upstream of stations 2 and 3. Clearly the highest values were above stations 4 and 5. Sites 7a and 8a also had higher values. This does not mean that the lower regions, upstream of stations 6 and 7 had lower contributions to turbidity. Many of the Ohio areas had crops growing right up to the edge of the stream. Although turbidity contributions were not measured directly from the fields, these undoubtedly contributed to turbidity. The highest values measured on the tributaries were generally from sites upstream of stations 4 and 5 clearly depicting these areas to be of primary concern for focussing of mitigation efforts.

Several areas of increased turbidity can be identified from the data. At nearly all sampling dates, the sites entering Fish Creek upstream of station 4 (labeled 4a - 4i, located in DeKalb County) on the mainstem have elevated turbidity values. Field observations report that this area often appears markedly turbid compared to other areas. Other areas of elevated turbidity include sites 5a - 5f (DeKalb County, IN and Williams County, OH) particularly on September 21, 1991, November 3, 1991, November 17, 1991, January 6, 1992, and February 14, 1992.

Bridge construction and stream edge work had left Fish Creek at station 1 with reduced ground cover in the area. This probably contributed to the higher turbidity reading at station 1 in relation to the other stations along the stream, specifically on March 1, 1992. The turbidity reading at station 1 is also higher than any of the tributaries that feed into it on this occasion, although this had occurred before. Station 1 exhibits the worst water quality for several parameters, including dissolved oxygen, turbidity, and some organismal parameters.

An oil sheen was observed on the stream water surface at station 1 on March 1, 1992 and March 16, 1992. This was attributed by direct physical evidence to creosote-covered bridge supports put in place to support a new bridge at station 1.

A clear shift in macroinvertebrate community composition exists between station 1 and the remainder of the sample stations. Station 1, an area with marked channelization, appears to be a biologically degraded environment. Station 1 is dominated by chironomids, most of which are in the pollution tolerant genus, *Chironomus*. The presence of oligochaetes (*Tubificidae*) and other classic pollution tolerant organisms supports this conclusion. Beginning with station 2, the organisms present suggest a shift to a higher quality environment and/or community, but it is not until station 5 (vicinity of suspected mussel habitat) that we find our most dramatic shift in community structure.

Upon interpretation of the macroinvertebrate community, stations 5 through 7 appear to be the location of the highest water quality. Here *Ephoron* made its initial appearance in great numbers. Station 5 is also the site of the greatest taxa richness and density of organisms. In addition, other pollution intolerant genera [Psephenus (*Coleoptera*) HBI = 1, Siphlonurus (*Ephemeroptera*) HBI = 0] first appear in significant numbers. HBI is the Hilsenhoff Biotic Index (Hilsenhoff, 1977).

Filter feeders such as *Hydropsyche* and *Ephoron* which utilize allochthonous fine particulate organic matter (FPOM) and associated bacteria and fungi, dominate stations 5 through 8 (Merritt and Cummins, 1984). Perhaps this reflects the quantities of organic particulates flushed from surfaces upstream of these stations (Knorr and Fairchild, 1987). Edmunds, et al. (1976) suggest that *Ephoron* numbers may greatly increase in nutrient poor streams subject to nutrient enrichment. Stations 2, 3, and 4 are apparently dominated by the scrapers and gastropods (*Stenelmis* and *Stenonema*). Scrapers efficiently utilize periphyton, sedimented detritus, and bacteria (Merritt and Cummins, 1984).

No conclusions, other than providing a baseline sampling event, can be reached by examination of the algal community sampled three times during this study. Some evidence, in terms of algal community composition and structure, exists that establishes station 1 as being somewhat different from the other sites. The number of algal species found during the study suggests that the water quality of the creek is conducive to a diverse algal community.

Principal findings, conclusions and recommendations

Baseline data has been collected on the water quality, nutrient concentrations, algae, and macroinvertebrates of Fish Creek. This data indicates Fish Creek to be of good water quality. Several macroinvertebrate species thought to be indicative of clean water were present at stations 5, 6, and 7. The presence of these organisms suggests that water quality at these stations is the best along this particular stream. These stations are also the area in which the white cat's paw pearly mussel was last found. Station 1 appears to have the poorest water quality. In contrast, many of the highest turbidity values measured in this study were found in Fish Creek tributaries upstream of stations 4 and 5. These high values, resulting from drainage ditches feeding into Fish Creek, need to be remedied.

Recommendations

1. Fish Creek must be recognized as a valuable resource containing an important and diverse mussel fauna, and high (although somewhat degraded) water quality.
2. Fish Creek must be protected from damaging stream and edge work, such as the bridge built at station 6 and the bridge and edgework performed at station 1. If work of this nature is performed, best management practices must be followed in order to minimize negative impacts on the stream and mussel communities.
3. Many sites along the stream were recognized as having increased turbidity (suspended solids). These sites, specifically those above stations 4 and 5, and other sites, and those fields with farming right up to the edge of the stream must be mitigated. It is suggested that low impact farming practices be adopted in the drainage area. In conjunction with the Soil Conservation Services in the three counties (Steuben and DeKalb, IN, and Williams County, OH), we strongly recommend the establishment and/or increased use of grass waterways, levies and dikes, no-till agriculture, and buffer strips between croplands and waterways. In addition, the practice of allowing cattle and hogs access to the streams must be discouraged.

Acknowledgments

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