NOAA Technical Memorandum
NOS MEMD 19

OLD WOMAN CREEK NATIONAL ESTUARINE RESEARCH RESERVE

USE OF BACKWATER MARSH AREAS BY FISH POPULATIONS IN OLD WOMAN CREEK AND SURROUNDING LAKE ERIE PRIOR TO HIGHWAY CONSTRUCTION

Washington, D.C.
April 1988

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / Marine and Estuarine Management Division

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UNITED STATES DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Ocean Service

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NOTICE

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NATIONAL OCEAN SERVICE
OFFICE OF OCEAN AND COASTAL RESOURCE MANAGEMENT
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WASHINGTON, D.C.

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This work is the result of research sponsored by the U.S.
Department of Commerce, National Oceanic and Atmospheric
Administration, National Ocean Service, Office of Ocean and
Coastal Resource Management, Marine and Estuarine Management Division
Under Contract NA86AA-D-CZ014

ABSTRACT

Our research was conducted to survey and to characterize a freshwater marsh-estuarine ecosystem, Old Woman Creek National Estuarine Research Reserve on the south shore of Lake Erie, prior to construction of a four-lane highway across a portion of the creek. Our objectives were to establish baseline environmental data for comparison to the post-construction environment, and to assess the effects of disturbance on fish communities in these sensitive marsh areas.

We selected four sites to monitor located throughout the upstream area of the estuary and began sampling on 15 March 1986, continuing through 18 October 1986. Fish populations were sampled by trapnetting and seining, zooplankton by filtration, and benthos by dredging. Standard physico-chemical water quality parameters were measured electronically. We ultimately collected 16 fish and water quality samples, 9 zooplankton samples, and 7 benthic samples.

Fish collections were dominated by species (e.g. brown bullhead) generally regarded as less sensitive to water quality. The rarity of more sensitive species (e.g. northern pike) probably indicates the influence of past disturbances over a large scale (i.e. the Lake Erie basin),

and the continued persistence of such species in the area may depend upon maintainence of habitat quality in the few remaining relatively undisturbed marsh-estuarine systems. Coincidence of high zooplankton abundances with large numbers of larval and juvenile fish attest to the continued importance of the estuary as a spawning and nursery area.

Detailed analysis of data collected in 1987 during the highway construction phase will allow us to assess the impact of that activity on the physical and biotic community we have described in this report.

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PREFACE

The 1986 data described in this report represent a baseline assessment of the physical, chemical, and biotic parameters of a relatively undisturbed freshwater marsh-estuarine ecosystem prior to a potentially damaging event (construction of a four-lane highway across the upper reaches of the system). 1987 data collected during the construction-phase are currently undergoing analysis, and the two data sets will be compared in our next major report.

Mike Czeczele of Bowling Green State University assisted in several areas of this project, and we thank him. We also thank the staff of Old Woman Creek National Estuarine Research Reserve for the provision of many items of equipment and their willing assistance.

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INTRODUCTION

Lake Erie, the second smallest of the Great Lakes, has historically been the most productive. Much of this productivity can be attributed to the once extensive coastal marsh and estuary system present along the south shore of the lake. These marsh areas provided essential habitat for over 40 species of Lake Erie fish, either as spawning, nursery, or feeding areas (Van Meter and Trautman 1970, Trautman 1981). Great Lakes coastal marsh-estuarine systems were also important to many other species of fish, as well as zooplankton and benthic invertebrates, by functioning as nutrient and sediment traps, resulting in increased clarity and quality of water entering Lake Erie.

Cultural developments in the Lake Erie drainage basin have resulted in the alteration or destruction of much of the original marsh estuarine system. Agricultural siltation, industrial waste discharge, draining and filling of marshes, and the damming and channelization of tributaries have resulted in decreased water clarity, destruction of spawning and nursery areas, and much poorer water quality today than was historically observed (Trautman 1981, Cairns 1980).

In conjunction with the destruction of these marsh-estuarine systems came a decrease in the species number and abundances of marsh-dependent fishes and an increase in the abundance of silt and turbidity-tolerant fauna. Today, several marsh species of benthos, plankton, and fish are extirpated or near extirpation from the lake.

Old Woman Creek National Estuarine Research Reserve represents a remnant of the once extensive coastal marsh-estuarine system. Prior to 1850, approximately 4000 km2 of coastal marsh stretched from Vermillion, Ohio, to the Detroit River. At present, only 100 km2 of natural marsh remains, including Old Woman Creek. Several sensitive microhabitats of swamp-forest and shallow marshland are threatened by the construction of the Ohio State Route 2 highway bypass project at Huron, Ohio. Our research was conducted to survey and to characterize these sensitive habitats prior to construction and to establish baseline environmental data for comparison to the post-construction environment. Through this comparison we hope to assess the effects of disturbance in these sensitive marsh areas and, thus, to provide a model for the effects of future development in Great Lakes estuarine systems.

HYPOTHESIS AND OBJECTIVES

The basic hypothesis we wish to examine is straightforward: highway construction will produce changes in the physical and chemical composition of the marsh-estuarine system such that population abundances of some fish species will be significantly affected. These changes may be due to the direct effects of physico-chemical alteration of the environment or through associated changes in the abundance and distribution of zooplankton and benthic invertebrates that support the fish.

To examine this hypothesis our project has the following specific objectives:

1. To assess the current fish community using the upstream marsh areas of Old Woman Creek prior to highway construction. This provides a baseline fish community to which the post-construction community can be compared. Seasonality of use and usage as spawning or nursery sites is also monitored.

2. To establish the baseline physical, chemical, and biological parameters of the marsh-estuarine system. Zooplankton and benthic invertebrates are censused simultaneously with physico-chemical measurements. Future monitoring programs can use these data in two ways: (1) as a baseline for comparison to the post-construction environment, and (2) for development of correlational relationships with fish species distribution and abundances.

METHODS

Study Site

Old Woman Creek estuary is a shallow, 40 ha marsh located on the south shore of the central basin of Lake Erie. Water sources to the marsh include both Lake Erie and the Old Woman Creek watershed (Figure 1). The drainage basin of the creek is relatively undeveloped, primarily draining agricultural lands; Berlin Heights, a small village (population less than 1000), is located approximately 7 km upstream. A secondary sewage treatment plant in Berlin Heights represents the primary point source of organic pollution into the stream.

The estuary consists of two distinct portions separated by a constriction created by a railroad causeway (Figure 1). The lower portion is a sheltered bay connected to Lake Erie by a narrow channel that periodically opens and closes due to a shifting barrier beach. Normal depth of the lower portion is $<$ 1 m except in the creek channel, where depths of 2 m are found. Estuarine water levels are affected by lake level, wind, and runoff from Old Woman Creek and its tributaries.

The upstream portion of the estuary consists of a well-defined channel approximately 10 m in breadth that meanders

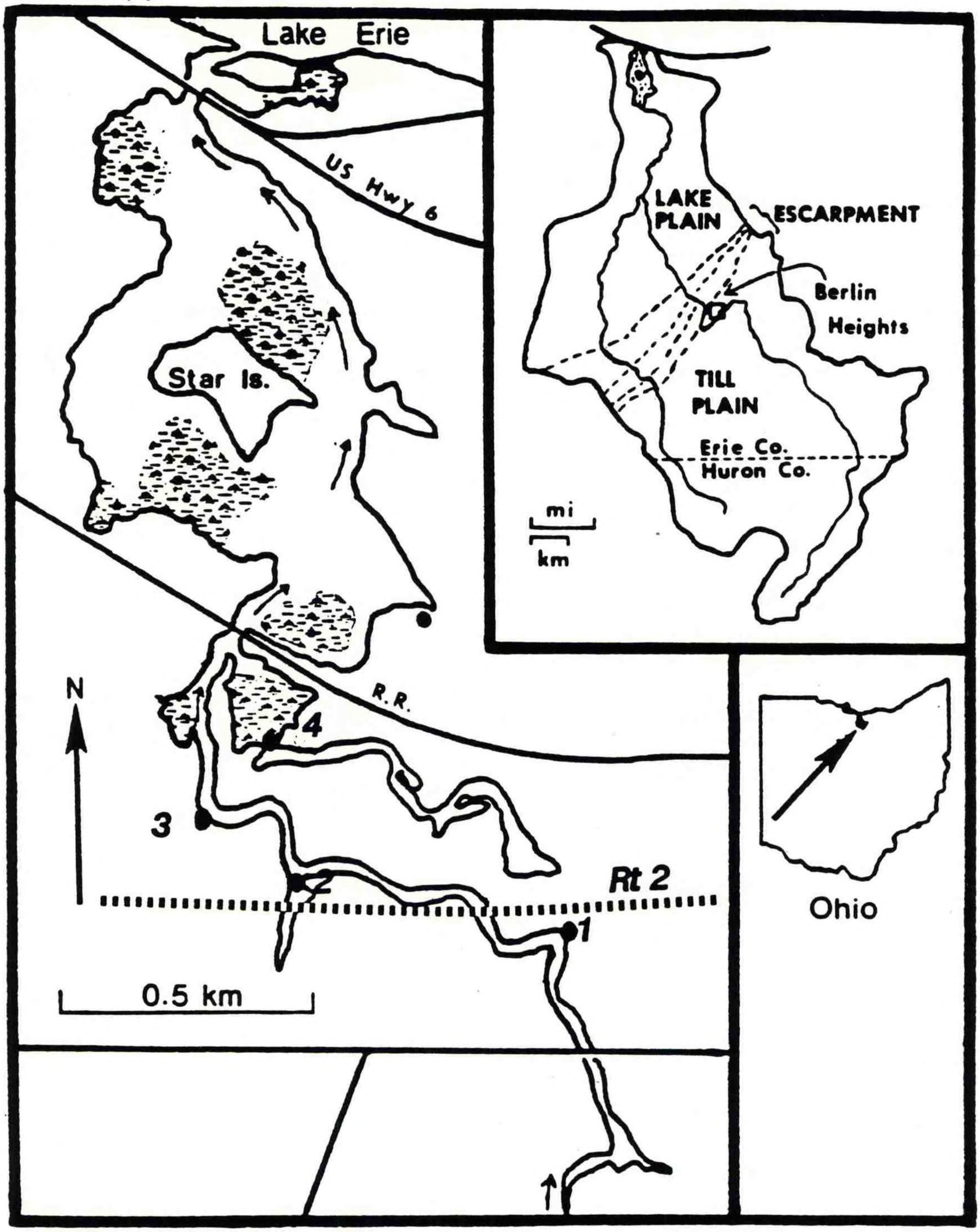

Figure 1. Map of Old Woman Creek National Estuarine Research Reserve. Insets show general location of OWCNERR in Ohio and details of the Old Woman Creek watershed. Numbered circles indicate locations of sampling sites mentioned in this study; heavy dotted line indicates proposed Ohio State Route 2 highway bypass.

through a forested lowland area. Normal channel depth is 1-2 m, with fluctuations occurring in association with seasonal changes in estuarine water levels. Surrounding the channel are discrete areas of marsh and swamp-forest habitat delineated by oxbow lakes and tributaries to Old Woman Creek. Water in these areas is permanent, shallow (usually < 1.5 m), and characterized by the presence of emergent terrestrial and aquatic vegetation.

It is these upstream areas that are threatened by the construction in 1987-1990 of the Ohio State Route 2 bypass. We expect that construction-related disturbance will directly affect some areas while indirectly affecting others downstream via increased turbidity and siltation and decreased water quality.

Four marsh areas adjacent to the channel were selected as sampling sites in the upper portion of the estuary in anticipation of the highway route: Site 1, upstream of the project; Site 2, directly affected; Site 3, downstream of the project and potentially indirectly affected; and Site 4, draining a separate area with anticipated minimal impact from highway construction (Figure 1). Although upstream, Site 1 was partially affected by construction when right-of-way was cleared in July, 1986, after our sampling had begun.

Sampling Methodology

We began collections of fish, benthos, zooplankton, and physico-chemical parameters on 15 March, 1986, and continued through 18 October. Fish collection were conducted by trap-netting weekly from March through May, seining monthly in June, July, and August, and trap-netting monthly in September and October. These collection methods were deemed the most effective for a sampling date given the physical and biological conditions of the sampling sites during any particular period. A single collection was taken at each site on each sampling date. Trap nets (1.2 m [4 ft] hoop diameter, 2.5 cm [1 in] mesh, 9 m [30 ft] lead lines) were set in the late afternoon (ca. 1700) and emptied the following morning between 700-1200. Seines (1.2 X 3.0 m [4 X 10 ft], 1.6 mm [1/16 in] mesh) were hauled three times for a total distance of approximately 30 m. All fish were identified, measured, and, except for a few voucher specimens, released.

We assayed a variety of physical and chemical parameters simultaneous with each fish collection at each site. We electronically measured temperature (oC), conductance (mmhos/cm), pH, dissolved oxygen (ppm), and turbidity (Nephelometric Turbidity Units, or NTUs). Water depth (cm) was recorded at the entrance to each sampling site. We estimated the percent of surface cover of emergent macrophytic vegetation at each site on a scale from 0 (no emergent vegetation) to 5 (100% vegetation cover).

Although intially zooplankton and benthos were sampled with each fish collection as a measure of resource availability, preliminary analysis of these data indicated that samples varied little from week to week. Thus we instituted bi-weekly sampling of invertebrates from mid-April through June, and then monthly with each fish collection thereafter.

Three replicate samples of zooplankton and benthos were collected from random locations within a site, then pooled for analysis. For zooplankton, each replicate consisted of 5 l of water strained through a 64 um plankton net. Net contents were emptied into 250 ml glass jars by backflushing the net thrice and adding each rinsate to the jar. Each sample was preserved within one hour of collection in 5% unbuffered formalin.

One-ml subsamples were extracted from each collection using a Henson-Stemple pipet and counted under a light microscope in a 1-ml Sedgwick-Rafter counting cell. Species were identified using the diagnostic keys of Torke (1974) and Balcer et al. (1984). Subsamples were counted until three repeated subsamples yielded no new species. Estimates of zooplankton density were calculated as:

$$\text{Density } (\#/l) = \frac{N\ (Vs)}{Va\ (Q)}$$

where N is the total number of zooplankters in the subsample, Vs is the sample volume (ml), Va is the combined volume of the subsamples (ml), and Q is the quantity of water filtered (usually 5 l).

Benthic invertebrates were collected using a 0.1 m3 Eckman grab sampler. Three replicates for each site were pooled and preserved within one hour of collection in 10% formalin. Benthic organisms were separated from the sediment by a series of washes and sieves, identified to family, and counted.

Statistical Analysis

All statistical analyses were performed using Statistical Analysis System software (SAS Institute 1982). Details of computation and interpretation of the standard techniques employed may be found in standard reference texts (e.g. Zar 1984 for univariate tests; Pielou 1984 for multivariate analyses). We used two-way analysis of variance without replication (Zar 1984:217) to test for statistically significant among-site and among-date differences in the various quantities we measured. In essence, this test allowed us to control for variation due to date of sampling when comparing sites, and to control for site differences when comparing dates. For example, although turbidity at two sites might appear similar when averaged over the entire sampling season, if one site expressed slight but consistently higher values on each sample date the overall difference would be adjudged significant.

RESULTS

The total number of samples collected and their temporal distribution is outlined in Table 1. Altogether we collected 16 samples of fish and associated water quality parameters, and 16 invertebrate samples. As all raw data are provided in appendices, what follows is a general summary of the patterns we observed for each of the classes of samples.

Water Quality

Because it seems likely that the principal direct effect of highway construction will be the modification of physical parameters of water quality (with subsequent indirect effects on the biota), we will present a somewhat detailed

Table 1. Summary of data collection activities at Old Woman Creek during 1986. As collecting usually spanned several days, dates listed are nominal (keyed to time of fish collection).

Date	Sampling Activity				
	Trap Netting	Seining	Water Quality	Zooplankton	Benthos
15 March	x		x		
22 March	x		x		
29 March	x		x		x
5 April	x		x	x	
12 April	x		x	x	x
19 April	x		x	x	
24 April	x		x		
3 May	x		x	x	x
10 May	x		x		
16 May	x		x	x	
31 May	x		x		
21 June		x	x	x	x
14 July		x	x	x	x
17 August		x	x	x	x
13 September	x		x	x	x
18 October	x		x		
Totals	13	3	16	9	7

outline of the results of our water quality sampling. These results provide the baseline against which future impacts will be assessed.

Physical parameters varied widely throughout the sampling period (Appendix 2.1-2.4). Temperature, for example, ranged from 4.5 to 29 oC, and dissolved oxygen fluctuated between extremes of 2.5 and 15.0 ppm. If we apply commonly accepted standards (Federal Water Pollution Control Administration 1968), we observed that water quality was generally "acceptable." Summer temperatures did not appear to exceed maxima incompatible with the well-being of most fish present, although early March temperatures may have been too high to promote sucessful development of eggs of pike and salmonids. Estimates of total dissolved solids (conductivity in mmhos/cm X 650) never exceeded 560 mg/l (well below the acceptable upper limit of 1500 mg/l), and pH was well within acceptable ranges. However, turbidity often exceeded 25 NTU in the spring and fall (levels above which are considered to be detrimental to sight-feeding fish), and dissolved oxygen was often less than 6 ppm in the late summer. The latter two parameters may set the ultimate limits to the composition of the fish community in this marsh-estuarine ecosystem..

Because most of these water quality parameters were highly intercorrelated (15 out of 21 intercorrelations were statistically significant in our sample; Appendix 2.5), we used Principal Components Analysis (see, for example, Pielou 1984) to describe the general patterns of variation in these data. This technique yields new synthetic variables (factors or components) that are composites of the original variables; the ecological interpretation of these synthetic factors depends on their correlation with the original variables. Just as a water sample has a score on each original variable (e.g. Site 1, June 28, DO = 5.5 ppm), so can it be assigned a score on each of the new factors; this score depends on the sample's values for each of the original variables and the variables' correlations with the new factor (see Appendix 2.6 for factor scoring coefficients). In essence, we can now describe a sample with respect to one or two new water quality parameters rather than the seven original ones, yet still preserve most of the ecologically relevant information that was contained in the original seven.

The first two principal components were the only ones with eigenvalues greater than 1.0 (a conventional criterion for interpretation), and together they accounted for almost 70% of the statistical variance expressed in the original seven variables (Table 2). The first factor contained high positive loadings for water depth, temperature, and vegetation cover, and high negative loadings for dissolved oxygen and pH. Thus, for example, a water sample with a

Table 2. Results of Principal Components Analysis of water quality data from Old Woman Creek during 1986. Data are pooled over 16 dates from 4 sites (N = 64).

	Factor I	Factor II
<u>Factor Pattern</u>[1]		
Depth	0.71	0.08
Temperature	0.72	0.44
Dissolved Oxygen	-0.75	0.15
pH	-0.67	0.55
Conductivity	0.14	0.81
Turbidity	-0.04	-0.90
Vegetation Cover	0.84	0.30
<u>PCA Summary Statistics</u>[2]:		
Eigenvalue	2.75	2.08
Percent of Total Variance	39.3	29.7
Cumulative Percent Variance	39.3	69.1

1 Correlation of original variables with factors.

2 After varimax rotation (Pielou 1984).

high positive score on Factor I would be warm, near neutral, contain relatively little oxygen, and come from relatively deep water with substantial emergent vegetation coverage. A sample with a high negative score would be cold, oxygen-rich, basic, and from a shallow, sparsely vegetated area. (Note that all relationships are relative; for example, "deep" water is a maximum of 106 cm.) Thus, for many cold-water fishes (including several important game species), this factor is inversely related to habitat quality.

Factor II had high loadings for conductivity (positive) and turbidity (negative), and moderate loadings for pH and temperature (both positive). Thus, a sample with a high positive score on Factor II would be relatively warm, basic, clear, and have a high concentration of dissolved solids, whereas one with a low score would be relatively cool, neutral, murky, and have few dissolved chemicals. In essence, the first factor principally described variation in the "physical" variables whereas the second described variation in the "chemical" ones.

The distribution of water samples in this two-dimensional water quality "space" is shown in Figure 2. Statistical analysis revealed two significant patterns of variation embedded in this set of observations; two-way analysis of variance without replication (site X date, no interaction term) shows that 1) as expected, water quality varied

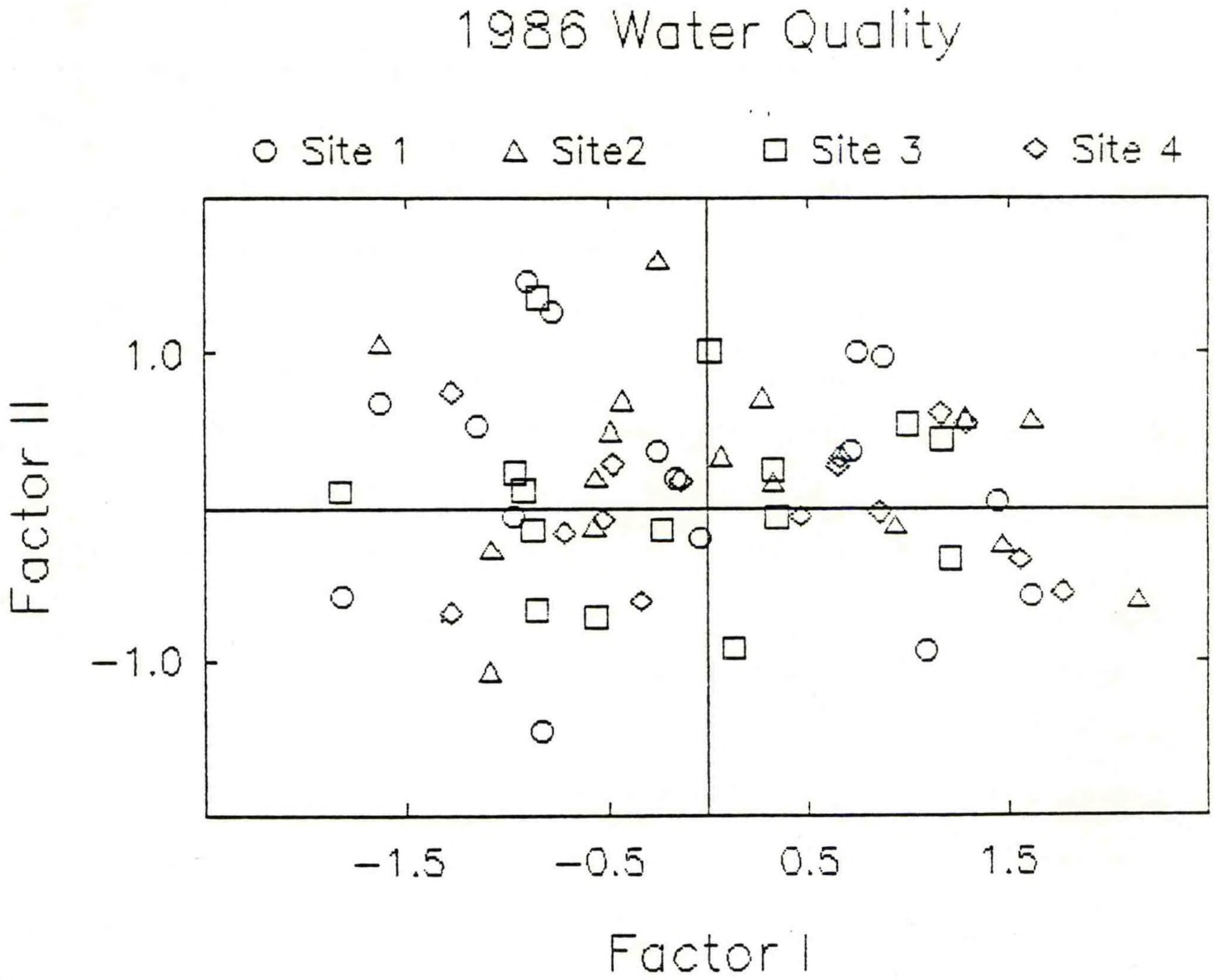

Figure 2. Water Quality at Old Woman Creek during 1986. Water samples taken from four sites are plotted against axes (factors) derived from Principal Components Analysis of seven water quality variables. See text for interpretation of factors.

significantly throughout the year with respect to both factors, and 2) sites differed significantly from one another with respect to Factor I (Table 3). These trends are summarized in Figure 3.

With respect to temporal variation in Factor I, we observed water temperatures, depth, and vegetation coverage increasing (while oxygen levels were decreasing) at all sites, peaking in late summer, then declining into the fall (Figure 3a). This pattern is typical of low elevation low gradient streams in this temperate climate zone. Because of low oxygen and high temperatures, the late summer likely represents a period of high stress for cool-water species and for larval and juvenile fish. If we assume that DO levels below 6 ppm are critical, then poor water quality is associated with Factor I scores greater than about 0.75 (Figures 2, 3a, and A2.7a).

Water conditions as indexed by Factor II changed rapidly in the spring, then more slowly throughout the rest of the sampling season (Figure 3b). This pattern was probably associated with the high discharge rates of the spring runoff, which has dissipated by late April-early May. The upward trend later in the year may be due to the effects of late-summer thunderstorms, which represent the principal events influencing discharge patterns during this period. Unfortunately, because we lack information on discharge

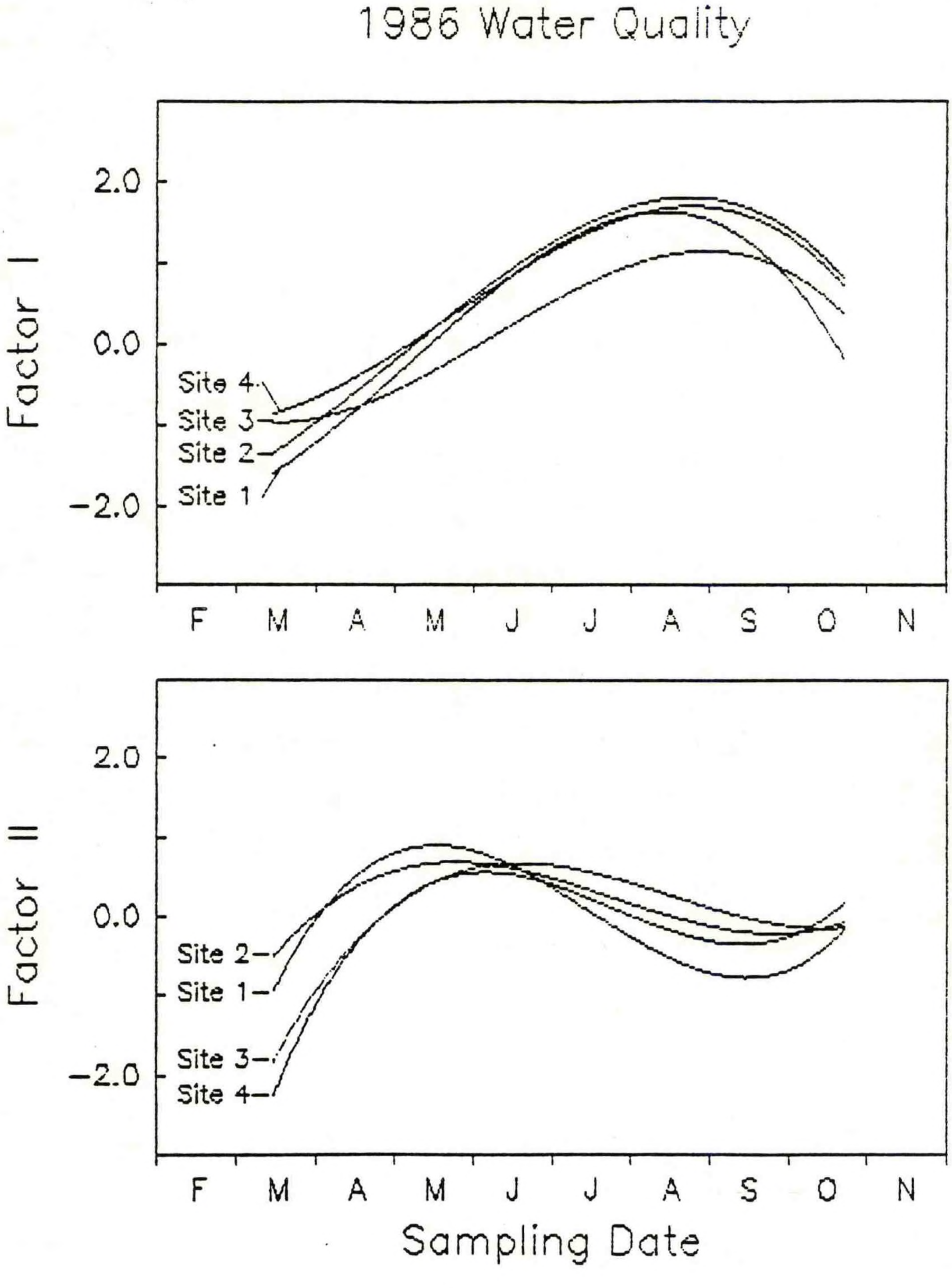

Figure 3. Site-specific variation in water quality at Old Woman Creek during 1986. Curves are third-order polynomials fitted to site factor scores and date of sampling. See text for interpretation of factors. See Figure A2.7 for raw data.

rates and the timing of major precipitation events, these relationships are speculative. If we assume that turbidity levels in excess of 25-30 NTU are critical, then poor water quality is associated with Factor II scores less than around 0.0 (Figures 2, 3b, and A2.7b).

Site 3 had significantly lower scores than Sites 3 and 4 (and Site 1 was significantly lower than Site 4) with respect to Factor I (Table 3); this difference was particularly pronounced during the critical summer period (Figure 3a). Although the mean score of water samples from Site 1 averaged over the entire season differed relatively little from those of 2 and 4 (Table 3), in virtually every sampling period those scores were lower (Figure 3a, Appendix 2.7). Site 1 scores declined in the fall much more rapidly than the other sites. Given our interpretation of this factor, we conclude that habitat quality for desirable fish species is greatest at Site 3 throughout most of the year, and improves rapidly at Site 1 after the summer nadir.

Although differences in scores on Factor II were not significant over the entire year (Table 3), it was evident that the downstream sites (3 and 4) changed much more rapidly early in the year than did the upstream ones (Fig 3b). Subsequent to the onset of summer, sites varied rather

Table 3. Analysis of variance of water quality data from Old Woman Creek during 1986. Two-way ANOVA without replication. Data from 16 dates and 4 sites (N = 64).

Dependent Variable	Source	SS	DF	MS	F
Factor I	Site	1.96	3	0.65	5.10**
	Date	55.26	15	3.68	28.69***
	Error	5.78	45	0.13	
	Total	63.00	63		
Factor II	Site	3.24	3	1.08	2.59
	Date	40.98	15	2.73	6.54***
	Error	18.79	45	0.42	
	Total	63.00	63		

**P < 0.01, ***P < 0.001

little with respect to this component. Again, these patterns appear to be related to variation in stream discharge rates.

Fish Populations

A total of 1576 fish representing 10 families, 22 species, and one hybrid was collected from the backwater marsh sampling sites by all sampling methods during the 1986 field season (Tables 4, 5; Appendix 3). Of these taxa, brown bullheads (see Appendix 1 for scientific names of all species mentioned in text or tables) were most abundant, followed by white and black crappie, carp, and gizzard shad. These five species accounted for 87% of all individuals captured. Fourteen species were collected in spawning condition (Table 4) and, based on informal observations in previous years, at least one other species (northern pike) is known to breed in this system as well.

Although most of the fish captured are from "warm-water" families (centrarchids, cyprinids, ictalurids; see, for example, Lagler [1956] for classification), several "cool-water' taxa were also present (catostomids, esocids, percids), and informal collecting in 1985 yielded spawning rainbow trout (a "cold-water" salmonid). The benthic feeding guild was most heavily represented (ictalurids,

Table 4. Total number of fish collected at each site (16 dates combined) at Old Woman Creek during 1986.

Species	Site 1	Site 2	Site 3	Site 4	Total	Rel. Abund.	Spawning
Longnose Gar	0	2	2	0	4	0.002	*
Gizzard Shad	2	17	27	15	61	0.038	May
Northern Pike	0	1	0	0	1	0.000	*
Carp	5	13	16	53	87	0.055	May
Goldfish	2	3	2	19	26	0.016	May
Carp X Gold hybrid	0	5	6	16	27	0.017	*
Emerald Shiner	0	0	6	0	6	0.003	*
Golden Shiner	0	0	0	1	1	0.000	*
Bluntnose Minnow	0	0	1	0	1	0.000	*
White Sucker	1	1	1	1	4	0.002	March
Spotted Sucker	4	30	1	9	44	0.027	March
Brown Bullhead	9	365	15	277	666	0.422	April
Yellow Bullhead	0	13	4	0	17	0.010	May
Tadpole Madtom	0	0	0	1	1	0.000	*
White Perch	0	5	2	3	10	0.006	May
Pumpkinseed	1	4	0	8	13	0.008	May
Bluegill	0	16	7	13	36	0.022	May
Orangespotted Sunfish	0	0	0	1	1	0.000	*
Largemouth Bass	0	1	0	5	6	0.003	*
White Crappie	28	109	162	85	384	0.243	June
Black Crappie	9	89	24	56	178	0.112	June
Yellow Perch	0	0	1	0	1	0.000	*
Freshwater Drum	0	1	0	0	1	0.000	*
Total Numbers	61	675	277	563	1576		
Avg. per sample	3.8	42.2	17.3	35.2			
Std. Dev	6.1	32.2	30.2	36.3			
Total Species	9	17	16	16	23		
Avg. per sample	1.8	5.3	2.8	5.1			
Std. Dev.	2.1	2.7	2.1	2.1			

* Not found in spawning condition

cyprinids, catostomids), although planktivores were abundant as well (centrarchids, clupeids, many larvae and juveniles). Not surprisingly, piscivores (pike, largemouth bass) were uncommon.

Trap netting (1055 net-hours) accounted for over 85% of all individuals (all of which were adult or large juvenile fish) and for 16 species taken. Seining collected 6 species (mostly small shiners, minnows, and madtoms) that did not appear in the trap nets. The bulk of the individuals seined, however, were larval white crappie and gizzard shad (Table 5).

Because most of the species we captured were relatively rare, we are unable to perform a Principal Components Analysis on the total fish community comparable to that of the water quality data; nonetheless, a number of patterns of variation in the fish community were evident. Two-way analysis of variance without replication (site X date) revealed significant variation among sites in both the average number of species and the average number of individuals collected (both $\underline{P} < 0.001$); Sites 1 and 3 consistently contained fewer species and fewer individuals than Sites 2 and 4 when sampled on the same date (Table 4). Although Sites 1 and 3 also differed from 2 and 4 with respect to water quality Factor I (Table 3), it is premature to suggest that this physical difference was responsible for

Table 5. Total numbers of fish collected on each sampling date (4 sites combined) at Old Woman Creek during 1986.

Species	3/15	3/25	3/29	4/5	4/12	4/19	4/24	5/3	5/10	5/16	5/31	6/21*	7/14*	8/17*	9/13	10/18	Total
	Date																
Longnose Gar									2		2						4
Gizzard Shad					7	5	3			10		22	6		3	5	61
Northern Pike																1	1
Carp	23	1	5	3	10	4	5	9	11	3	3	4	4	2			87
Goldfish	5	1	3	7	3	2		3		1					1		26
Carp X Gold hybrid	8	1	1	1		2	3	5	4						2		27
Emerald Shiner												5		1			6
Golden Shiner														1			1
Bluntnose Minnow													1				1
White Sucker		1		1											1	1	4
Spotted Sucker	11	11	10	1	3							1	1		6		44
Brown Bullhead	8		45	30	41	85	227	68	42	24	4		2		77	13	666
Yellow Bullhead									2	7					7	1	17
Tadpole Madtom														1			1
White Perch									1	1					7	1	10
Pumpkinseed		1	1		1				3		1				6		13
Bluegill	5		4			1	2	1			1	1	9	5	5	2	36
Orangespotted Sunfish														1			1
Largemouth Bass		1			1								1		2	1	6
White Crappie	5	5	28	13	17	13	13	13	9	2	2	98	35	18	44	69	384
Black Crappie	6	4	4	15	18	10	8	23	11	2	5				38	34	178
Yellow Perch														1			1
Freshwater Drum										1							1
Total Numbers	71	26	101	71	101	122	261	122	85	51	18	131	59	30	199	128	1576
Total Species	8	9	9	8	9	8	7	7	9	9	7	6	8	8	13	10	23

* Collected by seining; all others collected by trap netting

the biological difference, for neither number of species nor number of individuals was significantly correlated with Factor I (both $\underline{P} > 0.25$).

Despite the fact that the number of fish collected varied considerably throughout the season (Table 5, Figure 4), differences among sampling dates were not statistically significant (two-way ANOVA $\underline{P} > 0.20$). This was likely due to the high among-site variance noted above. The general pattern, however, was one of fish numbers increasing through the spring, peaking in late April-early May, then declining sharply in late May (Figure 4). Secondary peaks in summer and fall represent catches that consisted primarily of larval and juvenile fish.

Although species richness was relatively constant throughout most of the season (Table 5, Figure 4), the surge in the fall was sufficiently great to render temporal variation in species number statistically significant (two-way ANOVA $\underline{P} < 0.05$). This higher species diversity was not produced by the addition of the very rare species that were captured only one or a few times (they mostly appeared in the summer seine samples), but instead was due to the simultaneous occurrence of many of the more abundant ones. This implies that higher species diversity in the fall is real community phenomenon rather than statistical happenstance.

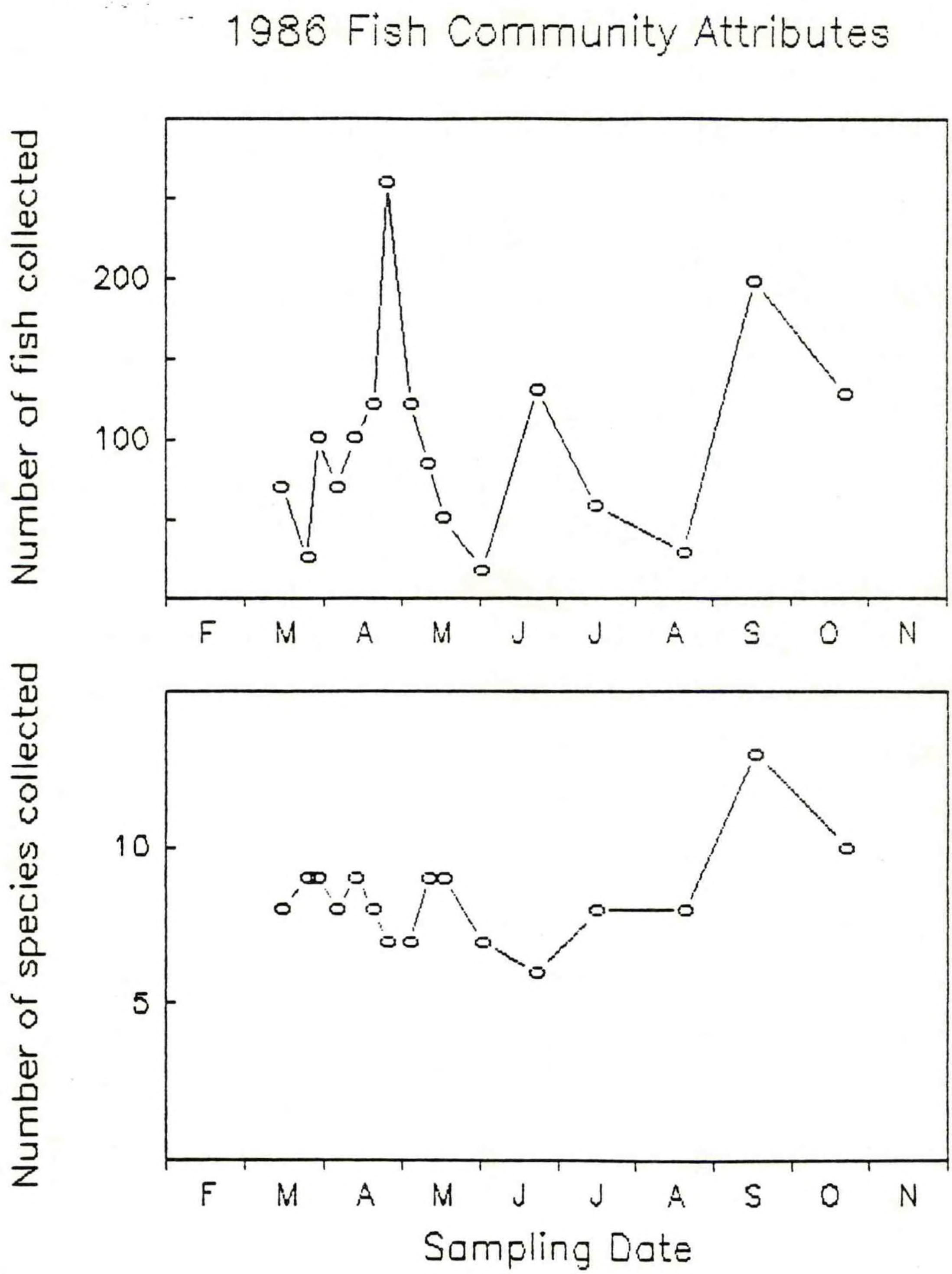

Figure 4. Attributes of fish communities at Old Woman Creek during 1986. Values represent data pooled from four sites.

Zooplankton

A total of 17 different species of zooplankton representing three major groups were collected from Old Woman Creek during 1986 (Table 6, Appendix 4). Bosmina longirostra was the most abundant zooplankter, representing over a quarter of all zooplankton collected (Table 7). With the exceptions of the other cladocerans Diaphanosoma birgei (18.8%) and Eubosmina coregoni (12.7%), no other zooplankton species accounted for more than 3% of the total (Table 7).

One striking feature of the zooplankton is the extreme patchiness of many species' occurances in time and space. Nine of the 17 recognizable species occurred at only one point in time (Table 6), and five occurred at only one point in space (Table 7). Despite this large degree of variability, large-scale patterns in the distribution of zooplankters were apparent.

Total zooplankton densities were highly variable through time, attaining a distinct peak in June approximately 100 times greater than densities in the spring (Table 6), and with relatively high densities persisting throughout late summer and fall. Two-way ANOVA without replication showed that these patterns were highly statistically significant ($P < 0.001$). The low-density spring fauna was dominated by cyclopoid copepods, whereas the summer-fall fauna contained

Table 6. Densities of zooplankton collected on each sampling date (4 sites combined) at Old Woman Creek during 1986.

Entries are in thousands of individuals per liter.

	Date									
Taxon	4/5	4/12	4/19	5/3	5/16	6/21	7/14	8/17	9/13	Total
Cladocerans										
Holopedium gibberum				3.0						3.0
Diaphanosoma birgei		1.8			20.2	620.6	134:2	73.1	174.7	1024.6
Alona spp.							14.5			14.5
Eubosmina coregoni					69.3		202.0	238.7	185.4	695.4
Bosmina longirostris				19.3	18.2	1329.7		34.0	42.5	1443.7
Daphnia galeata						70.5	13.1	6.2		89.8
Daphnia longiremis				4.4						4.4
Daphnia retrocurva					18.0	1.0	14.7	143.1		176.8
Moina micrura							18.6			18.6
Scapholeberis aurita						13.7				13.7
Calanoid copepods										
Skistodiaptomus oregonensis									37.8	37.8
Leptodiaptomus minutus		1.3					7.2			8.5
Epischura lacustris							6.5			6.5
Cyclopoid copepods										
Acanthocyclops vernalis	1.0	3.6	1.2	3.0	65.7	11.4		25.8	14.0	125.7
Diacyclops thomasi					34.4					34.4
Eucyclops agilis					7.1					7.1
Tropocyclops prasinus			2.0	6.8		39.3	13.4	45.1	23.7	130.3
unidentified copepodids	23.8	9.0	16.8	25.5	180.0	94.9	102.7	178.3		631.0
unidentified naupli		16.6		73.5		426.4	457.2			973.7
Total Numbers	24.8	32.3	20.0	135.5	412.9	2607.5	984.1	744.3	478.1	5439.5
Total Taxa	2	5	3	7	8	9	11	8	6	19

Table 7. Densities of zooplankton collected at each site (9 dates combined) at Old Woman Creek during 1986. Entries are in thousands of individuals per liter.

Taxon	Site 1	Site 2	Site 3	Site 4	Total	Rel. Abund.
Cladocerans						
Holopedium gibberum	0	0	3	0	3	0.000
Diaphanosoma birgei	549.9	118.5	73.5	282.7	1024.6	0.188
Alona spp.	0	7.3	0	7.2	14.5	0.002
Eubosmina coregoni	438.7	126	74.7	56	695.4	0.127
Bosmina longirostris	33.4	486.7	263.5	660.1	1443.7	0.265
Daphnia galeata	26.4	1.7	26.6	35.1	89.8	0.016
Daphnia longiremis	0	0	0	4.4	4.4	0.000
Daphnia retrocurva	96.7	53.1	20.5	6.5	176.8	0.032
Moina micrura	3.2	7.9	7.5	0	18.6	0.003
Scapholeberis aurita	11.3	0	2.4	0	13.7	0.002
Calanoid copepods						
Skistodiaptomus oregonensis	0	27.7	10.1	0	37.8	0.006
Leptodiaptomus minutus	0	0	0	8.5	8.5	0.001
Epischura lacustris	0	0	6.5	0	6.5	0.001
Cyclopoid copepods						
Acanthocyclops vernalis	30.7	24	26.6	44.4	125.7	0.023
Diacyclops thomasi	28.4	6	0	0	34.4	0.006
Eucyclops agilis	7.1	0	0	0	7.1	0.001
Tropocyclops prasinus	57.8	19.4	20.5	32.6	130.3	0.023
unidentified copepodids	283	93.2	129.8	125	631	0.116
unidentified naupli	173.7	282.1	386.1	131.8	973.7	0.179
Total Numbers	1740.3	1253.6	1051.3	1394.3	5439.5	

a mixture of cyclopoid copepods and cladocerans. Calanoid copepods were never particularly abundant compared to the other two major groups. Most of the variation in cyclopoid copepods was due to changes in the densities of *Acanthocyclops vernalis* and *Tropocyclops prasinus*; variation in cladocerans was driven by variation in *D. birgei*, *E. coregoni*, *B. longirostris*, and three species of *Daphnia*.

Differences in total zooplankton densities among sites were much less pronounced than differences among dates (Table 7) and were not statistically significant when controlling for date of sampling ($P > 0.50$). What differences that did exist appeared to be in terms of species composition. For example, Site 1 contained more cyclopoid copepods (and no calanoid copepods) compared to the downstream sites, and more *Diaphanosoma* and *Eubosmina* and fewer *Bosmina*.

Benthos

Benthic sampling produced organisms from eight families representing six orders (Appendix 5). Taxa were typical of mud-bottomed marshy areas, and generally tolerant of a wide range of environmental conditions (Merritt and Cummins 1984). Tubificid worms were the most common individuals sampled throughout the entire season (Table 8) and at each

Table 8. Total number of benthic organisms collected on each sampling date (4 sites combined) at Old Woman Creek during 1986.

Taxon	Date							
	3/25	4/12	5/3	6/21	7/14	8/17	9/13	Total
Annellida								
Tubificidae	58	41	7	7	28			141
Lumbricidae	2	5	2		1			10
Isopoda								
Asellidae	2							2
Amphipoda								
Gammaridae	1							1
Ephemeroptera								
Caenidae		1						1
Odonata								
Coenagriidae		1						1
Diptera								
Culicidae	3		2	3	1	8	4	21
Chironomidae	8	1	2	21	7			39
Total	74	49	13	31	37	8	4	216

site (Table 9), followed by chironomids, culicids, and lumbricids. Both worms and dipteran larvae are potential food resources for a variety of benthic feeding fishes, such as ictalurids and catostomids, which were abundant in our samples.

As with zooplankton, the distribution of benthic organisms was patchy in space and time (Tables 8 and 9), in part due to their overall low abundances. Although samples from the two upstream sites contained an average of twice as many benthic invertebrates as the downstream ones, these differences were not statistically significant (two-way ANOVA, $P > 0.25$). These differences were likely overwhelmed by the 18-fold variation in abundances associated with sampling date, which was significant (two-way ANOVA $P < 0.05$); the March samples contained significantly more individuals than the May, August, and September samples, although none of the other dates differed among themselves. Overall, the benthos was too sparsely distributed for our sampling design to allow us to make meaningful correlations with either water quality parameters or fish distributions.

Table 9. Total number of benthic organisms collected at each site (7 dates combined) at Old Woman Creek during 1986.

Taxon	Site 1	Site 2	Site 3	Site 4	Total
Annellida					
Tubificidae	35	63	17	26	141
Lumbricidae	2	5	2	1	10
Isopoda					
Asellidae	0	2	0	0	2
Amphipoda					
Gammaridae	0	0	0	1	1
Ephemeroptera					
Caenidae	0	0	1	0	1
Odonata					
Coenagriidae	1	0	0	0	1
Diptera					
Culicidae	0	8	5	8	21
Chironomidae	28	3	4	4	39
Total	66	81	29	40	216

DISCUSSION

The data we have presented provide a characterization of the aquatic community of the backwater marsh areas of Old Woman Creek that was present prior to the initiation of highway construction in late June, 1986. Although we are unwilling to speculate what the effects of that construction will be on the marsh-estuarine ecosystem, several components of our analyses merit further brief discussion. For example, virtually all our fish collections, regardless of the method used, were dominated by species generally regarded as less specialized or sensitive to water quality in their spawning requirements (e.g. brown bullhead). More sensitive (and usually more desirable) species, such as northern pike, are already present in low numbers, probably as a result of past disturbances in the drainage basin and in other nearby areas. The further decline of such sensitive species may be inevitable due to continued degradation of habitat outside the Old Woman Creek system; however their presence here even in low numbers argues strongly for attempts to preserve the quality of the estuary. Our tentative conclusion is that low levels of dissolved oxygen and high temperatures in late summer, combined with high turbidity in spring and fall, set limits on the occurrence of such sensitive species in Old Woman Creek.

The results of the seine collections confirm the use of Old Woman Creek backwaters as fish nursery areas. Site 3 (Appendix 3.3) seems particularly important, and this is likely a result of the higher water quality there in late summer, especially with respect to dissolved oxygen (Figure 3*a*, Appendix 2.3). Any construction-related activity that serves to alter summer water quality could potentially have a devastating effect on juvenile fish production in the marsh. Additionally, changes in salinity and pH produced by runoff of roadsalt and other deicing chemicals in the spring may seriously affect the quality of the estuary as a nursery by impairing development of fish eggs and larvae.

The importance of the backwaters as nursery areas is further enhanced by the concurrence of peak densities of zooplankton (Table 6) with peak abundance of larval and juvenile fish collected by seining (Table 4). Such zooplankton production provides an excellent source of forage for many species of young fish; white crappie, which were found in great abundance in June and July, are primarily zooplanktivorous during the first year of life (Scott and Crossman 1973). Diets of adult gizzard shad and yellow perch consist of up to 70% cladocerans and copepods (Price 1963). However, the importance of differences in zooplankton species composition among sites (Table 7) is currently unknown, as it depends on the role of each of these species in the diets of the various fish species, which is also unknown in any detail at this time. As a further complication, the highly patchy distribution of zooplankton renders them difficult to sample in sufficient detail to detect anything less than major changes in their abundances that might be produced by construction.

In summary, we have constructed a reasonably complete outline of the physical, chemical, and biotic community present at Old Woman Creek. As this report is being prepared (September 1987), we are nearing the end of the 1987 sampling season, during which highway construction was in full swing. Detailed analysis of the data generated during this season will allow us to begin to assess the impact of construction activity on that community and, we hope, to make recommendations regarding the amelioration of that impact on the community.

REFERENCES

Balcer, M.D., N.L. Korda, and S.I. Dodson. 1984. Zooplankton of the Great Lakes. University of Wisconsin Press, Madison, WI.

Cairns, J. (ed.). 1980. The Recovery Process in Damaged Ecosystems. Ann Arbor Scientific Publishing, Ann Arbor, MI. 167 pp.

Federal Water Pollution Control Administration. 1968. Water Quality Criteria. U.S. Department of Interior, Washington, DC. 234 pp.

Lagler,K.R. 1956. Freshwater Fishery Biology. Wm. C. Brown Co., Dubuque, IA. 2nd ed. 421 pp.

Merritt, R.W., and K.W. Cummins. 1984. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing Co., Dubuque, IA. 722 pp.

Pielou, E.C. 1984. The Interpretation of Ecological Data. John Wiley and Sons, New York, NY. 263 pp.

Price, J.W. 1963. A study of the food habits of some Lake Erie fish. Bull. Ohio Biol. Surv. 2:1-89.

SAS Institute. 1982. SAS User's Guide: Statistics. SAS Institute, Cary, North Carolina.

Scott, W.B., and E.J. Crossman. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada, Ottawa, ON. 966 pp.

Torke, B.G. 1974. An Illustrated Guide to the Identification of the Planktonic Crustacea of Lake Michigan with Notes on Their Ecology. Center for Great Lakes Studies Special Report No. 17, University of Wisconsin, Milwaukee, WI. 41 pp.

Trautman, M.B. 1981. Fishes of Ohio. Ohio State University Press, Columbus, OH. 2nd ed. 683 pp.

Van Meter, H.D., and M.B. Trautman. 1970. An annotated list of the fishes of Lake Erie and its tributary waters exclusive of the Detroit River. Ohio J. Sci. 70:65-78.

Zar, J.H. 1984. Biostatistical Analysis. Prentice-Hall Inc., Englewood Cliffs, NJ. 2nd ed. 718 pp.

APPENDICES

Appendix 1. Scientific names of all fish species mentioned in text or tables.

Appendix 2. Water quality data for all dates and sites at Old Woman Creek during 1986.

Appendix 3. Numbers of fish collected for all dates and sites at Old Woman Creek during 1986.

Appendix 4. Densities of zooplankton collected for all dates and sites at Old Woman Creek during 1986.

Appendix 5. Numbers of benthic organisms collected for all dates and sites at Old Woman Creek during 1986.

APPENDIX 1. Scientific names of all fish species mentioned in text or tables1.

Lepisosteidae	
Longnose Gar	*Lepisosteus osseus*
Clupeidae	
Gizzard Shad	*Dorosoma cepedianum*
Salmonidae	
Rainbow Trout	*Salmo gairdneri*
Esocidae	
Northern Pike	*Esox lucius*
Cyprinidae	
Carp	*Cyprinus carpio*
Goldfish	*Carassius auratus*
hybrid carp X goldfish	---
Emerald Shiner	*Notropus atherinoides*
Golden Shiner	*Notemigonus crysoleucas*
Bluntnose Minnow	*Pimephales notatus*
Catostomidae	
White Sucker	*Catostomus commersoni*
Spotted Sucker	*Minytrema melanops*
Ictaluridae	
Brown Bullhead	*Ictalurus nebulosus*
Yellow Bullhead	*Ictalurus natalis*
Tadpole Madtom	*Noturus gyrinus*

(continued)

APPENDIX 1. (continued)

Percichthyidae	
White Perch	_Morone americana_
Centrarchidae	
Pumpkinseed	_Lepomis gibbosus_
Bluegill	_Lepomis macrochirus_
Orangespotted Sunfish	_Lepomis humilis_
Largemouth Bass	_Micropterus salmoides_
White Crappie	_Pomoxis annularis_
Black Crappie	_Pomoxis nigromaculatus_
Percidae	
Yellow Perch	_Perca flavescens_
Sciaenidae	
Freshwater Drum	_Aplodinotus grunniens_

1 Nomenclature follows Trautman (1981).

Appendix 2.1. Water quality data for Site 1 at Old Woman Creek during 1986.

	Date															
Variable	3/15	3/25	3/29	4/5	4/12	4/19	4/24	5/3	5/10	5/16	5/31	6/21	7/14	8/17	9/13	10/18
Depth (cm)	40.0	41.0	38.0	43.0	65.0	53.0	54.0	52.0	37.0	78.0	50.2	65.0	91.0	66.0	67.5	56.0
Temperature (C)	4.5	9.5	13.8	13.0	10.0	15.5	13.0	15.5	16.5	20.0	21.0	22.0	22.0	25.0	20.0	10.0
Dissolved Oxygen (ppm)	10.6	15.0	15.0	9.9	12.4	8.8	10.0	8.4	7.2	6.3	4.1	4.4	2.5	4.6	4.5	7.3
pH	7.4	8.4	8.3	8.1	8.5	8.7	8.5	8.1	7.9	7.8	7.8	7.9	7.7	7.3	7.6	7.8
Conductivity (mmohs/cm)	0.5	0.4	0.6	0.5	0.5	0.7	0.6	0.5	0.5	0.6	0.7	0.7	0.5	0.6	0.5	0.6
Turbidity (NTU)	67.0	56.0	25.0	27.0	11.0	10.0	7.0	20.0	21.0	29.0	15.0	8.0	67.0	24.0	69.0	53.0
Vegetation (cover class)	0.0	0.0	0.0	0.0	1.0	1.0	2.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	2.0

Appendix 2.2. Water quality data for Site 2 at Old Woman Creek during 1986.

Variable	Date															
	3/15	3/25	3/29	4/5	4/12	4/19	4/24	5/3	5/10	5/16	5/31	6/21	7/14	8/17	9/13	10/18
Depth (cm)	52.0	51.0	48.0	76.0	68.5	55.0	64.0	66.0	54.0	81.0	50.4	74.0	106.0	85.0	81.0	76.0
Temperatmre (C)	4.5	8.0	10.0	13.2	11.0	16.5	13.0	17.0	17.0	19.0	24.0	21.0	22.0	29.0	22.0	12.0
Dissolved Oxygen (ppm)	13.1	14.2	9.4	8.4	10.6	8.8	11.5	7.5	8.5	9.6	13.6	5.5	4.5	9.2	5.8	5.8
pH	7.6	8.4	8.3	8.4	8.3	8.4	8.4	8.0	8.0	8.2	8.3	7.8	7.5	7.5	7.7	7.6
Conductivity (mmohs/cm)	0.4	0.8	0.5	0.5	0.5	0.6	0.6	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.4	0.6
Turbidity (NTU)	33.0	43.0	59.0	42.0	20.0	28.0	55.0	20.0	21.0	21.0	11.0	19.0	85.0	17.0	36.0	33.0
Vegetation (cover class)	0.0	0.0	0.0	0.0	2.0	2.0	3.0	3.0	3.0	3.0	4.0	5.0	5.0	5.0	5.0	4.0

Appendix 2.3. Water quality data for Site 3 at Old Woman Creek during 1986.

Variable	Date															
	3/15	3/25	3/29	4/5	4/12	4/19	4/24	5/3	5/10	5/16	5/31	6/21	7/14	8/17	9/13	10/18
Depth (cm)	35.5	31.0	29.0	46.0	47.5	35.0	44.0	41.0	43.0	54.0	30.5	55.0	77.0	60.0	62.0	49.5
Temperature (C)	5.0	9.0	16.0	14.0	12.0	15.5	13.0	17.0	17.5	20.5	24.5	28.0	28.0	29.0	22.0	12.0
Dissolved Oxygen (ppm)	8.3	14.2	6.5	7.5	10.2	9.6	12.0	8.7	7.5	7.0	14.6	14.0	8.2	10.2	5.4	6.4
pH	7.2	8.3	8.4	8.0	8.2	8.3	8.2	7.9	7.7	7.8	8.4	8.2	7.8	7.5	7.5	7.6
Conductivity (mmohs/cm)	0.3	0.5	0.5	0.5	0.4	0.5	0.4	0.5	0.5	0.6	0.6	0.5	0.5	0.6	0.4	0.6
Turbidity (NTU)	150.0	36.0	21.0	57.0	30.0	38.0	61.0	30.0	78.0	25.0	21.0	26.0	30.0	17.0	25.0	39.0
Vegetation (cover class)	0.0	0.0	0.0	0.0	1.0	1.0	2.0	2.0	2.0	2.0	3.0	4.0	4.0	4.0	4.0	3.0

Appendix 2.4. Water quality data for Site 4 at Old Woman Creek during 1986.

	Date															
Variable	3/15	3/25	3/29	4/5	4/12	4/19	4/24	5/3	5/10	5/16	5/31	6/21	7/14	8/17	9/13	10/18
Depth (cm)	60.0	64.0	64.0	78.0	69.0	50.0	4.0	57.0	59.0	85.0	50.4	71.0	99.5	83.0	78.0	76.0
Temperature (C)	6.0	8.5	12.0	14.8	11.0	16.0	13.0	17.0	19.0	20.0	27.0	23.0	25.0	28.0	22.0	12.0
Dissolved Oxygen (ppm)	10.0	13.2	9.3	7.8	10.4	9.1	9.9	11.0	5.8	7.2	8.7	3.3	9.0	9.7	6.0	6.5
pH	7.2	8.3	8.2	8.3	8.3	8.3	8.3	7.8	7.8	7.9	7.9	7.5	8.2	7.8	7.5	7.6
Conductivity (mmohs/cm)	0.1	0.7	0.5	0.4	0.4	0.5	0.4	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.6
Turbidity (NTU)	220.0	34.0	38.0	60.0	34.0	30.0	70.0	31.0	38.0	29.0	52.0	50.0	30.0	31.0	32.0	23.0
Vegetation (cover class)	0.0	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	4.0	5.0	5.0	5.0	5.0	4.0

Appendix 2.5. Correlational structure of water quality variables sampled from Old Woman Creek during 1986. Data from 16 dates and 4 sites. Measure is product-moment correlation coefficient.

	Temp.	Dis. O2	pH	Cond.	Turb.	Vegetation
Depth	0.40***	-0.42***	-0.28*	0.14	-0.08	0.54***
Temperature		-0.34**	-0.20	0.31*	-0.37**	0.77***
Dis. O2			0.54	-0.09	-0.04	-0.42***
pH				0.23	-0.40**	-0.38**
Conductivity					-0.64***	0.25*
Turbidity						-0.27*

$*P < 0.05$, $**P < 0.01$, $***P < 0.001$

Appendix 2.6. Standardized scoring coefficients for water quality samples from Old Woman Creek. Based on Principal Components Analysis of water quality data taken over 16 dates from 4 sites (N = 64).

	Factor I	Factor II	Mean	Std. Dev.
Depth	0.257	0.005	58.9	18.4
Temperature	0.241	0.178	16.7	6.38
Dis. O2	-0.285	0.113	8.82	3.03
pH	-0.275	0.302	7.97	0.37
Conductivity	0.010	0.386	0.52	0.11
Turbidity	0.030	-0.438	39.7	32.4
Vegetation	0.294	0.102	2.23	1.69

To score any water quality sample (which must include values for all seven variables) on a factor:

(1) subtract the appropriate mean shown above from the observed value for each variable;

(2) divide each result for each variable by the appropriate standard deviation shown above;

(3) multiply each result for each variable by the appropriate scoring coefficient shown above;

(4) sum the seven values to derive the score of the new sample on a factor.

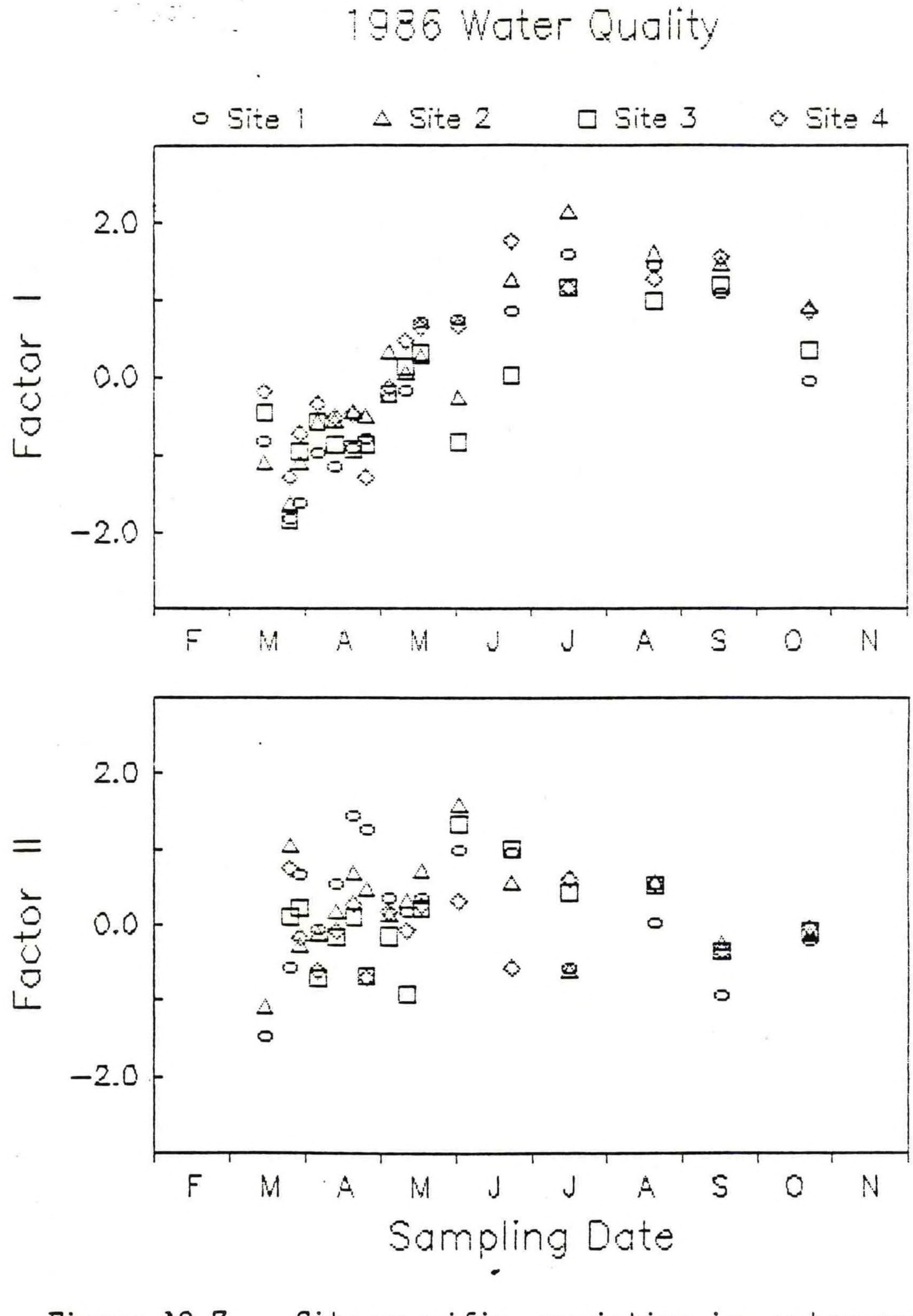

Figure A2.7. Site-specific variation in water quality at Old Woman Creek during 1986. Values are site factor scores plotted against date of sampling.

Appendix 3.1. Numbers of fish collected at Site 1 at Old Woman Creek during 1986.

Species	Date																Total
	3/15	3/25	3/29	4/5	4/12	4/19	4/24	5/3	5/10	5/16	5/31	6/21*	7/14*	8/17*	9/13	10/18	
Longnose Gar																	0
Gizzard Shad															1	1	2
Northern Pike																	0
Carp				1	1			1					2				5
Goldfish								1							1		2
Carp X Gold hybrid																	0
Emerald Shiner																	0
Golden Shiner																	0
Bluntnose Minnow																	0
White Sucker				1													1
Spotted Sucker		1			2										1		4
Brown Bullhead				1				2		1	1				4		9
Yellow Bullhead																	0
Tadpole Madtom																	0
White Perch																	0
Pumpkinseed		1															1
Bluegill																	0
Orangespotted Sunfish																	0
Largemouth Bass																	0
White Crappie				1	2			3					1		7	14	28
Black Crappie					1			1							3	4	9
Yellow Perch																	0
Freshwater Drum																	0
Total Numbers	0	2	0	4	6	0	0	8	0	1	1	0	3	0	17	19	61
Total Species	0	2	0	4	4	0	0	5	0	1	1	0	2	0	6	3	9

* Collected by seining; all others collected by trap netting

Appendix 3.2. Numbers of fish collected at Site 2 at Old Woman Creek during 1986.

	Date																
Species	3/15	3/25	3/29	4/5	4/12	4/19	4/24	5/3	5/10	5/16	5/31	6/21*	7/14*	8/17*	9/13	10/18	Total
Longnose Gar											2						2
Gizzard Shad					4					7					2	4	17
Northern Pike																1	1
Carp	1				4				1	3		2		2			13
Goldfish				1	1			1									3
Carp X Gold hybrid		1				1	2								1		5
Emerald Shiner																	0
Golden Shiner																	0
Bluntnose Minnow																	0
White Sucker																1	1
Spotted Sucker	11	6	10	1	1										1		30
Brown Bullhead	6		45	22	29	21	91	37	36	23	3				49	3	365
Yellow Bullhead									2	7					3	1	13
Tadpole Madtom																	0
White Perch									1	1					2	1	5
Pumpkinseed			1						1		1				1		4
Bluegill	3		3			1	2	1					1	1	2	2	16
Orangespotted Sunfish																	0
Largemouth Bass															1		1
White Crappie	1	1	12	12	10	13	13	7	9	2	1		4		6	18	109
Black Crappie			2	11	8		7	10	11	2	4				9	25	89
Yellow Perch																	0
Freshwater Drum										1							1
Total Numbers	22	8	73	47	57	36	115	56	61	46	11	2	5	3	77	56	675
Total Species	5	3	6	5	7	4	5	5	7	8	5	1	2	2	11	9	17

* Collected by seining; all others collected by trap netting

Appendix 3.3. Numbers of fish collected at Site 3 at Old Woman Creek during 1986.

	Date																
Species	3/15	3/25	3/29	4/5	4/12	4/19	4/24	5/3	5/10	5/16	5/31	6/21*	7/14*	8/17*	9/13	10/18	Total
Longnose Gar									2								2
Gizzard Shad						1						22	4				27
Northern Pike																	0
Carp	1				3			3	7			1	1				16
Goldfish		1			1												2
Carp X Gold hybrid						1		1	4								6
Emerald Shiner												5		1			6
Golden Shiner																	0
Bluntnose Minnow													1				1
White Sucker		1															1
Spotted Sucker													1				1
Brown Bullhead	1					2			4						8		15
Yellow Bullhead															4		4
Tadpole Madtom																	0
White Perch															2		2
Pumpkinseed																	0
Bluegill	2										1	1	3				7
Orangespotted Sunfish																	0
Largemouth Bass																	0
White Crappie	1				1			1			1	90	26	7	17	18	162
Black Crappie						5		2							14	3	24
Yellow Perch														1			1
Freshwater Drum																	0
Total Numbers	5	2	0	0	5	9	0	7	17	0	2	119	36	9	45	21	277
Total Species	4	2	0	0	3	4	0	4	4	0	2	5	6	3	5	2	16

* Collected by seining; all others collected by trap netting

Appendix 3.4. Numbers of fish collected at Site 4 at Old Woman Creek during 1986.

Species	3/15	3/25	3/29	4/5	4/12	4/19	4/24	5/3	5/10	5/16	5/31	6/21*	7/14*	8/17*	9/13	10/18	Total
Longnose Gar																	0
Gizzard Shad					3	4	3			3			2				15
Northern Pike																	0
Carp	21	1	5	2	2	4	5	5	3		3	1	1				53
Goldfish	5		3	6	1	2		1		1							19
Carp X Gold hybrid	8		1	1			1	4							1		16
Emerald Shiner																	0
Golden Shiner														1			1
Bluntnose Minnow																	0
White Sucker															1		1
Spotted Sucker		4										1			4		9
Brown Bullhead	1			7	12	62	136	29	2				2		16	10	277
Yellow Bullhead																	0
Tadpole Madtom														1			1
White Perch															3		3
Pumpkinseed					1				2						5		8
Bluegill			1										5	4	3		13
Orangespotted Sunfish														1			1
Largemouth Bass		1			1								1		1	1	5
White Crappie	3	4	16		4			2				8	4	11	14	19	85
Black Crappie	6	4	2	4	9	5	1	10			1				12	2	56
Yellow Perch																	0
Freshwater Drum																	0
Total Numbers	44	14	28	20	33	77	146	51	7	4	4	10	15	18	60	32	563
Total Species	6	5	6	5	8	5	5	6	3	2	2	3	6	5	10	4	16

* Collected by seining; all others collected by trap netting

Appendix 4.1 Densities of zooplankton collected at Site 1 at Old Woman Creek during 1986.

Entries are in thousands of individuals per liter.

Taxon	Date									
	4/5	4/12	4/19	5/3	5/16	6/21	7/14	8/17	9/13	Total
Cladocerans										
Holopedium gibberum										0.0
Diaphanosoma birgei		1.8				430.7	75.8	6.4	35.2	549.9
Alona spp.										0.0
Eubosmina coregoni							165.3	232.0	41.4	438.7
Bosmina longirostris				13.3		11.3			8.8	33.4
Daphnia galeata						26.4				26.4
Daphnia longiremis										0.0
Daphnia retrocurva								96.7		96.7
Moina micrura							3.2			3.2
Scapholeberis aurita						11.3				11.3
Calanoid copepods										
Skistodiaptomus oregonensis										0.0
Leptodiaptomus minutus										0.0
Epischura lacustris										0.0
Cyclopoid copepods										
Acanthocyclops vernalis		3.6			14.2			12.9		30.7
Diacyclops thomasi					28.4					28.4
Eucyclops agilis					7.1					7.1
Tropocyclops prasinus			2.0			3.8	6.9	45.1		57.8
unidentified copepodids	2.5	1.8	6.0	8.9	106.7	11.3	62.0	83.8		283.0
unidentified nauplii		5.3		31.1		34.0	103.3			173.7
Total Density	2.5	12.5	8.0	53.3	156.4	528.8	416.5	476.9	85.4	1740.3

Appendix 4.2 Densities of zooplankton collected at Site 2 at Old Woman Creek during 1986.

Entries are in thousands of individuals per liter.

	Date									
Taxon	4/5	4/12	4/19	5/3	5/16	6/21	7/14	8/17	9/13	Total
Cladocerans										
Holopedium gibberum										0.0
Diaphanosoma birgei					6.0	8.3	36.7		67.5	118.5
Alona spp.							7.3			7.3
Eubosmina coregoni					48.0		36.7		41.3	126.0
Bosmina longirostris					6.0	445.0		20.7	15.0	486.7
Daphnia galeata						1.7				1.7
Daphnia longiremis										0.0
Daphnia retrocurva					18.0		14.7	20.4		53.1
Moina micrura							7.9			7.9
Scapholeberis aurita										0.0
Calanoid copepods										
Skistodiaptomus oregonensis									27.7	27.7
Leptodiaptomus minutus										0.0
Epischura lacustris										0.0
Cyclopoid copepods										
Acanthocyclops vernalis					24.0					24.0
Diacyclops thomasi					6.0					6.0
Eucyclops agilis										0.0
Tropocyclops prasinus				2.4					17.0	19.4
unidentified copepodids	1.7	5.9	5.4	12.2	54.0	6.7	7.3			93.2
unidentified naupli				17.1		118.3	146.7			282.1
Total Density	1.7	5.9	5.4	31.7	162.0	580.0	257.3	41.1	168.5	1253.6

Appendix 4.3 Densities of zooplankton collected at Site 3 at Old Woman Creek during 1986.

Entries are in thousands of individuals per liter.

Taxon	Date									
	4/5	4/12	4/19	5/3	5/16	6/21	7/14	8/17	9/13	Total
Cladocerans										
Holopedium gibberum				3.0						3.0
Diaphanosoma birgei					14.2	29.3			30.0	73.5
Alona spp.										0.0
Eubosmina coregoni					21.3			6.7	46.7	74.7
Bosmina longirostris				6.0	7.1	237.1		13.3		263.5
Daphnia galeata						7.3	13.1	6.2		26.6
Daphnia longiremis										0.0
Daphnia retrocurva								20.5		20.5
Moina micrura							7.5			7.5
Scapholeberis aurita						2.4				2.4
Calanoid copepods										
Skistodiaptomus oregonensis									10.1	10.1
Leptodiaptomus minutus										0.0
Epischura lacustris							6.5			6.5
Cyclopoid copepods										
Acanthocyclops vernalis			1.2	3.0	7.1	2.4		12.9		26.6
Diacyclops thomasi										0.0
Eucyclops agilis										0.0
Tropocyclops prasinus						7.3	6.5		6.7	20.5
unidentified copepodids	5.6				14.2	17.1	26.2	66.7		129.8
unidentified nauplii		6.0		12.0		204.2	163.9			386.1
Total Density	5.6	6.0	1.2	24.0	63.9	507.1	223.7	126.3	93.5	1051.3

Appendix 4.4 Densities of zooplankton collected at Site 4 at Old Woman Creek during 1986.

Entries are in thousands of individuals per liter.

Taxon	4/5	4/12	4/19	5/3	5/16	6/21	7/14	8/17	9/13	Total
	Date									
Cladocerans										
Holopedium gibberum										0.0
Diaphanosoma birgei						152.3	21.7	66.7	42.0	282.7
Alona spp.							7.2			7.2
Eubosmina coregoni									56.0	56.0
Bosmina longirostris					5.1	636.3			18.7	660.1
Daphnia galeata						35.1				35.1
Daphnia longiremis				4.4						4.4
Daphnia retrocurva						1.0		5.5		6.5
Moina micrura										0.0
Scapholeberis aurita										0.0
Calanoid copepods										
Skistodiaptomus oregonensis										0.0
Leptodiaptomus minutus		1.3					7.2			8.5
Epischura lacustris										0.0
Cyclopoid copepods										
Acanthocyclops vernalis	1.0				20.4	9.0			14.0	44.4
Diacyclops thomasi										0.0
Eucyclops agilis										0.0
Tropocyclops prasinus				4.4		28.2				32.6
unidentified copepodids	14.0	1.3	5.4	4.4	5.1	59.8	7.2	27.8		125.0
unidentified naupli		5.3		13.3		69.9	43.3			131.8
Total Density	15.0	7.9	5.4	26.5	30.6	991.6	86.6	100.0	130.7	1394.3

Appendix 5.1 Numbers of benthic organisms collected at Site 1 at Old Woman Creek during 1986.

Taxon	Date 3/25	4/12	5/3	6/21	7/14	8/17	9/13	Total
Annellida								
Tubificidae	27	4	2		2			35
Lumbricidae		1	1					2
Isopoda								
Asellidae								0
Amphipoda								
Gammaridae								0
Ephemeroptera								
Caenidae								0
Odonata								
Coenagriidae		1						1
Diptera								
Culicidae								0
Chironomidae	6			21	1			28
Total	33	6	3	21	3	0	0	66

Appendix 5.2. Numbers of benthic organisms collected at Site 2 at Old Woman Creek during 1986.

Taxon	Date 3/25	4/12	5/3	6/21	7/14	8/17	9/13	Total
Annellida								
Tubificidae	18	29	3	5	8			63
Lumbricidae	1	3			1			5
Isopoda								
Asellidae	2							2
Amphipoda								
Gammaridae								0
Ephemeroptera								
Caenidae								0
Odonata								
Coenagriidae								0
Diptera								
Culicidae	2		1	2		2	1	8
Chironomidae			2		1			3
Total	23	32	6	7	10	2	1	81

Appendix 5.3. Numbers of benthic organisms collected at Site 1 at Old Woman Creek during 1986.

	Date							
Taxon	3/25	4/12	5/3	6/21	7/14	8/17	9/13	Total
Annellida								
Tubificidae	5	6			6			17
Lumbricidae	1		1					2
Isopoda								
Asellidae								0
Amphipoda								
Gammaridae								0
Ephemeroptera								
Caenidae		1						1
Odonata								
Coenagriidae								0
Diptera								
Culicidae			1	1	1	2		5
Chironomidae					4			4
Total	6	7	2	1	11	2	0	29

Appendix 5.4. Numbers of benthic organisms collected at Site 1 at Old Woman Creek during 1986.

Taxon	Date							
	3/25	4/12	5/3	6/21	7/14	8/17	9/13	Total
Annellida								
Tubificidae	8	2	2	2	12			26
Lumbricidae		1						1
Isopoda								
Asellidae								0
Amphipoda								
Gammaridae	1							1
Ephemeroptera								
Caenidae								0
Odonata								
Coenagriidae								0
Diptera								
Culicidae	1					4	3	8
Chironomidae	2	1			1			4
Total	12	4	2	2	13	4	3	40