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Seasonal Investigation of Native Fishes and Their Habitats in Missouri River and Yellowstone River Backwaters

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SEASONAL INVESTIGATION OF NATIVE FISHES AND THEIR HABITATS IN MISSOURI RIVER AND YELLOWSTONE RIVER BACKWATERS

By

Shannon J. Fisher

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SEASONAL INVESTIGATION OF NATIVE FISHES AND THEIR HABITATS IN MISSOURI RIVER AND YELLOWSTONE RIVER BACKWATERS

This dissertation is approved as a creditable and independent investigation by a candidate for the Doctor of Philosophy degree and is acceptable for meeting the dissertation requirements for this degree. Acceptance of this dissertation does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Dr. David W. Willis Date
Major Advisor

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Acknowledgments and Dedication

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A special thank you to my family and friends who believed in my abilities and never doubted my sometimes unrealistic visions - your confidence and encouragement ensured my success. A special thank you to Jeremy Hanks for his continued friendship and foundational support that made even the worst times not so bad - your presence in my life has been a blessing. This dissertation is dedicated to those with a love for the resource, because it is so much more than statistics and politics.

Abstract

SEASONAL INVESTIGATION OF NATIVE FISHES AND THEIR HABITATS IN MISSOURI RIVER AND YELLOWSTONE RIVER BACKWATERS

Shannon J. Fisher

22 November 1999

Interactions between the Missouri River and its floodplain have been severely degraded due to channelization and impoundment. Ecologists have assumed that backwaters are a critical habitat component for certain life stages of native fishes; however, documented relationships are limited. During this study, I monitored fishes, invertebrates, and habitats to help determine the importance of backwaters to native fishes of various life stages, and to assess the changes that occur in habitat characteristics and invertebrate densities during periods with differential connectivity.

Seven assemblages of fishes, identified with catch-per-unit-effort data, had at least some relationship with the backwaters. The assemblages included two groups of residential fishes, two groups of transient fishes, and single groups of backwater spawners, lotic obligates, and age-0 drifters. The most prominent of these assemblages were the primary residents and the backwater spawners. Species such as black bullhead *Ameiurus melas* and white crappie *Pomoxis annularis* were residential and abundant in the backwater communities. Age-0 bigmouth *Ictiobus cyprinellus* and smallmouth buffalo *I. bubalus* were also abundant in autumn after being spawned in the backwaters during the flood pulse and utilizing the backwaters as nursery habitat. All life stages of other species, such as walleye *Stizostedion vitreum* and sauger *S. canadense*, were more transient and appeared sporadically. Some native larval fishes, such as blue sucker *Cycleptus elongatus* and burbot *Lota lota*, drifted into and utilized backwater habitats, but not necessarily during peak flows. Other species, although present near the backwater connection in the Missouri River, did not appear to directly utilize the backwater habitats and were more obligated to the flowing water habitats.

Stable nitrogen and carbon analyses, along with food habits data, were used to assess community structure and energy flow. Chironomidae and Corixidae were an important link between the producers and secondary consumers. In autumn, the age-0 fish community also assimilated energy through a zooplankton pathway and then served as prey, transferring nutrients to the tertiary consumers. In general, detritus appeared to be an important energy source in the spring, but became secondary to primary production energy resources during the summer and autumn month; hence, primary production is also an important carbon source in the backwater systems. Although backwater habitats can be very productive, fishes such as the flathead chub *Platygobio gracilis* and sicklefin chub *Macrhybopsis meeki* did not heavily utilize the backwaters proper, but likely benefitted from backwater prey production that flushed into the channel during connection periods. The lateral dimension in river ecology has several processes that promote the health of populations, nutrient cycles, and the entire ecosystem. These results lend support to the importance of backwater habitats to numerous fish species and to the entire Missouri River system; however, further information on several topics, such as connectivity duration and prey flushing, would help clarify the importance of backwater habitats to several native species of concern.

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List of Abbreviations

ANOVA	analysis of variance
C	Celsius or Carbon (dependent on context)
CB	Confluence Backwater
cm	centimeter
CPUE	catch per unit effort
CPOM	coarse particulate organic matter
d	day
DO	dissolved oxygen
EIS	Erickson Island Slough
g	gram
GLM	general linear model
GN	gill net
h	hour
ha	hectare
km	kilometer
m	meter
MC	Missouri River main channel
min	minute
mm	millimeter
N	nitrogen or sample number (dependent on context)

NTU	Nephelometric Turbidity Units
ND	no length designation
NS	non-significant
NA	not available
P	probability value
SE	standard error
sec	second
sp	single unidentified species
spp	multiple unidentified species
TL	total length
TN	trap net
μm	micrometers

Abbreviations for fish species and categories are defined in Appendix 1. Food habits items, zooplankton, invertebrates and sediments abbreviations are defined in Appendix 3.

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Chapter 1.

Introduction

Historically, the Missouri River had a diversity of habitat types, including backwaters, or off-channel wetlands, with low or absent flow. Hesse et al. (1989) determined that greater than 100,000 ha of permanent aquatic habitats and more than 150,000 ha of wetlands and riparian areas have been lost in the lower Missouri River basin due to channelization, agriculture, and human encroachment. Fraser (1972) and Ward and Stanford (1983) both stated that the most visible and devastating changes caused by anthropogenic activity are alterations to the natural hydrograph and the subsequent modifications of riverine habitats. The entire Missouri River ecosystem has been profoundly altered by impoundment and channelization, and the hydrograph has diverged from natural processes and cycles (Hesse and Mestl 1993). These hydrograph alterations have disrupted the sustainable structure and function of most Missouri River habitats, catalyzing deleterious changes in floodplain connectivity and biotic communities.

The historical Missouri River hydrograph, including flood-pulses and the annual spring rise, caused a large-scale connection between the river and the floodplain (Hesse and Mestl 1993). The dynamic processes associated with the lateral dimension, or the interactions between the channel and floodplain, are absent, or inhibited, in regulated rivers. Sedell et al. (1990) suggested that the expansion and contraction of the wetted area of the floodplain had, on an evolutionary scale, helped create highly developed communities that relied on the annual dynamic pattern. Early river research (e.g., Richardson 1921) and more recent endeavors (e.g., Guillory 1979) noted that fish yield increased with the presence of functional backwater habitats. Amoros (1991) and Copp (1989) both noted that overall backwater productivity was often greater than 10 times that of the Rhone and Danube river channels. The importance of the floodplain connection to overall fish production has also been studied on the Missouri River. Whitley and Campbell (1974) found that Missouri River fish yields may have decreased by six-fold due to the 60% loss of floodplain connections.

The stretch of the Missouri River in North Dakota between the headwaters of Lake Sakakawea and the Yellowstone River confluence is a historical remnant of the natural ecosystem. In this segment of the Missouri River, the hydrograph has natural flood pulses because of the unregulated Yellowstone River discharge. The natural flood pulse has been hypothesized as a major contributor to the continued existence of relatively stable fish and invertebrate populations. This natural hydrograph and presence of fishes that are seriously declining elsewhere created an opportunity to start testing the hypothesis that backwaters are a valuable macrohabitat. The goals of this research were 1) to assess the seasonal use of backwaters by native fishes and invertebrates (Chapter 2), 2) to robustly estimate changes in backwater habitats during different hydrologic conditions (Chapter 2), 3) to integrate the seasonal fish data and identify some important ecological interactions (Chapters 3-6), and 4) to provide a discussion of backwater importance to the upper Missouri River ecosystem, including management recommendations and direction of future research (Chapter 7) in the relatively unaltered segment of the Missouri River.

Study Sites and Sampling Strategies

This study was conducted in the stretch of the Missouri River within the segment from the headwaters of Lake Sakakawea to the confluence with the Yellowstone River [inclusive of river kilometers 2,510 to 2,538 (river miles 1,569-1,574)] in northwestern North Dakota during the periods designated below in 1997, 1998, and 1999. For this study, a backwater was defined as an off-channel habitat that contained water with limited or absent flow and was connected during all or a portion of the annual hydrographic cycle. Two backwater habitats were selected as study sites, Erickson Island Slough (EIS) and what I will refer to as the Confluence Backwater (CB).

The CB is a highly dynamic floodplain wetland located near the Missouri River and Yellowstone River confluence. The backwater is reduced to <20 ha during dry periods, does not exceed 300 ha during any period, is highly connected to the main river channel, and fluctuates swiftly in response to changes in channel flow rates. EIS is a less dynamic backwater located on the border between Williams and McKenzie counties. This backwater tends to have a delayed response to changes in the main river channel flow rates because it is further removed from the channel proper. EIS has a surface area of approximately 1,100 ha. Area designations for both backwaters are variable depending upon the prevailing hydrologic conditions. In addition to the two backwaters, Missouri River channel habitats, primarily sandbar complexes, were sampled with some gear types.

To better understand backwater use by native fishes, changes in habitat, and invertebrate dynamics during the annual hydrograph cycle, four sample periods representing differential flow regimes and temporal intervals were selected. The following criteria were used to help identify appropriate sample periods. Sampling during period 1 (pre-connection period), was to be completed after ice-out, preferably during slightly rising water conditions due to local snowmelt, and between 1 April and 1 May of each year. Sample period 2 (connection period), encompassed the ascending limb of the primary flood-pulse caused by mountain snowmelt and the time span of 10 May to 10 June of each year. Sampling during period 3 (disconnection period), was to be completed during the descending water levels after peak flows had occurred and between 25 June and 15 July of each year. Period 4 (post-connection period) sampling was completed between 25 August and 15 September and during relatively static water conditions. Although the sample periods can be easily defined, identifying the actual periods was difficult and targeted sample times varied among years (Figure 1-1).

During the three-year period of this study, three substantially different hydrographs occurred. The study sites I selected were strongly influenced by the Yellowstone River discharge; however, the Missouri River flow inevitably had some effect on the hydrologic conditions. Therefore, for the purpose of this study, I combined the daily mean flow rates for the Yellowstone River and Missouri River (USGS 1999) and used the cumulative hydrograph during subsequent discussions. Two cautions about the cumulative hydrograph should be noted. The first is that flow rates are a function of channel morphology, velocity, and groundwater inputs (Allan 1995); therefore, the flow rates of the Missouri and Yellowstone rivers are not cumulative. The second caution is that the flow data, particularly for 1999, are provisional and may yet be revised by the U.S. Geological Survey hydrologists.

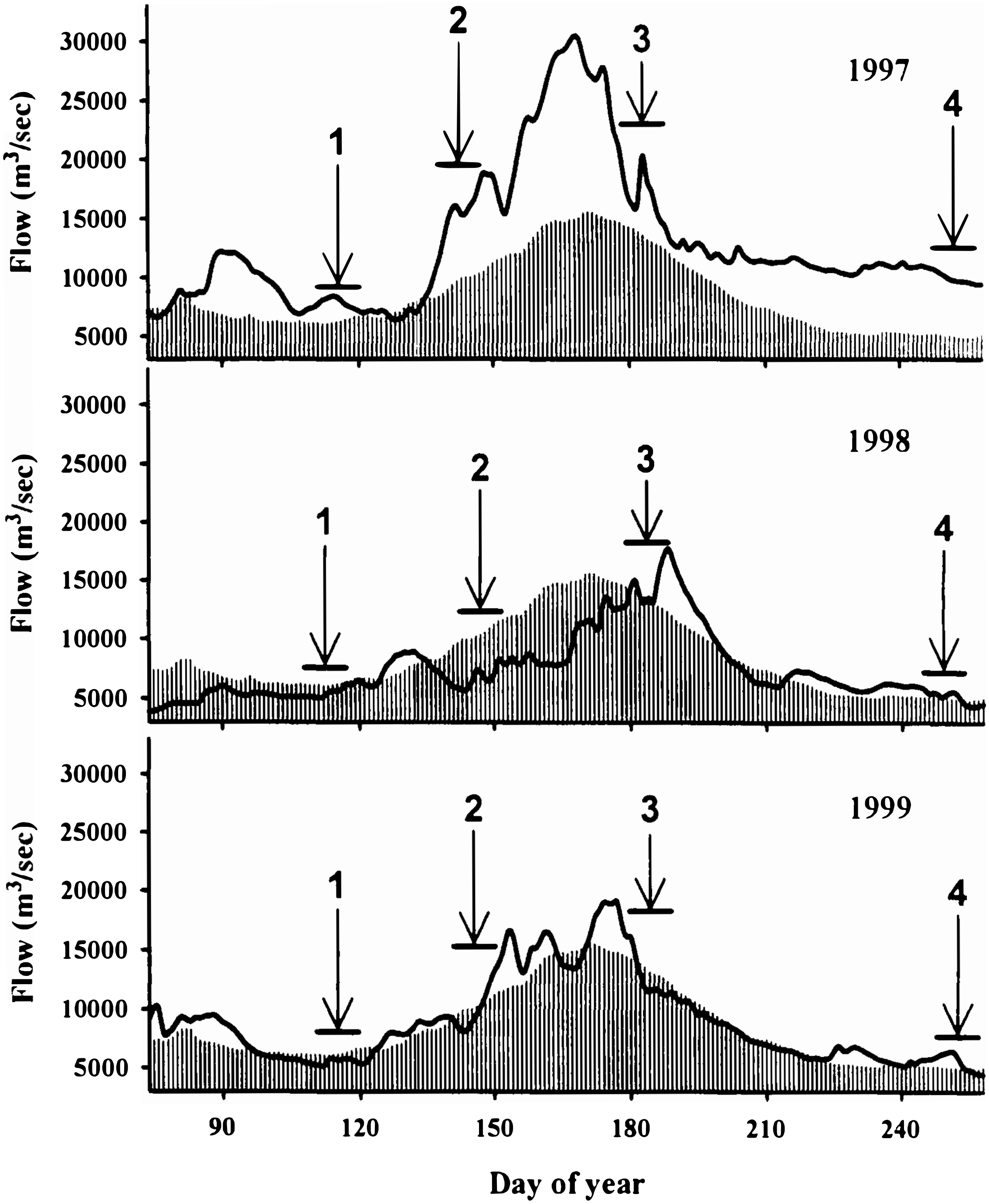

Figure 1-1. Cumulative flow index (m^3/sec) for the Missouri River below the Yellowstone River confluence and above the Lake Sakakawea headwaters in North Dakota from 15 March through 15 September of 1997-1999. The dates (day of year), sample periods, and years are denoted. The solid line indicates the indexed hydrograph for each year and the shaded area represents the mean 40-year indexed hydrograph (1959-1999).

Chapter 2.

Seasonal Dynamics of the Backwater Habitat and Biotic Community

Researchers have suggested that floodplain productivity is a critical component sustaining the structure and function of undisturbed riverine ecosystems (e.g., Welcomme 1985; Saunders and Lewis 1988). Many studies have demonstrated that floodplain wetlands, a term I will use interchangeably with backwaters, are important sources of organic matter and energy production (e.g., Amoros 1991), zooplankton and macroinvertebrate biomass (e.g., Eckblad et al. 1984), and fish yields (e.g., Sheaffer and Nickum 1986). In general, lotic ecologists, such as Pringle et al. (1988), recognize that backwaters are an integral part of riverine ecosystems; however, understanding the lateral dimension dynamics of the river-floodplain relationship is a difficult task.

Stalnaker et al. (1989) indicated that a river floodplain often contains up to 90% of the fish community biomass while only composing 10% of the total surface area. The loss of functional backwaters has been a notable habitat change in the impounded and channelized portions of the Missouri River system. Despite the confidence of many ecologists that backwater habitat availability is a critical component supporting stable fish communities in large river ecosystems, research remains limited and clearly established connections have rarely been demonstrated. Regardless, several agencies have expressed concern about further loss of floodplain wetlands and the procurement of reliable data that will allow evaluation of ecological backwater importance.

Although the decline in several native riverine species, such as the flathead chub *Platygobio gracilis* (Grady and Milligan 1998), pallid sturgeon *Scaphirhynchus albus*

(Duffy et al. 1996), and sicklefin chub *Macrhybopsis meeki* (Reigh and Elsen 1979), has been documented, the relationship between these declines and backwater connectivity is not understood. In 1990, the pallid sturgeon was federally listed as an endangered species and several other native Missouri River fishes, including flathead chub, sicklefin chub, sturgeon chub *M. gelida*, blue sucker *Cycleptus elongatus*, paddlefish *Polyodon spathula*, western silvery minnow *Hybognathus argyritis*, and plains minnow *H. placitus* were federally listed as "candidate" species (Williams et al. 1989). Although the candidate designation is no longer used, biologists still remain concerned about all of these species.

Fishes are not the only component of the riverine ecosystem to benefit from the presence of functioning backwaters. Amoros (1991) found that during periods of connection, floodplain wetlands contributed a substantial portion of their biotic production, including both flora and fauna, to the main river channel. Eckblad et al. (1984) and Cellot and Bournard (1987) both noted that moderate flushing of backwaters increased invertebrate densities in the drift below backwater connections by as much as 4,000%; however, invertebrate contributions were highly variable and depended on the intensity and frequency of flushing events. Bouvert et al. (1985) suggested that backwaters play a multi-faceted role in large river ecology, providing energy resources from primary production and contributing large amounts of biomass in the form of zooplankton, macroinvertebrates, and fishes.

As stated earlier, the value of backwaters has been assumed by many riverine researchers; however, our understanding of the magnitude of backwaters habitat loss and the ecological value of backwater habitat processes is has not been fully developed.

Continued pressure to develop remaining floodplain wetlands and desires to manage discharge cycles for other river services has fueled the need for data concerning the importance of functional wetlands under natural hydrograph conditions. Therefore, the three primary objectives for research detailed in Chapter 2 were 1) to monitor seasonal changes in habitat, water quality parameters, and invertebrate and piscine community structure, 2) to identify assemblages of fishes incorporating backwaters into their life history strategies, and 3) to discuss backwater ecology with reference to the population ecology of native fishes in the upper Missouri River basin.

Methods and Analysis

Habitat and water quality data collection techniques

Several habitat characteristics were assessed in EIS and the CB and water quality parameters were also assessed in each backwater and the main Missouri River channel (MC) during each sample period in 1997-1999 (refer to Chapter 1 for additional study site information). All habitat and water quality data were collected between 1300 and 1600 h on full sun days when wind speed did not exceed 15 km/h. The habitat characteristics included depth, submergent and emergent vegetation, substrate, and woody debris. The water quality measurements included temperature, dissolved oxygen (DO), turbidity, conductivity, pH, and chlorophyll-*a* concentration. During each sample period, I randomly selected five transects across the water body. Along each transect, five random locations were selected and the habitat characteristics listed above were assessed. At one randomly selected location along each transect in the backwaters and at five randomly selected locations in the main channel (within the study reach), the water quality parameters were also measured.

Substrates were collected with a petite ponar grab at each location and categorized into one of three classes, including organic substrates (flooded and decaying vegetation including detritus matter with limited sediments), mud and coarse silt (fine particles <0.5 mm in diameter), and coarse sand or gravel (particles $\geq$0.5 mm in diameter). Depth (cm) was measured with a marked and weighted rope. Care was taken not to compensate for loose layers of silt that made reliable depth measurements difficult to obtain. Submergent vegetation, emergent vegetation, and woody debris were each recorded as present or absent by visually inspecting a 20-m^2 area at each location.

Water temperatures (°C), conductivity (μS/cm), pH, turbidity (nephelometer turbidity units; NTU), and DO (mg/L) were recorded at 0.5-m depth intervals beginning 10 cm subsurface in the backwaters with a Yellow Springs Instruments (YSI) 3800 Water Quality Logging System. Unfortunately, a *post facto* assessment of the water quality logger revealed a problem that deemed measurements recorded at depths $\geq$30 cm in 1998 and 1999 unreliable. Water quality parameters in the MC were assessed at 10 cm subsurface only. In 1999, a logger that recorded water temperatures at 0500, 1100, 1700, and 2300 h was placed in EIS from 22 April to 5 September. The daily minimum and maximum temperatures recorded on these dates are reported. Chlorophyll-*a* was sampled by filtering a known volume of water through a 0.8-μm glass micro-fiber filter. Filters were then placed in desiccant and frozen for later analysis. Chlorophyll-*a* concentration (mg/L) was determined using standard procedures described in Lind (1985).

Habitat and water quality data analysis

Depth, DO, temperature, conductivity, pH, chlorophyll-*a*, and turbidity data were tested for normality with a Shapiro-Wilkes test (UNIVARIATE procedure; SAS 1990). Other than the depth data, none of the data sets were normally distributed; however, after inspection of the data plots, the lack of normality was probably due to low sample size, not alternative distribution patterns. Therefore, both the normally distributed depth data and the other data sets were each analyzed with a three-way analysis of variance (ANOVA; ANOVA procedure, SAS 1990) with the main effects including sample location (EIS, CB, or MC), sample period, and year. The null hypotheses for this and all subsequent tests simply stated that there would be no significant differences in measured parameters among sample locations, periods, and years. Null hypotheses were accepted or rejected at $\propto=0.05$. Significant interaction terms indicated that the main effects were not independent, but were interacting in some manner, making discussion of the main effects inappropriate. However, due to the dynamic nature of the Missouri River ecosystem, I suspected that period- and year-driven interactions would be present; therefore, given the lack of replications and the need to secure some type of within-study comparisons, I also completed three one-way ANOVA assessments to evaluate differences among 1) years within sites and periods, 2) sites within years and periods, and 3) periods within sites and years. When significant differences were detected, a Tukey's multiple range test was used to identify statistically different. The one-way ANOVA assessments provided a starting point for discussion regarding the three main effects in this highly dynamic ecosystem.

The categorical data, including substrates and the presence-absence information for submergent vegetation, emergent vegetation, and woody debris, were each assessed with a Chi-square test for homogeneity (Daniel 1990) to determine if the proportional coverage of each parameter differed significantly among 1) years within sites and periods, 2) sites within years and periods, and 3) periods within sites and years. Substrate classifications were each tested separately, meaning that no test was completed for differences among substrate types within a period, year, and site.

The temperature and DO profiles from EIS during period 3 in 1997 were salvaged and assessed with an ANOVA to determine if significant differences were present among the depth intervals (GLM procedure, SAS 1990). Depth, temperature, DO, and turbidity data for all years were combined by site and period to facilitate discussion about changes in habitat and differences among sites and periods. The combined data were analyzed with a two-way ANOVA and significant differences were detected with a Tukey's multiple range test in the absence of significant interaction terms.

Zooplankton and macroinvertebrate data collection techniques

Eight zooplankton samples were collected at randomly selected locations in each backwater and within the study area channel reach during each period and year with a 1-m tube sampler (75-mm diameter; DeVries and Stein 1991). All zooplankton samples were collected between 1100 and 1400 h. At each sample location, three 1-m tube samples were collected, filtered through a 63-μm plankton net, and preserved in 4% sucrose-formalin solution (Haney and Hall 1973). Each sample was enumerated in the laboratory and up to 20 specimens per taxonomic group were measured to the nearest 0.1-mm total length. Zooplankton data were expressed by taxonomic group as number/L and size structure was also determined for the most abundant taxa.

Six benthic macroinvertebrate samples were collected during each sample period and backwater with a petite ponar dredge that enclosed an area of 0.0238 m^2. The dredge samples were sifted through a No. 30 (0.59-mm bar measure) mesh screen, preserved in 10% formalin, and organisms sorted from other debris in the laboratory. Benthic macroinvertebrate samples were not collected in the MC due to high flows. Organisms were enumerated and expressed as number/m^2. Limnetic macroinvertebrates were collected with modified quatrefoil light traps (Floyd et al. 1984; 25-cm high x 30-cm wide with two 2-mm and two 4-mm slot openings). Ten randomly placed light trap sets were completed in each backwater during each sample period. My intent was to also use the light traps to sample calm channel areas; however, high flows caused excessive physical damage to the traps. The light traps were deployed between 1600 and 1800 h and emptied prior to 1100 h the following day. Two 12-h photochemical light sticks were used as the light source in each light trap each night. Photochemical light stick intensity and light duration can vary with temperature; however, Kissick (1993) found that photochemical sticks typically attract larvae for at least 1 h. All photochemical sticks used in this study were found to continue glowing up to 24-h after initial use; regardless, light sticks were replaced each night. Limnetic macroinvertebrates were preserved in 5% formalin, enumerated, and indexed as number/trap night.

Zooplankton and macroinvertebrate data analysis

Zooplankton and macroinvertebrate density data were tested for normality as described above. The zooplankton data were found to be normally distributed and were analyzed with a 3-way ANOVA. The macroinvertebrate data were found to not be normally distributed. These data were transformed [$\log_{10}(n+1)$] and again analyzed for normality. The transformation normalized the limnetic invertebrate data and analyses were similar to that for zooplankton density described above. The benthic invertebrate data sets were still not normally distributed after transformation; therefore, a Kruskal-Wallis ANOVA by ranks (NPAR1WAY procedure; SAS 1990) was utilized to assess each main effect. When a significant difference was detected, a Mann-Whitney U test (NPAR1WAY procedure, SAS 1990) was used to locate those differences.

Significant interaction terms were present for all of the zooplankton and limnetic macroinvertebrate data sets, again revealing that the main effects of site, sample period, and years were not independently influencing the data. As described above, three 1-way ANOVA tests were completed. Zooplankton size structure, based on zooplankter length, was documented for cyclopoid Copepoda, *Daphnia* spp., and *Bosmina* spp., the three numerically dominant taxa in the overall zooplankton collections (excluding Copepoda nauplii).

Fish data collection techniques

Fishes were sampled in each backwater during each sample period and year and on sandbars in the main channel when possible. Adult and juvenile fishes were sampled with experimental gill nets (38-long x 1.8-m high; 7.6-m panels of 19-, 25-, 38-, 51-, and 76-mm bar monofilament mesh), trap nets (three nets with 0.9- x 1.8-m frames, 9.5-mm bar mesh, and 16- x 1.9-m leads and three nets with 0.6- x 0.9-m frames, 9.5-mm bar mesh, 3-mm bar mesh on hoops, and 7.0- x 0.6-m leads), bag seine (30-m long x 1.8-m high, 1.8 x 1.8 x 1.8-m bag and 6-mm bar mesh), and cloverleaf traps (70-cm diameter, 6-mm bar mesh, 15-mm throats). Larval fishes were collected with light traps (described above) and surface trawls (50-cm diameter mouth, 500-μm bar measure mesh). The cloverleaf traps were used in 1997, but were discontinued in 1998 because this gear did not appear to collect any unique or useful data. All captured fishes were identified to species, except *Lepomis* spp., *Stizostedion* spp. <17-cm total length (TL), *Pomoxis* spp., *Ictiobus* spp. <25 cm TL, and *Hybognathus* spp. because separation of the species belonging to these genera was difficult. Identified fishes were then classified into stages including larvae, juvenile, or adult. Some smaller species, such as the flathead chub were not categorized into any stage category due to truncated length ranges (refer to Appendix 1 for separation criteria and fish species abbreviations).

Ten gill net sets were used per sample period at randomly selected locations, preferably in depths of ≥1 m; however, low water depths sometimes forced the use of areas with depths <1 m. Gill net efforts were completed between 0800 and 1100 h, collected fishes were enumerated and released, and catches were indexed as number/h. Eighteen trap net nights were used per sample period and backwater, except when reduced surface area of the CB in periods 1 and 4 of 1998 and 1999 and period 2 of 1998 resulted in a reduction of the net nights to six. Trap nets were set overnight along shorelines or other structure (e.g., brush lines) where possible. Shallow water prevented the use of shoreline areas during some sample periods; therefore, some sets were made in open water regions by anchoring a lead or leads (if multiple traps used) and stretching the trap net(s) away from that point. Captured fishes were enumerated and released. Fishes that could not be readily identified were euthanized and returned to the laboratory for species verification. Trap net catch-per-unit-effort (CPUE) data were summarized as number/net night.

Six shoreline seine hauls were attempted during each period and in both backwaters and the main channel. Seining the backwater habitats proved to be a difficult to nearly impossible task. During low water periods, excessive siltation inhibited seine use and during high water periods, the shorelines were located in tree belts and brush fields where seining could not be completed. Bag seine sampling, however, was completed when possible. Seine hauls were approximately 20 m in length and then arched to the shoreline. Captured fishes were enumerated, released and expressed as number/haul. Shoreline seining was completed on sandbar habitats in the MC during all periods except period 2 of 1997 when record-high flows inundated sandbar habitats.

Ten light trap sets were used to capture larval fishes during each sample period and surface trawls were used during periods 2 and 3. Refer to the macroinvertebrate collection methods above for more information on light trap sampling protocol. Surface trawls were towed slightly subsurface at 1-2 m/sec for 2-4 min at randomly selected locations within a stratum defined as $\geq$75 cm and free from debris that might damage the trawl. Surface trawls were completed between 1000 and 1400 h. Given the continually changing depths of each backwater, the defined stratum was limited or absent and no surface trawls samples could be obtained during periods 1 and 4. An attached flow meter allowed the determination of water volume filtered. Although I had intended to use the surface trawl gear in the main river channel, safety concerns due to high flows and insufficient sampling equipment precluded the completion of that assessment. Captured larval fishes were euthanized, preserved in 5% formalin and returned to the laboratory for identification. Larval fishes were sorted using the guides from Auer (1982) and Holland-Bartells et al. (1990). Case specimens were sent to the Larval Fish Laboratory at Colorado State University for verification.

Fish data analysis

Fish of different stages within each taxon were analyzed separately with the same methods described for zooplankton density above. The catch data were not normally distributed and a $\log_{10}$ (n+1) transformation was performed. The data were retested for normality and analyzed with a 3-way ANOVA if found to be normally distributed. Data for taxa, however, were not normally distributed and were assessed with a Kruskal-Wallis ANOVA by ranks as described for benthic macroinvertebrates above. As described in the previous assessments, the 3-way ANOVA tests often had significant interactions that complicated assessment of the main effects. One-way ANOVA tests were completed and used in the discussion of among-season, -site, and -period differences. Fish length-frequency data for selected species were developed to better visualize the seasonal use of backwater habitats by different fish stages.

To better understand and identify fish assemblages, I categorized fishes based on the following criteria that help describe each species relationship with the backwater habitats. There were no *a priori* assemblage categories because I did not know how many different groups might be identified. The criteria included answers to each of the following questions.

1) Did the species exhibit a significant change in the CPUE of adult members?

If yes: A) During which period did significant increases occur?

B) Were there indications that the species was there to spawn?

2) Were the adults of the species, if present at all, present during all sample periods?

3) Did the species exhibit a significant changes in the CPUE of juvenile members?

If yes: A) During which period did significant increases occur?

B) Were the juveniles residential or immigrants?

4) Did the species exhibit a significant increase in CPUE of larval members?

If yes: A) During which period did significant increases occur?

B) Did the adults of this species appear to spawn in the backwater?

5) According to the literature, does the species prefer lentic- or lotic-oriented habitats?

Results and Discussion

The CB does not fully meet the original site selection criterion of being strongly influenced by the natural hydrograph produced by the Yellowstone River discharge. As I will suggest with temperature and several other habitat and invertebrate observations, the CB may be primarily regulated from the Missouri River flows and *in situ* groundwater upwellings observed at locations within the backwater. The Missouri River water, until it homogenizes with Yellowstone River discharge, appears to be physically, chemically, and biologically different than the Yellowstone River water, possibly due to its release from Fort Peck Reservoir. Therefore, the discussion pertaining to naturally functioning backwaters will tend to be geared toward EIS; however, there are some differences and similarities worth noting.

Habitat and water quality

As expected, mean water temperatures were significantly higher during sample period 3 than other sample periods during all years and the higher temperatures were recorded regardless of sample site (Table 2-1). Water temperatures in each backwater were also significantly higher during most sample periods than the temperatures in the main river channel (Figure 2-1); however, the seasonal temperature patterns in EIS tended to mimic channel temperature patterns much more closely than the CB. In 1997, the year of record discharge from the Yellowstone River, temperatures also remained significantly cooler during period 2 than they did during the low and moderate flow years of 1998 and 1999. Wetzel (1975) noted that the particulate matter in highly turbid waters allows more efficient absorption of light energy, resulting in a greater increase in water temperatures for a given unit of light energy. Daily differences between mean and maximum temperatures in EIS during 1999 were as high as 10°C in the spring and autumn periods, but tended to be less extreme during the warmer summer months; therefore, the relationship between temperature flux and turbidity in the backwaters is not well

Table 2-1. Summary of water quality data collected in the Missouri River channel (MC) and two Missouri River backwaters in North Dakota [Erickson Island Slough (EIS) and the confluence backwater (CB)] in late April (Period 1), mid-May (Period 2), late June and early July (Period 3), and September (Period 4) of 1997-1999. For each period, year, and backwater, the mean for each parameter, standard error (in parentheses), and results from statistical tests are noted. Due to the consistency of the pH and conductivity data recorded during each sample period, standard errors are not reported. For each parameter, the letters a-d designate the among-period comparisons within each year and backwater. The letters n-p denote the among-year comparisons within each backwater and period. The letters x-z represent the comparison between the two backwaters and the channel within each year and period. Cells with the same letters were not statistically different (P>0.05).

		1997			1998			1999	
Parameter/Period	EIS	CB	MC	EIS	CB	MC	EIS	CB	MC
Temperature (°C)									
Period 1	12.2 (0.7) c-o-x	11.1 (0.8) c-o-x	11.2 (0.1) d-o-x	14.9 (0.7) c-n-x	16.7 (0.5) c-n-x	11.8 (0.2) d-n-y	12.3 (0.1) d-o-x	12.8 (0.4) c-o-x	10.6 (0.2) d-p-y
Period 2	13.4 (0.2) c-p-x	14.9 (0.6) b-p-x	13.6 (0.4) c-p-x	18.7 (0.6) b-o-x	19.7 (0.3) b-o-x	17.0 (0.1) c-n-y	16.8 (0.2) c-o-y	21.9 (0.7) a-n-x	16.1 (0.1) b-o-y
Period 3	23.1 (0.3) a-o-x	22.5 (0.4) a-n-x	21.3 (0.1) a-n-y	25.6 (0.7) b-o-y	21.2 (0.5) b-o-y	18.4 (0.1) a-o-x	22.9 (0.3) a-o-x	22.8 (0.3) a-n-x	19.4 (0.1) a-o-y
Period 4	17.3 (0.2) b-o-x	16 0 (0.4) b-p-x	16.0 (0.5) b-o-x	23.8 (0.5) a-n-x	24.1 (0.4) a-n-x	20.8 (0.1) b-o-x	18.7 (0.5) b-o-x	19.5 (0.6) b-o-x	14.4 (0.1) c-p-y
Dissolved oxygen (mg/L)									
Period 1	NA	NA	NA	5.7 (0.6) d-o-y	11.0 (0.6) a-n-x	10.7 (0.1) a-n-x	7.8 (0.2) c-n-y	11.0 (0.2) a-n-x	8.3 (0.1) b-o-y
Period 2	9.7 (0.3) a-n-x	9.0 (0.2) a-o-x	9.6 (0.2) a-n-x	8.2 (0.4) c-o-y	11.1 (0.8) a-n-x	8.1 (0.1) c-o-y	6.8 (0.4) c-p-y	8.5 (0.2) a-o-x	6.6 (0.1) c-p-y
Period 3	7.4 (0.2) c-p-x	6.5 (0.2) c-p-y	6.7 (0.1) c-p-y	11.0 (0.5) b-n-x	8.3 (0.2) b-n-y	9.9 (0.2) b-n-x	9.5 (0.2) b-o-x	7.3 (0.2) a-o-z	8.5 (0.1) b-o-y
Period 4	8.5 (0.1) b-o-x	8.0 (0.1) b-n-y	7.7 (0.1) b-o-y	13.3 (0.5) a-n-x	10.5 (0.5) ab-n-y	8.2 (0.2) c-o-z	13.3 (0.2) a-n-x	8.7 (1.7) a-n-z	9.2 (0.1) a-n-y
pH									
Period 1	NA	NA	NA	9.0 a-n-x	8.9 a-n-x	9.2 a-n-x	8.8 b-n-x	8.7 a-n-x	8.9 a-o-x
Period 2	8.6 a-n-x	8.3 a-o-xy	8.2 ab-o-y	8.5 b-n-x	8.5 a-o-x	8.1 c-n-x	8.7 b-n-x	8.7 a-n-x	8.6 bc-b-x
Period 3	8.1 b-o-x	7.8 b-o-y	8.0 b-p-xy	8.8 a-n-x	8.4 a-n-y	8.3 b-o-y	8.8 b-n-x	8.3 b-n-y	8.7 b-n-x
Period 4	8.5 a-p-x	8.3 a-o-y	8.4 a-o-xy	9.0 a-o-x	8.8 a-n-xy	8.6 b-n-y	9.6 a-n-x	8.6 ab-n-y	8.5 c-no-y

Table 2-1. Continued.

Parameter/Period	1997 EIS	 CB	 MC	1998 EIS	 CB	 MC	1999 EIS	 CB	 MC
Conductivity (μS/cm)									
Period 1	NA	NA	NA	490 a-n-y	1004 a-o-x	611 a-n-y	636 b-n-y	1165 a-n-x	540 b-n-y
Period 2	460 b-o-x	530 b-o-x	351 b-p-y	692 a-n-y	1062 a-n-x	432 c-o-z	742 a-n-y	1106 a-n-x	615 a-n-y
Period 3	466 b-n-x	642 a-n-y	406 b-o-z	520 a-n-x	560 c-o-x	316 d-p-y	473 c-n-y	625 c-n-x	441 c-n-y
Period 4	540 a-o-x	503 c-o-y	490 a-o-y	632 a-n-y	816 b-n-x	551 b-n-y	575 b-n-y	834 b-n-x	560 ab-n-y
Turbidity (NTU)									
Period 1	NA	NA	NA	16 (3) c-o-y	13 (3) b-n-y	45 (1) c-o-x	56 (5) a-n-x	9 (3) b-n-y	74 (9) b-n-x
Period 2	27 (5) a-n-y	10 (3) a-o-y	216 (24) a-n-x	34 (4) b-n-y	32 (1) a-n-y	66 (1) b-p-x	45 (6) a-n-y	27 (3) a-n-z	135 (2) a-o-x
Period 3	18 (3) ab-o-y	9 (1) a-n-y	156 (6) b-o-x	25 (1) bc-n-y	4 (1) b-n-y	197 (5) a-n-x	NA	NA	NA
Period 4	13 (1) b-o-y	8 (1) a-o-y	38 (5) c-n-x	78 (7) a-n-x	30 (6) a-n-y	35 (1) c-n-y	NA	NA	NA
Chlorophyll-*a* (μg/L)									
Period 1	NA	NA	NA	0.4 (0.2) b-n-x	0.7 (0.4) a-n-x	0.5 (0.3) a-n-x	0.4 (0.4) b-n-x	1.3 (0.9) a-n-x	1.0 (0.1) a-n-x
Period 2	1.7 (0.6) a-n-x	0.7 (0.7) a-n-x	6.4 (3.1) a-n-x	0.3 (0.3) b-n-x	2.0 (2.0) a-n-x	1.3 (1.1) a-n-x	1.9 (1.2) b-n-x	2.2 (1.1) a-n-x	1.6 (0.6) a-n-x
Period 3	1.5 (0.8) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	1.4 (0.9) ab-n-x	0.8 (0.4) a-n-x	2.3 (1.5) a-n-x	2.0 (0.8) b-n-x	1.2 (0.5) a-n-x	2.5 (0.8) a-n-x
Period 4	0.2 (0.2) a-o-x	0.5 (0.3) a-o-x	0.0 (0.0) a-o-x	5.9 (2.4) a-o-x	3.3 (0.7) a-o-x	3.3 (1.3) a-no-x	37.9 (9.4) a-no-x	3.5 (1.0) a-n-y	4.3 (1.5) a-n-y

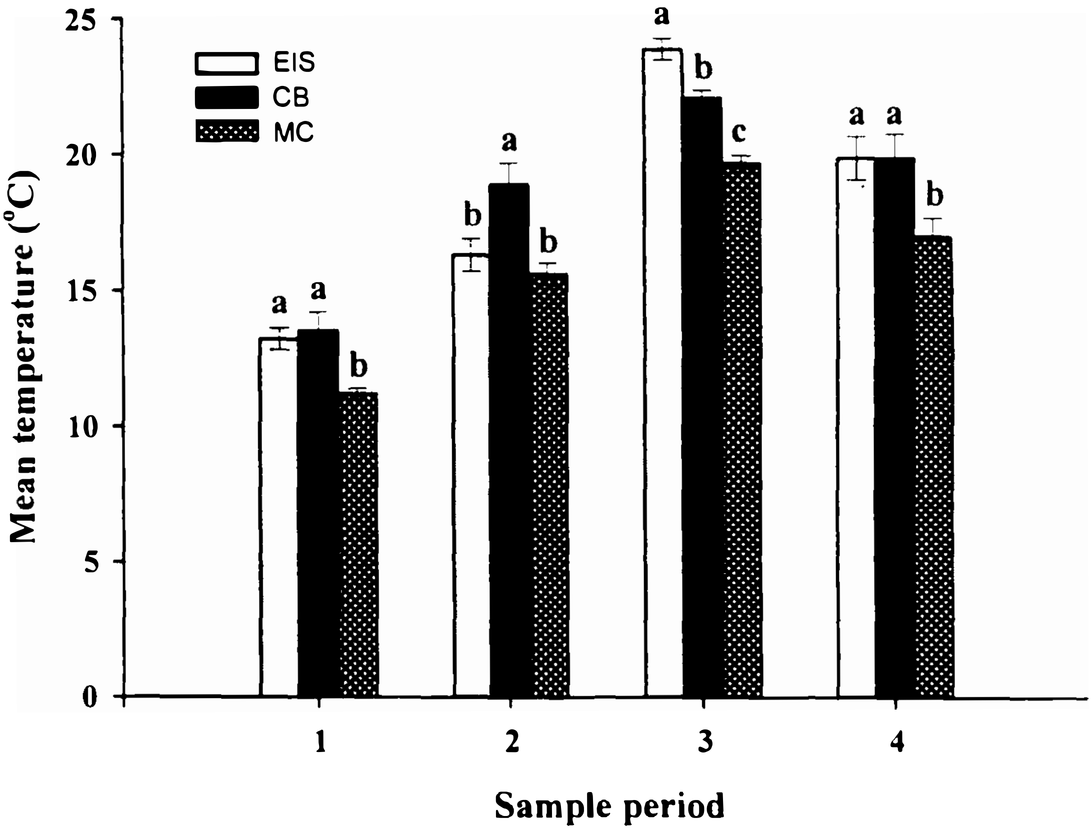

Figure 2-1. Mean water temperatures (°C) from Erickson Island Slough (EIS), the Confluence Backwater (CB), and the Missouri River channel (MC) in northwestern North Dakota. The means represent data collected in late April (Period 1), mid- to late May (Period 2), late June and early July (Period 3), and early September (Period 4). The vertical bars represent one standard error and the letters represent an among site comparison within each period (means with the same letter are statistically similar).

supported. However, as Figure 2-2 depicts, the daily minimum and maximum temperatures were highly variable during all seasons, altering quickly in response to changing ambient conditions. It is plausible, though, that the temperature extremes may be a phenomenon of the extreme upper water column, where sun penetration and heat absorption are the most noteworthy in the highly turbid waters. Temperature profiles completed in period 3 of 1997 at EIS indicated that a statistically significant gradient existed between surface and 2-m subsurface water temperatures (Figure 2-3). At 60-cm subsurface, a statistically significant decline of 1.2°C was present and by 210-cm subsurface, temperatures had dropped by more than 2.3°C. Sabo et al. (1991) found that temperatures in Mississippi River floodplain ponds also exhibited extreme conditions and when combined with DO and other abiotic variables, had a substantial influence on larval fish production.

DO profiles from EIS during period 3 of 1997 also demonstrated a statistically significant decline in deeper waters. DO concentrations exceeded 7 mg/L near the surface, then steadily declined with increasing depth, but did not reach a statistically lower concentration until 160-cm subsurface. Photosynthetic activity is highest in the photic water layer; however, Ellis (1936) realized that the primary production layer in turbid systems was quite narrow. Given that colder water in the lower water column has the capability of retaining greater DO amounts than the warmer surface waters and considering that inflows and wind action help mix the entire water column, the lack of DO near the bottom was initially confusing. As discussed above, large amounts of inundated vegetation and detrital influx are likely increasing the organic load of each

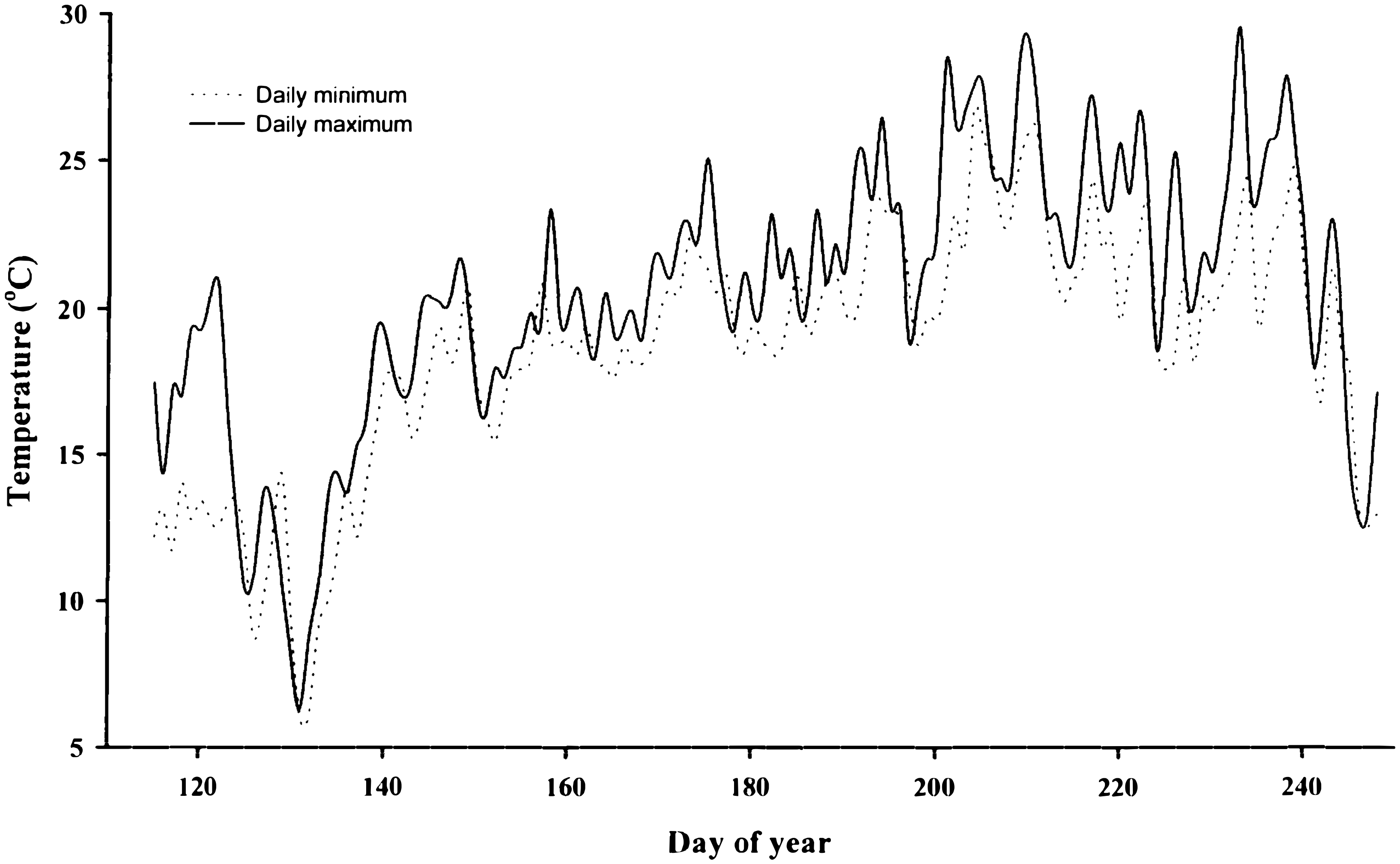

Figure 2-2. Minimum and maximum daily water temperatures recorded in Erickson Island Slough, North Dakota from 15 April 1999 (Day 105) to 15 September 1999 (Day 258) 1999.

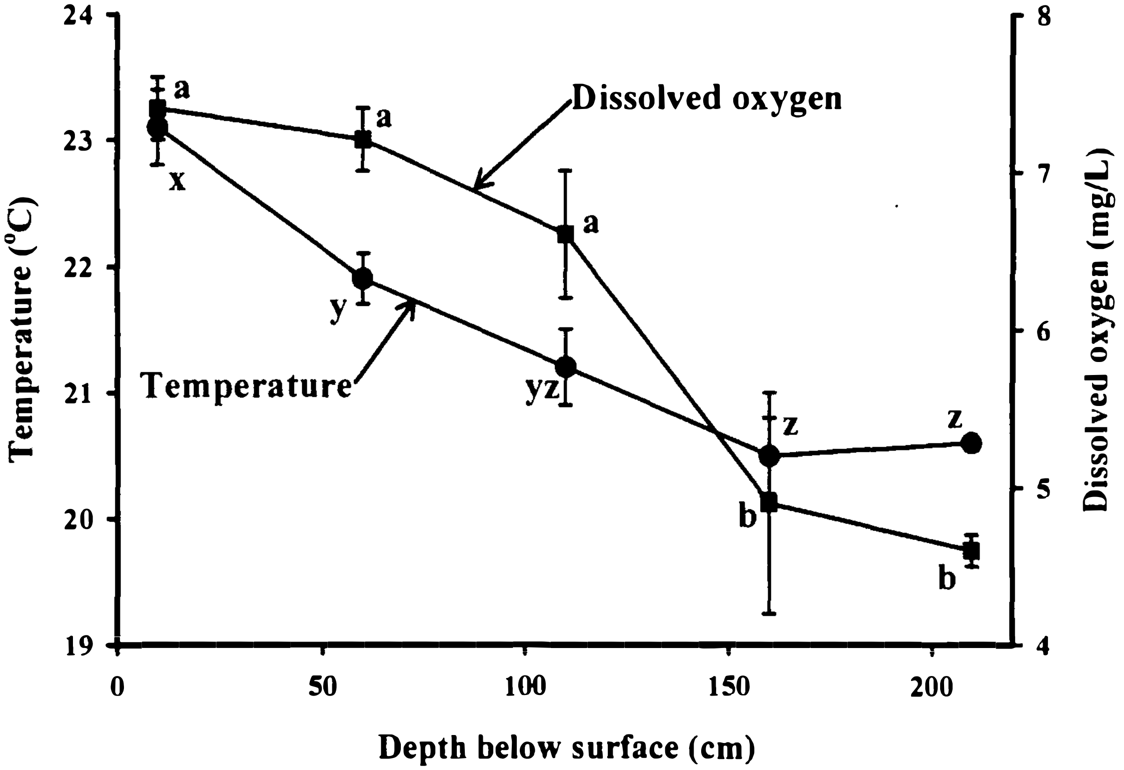

Figure 2-3. Mean temperature (°C) and dissolved oxygen (mg/L) profile (50-cm increments) from Erickson Island Slough in northwestern North Dakota in 1997. The vertical bars represent one standard error. The letters a and b represent a statistical comparison among dissolved oxygen means and the letters x, y, and z represent a statistical comparison among temperature means. Means with the same letters are not statistically different ($P>0.05$).

backwater during the flood-pulse. This increased load may be followed by a strong increase in biological oxygen demand, particularly near the sediment-water interface where substantial decomposition is occurring.

The combined drop in temperatures and DO may be a substantial stressor for benthic-oriented fishes; however, the condition is probably natural and fish of turbid rivers can withstand DO levels as low as 1-2 mg/L, but prefer >5 mg/L (Barton and Taylor 1996). Bodensteiner and Lewis (1992) noted that DO frequently dropped as low as 1.2 mg/L in Mississippi River backwaters, even when channel DO levels remained constant. Suthers and Gee (1986) suggested that decomposition of seasonally produced vegetation was correlated with microhabitats containing hypoxic (<1.5 mg/L) conditions. Therefore, I hypothesize that inundated vegetation, combined with allochthonous silt and detrital materials in conjunction may be contributing to the overall DO decline during summer and autumn months in the backwaters. In general, no patterns in DO levels could be detected; however, EIS tended to maintain statistically lower DO concentrations during period 1 than the CB and channel and likely due to high primary production, statistically exceeded the other sites during periods 2 and 3 (Figure 2-4).

Photosynthetic DO production is often regulated indirectly by turbidity levels. LaPerriere et al. (1983) and Pain (1987) both found that primary production was inversely correlated with NTUs and that 170 NTUs reduced photosynthetic activity by as much as 175%. Van Nieuwenhuyse and LaPerriere (1986) also noted that high turbidity levels created nearly suffocating environments for riverine macrophytes and periphytic growth. Lloyd et al. (1987) found that a 25% increase in physical turbidity directly resulted in a

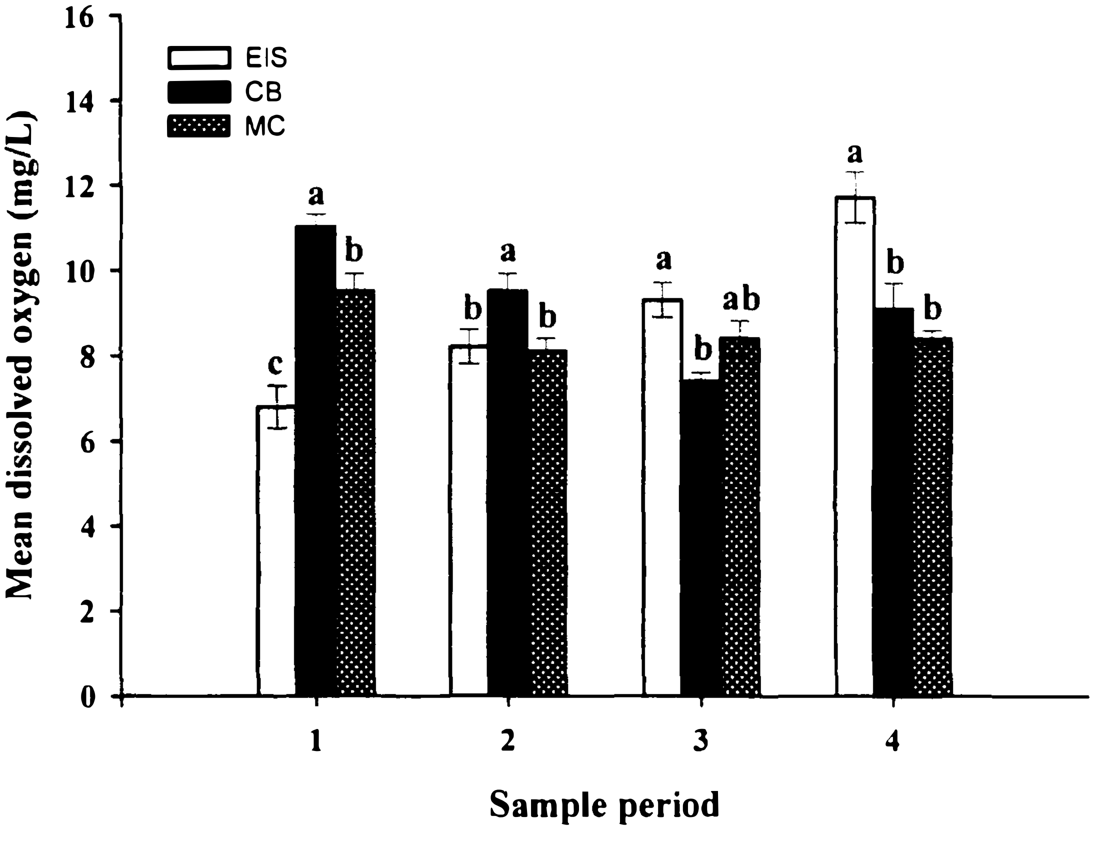

Figure 2-4. Mean dissolved oxygen (mg/L) from Erickson Island Slough (EIS), the Confluence Backwater (CB), and the Missouri River channel (MC) in northwestern North Dakota. The means represent data collected in late April (Period 1), mid- to late May (Period 2), late June and early July (Period 3), and early September (Period 4). The vertical bars represent one standard error and the letters represent an among-site comparison within each period (means with the same letters are statistically similar).

19% decline in overall aquatic productivity. Waters (1995) also noted that sedimentation depletes faunal production be catalyzing the immigration of organisms to more suitable areas. The Missouri River and Yellowstone River are both highly turbid systems and therefore, turbidity is an important abiotic feature.

A noteworthy observation is the filtering ability of the backwaters. During nearly all sample periods, the turbidity readings in the backwaters were significantly lower than those found in the channel (Table 2-1). In fact, during periods 2 and 3, the water flowing into each backwater from the main channel exceeded NTU readings of 140; however, during these same periods, backwater NTU values rarely exceeded 40 (Figure 2-5). Therefore, the backwaters apparently have the capability to remove up to 70% of the total suspended materials. This aggradation process is natural and Amoros (1991) noted that the process of sediment accumulation ages backwaters, causing declines in connectivity and the formation of fluvial plugs; however, in high water years, such as 1997, these plugs can be scoured away and backwater functions restored. As I will discuss later, siltation is an obvious and active process in these backwaters, but strong flood pulses, such as the one that occurred in 1997, can affect substrate composition.

Chlorophyll-*a* concentrations were variable across all seasons, years, and sites making the discussion of patterns rather difficult. As an index to productivity, though, the chlorophyll-*a* data illustrated two interesting points. In general, chlorophyll-*a* concentrations were significantly lower in 1997 than they were in 1998 and 1999. Olmsted (1981) and Amoros (1991) both noted that during periods of connection and exchange, a floodplain wetland typically donates nearly all of its primary productivity

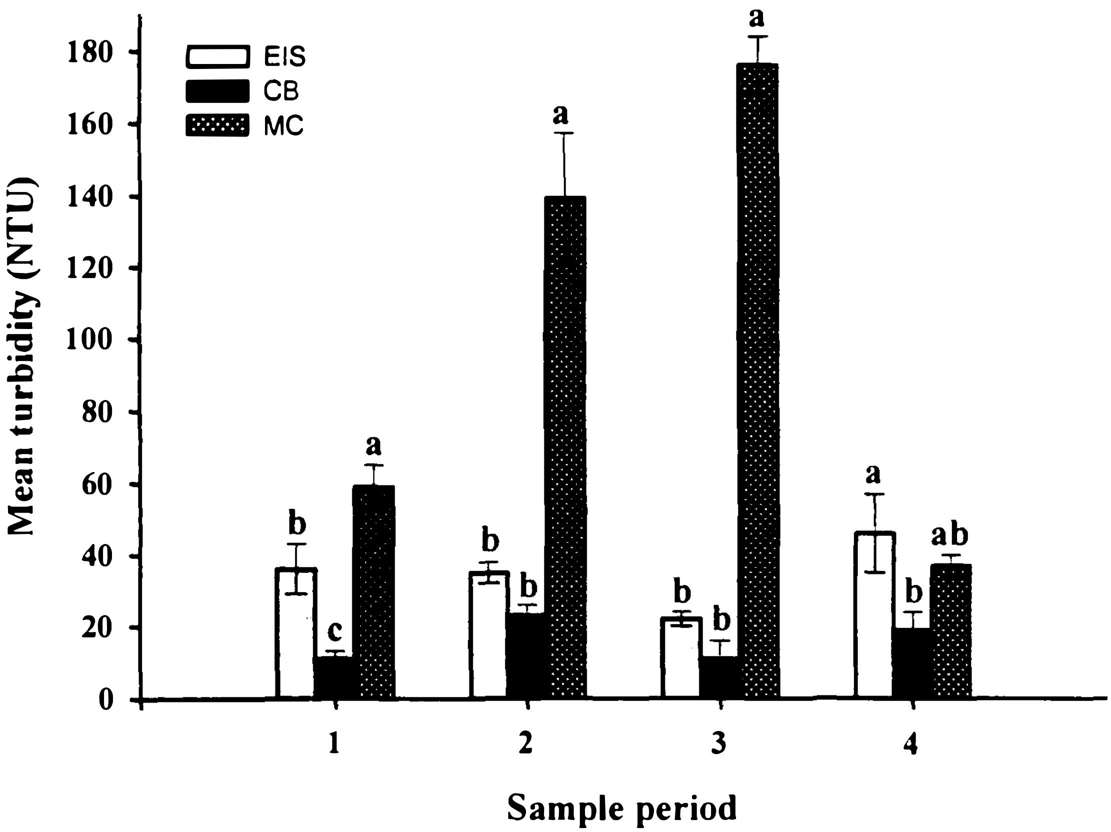

Figure 2-5. Mean turbidity (NTU) from Erickson Island Slough (EIS), the Confluence Backwater (CB), and the Missouri River channel (MC) in northwestern North Dakota. The means represent data collected in late April (Period 1), mid- to late May (Period 2), late June and early July (Period 3), and early September (Period 4). The vertical bars represent one standard error and the letters represent an among-site comparison within each period (means with the same letters are statistically similar).

base to the channel. Therefore, during the high water year of 1997, the backwaters were flushed at a greater rate than in 1998 and 1999, diminishing photosynthetic stores. Kennedy (1979) also noted that too much flushing can be detrimental when productivity loss from a backwater becomes excessive. Overall, period 4 was also the most photosynthetically active and EIS chlorophyll-*a* concentrations approached 38 μg/L during an algal bloom in early September of 1999 (Table 2-1). Sabo et al. (1991) found that Mississippi River floodplain wetlands often maintained chlorophyll-*a* concentrations of <2 μg/L, and Heiskary and Walker (1988) suggested that eutrophic lakes have chlorophyll-*a* concentrations of 10-30 μg/L. Therefore, assuming that my chlorophyll-*a* data are reliable, the Missouri River backwaters that I studied were more photosynthetically active than previously suspected and at times approached nearly hypereutrophic status.

The pH and conductivity data did not reveal any substantial patterns; however, there were a couple of noteworthy observations. Although the pH values for nearly all of my sites during all sample periods did not exceed 9.0, a value of 9.6 was recorded in EIS during period 4 of 1999 (Table 2-1). Probably not coincidentally, the chlorophyll-*a* concentrations were very high during this same period. Hessen and Nilssen (1983) and Malley et al. (1988) both noted that excessive primary production can lead to alkaline conditions where pH exceeds 9.5. Overall, the pH values found in my study region were slightly higher than those reported for the River Endrick (7.1-7.3; Doughty and Maitland 1994) and Mississippi River floodplains (7.3-7.7; Ihrig 1989), but were similar to other Missouri River values (7.8-8.0) reported by Todd and Bender (1982) for the period prior to reservoir establishment.

Conductivity values in my study sites ranged from approximately 310 to greater than 1,100 μS/cm; however, I was unable to detect the presence of any conductivity patterns. In periods 1, 2 and 4 of 1998 and 1999 in the CB, higher conductivity values were recorded and during these periods, the disjunct patchwork of remaining water bodies in the backwater appear to be uncoupled from the channel. Therefore, during periods 1 and 2, an evaporative effect may be concentrating the ions in the remaining water. Then, during the flood pulse (period 3), the conductivity is reduced and mimics channel observations; however, during period 4, increasing conductivity values can again be noted (Table 2-1). Ions introduced from groundwater inputs may be adding to the ion concentration. Several springs were located during this study that may also help explain the overwinter survival of several fish species inhabiting these shallow (<0.5 m) silt-laden and isolated pools. For sake of comparison, Sabo et al. (1991) reported conductivity values of 348-414 μS/cm in the lower Mississippi floodplain and Todd and Bender (1982) noted pre-reservoir Missouri River conductivities between 660 and 730 μS/cm.

Mean depth in the two backwaters changed seasonally due to increased water inputs and scouring that relocated silt and detritus deposits. Not surprising, the statistically greater depths occurred during periods 2 and 3 during each year (Table 2-2). During these periods, the flood pulse of the natural hydrograph typically reaches its peak and then declines back to more stable autumn flows. In general, EIS attained a greater peak depth than the CB; however, differences in mean depth across all years were only significant during periods 2 and 3 and both averaged water depths of <50 cm during

Table 2-2. Summary of habitat parameter observations from two Missouri River backwaters in North Dakota [Erickson Island Slough (EIS) and the confluence backwater (CB)] in late April (Period 1), mid-May (Period 2), late June and early July (Period 3), and September (Period 4) of 1997-1999. Information is noted for each period, year, and backwater. The mean depth, standard error (in parentheses), and results from statistical tests are noted. Categorical analyses for vegetation and woody debris presence are also included. The letters a-d designate the among-period comparisons within each year and backwater. The letters n-p denote the among-year comparisons within each backwater and period. The letters x-y represent the pairwise comparison between the two backwaters within each year and period. Cells with the same letters were not statistically different (P>0.05).

	1997		1998		1999	
Parameter/Period	EIS	CB	EIS	CB	EIS	CB
Depth (cm)						
Period 1	45.1 (4.7) b-n-x	37.2 (5.4) c-n-x	15.2 (1.5) c-o-y	32.4 (2.4) b-n-x	16.7 (1.9) c-no-y	29.6 (3.2) c-o-x
Period 2	186.4 (12.4) a-n-x	168.4 (12.2) a-n-x	77.3 (8.2) b-o-x	44.6 (4.8) b-o-y	58.7 (4.3) b-o-x	58.4 (6.5) b-o-x
Period 3	173.1 (8.3) a-n-x	128.8 (9.2) b-n-y	145.1 (10.4) a-no-x	136.1 (6.1) a-n-x	118.8 (8.1) a-o-x	93.2 (7.6) a-o-y
Period 4	75.4 (6.4) b-n-x	68.5 (6.9) c-n-x	33.3 (6.9) c-o-x	20.0 (2.1) a-o-y	31.1 (2.7) c-o-x	24.9 (2.0) c-o-x
Submergent vegetation (presence %)						
Period 1	0 b-n-x	0 b-n-x	0 a-n-x	4 b-n-x	0 b-n-x	0 a-n-x
Period 2	40 a-n-x	48 a-n-x	8 a-o-y	28 a-n-x	24 a-n-x	24 b-n-x
Period 3	0 b-n-y	32 a-n-x	12 a-n-y	48 a-n-x	0 b-n-y	48 b-n-x
Period 4	12 b-n-x	28 a-n-x	8 a-n-y	16 a-n-x	0 b-n-y	12 b-n-x
Emergent vegetation (presence %)						
Period 1	0 b-n-x	0 b-n-x	0 b-n-x	8 a-n-x	4 b-n-x	8 b-n-x
Period 2	16 b-no-x	0 b-o-y	0 b-o-y	20 a-o-x	24 a-n-x	68 a-n-x
Period 3	44 a-n-y	72 a-n-x	28 a-n-x	36 a-o-x	44 c-n-x	60 a-n-x
Period 4	32 a-n-y	60 a-n-x	12 a-n-x	28 a-o-x	24 a-n-x	24 b-o-x
Woody debris (presence %)						
Period 1	20 b-n-x	8 b-n-y	16 a-n-x	16 b-n-x	24 a-n-x	12 b-n-x
Period 2	64 a-n-x	52 a-n-x	44 a-n-x	20 b-o-y	40 a-n-x	24 b-o-x
Period 3	52 a-n-x	60 a-n-x	48 a-n-x	68 a-n-y	36 a-n-x	52 a-n-x
Period 4	40 a-n-x	24 b-n-x	36 a-no-x	16 b-n-x	20 a-o-x	28 b-n-x

periods 1 and 4 (Figure 2-6). As flows increased through the backwaters during periods 2 and 3, the substrates became firmer. Although it is difficult to assess how much silt may have been removed from the backwaters, the increased turbidity in the main channel indicates that sediments were being transported from the floodplain to the river.

Substrate compositions, although dominated by mud and silt during periods 1 and 4, changed with the rise and fall of water levels (Table 2-3). During periods 2 and 3, the backwaters swelled and inundated large portions of the surrounding terrestrial riparian areas. The increase in backwater surface areas resulted in the addition of a large organic component to the substrate. Although substrates are often discussed based on their abiotic characteristics, large areas of the backwater bottom consisted of organic materials during the high water periods. Detritus buildup, due to the senescence and subsequent decomposition of flooded vegetation, resulted in a thick substrate layer consisting of organic materials mixed with particulate organic matter transported by channel inflow. During the high flows of 1997, scouring action was sufficient to remove all of the silt and detrital substrates from sections of the CB and during periods 3 and 4 of that year, 44% and 24% of the substrates actually consisted of sand and gravel (Table 2-3). During 1998 and 1999, the sand and gravel substrate was less pronounced and typically by period 4, the inundated vegetation was exposed, removing the organic substrate presence, when the water levels receded. As flows slowed, mud and silt were again the dominant substrate types. At times, a nearly liquid layer of silt was observed to exceed 1 m in depth and made sampling and maneuvering extremely difficult.

The silt-dominated substrates, combined with relatively high turbidity levels that

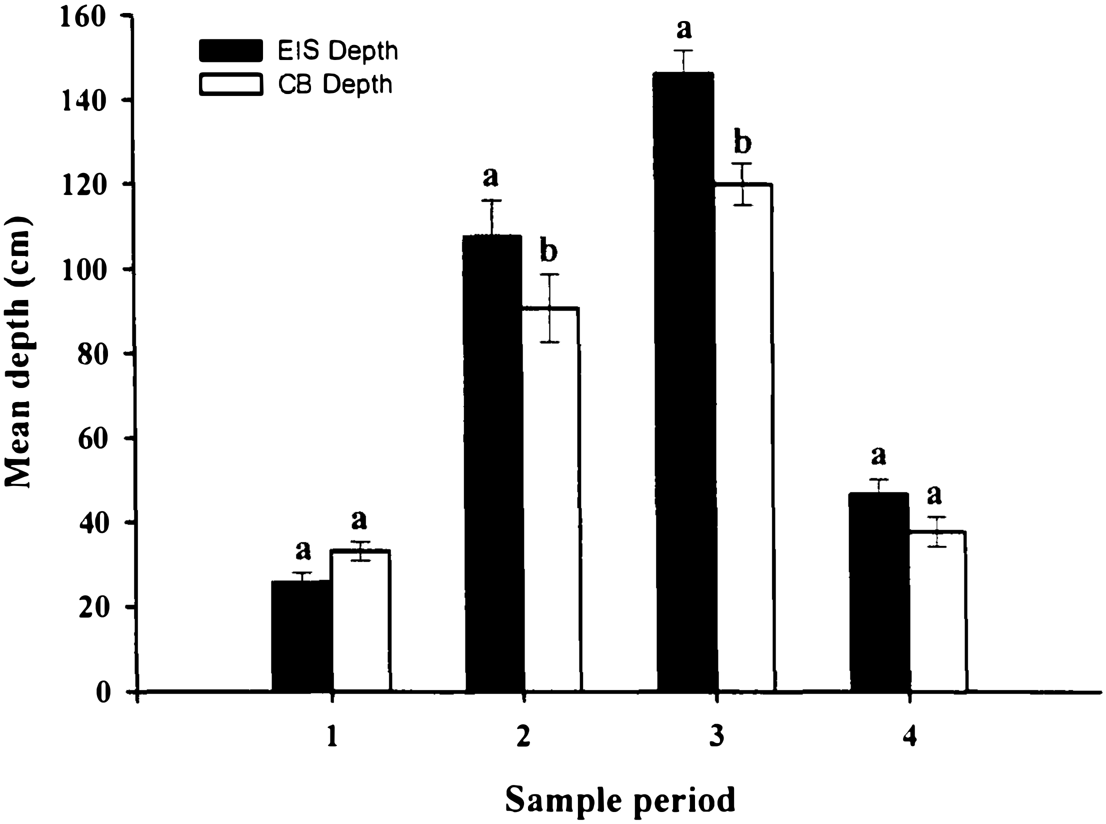

Figure 2-6. Mean depths (cm) from Erickson Island Slough (EIS) and the Confluence Backwater (CB) in northwestern North Dakota. The means represent data collected in late April (Period 1), mid- to late May (Period 2), late June and early July (Period 3), and early September (Period 4). The vertical bars represent one standard error and the letters represent a between-site comparison within each period. Means within a period with the same letters are statistically similar.

Table 2-3. Summary of substrate compositions observed in two Missouri River backwaters in North Dakota [Erickson Island Slough (EIS) and the confluence backwater (CB)] in late April (Period 1), mid-May (Period 2), late June and early July (Period 3), and September (Period 4) of 1997-1999. Categorical analyses for each substrate type are also included. For each parameter, the letters a-d designate the among-period comparisons within each year and backwater. The letters n-p denote the among-year comparisons within each backwater and period. The letters x-y represent the pairwise comparison between the two backwaters within each year and period. Cells with the same letters were not statistically different (P>0.05).

		1997		1998		1999	
Period	Substrate	EIS	CB	EIS	CB	EIS	CB
Period 1	Organic	0 b-n-x	0 b-n-x	0 b-n-x	12 b-n-x	0 b-n-x	0 b-n-x
	Mud/silt	100 a-n-x	100 a-n-x	100 a-n-x	88 a-n-x	100 a-n-x	100 a-n-x
	Sand/gravel	0 a-n-x	0 a-n-x	0 b-n-x	0 a-n-x	0 a-n-x	0 a-n-x
Period 2	Organic	48 a-n-x	56 a-n-x	0 a-p-x	0 b-o-x	24 a-o-x	44 a-n-x
	Mud/silt	52 b-o-x	44 b-o-x	100 a-n-x	100 a-n-x	76 ab-no-x	48 b-o-y
	Sand/gravel	0 a-n-x	0 a-n-x	0 a-n-x	0 a-n-x	0 a-n-x	8 a-n-x
Period 3	Organic	40 a-o-x	16 b-o-y	88 a-n-x	56 a-n-y	32 a-o-x	36 a-no-x
	Mud/silt	60 b-n-x	40 b-o-x	12 b-o-y	44 b-no-x	68 b-n-x	64 b-n-x
	Sand/gravel	0 a-n-y	44 b-n-x	0 a-n-x	0 a-n-x	0 a-n-x	0 a-o-x
Period 4	Organic	0 b-o-x	0 b-o-x	64 a-n-x	48 a-n-x	20 ab-o-x	0 b-o-x
	Mud/silt	100 a-n-x	46 b-o-y	36 b-o-x	52 b-o-x	80 ab-n-x	100 a-n-x
	Sand/gravel	0 a-n-y	24 b-n-x	0 a-n-x	0 a-o-x	0 a-n-x	0 a-o-x

likely limited solar penetration, inhibited the establishment of large submerged macrophyte beds. The CB contained a significantly higher proportion of submerged macrophytes, likely due to firmer substrates and greater water clarity. The submerged macrophtyes were not identified to species, and in reality, primarily consisted of inundated terrestrial flora. The most noteworthy macrophyte presence in the backwaters were the large beds of marsh and pond smartweed *Polygonum* spp. Although the smartweeds are considered semiaquatic or amphibious (Larson 1993), they provided the only true emergent macrophyte that was noted in both backwaters during each sample year. The smartweed beds were so prevalent in portions of each backwater that boat access was limited and at times greater than 70% of the CB area was covered with exposed smartweed (Table 2-2). Kennedy (1979) found that cattails *Typha* spp. were an abundant emergent species in backwaters of the Colorado River; however, during the course of this study, no cattails were found in either backwater and inundated terrestrial flora, such as sedges (Cyperaceae family) and leaf production from sandbar and peachleaf willows *Salix* spp. appeared to be more important.

The presence of woody debris has been considered an important component of aquatic systems (Schlosser 1982; Angermeier and Karr 1984) and efforts to add or maintain woody structures are often completed (e.g., Erickson 1993). A large proportion of both EIS and the CB contained some type of woody debris during all sample periods; however, during the flood pulse, inundated terrestrial habitats resulted in a significantly greater area with the presence of woody debris (Table 2-2). Discussions with local ranchers indicated that both backwaters remained nearly dry from the late 1970s until the wet cycle started in the early 1990s. During this period when inundation appeared to be limited, large areas of willows became established and during the course of my study, I noted a steady deterioration of willow thickets in inundated backwater segments, which ultimately contributed to the presence of woody debris. I could not detect any notable differences in woody debris presence between the two backwaters and even though the flood pulse in 1997 was much stronger than in 1998 and 1999, no prominent differences in woody debris presence among years could be detected.

Zooplankton and macroinvertebrates

Williams (1966) noted that Rotifera are better suited for life in flowing waters and that they tend to dominate the plankton community in river ecosystems. Although rotifers were present in my samples, their abundance was either low or they were not retained with the 63-μm mesh on the zooplankton net that I used. Rotifera, for all samples combined, constituted less than 1% by number and were not included in this summary. Mizzi (1994) sampled large numbers of Rotifera in the upper Missouri River and Wetzel (1975) noted that mesh size is critical for Rotifera retention; therefore, inappropriate mesh size was probably the ultimate reason for the lack of rotifers in the data set.

Numerically, the most abundant zooplankton were the Copepoda, particularly the adults and nauplii of cyclopoid Copepoda such as *Diacyclops thomasi* (Table 2-4). Mizzi (1994) also noted that cyclopoid Copepoda were a major component of the upper Missouri River plankton community, with densities of up to 80 individuals/L (Copepoda adults and nauplii combined) for both channel and backwater habitats during spring and

Table 2-4. Summary of zooplankton densities from the Missouri River channel (MC) and two backwaters in North Dakota [Erickson Island Slough (EIS) and the confluence backwater (CB)] in late April (Period 1), mid-May (Period 2), late June and early July (Period 3), and September (Period 4) of 1997-1999. For each period, year, and backwater, the densities (number/L), standard error (in parentheses), and results from statistical tests are noted. For each species, the letters a-d designate the among-period comparisons within each year and backwater. The letters n-p denote the among-year comparisons within each backwater and period. The letters x-z represent the among-site comparisons within each year and period. Cells with the same letters were not statistically different (P>0.05).

		1997			1998			1999	
Taxon/Period	EIS	CB	MC	EIS	CB	MC	EIS	CB	MC
Calanoid Copepoda									
Period 1	0.1 (0.1) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	1.2 (0.8) b-n-xy	0.3 (0.3) a-n-y	3.1 (1.0) a-n-x
Period 2	0.1 (0.1) a-no-x	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) b-o-x	69.4 (56.9) a-n-x	0.0 (0.0) a-o-x	1.0 (0.5) b-n-x	0.7 (0.5) a-n-x	0.5 (0 1) B-n-x
Period 3	0.0 (0.0) a-o-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-o-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	9.8 (2.8) a-n-x	0.7 (0.7) a-n-y	0.0 (0.0) b-n-y
Period 4	1.1 (0.7) a-o-x	18.9 (11.0) a-n-x	0.1 (0.1) a-n-x	14.9 (4.0) a-n-x	4.8 (1.8) a-n-y	0.1 (0.1) a-n-xy	0.0 (0.0) b-o-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x
Cyclopoid Copepoda									
Period 1	106.0 (25.8) b-n-x	72.6 (25.6) b-n-xy	5.3 (2.1) ab-o-y	31.6 (12 9) b-o-x	164.8 (91.7) a-n-x	9.8 (2.4) a-o-x	76.9 (17.9) c-no-x	41.6 (14.1) c-n-xy	29.3 (3.9) a-n-y
Period 2	20.9 (5.7) b-o-x	21.4 (6.9) b-o-x	13.1 (3.3) a-n-x	80.6 (16.7) b-o-x	491.4 (153.4)a-n-x	3.6 (0.9) b-o-y	290.0 (26.6) b-n-y	545.2 (60.8) a-n-x	5.2 (1.3) b-o-z
Period 3	14.6 (4.3) b-o-x	9.0 (1.6) b-o-xy	3.8 (0.9) b-n-y	296.2 (86.8) b-n-x	67.6 (45.5) a-no-y	0.3 (0.1) b-o-y	105.8 (33.0) bc-n-xy	303.9 (106.5) b-n-x	0.7 (0.2) b-o-y
Period 4	306.7 (54.4) a-o-xy	581.1 (219.3)a-n-x	2.2 (0.8) b-n-y	2280.7 (386.6)a-n-x	372.9 (150.8)a-n-y	0.6 (0.1) b-o-y	586.0 (86.6) a-o-x	84.4 (10.7) bc-n-y	0.3 (0.1) b-o-y
Copepoda nauplii									
Period 1	399.2 (65.7) a-o-x	889.1 (434.4)a-n-x	15.6 (10.9) a-n-x	146.0 (56.1) b-o-x	964.0 (541.0)a b-n-x	10.1 (3.2) a-n-x	1339.6 (277.6) b-n-x	277.6 (56.7) b-n-y	29.1 (5.4) a-n-y
Period 2	48.0 (11.1) b-o-x	45.9 (7.8) a-o-x	30.8 (13.3) a-n-x	388.0 (121.1) b-o-y	2184.3 (710.0)a-n-x	1.2 (0.3) b-o-y	1442.5 (283.6) b-n-x	1381.4 (116.2) a-no-x	6.7 (1.2) b-no-y
Period 3	23.6 (8.5) b-o-x	25.3 (5.2) a-o-x	2.3 (0.6) a-n-y	988.7 (233.0) b-n-x	41.1 (24.0) b-o-y	0.6 (0.3) b-o-y	96.4 (27.4) c-o-y	423.6 (152.7) b-n-x	0.6 (0.2) b-o-y
Period 4	710.0 (168.5)a-p-x	690.3 (296.4)a-n-xy	1.7 (1.1) a-n-y	4765.4 (353.5) a-n-x	787.6 (300.1)a b-n-y	0.1 (0.1) b-n-y	2562.5 (283.3)a-o-x	550.3 (91.5) b-n-y	0.1 (0.1) b-n-y

Table 2-4. Continued.

		1997			1998			1999	
Taxon/Period	EIS	CB	MC	EIS	CB	MC	EIS	CB	MC
Daphnia spp.									
Period 1	0.8 (0.2) b-n-x	0.3 (0.2) a-n-y	0.0 (0.0) b-n-y	0.5 (0.2) b-n-x	0.9 (0.6) a-n-x	0.0 (0.0) a-n-x	0.9 (0.4) b-n-x	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x
Period 2	2.1 (0.7) b-o-x	1.7 (0.7) a-n-xy	0.1 (0 1) ab-o-y	0.2 (0.1) b-o-x	76.6 (49.9) a-n-x	0.1 (0.1) a-o-x	16.0 (3.8) a-n-x	4.7 (2.5) a-n-y	0.3 (0.1) b-n-y
Period 3	1.6 (0.7) b-o-x	2.6 (0.3) a-n-x	1.1 (0.5) a-n-x	36.3 (12.4) b-n-x	0.6 (0.3) a-n-y	0.3 (0.1) a-n-y	6.4 (2.1) ab-o-x	1.9 (1.2) a-n-xy	0.0 (0 0) b-n-y
Period 4	25.6 (11.2) a-o-x	33.6 (18.3) a-o-x	0.1 (0.1) ab-n-x	431.4 (42.7) a-n-x	59.9 (39.9) a-n-y	0.1 (0.1) a-n-y	14.6 (3.1) a-o-x	0.0 (0.0) a-n-y	0.0 (0.0) b-n-y
Bosmina spp.									
Period 1	0.5 (0.2) b-n-x	0.7 (0.3) b-n-x	0.0 (0.0) b-n-x	0.7 (0.3) b-n-x	9.6 (9.2) a-n-x	0.3 (0.1) a-n-x	1.7 (0.9) b-n-x	0.1 (0.1) b-n-x	0.1 (0.1) a-n-x
Period 2	0.6 (0.2) b-o-x	0.6 (0.3) b-n-x	0.3 (0.2) b-n-x	1.5 (0.6) b-o-x	877.9 (785.2)a-n-x	0.3 (0.1) a-n-x	14.5 (1.3) a-n-x	4.2 (1.6) b-n-y	0.3 (0.2) a-n-y
Period 3	4.5 (1.0) ab-o-x	4.0 (1.0) ab-o-x	5.3 (2.4) a-n-x	29.3 (8.2) b-n-x	0.7 (0.5) a-o-y	0.0 (0.0) a-o-y	8.3 (4.0) ab-o-xy	23.1 (7.8) b-n-x	0.5 (0.1) a-no-y
Period 4	10.7 (3.2) a-o-x	52.4 (26.0) a-o-x	0.3 (0.2) b-n-x	7006.9 (691.2) a-n-x	2.9 (2.1) a-o-y	0.1 (0.1) a-n-y	0.7 (0.5) b-o-y	215.4 (47.0) a-n-x	0.8 (0.4) a-n-y
Other Cladocera									
Period 1	0.2 (0.2) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.2 (0.1) b-o-x	0.5 (0.3) b-n-x	0.1 (0.1) a-n-x	0.3 (0.3) b-n-x	0.1 (0.1) b-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) b-n-x	7.1 (6.3) b-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) b-o-x	0.0 (0.0) b-n-x	0.0 (0.0) a-o-x	9.6 (4.1) b-n-y	87.4 (62.9) b-n-x	0.1 (0.1) a-n-x
Period 4	0.0 (0.0) a-o-x	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	35.5 (7.4) a-n-xy	368.9 (168.3)a-n-x	0.0 (0.0) a-n-y	0.4 (0.4) b-n-xy	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x

summer periods. During period 1 of my study, backwater adult Copepoda densities ranged from 31 to 165 individuals/L and nauplii densities ranged up to 1,340 individuals/L (Table 2-4). A notable observation was the difference in zooplankton density during periods 3 and 4 among years. In 1997, when water levels were well above average, considerable flushing of backwater habitats occurred and appeared to result in a significant decline in zooplankton abundance in the backwaters and a significant increase in zooplankton density in the channel (Table 2-4), suggesting large-scale transport of plankton out of the backwater habitats. It is possible, however, that the significant declines in density were merely a dilution of available zooplankton in the increased water volume during the designated periods. The evidence collected during 1998 and 1999 would suggest that removal of the zooplankton was more probable in 1997 because during periods 2 and 3, zooplankton densities actually increased, even though water levels also increased (Table 2-4).

After the flood pulse had passed each year and the backwater habitats stabilized somewhat, statistically greater densities of zooplankton, especially densities of phytoplanktivorous zooplankton such as *Daphnia* spp., were observed. Phytoplankton production was higher during this period, as was indicated by the increases in chlorophyll-*a* and DO concentrations and algal turbidity. During most sample periods, the density of zooplankton in the backwater habitats was statistically greater than those found in the main channel. Regardless of sample period, EIS and the CB appeared to both be highly productive zoo- and phytoplankton habitats. Zooplankton densities in the backwaters and Missouri River greatly exceeded the densities reported for Lake

Sakakawea (Power and Owen 1984), the Ohio River (Thorp et al. 1994), and the Missouri River segment below Garrison Dam (Mizzi 1994; Speas 1995), but were low in comparison to the zooplankton production reported by Persons (1979) for constructed floodplain ponds in the lower Missouri River basin.

The discharge of zooplankton from Fort Peck reservoir may have contributed to the channel zooplankton densities and composition. Hynes (1970) and Repsys and Rogers (1982) both found that large proportions of zooplankton originating in reservoirs can still be found as far as 650 km downstream of the impoundment. Mohgraby (1977), however, noted that due to the mechanical damage caused to reservoir-released zooplankton, especially in a turbid river system, survival is poor and the released plankters are depleted from the system at a high rate. During period 1 of 1998 and 1999, backwater zooplankton contributions to the channel were likely limited due to nearly absent connectivity. Of interest, though, is that during this period, significantly higher densities of Copepoda were detected in the Missouri River channel. Missouri River flow records (USGS 1999) indicated that during this period of 1998 and 1999, releases from Fort Peck were higher than they were during other periods possibly in an effort to lower water levels in the reservoir in preparation for mountain snow melt. In 1997, Fort Peck releases were lower during period 1 than they were in 1998 and 1999. The lower releases were likely an effort to retain as much water as possible in the upper basin and allow depletion of lower reservoir reserves in anticipation of a record water year primarily entering the Missouri River from the Yellowstone River below Fort Peck. The point of this observation is that zooplankton densities were lower in 1997 during period 1, possibly supporting the contention that some zooplankton found in the study site originated from Fort Peck Reservoir in Montana.

Zooplankton lengths were recorded for the three most numerically abundant taxa in the data base (i.e., cyclopoid Copepoda [excluding nauplii], *Bosmina* spp., and *Daphnia* spp.). Although the data were analyzed similarly to zooplankton density, no statistically significant observations were detected; therefore, the zooplankton length data were visually assessed in attempt to identify any notable trends. Overall, the mean zooplankton lengths were higher in 1998 than they were in 1997 and 1999; however, the mean lengths in period 4 of 1998 exhibited the largest decline from the previous period. As will be discussed later, the 1998 age-0 fish community, most of which are zooplanktivorous, were numerically greater in abundance in 1998 than they were in the other years. Mean lengths for *Daphnia* spp. and *Bosmina* spp. were notably lower during periods 3 and 4 of 1997, whereas cyclopoid Copepoda lengths tended to increase (Figure 2-7). Kennedy (1979) suggested that large-bodied Cladocera were transported at a greater rate than smaller individuals from a backwater during a flushing event than other zooplankton with greater mobility. Therefore, the high flows of 1997 may have impacted Cladocera size structure during periods 3 and 4.

There were only four taxa present in the benthos samples in numerically sufficient densities to facilitate analyses and discussion; these were Oligochaeta (aquatic earthworms), Ceratapogonidae (biting midges), Chironomidae (midges), and Trichoptera (caddisflies). Chironomidae and Oligochaeta were the largest and most consistent components of the benthic macroinvertebrate community (Table 2-5). As will be

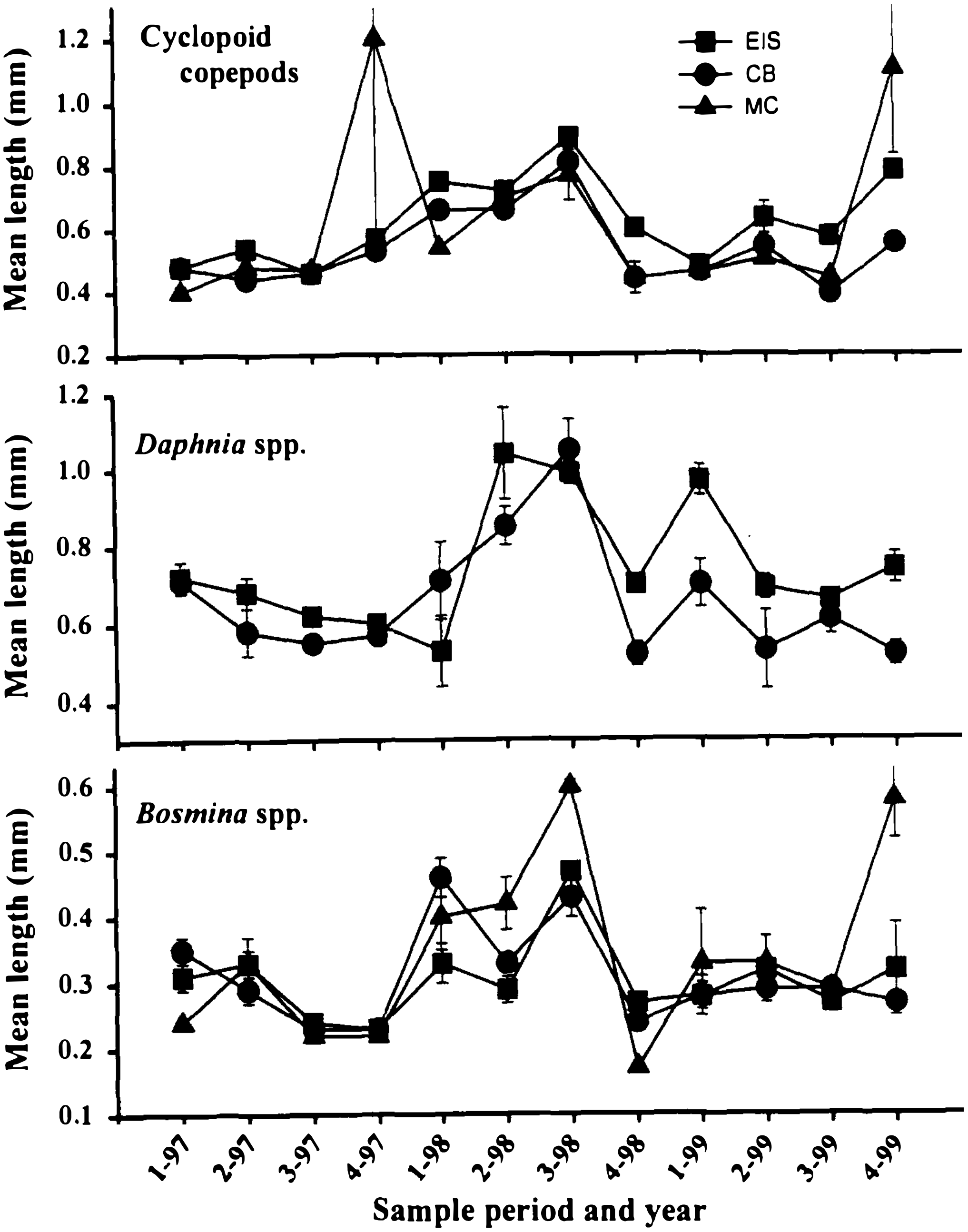

Figure 2-7. Mean length (mm) of cyclpoid copepods, *Daphnia* spp., and *Bosmina* spp. collected in Erickson Island Slough (EIS), the confluence backwater (CB), and the Missouri River channel (MC) during four sample periods and three years. The sample periods included late April (1), mid- to late May (2), late June and early July (3), and early September (4) from 1997 to 1999. One standard error is represented by the vertical bars.

Table 2-5. Summary of benthic macroinvertebrate densities in two Missouri River backwaters in North Dakota [Erickson Island Slough (EIS) and the confluence backwater (CB)] during late April (Period 1), mid-May (Period 2), late June and early July (Period 3), and September (Period 4) of 1997-1999. For each period, year, and backwater, the estimated density (number/m^2) and the standard error (in parentheses) are presented. All statistical analyses for the benthic invertebrate data revealed the absence of any significant differences among the means. Therefore, no statistical comparison information is included in the table.

		1997		1998		1999	
Taxon	Period	EIS	CB	EIS	CB	EIS	CB
Oligochaeta (aquatic earthworms)							
	Period 1	48.7 (19.7)	97.9 (25.6)	7.1 (3.5)	84.0 (26.5)	294.1 (138.7)	281.5 (151.3)
	Period 2	76.9 (27.3)	97.9 (39.9)	76.9 (33.2)	13.9 (8.8)	196.2 (94.5)	49.2 (27.3)
	Period 3	34.9 (16.8)	34.9 (12.9)	63.0 (40.2)	7.1 (7.1)	113.4 (88.2)	49.2 (27.3)
	Period 4	7.1 (7.1)	7.1 (7.1)	13.9 (13.9)	42.0 (21.4)	118 9 (41.2)	336.1 (109.2)
Ostracoda (seed shrimp)							
	Period 1	117.6 (64.7)	84.0 (28.6)	91.2 (44.1)	21.0 (21.0)	0.0 (0.0)	413.0 (7.1)
	Period 2	48.7 (31.5)	0.0 (0.0)	97.9 (45.4)	49.2 (22.7)	560.1 (218.5)	344.5 (205.9)
	Period 3	63.0 (42.9)	0.0 (0.0)	139.9 (109.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	Period 4	21.3 (21.3)	0.0 (0.0)	265.9 (93 7)	21.0 (14.3)	0.0 (0.0)	0.0 (0.0)
Ceratapogonidae (biting midges)							
	Period 1	48.7 (19.7)	55.9 (20.8)	7.1 (7.1)	13.9 (13.9)	7.1 (7.1)	7.1 (7.1)
	Period 2	34.9 (22.7)	7.1 (7.1)	91.2 (25.2)	13.9 (8.8)	55.6 (25.6)	42.0 (26.5)
	Period 3	55.9 (17.6)	7.1 (7.1)	42.0 (29.4)	21.0 (14.3)	21.3 (14.3)	0.0 (0.0)
	Period 4	21.3 (21.3)	7.1 (7.1)	76.9 (41.2)	97.9 (67.2)	0.0 (0.0)	0.0 (0.0)
Chironomidae (midges)							
	Period 1	413.0 (105.0)	595.4 (130.7)	287.0 (68.9)	413.0 (105.9)	1,925.6 (239.1)	323.5 (172.3)
	Period 2	504.2 (79.8)	147.1 (31.9)	455.0 (167.6)	202.9 (70.2)	798.3 (388.7)	651.3 (231.1)
	Period 3	434.0 (121.8)	147.1 (45.4)	819.3 (163.9)	680.7 (58.8)	497.1 (338.2)	266.0 (92.8)
	Period 4	223.9 (74.8)	63.0 (21.0)	791.2 (236.6)	1,756.3 (611.8)	743.7 (228.9)	420.2 (159.7)
Trichoptera (caddisflies)							
	Period 1	28.2 (13.9)	84.0 (36.1)	48.7 (3.5)	42.0 (21.8)	0.0 (0.0)	0.0 (0.0)
	Period 2	13.9 (8.8)	7.1 (7.1)	42.0 (21.4)	7.1 (7.1)	0.0 (0.0)	0.0 (0.0)
	Period 3	7.1 (7.1)	7.1 (7.1)	0.0 (0.0)	21.0 (9.2)	0.0 (0.0)	0.0 (0.0)
	Period 4	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	21.0 (14.3)	0.0 (0.0)	0.0 (0.0)

discussed in Chapter 6, the contributions of Chironomidae to the backwater food webs are substantial. Chironomidae and Oligochaeta were numerically less abundant in 1997 and the early periods of 1998, but were more abundant late in 1998 and during 1999 (Figure 2-8). These same two taxa were also noted by (Mizzi 1994) as the numerically dominant benthic invertebrates in the North Dakota Missouri River stretch and her reported densities were similar to those I documented. The absence of gill-breathing and filter-feeding benthos is not surprising, as Waters (1995) noted that sedimented habitats generally to do not support invertebrates that are susceptible to physical damage caused by colloidal turbidity or smothering. The benthic invertebrate analyses resulted in no significant differences among years, periods, or backwaters; however, due to low sample size and high variance, the power of this assessment was low, making the lack of significant observations a moot point.

Other large and active components of the backwater macroinvertebrate community are those organisms that inhabit the upper water columns and utilize substrates such as periphyton and macrophyte stems as their primary habitat. Limnetic invertebrates, sampled with the light traps, indicated the presence of 14 taxonomic groups using the open water habitats, including typically benthic organisms such as Chironomidae, Trichoptera, Plecoptera, and Ephemeroptera. There were numerous statistically significant different observations among sample periods, years, and sites; however, few patterns emerged. A few taxa, such as the Hydracarina, Hemiptera, and Chaoboridae, appeared to be coupled with the hydrograph and may be flushed out of the backwaters during high flow periods (Table 2-6). These taxa appeared to be greatly

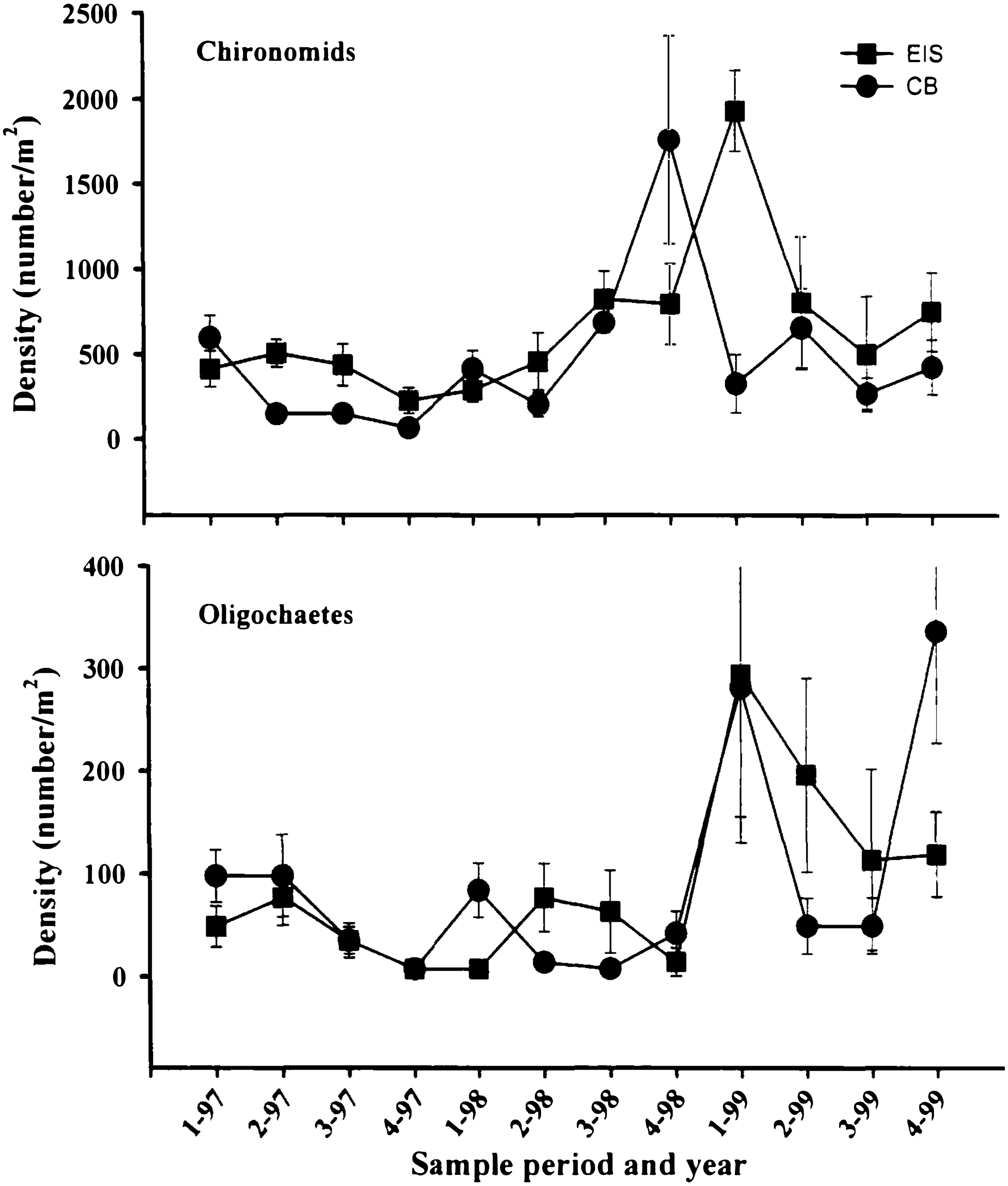

Figure 2-8. Mean density (number/m^2) of chironomids and oligochaetes in Erickson Island Slough (EIS) and the confluence backwater (CB) in North Dakota during four sample periods and three years. The sample periods included late April (1), mid- to late May (2), late June and early July (3), and early September (4) from 1997-1999. One standard error is represented by the vertical bars.

Table 2-6. Summary of macroinvertebrates captured with light traps in two Missouri River backwaters in North Dakota [Erickson Island Slough (EIS) and the confluence backwater (CB)] in late April (Period 1), mid-May (Period 2), late June and early July (Period 3), and September (Period 4) of 1997-1999. For each period, year, and backwater, the catch per unit effort (number/trap night), standard error (in parentheses), and results from statistical tests are noted. For each species, the letters a-d designate the among-period comparisons within each year and backwater. The letters n-p denote the among-year comparisons within each backwater and period. The letters x-y represent the pairwise comparison between the two backwaters within each year and period. Cells with the same letters were not statistically different (P>0.05).

		1997		1998		1999	
Taxon	Period	EIS	CB	EIS	CB	EIS	CB
Amphipoda (scuds)							
	Period 1	9.2 (4.3) a-n-x	2.1 (0.5) b-p-x	5.1 (1.8) ab-n-y	564.7 (105.8) a-n-x	10.7 (3.1) a-n-x	8.2 (2.2) a-o-x
	Period 2	28.6 (15.7) a-n-x	1.3 (0.7) b-o-y	28.0 (12.2) a-n-y	151.4 (76.1) b-n-x	1.6 (1.1) b-o-x	0.1 (0.1) b-o-x
	Period 3	36 7 (16.9) a-n-x	1.3 (0.8) b-n-y	3.5 (2.1) b-no-x	2.7 (1.1) c-n-x	1.8 (1.4) b-o-x	0.0 (0.0) b-o-x
	Period 4	1.1 (0.7) a-n-y	18.8 (6.2) a-n-x	0.3 (0.2) b-n-x	0.3 (0.2) c-o-x	0.0 (0.0) b-n-x	0.0 (0.0) b-o-x
Hirudinea (leeches)							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.7 (0.4) a-n-x	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.4 (0.3) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.4 (0.2) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Hydracarina (water mites)							
	Period 1	10.1 (4.9) a-n-x	0.4 (0.2) b-p-y	25.2 (13.8) a-n-y	3,085.7 (856.6) a-n-x	63.7 (30.4) a-n-x	29.5 (10.6) a-o-x
	Period 2	5.3 (3.4) a-no-x	0.0 (0.0) b-p-y	16.2 (5.6) a-n-y	193.2 (78.4) b-n-x	3.4 (1.3) a-o-x	2.1 (0.5) b-o-x
	Period 3	8.5 (4.4) a-n-x	0.6 (0.4) b-n-y	5.0 (1.2) a-n-x	1.6 (1.2) c-n-y	14.3 (5.2) a-n-x	4.8 (2.5) b-n-y
	Period 4	30.4 (14.1) a-n-x	93.5 (65.1) a-o-x	8.2 (2.7) a-n-y	242.5 (78.6) b-n-x	6.1 (3.2) a-n-y	155.9 (71.4) a-no-x
Coleoptera (beetles)							
	Period 1	0.1 (0.1) a-n-x	0.0 (0.0) b-o-x	0.3 (0.2) b-n-y	27.1 (13.1) a-n-x	0.2 (0.1) ab-n-x	1.9 (1.1) a-o-x
	Period 2	0.6 (0.3) a-o-x	0.3 (0.2) b-o-x	6.7 (3.4) a-n-x	75.9 (48.5) a-n-x	0.4 (0.3) ab-o-x	0.7 (0.5) a-o-x

Table 2-6. Continued.

		1997		1998		1999	
Taxon	Period	EIS	CB	EIS	CB	EIS	CB
	Period 3	0.6 (0.3) a-n-y	2.3 (0.7) a-n-x	0.5 (0.3) b-n-y	5.8 (2.8) ab-n-x	1.0 (0.4) a-n-x	1.5 (0.4) a-n-x
	Period 4	0.2 (0.1) a-n-x	0.1 (0.1) b-n-x	0.6 (0.6) b-n-x	0.6 (0.3) b-n-x	0.0 (0.0) b-n-x	0.2 (0.2) a-n-x
Anostraca (fairy shrimp)							
	Period 1	0.0 (0.0) a-n-y	3.7 (0.9) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	90.5 (67.8) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
	Period 3	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.5 (0.4) b-n-x	0.2 (0.1) a-n-x
	Period 4	0.0 (0.0) a-o-x	0.0 (0.0) b-n-x	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	2.1 (0.8) a-n-x	0.5 (0.3) a-n-y
Chaoboridae (phantom midges)							
	Period 1	4.6 (2.1) b-n-x	0.0 (0.0) b-o-y	4.3 (2.2) b-n-x	0.0 (0.0) c-o-x	2.8 (1.5) a-n-x	22.6 (17.6) b-n-x
	Period 2	1.0 (0.5) b-no-x	0.0 (0.0) b-o-y	0.0 (0.0) b-o-y	22.7 (5.8) bc-n-x	2.4 (0.8) a-n-y	46.6 (34.9) ab-n-x
	Period 3	79.7 (37.3) a-n-x	0.0 (0.0) b-o-y	6.3 (4.9) b-o-x	4785.8 (3574.8) b-n-x	18.1 (6.8) a-no-x	13.2 (5.0) ab-no-x
	Period 4	3.4 (1.9) b-o-y	151.7 (65.0) a-o-x	64.1 (17.8) a-n-y	2524.2 (1200.0) a-n-x	8.1 (7.0) a-o-y	122.6 (63.0) a-o-x
Chironomidae (midges)							
	Period 1	5.1 (2.2) ab-o-x	0.7 (0.3) a-o-x	19.4 (8.4) a-o-x	4.6 (3.1) a-o-y	46.8 (11.0) a-n-x	29.5 (5.7) a-n-x
	Period 2	0.6 (0.4) ab-o-x	0.1 (0.1) a-o-x	3.9 (2.3) a-no-y	84.8 (55.7) a-n-x	36.1 (19.3) ab-n-x	67.9 (27.4) a-n-x
	Period 3	37.9 (23.6) a-n-x	1.6 (0.6) a-o-x	21.9 (16.8) a-n-x	4.7 (2.6) a-o-x	92.4 (78.3) ab-n-x	27.9 (5.8) a-n-x
	Period 4	0.5 (0.4) b-o-x	2.3 (1.6) a-o-x	17.7 (6.0) a-n-x	31.2 (16.4) a-n-x	8.9 (6.2) b-n-x	8.8 (3.6) b-no-x
Diptera (true flies)							
	Period 1	3.4 (1.1) a-o-x	11.0 (4.0) a-o-x	12.0 (3.8) a-n-y	300.1 (202.5) a-n-x	0.0 (0.0) b-p-x	0.0 (0.0) d-p-x
	Period 2	1.3 (0.4) a-o-x	0.2 (0.2) b-p-y	7.1 (1.6) a-n-x	42.1 (23.2) a-n-x	1.2 (0.4) b-o-x	4.2 (1.4) c-o-x

Table 2-6. Continued.

		1997		1998		1999	
Taxon	Period	EIS	CB	EIS	CB	EIS	CB
	Period 3	14.2 (7.8) a-n-x	8.7 (5.0) ab-n-x	6.5 (0.7) a-n-x	2.884.5 (2176.0) a-n-x	26.9 (9.2) a-n-y	74.1 (24.0) a-n-x
	Period 4	2.7 (1.2) a-o-y	54.4 (24.0) a-n-x	12.3 (2.9) a-n-x	64.4 (21.6) a-n-x	12.2 (3.8) a-n-x	24.9 (6.1) b-n-x
Ephemeroptera (mayflies)							
	Period 1	1.4 (0.4) b-n-y	7.1 (3.0) a-n-x	0.9 (0.3) ab-no-x	6.7 (3.9) a-n-x	0.1 (0.1) b-o-y	4.0 (1.3) a-n-x
	Period 2	0.1 (0.1) b-n-x	0.2 (0.2) b-n-x	0.1 (0.1) ab-n-x	17.5 (13.4) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x
	Period 3	36.4 (18.1) a-n-x	11.6 (7.1) a-n-x	4.3 (2.4) a-o-x	0.1 (0.1) a-o-x	7.7 (4.8) a-no-x	1.5 (0.6) ab-no-x
	Period 4	0.0 (0.0) b-o-y	2.3 (1.0) ab-n-x	0.0 (0.0) b-o-x	0.1 (0.1) a-o-x	1.9 (0.8) ab-n-x	0.0 (0.0) b-o-y
Hemiptera (corixids)							
	Period 1	150.8 (59.5) ab-n-x	3.1 (0.9) b-p-y	174.2 (72.7) a-n-y	483.6 (115.1) ab-n-x	325.9 (102.1) ab-n-x	72.7 (13.4) b-o-x
	Period 2	54.9 (20.2) b-o-x	1.2 (0.8) b-p-y	270.4 (59.3) a-n-y	717.4 (232.5) a-n-x	75.2 (15.4) b-o-x	136.6 (49.1) b-o-x
	Period 3	1,005.9 (394.1) a-n-x	45.3 (23.8) a-o-y	225.8 (42.9) a-n-x	266.3 (83.6) b-no-x	709.2 (281.3) a-n-x	1,437.5 (451.9) a-n-x
	Period 4	212.6 (94.7) a-n-x	386.1 (165.3) a-o-x	152.0 (26.8) a-n-y	349.8 (59.9) ab-o-x	215.9 (43.2) ab-n-y	1,359.2 (334.5) a-n-x
Hymenoptera (bees and ants)							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 2	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.2 (0.1) a-n-x	0.6 (0.3) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.8 (0.6) a-n-x	0.0 (0.0) a-n-x	0.5 (0.5) a-n-x	0.5 (0.3) a-n-x	1.0 (0.7) a-n-x	0.3 (0.2) a-n-x
Odonata (dragonflies)							
	Period 1	0.3 (0.2) a-n-x	02. (0.1) a-n-x	0.1 (0.1) a-n-x	0.8 (0.4) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 2	0.0 (0.0) a-o-x	0.3 (0.2) a-no-x	0.0 (0.0) a-o-y	2.7 (1.8) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-o-x

Table 2-6. Continued.

		1997		1998		1999	
Taxon	Period	EIS	CB	EIS	CB	EIS	CB
	Period 3	0.0 (0.0) a-n-x	0.7 (0.5) a-n-x	0.4 (0.3) a-n-x	0.0 (0.0) a-n-x	0.3 (0.2) a-n-x	0.4 (0.2) a-n-x
	Period 4	0.3 (0.2) a-n-x	0.8 (0.5) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Plecoptera (stoneflies)							
	Period 1	0.0 (0.0) a-n-y	0.7 (0.3) a-no-x	0.2 (0.1) a-n-y	7.8 (4.8) a-n-x	0.1 (0.1) b-n-x	0.1 (0.1) a-o-x
	Period 2	0.2 (0.1) a-n-x	0.0 (0.0) a-o-x	0.4 (0.2) a-n-y	1.7 (0.6) a-n-x	0.0 (0.0) b-n-x	0.1 (0.1) a-o-x
	Period 3	1.0 (0.7) a-n-x	0.4 (0.2) a-n-x	2.6 (2.2) a-n-x	0.0 (0.0) b-n-x	1.0 (0.4) a-n-x	0.0 (0.0) a-n-y
	Period 4	0.1 (0 1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Trichoptera (caddisflies)							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.4 (0.3) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	1.4 (1.1) a-n-x	0.0 (0.0) a-n-x	1.5 (1.5) a-n-x
	Period 3	0.4 (0.3) a-n-x	0.3 (0.2) a-o-x	0.7 (0.3) a-n-x	12.6 (8.7) a-n-x	0.7 (0.4) a-n-x	0.5 (0.3) a-o-x
	Period 4	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.6 (0.5) a-n-x	0.3 (0.2) b-n-x	0.3 (0.3) a-n-x	0.0 (0.0) a-n-x

affected by the 1997 high flows, as their relative abundance was significantly lower in 1997 than in 1998 and 1999.

The production of limnetic macroinvertebrates appears to be an important function of the backwater habitats. Olmsted (1981) noted that numerous macroinvertebrates flushed out of backwater habitats into the main river channel during connection periods with the Broad River in South Carolina. Eckblad et al. (1984) also noted that backwater contributions of invertebrates can increase channel densities by as much as 800% below backwater connection zones. Cellot and Bournard (1987) also noted that even moderate changes in backwater flushing rates (20-40%) can increase invertebrate drift by almost 40,000%. Numerically, the Hemiptera appeared to be the predominant limnetic macroinvertebrate. As I will discuss in Chapter 5, the Hemiptera contributed in several important manners to the overall backwater community. Although a rather minute observation, of interest was the relative abundance of Anostraca (fairy shrimps) in several disjunct wetlands in the CB site during period 1 of 1997 and 1999. With the exception of Hydracarina, these small isolated wetlands did not exhibit other significant increases in macroinvertebrate densities. Sedell et al. (1990) noted that when floodplains are uncoupled from the channel, some biotic interactions (e.g., predation and competition) are terminated providing refuge sites for certain species.

Fishes

During the three years of this study, more than 80,000 fish representing 45 species were captured during one or more periods and years. Appendix 2 provides an overview of presence-absence information for each species by period and sample location. The most numerically abundant native fishes were the black bullhead *Ameiurus melas* and *Pomoxis* spp., smallmouth buffalo *Ictiobus bubalus*, goldeye *Hiodon alosoides*, and river carpsucker *Carpiodes carpio*. Several species not indigenous to the area were also present, including common carp *Cyprinus carpio*, yellow bullhead *Ameiurus natalis*, and tadpole madtom *Noturus gyrinus*; however, with the exception of common carp, constituted a small fraction of the total catch. Several important gamefish species, such as northern pike *Esox lucius*, sauger *Stizostedion canadense*, and channel catfish *Ictalurus punctatus* also utilized the backwater habitats.

The production potential of the backwater habitats appeared to be quite high. Antipa 1928, Holcick and Bastl 1977, and Copp et al. 1994 all noted that the greatest annual fish productions occur during years when there is an extensive connection between the river and the floodplain. Scott and Nielsen (1989) and Killgore and Baker (1996) found that many fishes undergo regular migrations into inundated floodplain habitats to fulfill certain life history stage requirements, including spawning, accessing nursery habitat, foraging, and refuge. Leitman et al. (1991) also noted, however, that some species tend to be more residential in floodplain wetlands, etching out a niche in these sometimes hostile environments. To better understand the use of backwater habitats by native fishes in the upper Missouri River, the relationships that I observed among the fish communities within the backwater habitats are summarized and the assemblage construction is discussed.

A large proportion of backwater research has focussed on the importance of floodplain habitats as nursery and rearing areas for larval fishes (e.g., Wazenbock and Scheimer 1989). In my assessment, three species were observed in the backwaters during period 1, including burbot *Lota lota*, northern pike and *Stizostedion* spp. In 1997 and to a significantly lesser extent in 1999, burbot larvae were sampled in EIS and the CB (Table 2-7). This is noteworthy because larval burbot are rarely sampled in lotic systems and some riverine burbot populations are in a serious state of decline (Paragamian et al. 1998). Burbot spawn from January through March and prefer running waters over gravel or rubble substrates (Baxter and Stone 1995). The presence of relatively large numbers of larval burbot and *Stizostedion* spp., followed by the subsequent presence of juveniles in EIS during 1997, may be an indication that sufficient connectivity is needed early in the hydrograph cycle to allow these early channel-spawned larvae to drift into backwater habitats. An extended discussion of burbot early life history is in Chapter 4. A single northern pike larvae was collected, even though the species is known to spawn in backwater habitats and research has long indicated that floodplain backwaters are important to the species (Franklin and Smith 1963). Given the sedentary early life history of northern pike, the larvae are unlikely to be captured by either the light traps or the surface trawls.

During period 2, six larval taxa were sampled with one or both of the larval sampling gears [i.e., light traps (Table 2-7) and surface trawls (Table 2-8)], including common carp, yellow perch *Perca flavescens*, *Stizostedion* spp., rainbow smelt *Osmerus mordax*, lake herring *Coregonus artedi*, and white sucker *Catostomus commersoni*. Given the presence of adult yellow perch and common carp in the backwaters and their

Table 2-7. Summary of larval fishes (<2-cm total length) captured with light traps in two Missouri River backwaters in North Dakota [Erickson Island Slough (EIS) and the confluence backwater (CB)] in late April (Period 1), mid-May (Period 2), late June and early July (Period 3), and September (Period 4) of 1997-1999. Fish species abbreviations are defined in Appendix 1. For each period, year, and backwater, the catch per unit effort (number/light trap night), standard error (in parentheses), and results from statistical tests are noted. For each species, the letters a-d designate the among-period comparisons within each year and backwater. The letters n-p denote the among-year comparisons within each backwater and period. The letters x-y represent the pairwise comparison between the two backwaters within each year and period. Cells with the same letters were not statistically different (P>0.05).

		1997		1998		1999	
Species	Period	EIS	CB	EIS	CB	EIS	CB
BRS							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	1.0 (1.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0 0) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
BUF							
	Period 1	0.0 (0.0) b-n-x	0.0 (0 0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
	Period 2	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
	Period 3	3.6 (1.4) a-o-y	10.0 (3.7) a-n-x	75.5 (20.94) a-n-x	2.2 (0.6) a-n-y	6.4 (2.5) a-o-y	37.0 (8.8) a-n-x
	Period 4	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
BUR							
	Period 1	0.6 (0.4) a-n-x	0.4 (0.4) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) a-o-x	0.1 (0.1) a-o-x	0.0 (0.0) a-o-x
	Period 2	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
COC							
	Period 1	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
	Period 2	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.5 (0.4) b-n-x
	Period 3	0.9 (0.3) a-o-x	1.0 (0.5) a-n-x	276.8 (103.6) a-n-x	6.6 (3.0) a-n-y	1.1 (0.5) a-o-y	4.8 (2.9) a-n-x

Table 2-7. Continued.

		1997		1998		1999	
Species	Period	EIS	CB	EIS	CB	EIS	CB
	Period 4	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
EMS							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x
	Period 3	0.4 (0.4) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	9.8 (7.2) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) a-o-x
FHM							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
LAH							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.7 (0.6) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
LEP							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x

Table 2-7. Continued.

		1997		1998		1999	
Species	Period	EIS	CB	EIS	CB	EIS	CB
NOP							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
POM							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.2 (0.2) a-no-x	0.0 (0.0) a-n-x	1.6 (0.7) a-n-x	0.0 (0 0) a-n-y
	Period 4	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
RIC							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0 0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0 0) b-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
	Period 3	0.0 (0.0) a-p-y	0.9 (0.4) b-n-x	27.6 (7.5) b-n-x	0.3 (0.3) b-n-y	5.1 (1.9) b-o-x	0.6 (0.3) b-n-y
	Period 4	0.0 (0.0) b-n-x	0.2 (0.1) ab-n-x	0.0 (0.0) b-n-x	0.2 (0.2) ab-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
SHR							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
SPS							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x

Table 2-7. Continued.

		1997		1998		1999	
Species	Period	EIS	CB	EIS	CB	EIS	CB
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.3 (0.3) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
STZ							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.3) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.5 (0.2) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
WHS							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) a-n-x	0.1 (0.1) ab-n-x
	Period 3	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	1.9 (0.9) a-n-x	0.5 (0.4) a-n-y	0.4 (0.4) a-no-x	1.0 (0.5) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x
YEP							
	Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.8 (0.8) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x

Table 2-8. Summary of larval fishes (<2-cm total length) captured with a surface trawl in two Missouri River backwaters in North Dakota [Erickson Island Slough (EIS) and the confluence backwater (CB)] in May (Period 2) and late June and early July (Period 3) of 1997-1999. Fish species abbreviations are defined in Appendix 1. For each period, year, and backwater, the catch per unit effort (number/1,000 L), standard error (in parentheses), and results from statistical tests are noted. For each species, the letters a-d designate the among-period comparisons within each year and backwater. The letters n-p denote among-year comparisons within each backwater and period. The letters x-y represent the pairwise comparison between the two backwaters within each year and period. Cells with similar letters were not statistically different (P>0.05).

		1997		1998		1999	
Species	Period	EIS	CB	EIS	CB	EIS	CB
BSR							
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-y	0.8 (0.8) a-o-x	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) a-n-y	2.9 (1.9) a-n-x
BUF							
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.4 (0.4) a-n-x	0.0 (0.0) b-n-x
	Period 3	0.0 (0.0) a-o-y	3.3 (2.1) a-o-y	356.0 (118.9) a-n-x	13.3 (4.9) a-n-y	2.2 (0.7) a-o-x	14.7 (10.2) a-n-x
COC							
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	1.4 (1.1) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	25.2 (16.3) a-n-y	98.8 (47.2) a-n-x	0.0 (0.0) a-n-x	0.4 (0.4) a-o-x
GOE							
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.5 (0.5) a-n-x	0.0 (0.0) a-n-x	0.7 (0.5) a-n-x	0.0 (0.0) a-n-x
LAH							
	Period 2	0.0 (0.0) a-n-y	2.7 (1.6) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.8 (0.5) a-n-x	0.0 (0.0) a-o-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
LEP							
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x

Table 2-8. Continued.

		1997		1998		1999	
Species	Period	EIS	CB	EIS	CB	EIS	CB
POM							
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.4 (0.4) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	1.1 (0.8) a-n-x	0.0 (0.0) a-n-x
RBS							
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.6 (0.6) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
RIC							
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-p-x	0.0 (0.0) a-o-x	187.4 (60.2) a-n-x	21.0 (18.1) a-n-y	34.6 (31.8) a-o-x	0.0 (0.0) a-n-y
SHR							
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.3 (0.3) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
STZ							
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.4 (0.4) a-n-x
WHS							
	Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
	Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	1.4 (1.1) a-n-x	0.4 (0.4) a-n-x
YEP							
	Period 2	0.9 (0.9) b-n-x	0.0 (0.0) a-n-x	2.2 (1.2) a-n-x	0.0 (0.0) a-n-y	1.1 (0.8) a-n-x	0.0 (0.0) a-n-y
	Period 3	2.6 (1.3) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) b-o-x	0.0 (0.0) a-n-x	0.0 (0.0) b-o-x	0.0 (0.0) a-n-x

affinity to spawn in lentic waters (McClane 1978), I had anticipated the presence of larvae for both these species. Lake herring, rainbow smelt, and burbot are all large components of the Fort Peck Reservoir fish community (Mullins 1991); therefore, some of the larvae for these species that were observed in the Missouri River backwaters may have been imported with the drift. No adult lake herring or rainbow smelt specimens were documented in the backwaters with any gears during the course of my study. The continued presence of *Stizostedion* spp. implies that an extended process of drift immigration for sauger and walleye *S. vitreum* was continuing and the presence of white sucker larvae suggested the species also uses backwaters as rearing habitat.

Larval fishes were most abundant during period 3. Brook stickleback *Culea inconstans*, *Ictiobus* spp., common carp, emerald shiner *Notropis atherinoides*, fathead minnow *Pimephales promelas*, goldeye, white crappie *Pomoxis annularis*, river carpsucker, shorthead redhorse *Moxostoma macrolepidotum*, walleye, sauger, white sucker, yellow perch, blue sucker, and *Stizostedion* spp., were all sampled with one or both gears during period 3 (Tables 2-7 and 2-8). Of these taxa, *Ictiobus* spp., common carp, and river carpsucker were the most abundant. Wolf et al. (1996) documented that *Catostomus* spp. and *Ictiobus* spp. were the most abundant larvae captured below the Garrison Dam. Sexually mature (ripe) bigmouth buffalo *Ictiobus cyprinellus*, smallmouth buffalo, and river carpsucker were captured and observed spawning in the backwaters during each sample period. Ripe river carpsuckers were found in both backwaters during periods 3 and 4, suggesting that the late spawning season observed by Behmer (1965) was also occurring in my study sites. Other species, such as the emerald shiner and white crappie also appeared to spawn in the backwater habitats. Shorthead redhorse typically spawn in tributary streams (Brown 1971) and their larvae were likely imported from the channel.

Goldeye are believed to spawn in various habitats, but McClane (1978) suggested that they prefer gravel sandbar habitats. A few adult goldeye captured in periods 1 and 2 displayed some spawning characteristics, but the location of spawning was not clear. Few larval goldeye were captured; however large numbers of juveniles were present, suggesting that the species may have migrated into the backwater habitats as juveniles and adults for foraging, rather than for reproduction. Moon et al. (1998) investigated the potential predation of larval fishes by migrating goldeye, but found that insects, especially Coleoptera and Hemiptera were the primary food items targeted. The most noteworthy period 3 observation was the collection of five blue sucker larvae in the CB. These specimens were captured with the surface trawl on the margins of smartweed beds in close proximity to the channel-backwater connection areas. Hand (1999) did not collect blue suckers younger than age 3 in the Yazoo River in Mississippi and the U.S. Fish and Wildlife Service has expressed concern about blue sucker status (Elstad and Werdon 1993).

Relatively few larval fishes were captured with the light traps during period 4. By this period, most larval fishes had transformed into their juvenile forms and could no longer be sampled. The few larvae that were sampled included some apparently late-spawned river carpsucker, white crappie, spottail shiner *Notropis hudsonius*, and shorthead redhorse. Large numbers of emerald shiners were also captured in the light traps during period 4; however, the specimens exceeded 2 cm and not considered larvae.

The bag seining data were highly variable and did not exhibit many significant differences (Table 2-9). The most important documentation from the seining data was the significant differences in CPUE of several cyprinids. Although small flathead chubs (<12-cm TL) were captured in both EIS and the CB, their CPUE was significantly lower than in the main river channel. Although the backwater habitats were not found to be important physical habitats for flathead chubs, the indirect benefits may include prey production, as discussed in Chapter 5. Conversely, the CPUE of emerald shiners, juvenile goldeye, and juvenile river carpsuckers was found to be significantly greater in the backwater habitats. Several fish species were not sampled in the backwaters, but were documented by sandbar seining during one or more sample periods, including shovelnose sturgeon *S. platorynchus*, sturgeon chub, and five sicklefin chubs. The sicklefin chub is another species closely being monitored by the U.S. Fish and Wildlife Service due to its apparent decline in abundance (Grady and Milligan 1998).

The gill-net and trap-net samples indicated significant changes in CPUE of several fish species including, bigmouth buffalo, smallmouth buffalo, river carpsucker, freshwater drum *Aplodinotus grunniens*, goldeye, and emerald shiner across years and periods and between sites (Tables 2-10 and 2-11). Other species, such as adult sauger, adult shortnose gar *Lepisosteus platostomus*, stonecat *Noturus flavus*, juvenile longnose sucker *Catostomus catostomus*, and shorthead redhorse also exhibited periodic migrations into the backwaters for reasons other than reproduction, primarily during periods 2 and 3 when water levels provided sufficient corridors between the river and backwater.

Table 2-9. Summary of fishes captured (species and total length noted) with a bag seine in the Missouri River channel (MC) and two backwaters in North Dakota [Erickson Island Slough (EIS) and the confluence backwater (CB)] in late April (Period 1), mid-May (Period 2), late June and early July (Period 3), and September (Period 4) of 1997-1999. Fish species abbreviations are defined in Appendix 1. For each period, year, and backwater, the catch per unit effort (number/haul), standard error (in parentheses), and statistical results are noted. For each species, the letters a-d designate the among-period comparisons within each year and backwater. The letters n-p denote the among-year comparisons within each backwater and period. The letters x-y represent the pairwise comparison between the two backwaters within each year and period. Cells with the same letters were not statistically different (P>0.05).

	1997			1998			1999		
Taxon/Period	EIS	CB	MC	EIS	CB	MC	EIS	CB	MC
BLB (<15 cm)									
Period 1	1.7 (0.8) a-x	0.8 (0.5) b-x	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
Period 2	1.0 (1.0) a-o-x	0.0 (0.0) b-n-x	NA	7.8 (2.1) a-n-x	NA	0.0 (0.0) a-n-y	0.2 (0.2) a-o-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.5 (0.5) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0 0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-y	3.7 (2.3) a-x	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
BRS (no length designation)									
Period 1	0.0 (0.0) a-x	0.2 (0.2) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0 0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
BUF (<25 cm)									
Period 1	0.0 (0.0) b-x	0.0 (0.0) b-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0 0) a-n
Period 2	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) b-n-x	2.2 (1.4) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	2.5 (0.8) a-n-x	5.5 (2.2) a-n-x	0.0 (0.0) a-n-x
Period 4	2.2 (1.8) a-x	0.5 (0.3) ab-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
BUR (<20 cm)									
Period 1	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n

Table 2-9. Continued.

	1997			1998			1999		
Taxon/Period	EIS	CB	MC	EIS	CB	MC	EIS	CB	MC
CCF (<28 cm)									
Period 1	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.7 (0.4) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-y	0.0 (0.0) a-n-y	0.5 (0.3) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-y	0.0 (0.0) a-y	0.3 (0.3) a-n-x	NA	NA	0.2 (0.2) a-n	NA	NA	0.7 (0.5) a-n
COC (<28 cm)									
Period 1	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.2 (0.2) a-n-y	1.5 (0.8) a-n-x	0.0 (0.0) a-n-y
Period 3	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.3) a-n-x	2.0 (2.0) a-n-x
Period 4	0.0 (0.0) a-y	3.7 (2.5) a-x	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
EMS (no length designation)									
Period 1	0.7 (0.7) a-x	0.3 (0.3) a-x	0.0 (0.0) a-n-x	NA	NA	0.2 (0.2) a-n	NA	NA	0.0 (0.0) a-n
Period 2	1.5 (0.7) a-o-x	0.0 (0.0) a-o-x	NA	0.0 (0.0) a-o-x	NA	0.0 (0.0) a-n-x	6.8 (5.9) a-n-x	3.0 (1.0) a-n-xy	0.0 (0.0) a-n-y
Period 3	6.2 (4.0) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) a-o-y	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x	0.3 (0.2) a-no-x	2.8 (0.7) a-no-x	0.5 (0.3) a-n-y	1.2 (0.4) a-n-y
Period 4	5.0 (3.7) a-x	0.3 (0.3) a-y	0.0 (0.0) a-o-y	NA	NA	0.7 (0.5) a-n	NA	NA	0.8 (0.8) a-n
FHM (no length designation)									
Period 1	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.2 (0.2) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	1.0 (0.6) a-n-x
Period 4	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n

Table 2-9. Continued.

	1997			1998			1999		
Taxon/Period	EIS	CB	MC	EIS	CB	MC	EIS	CB	MC
FLC (no length designation)									
Period 1	0.2 (0.2) a-y	0.0 (0.0) a-y	12.3 (3.2) b-n-x	NA	NA	17.2 (5.6) ab-n	NA	NA	18.7 (8.1) c-n
Period 2	0.0 (0.0) a-n-x	0.3 (0.2) a-n-x	NA	0.0 (0.0) a-n-y	NA	7.0 (0.9) b-n-x	0.3 (0.2) a-n-y	0.0 (0.0) a-n-y	12.5 (6.3) c-n-x
Period 3	0.0 (0.0) a-n-y	0.2 (0.2) a-n-y	24.2 (3.1) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) a-n-y	17.8 (3.6) ab-n-x	0.2 (0.2) a-n-y	0.0 (0.0) a-n-y	85.8 (51.3) a-n-x
Period 4	0.0 (0.0) a-y	0.0 (0.0) a-y	29.2 (9.7) a-n-x	NA	NA	25.7 (7.6) a-n	NA	NA	55.8 (22.5) b-n
FRD (<20 cm)									
Period 1	0.0 (0.0) b-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.5 (0.3) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
GOE (<10 cm)									
Period 1	0.0 (0.0) b-x	0.0 (0.0) b-x	0.5 (0.5) a-n-x	NA	NA	0.3 (0.3) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) b-o-x	0.0 (0.0) b-o-x	NA	0.3 (0.3) a-o-x	NA	0.0 (0.0) a-n-x	1.0 (0.3) b-n-x	1.7 (0.7) a-n-x	0.0 (0.0) a-n-y
Period 3	2.7 (1.0) ab-n-x	0.0 (0.0) b-n-y	0.0 (0.0) a-n-y	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	5.8 (3.9) a-n-x	0.0 (0.0) b-n-y	0.0 (0.0) a-n-y
Period 4	6.7 (3.8) a-x	4.5 (1.8) a-x	0.0 (0.0) a-n-y	NA	NA	0.3 (0.2) a-n	NA	NA	0.0 (0.0) a-n
GOS (no length designation)									
Period 1	0.2 (0.2) ab-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.8 (0.7) a-x	0.2 (0.2) a-xy	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n

Table 2-9. Continued.

	1997			1998			1999		
Taxon/Period	EIS	CB	MC	EIS	CB	MC	EIS	CB	MC
HYB (no length designation)									
Period 1	0.3 (0.2) a-x	0.2 (0.2) a-x	1.5 (1.1) a-n-x	NA	NA	0.8 (0.5) a-n	NA	NA	0.3 (0.3) b-n
Period 2	0.3 (0.2) a-n-x	0.8 (0.4) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.3 (0.2) a-n-x	0.3 (0.3) a-n-x	3.0 (1.8) a-n-x	0.3 (0.3) b-n-x
Period 3	1.3 (0.5) a-n-y	0.3 (0.3) a-n-y	4.2 (2.0) a-o-x	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x	1.5 (0.7) a-o-x	1.8 (0.7) a-n-y	0.0 (0.0) a-n-y	21.5 (21.3) a-n-x
Period 4	0.0 (0.0) a-x	1.3 (0.5) a-x	0.5 (0.3) a-n-x	NA	NA	3.0 (2.0) a-n	NA	NA	0.3 (0.2) b-n
LAH (no length designation)									
Period 1	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-x	0.0 (0.0) a-x	0.3 (0.2) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
LEP (no length designation)									
Period 1	0.0 (0.0) a-y	0.7 (0.3) a-x	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.2 (0.2) a-y	1.2 (0.6) a-x	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
NOP (<35 cm)									
Period 1	0.0 (0.0) a-x	0.2 (0.2) b-x	0.0 (0.0) a-n-x	NA	NA	0.5 (0.3) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.3 (0.3) a-n-x	0.0 (0.0) b-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.7 (0.5) ab-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.8 (0.5) a-n-x	0.5 (0.2) a-n-x	0.0 (0.0) a-n-y
Period 4	0.3 (0.3) a-y	5.8 (2.6) a-x	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n

Table 2-9. Continued.

	1997			1998			1999		
Taxon/Period	EIS	CB	MC	EIS	CB	MC	EIS	CB	MC
POM (<13 cm)									
Period 1	0.0 (0.0) b-x	0.0 (0.0) b-x	0.0 (0.0) b-n-x	NA	NA	0.0 (0.0) b-n	NA	NA	0.0 (0.0) b-n
Period 2	0.2 (0.2) b-n-x	0.0 (0.0) b-n-x	NA	0.0 (0.0) b-n-x	NA	0.2 (0.2) b-n-x	0.3 (0.2) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
Period 3	0.5 (0.5) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x	0.3 (0.3) a-n-x	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x
Period 4	126.2 (58.6) a-x	27.0 (10.3) a-x	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
RBS (no length designation)									
Period 1	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.2 (0.2) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
RIC (<13 cm)									
Period 1	0.5 (0.3) a-x	0.5 (0.5) b-x	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) b-n	NA	NA	0.2 (0.2) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) b-n-x	0.7 (0.5) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-y
Period 3	0.0 (0.0) a-n-x	0.3 (0.2) b-n-x	0.3 (0.3) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.5 (0.3) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.3) a-n-x
Period 4	0.0 (0.0) a-y	14.7 (6.8) a-x	0.0 (0.0) a-o-y	NA	NA	5.8 (3.2) a-n	NA	NA	0.2 (0.2) a-n
SHR (<10 cm)									
Period 1	0.0 (0.0) a-y	3.8 (1.3) a-x	0.0 (0.0) a-n-y	NA	NA	0.2 (0.2) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-y	1.0 (0.4) a-n-x	0.2 (0.2) a-n-y	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-x	0.7 (0.7) ab-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n

Table 2-9. Continued.

	1997			1998			1999		
Taxon/Period	EIS	CB	MC	EIS	CB	MC	EIS	CB	MC
SHS (<25 cm)									
Period 1	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) b-o-x	NA	NA	0.0 (0.0) a-o	NA	NA	0.7 (0.4) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) a-n-y	0.3 (0.2) a-n-x
Period 3	0.0 (0.0) a-n-y	0.0 (0.0) a-n-y	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x
Period 4	0.0 (0.0) a-y	0.0 (0.0) a-y	0.5 (0.3) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) b-n
SIC (no length designation)									
Period 1	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) b-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x
Period 4	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-o-x	NA	NA	0.2 (0.2) a-no	NA	NA	0.7 (0.3) a-n
SNC (no length designation)									
Period 1	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) b-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) a-n-y	3.5 (2.9) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.3) ab-n-x
Period 4	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.3 (0.2) ab-n
SPS (no length designation)									
Period 1	0.0 (0.0) a-x	0.5 (0.3) b-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) b-o-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-y	1.0 (0.4) a-n-x	0.0 (0.0) a-n-y
Period 3	0.0 (0.0) a-n-y	2.3 (2.3) a-n-x	0.0 (0.0) a-n-y	0.3 (0.2) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.3) a-no-x	0.3 (0.3) a-n-x
Period 4	0.0 (0.0) a-y	18.5 (11.5) a-x	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n

Table 2-9. Continued.

	1997			1998			1999		
Taxon/Period	EIS	CB	MC	EIS	CB	MC	EIS	CB	MC
STZ (<17 cm)									
Period 1	0.0 (0.0) a-x	0.0 (0.0) b-x	0.2 (0.2) a-n-x	NA	NA	0.7 (0.3) ab-n	NA	NA	0.3 (0.2) b-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) b-n-x	0.2 (0.2) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
Period 3	0.0 (0.0) a-n-y	1.7 (0.4) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) b-n-x	0.5 (0.2) a-n-x	1.0 (0.5) a-n-x	0.3 (0.3) b-n-x
Period 4	0.0 (0.0) a-y	1.7 (1.2) a-x	0.0 (0.0) a-o-y	NA	NA	3.2 (1.1) a-n	NA	NA	1.8 (0.7) a-n
WHS (<13 cm)									
Period 1	0.0 (0.0) a-x	0.0 (0.0) a-x	0.0 (0.0) a-n-x	NA	NA	0.3 (0.2) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-y	1.5 (1.0) a-x	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
YEP (<13 cm)									
Period 1	0.5 (0.3) b-x	0.2 (0.2) a-x	0.0 (0.0) a-n-x	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n
Period 2	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	NA	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) b-n-x	0.3 (0.3) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x
Period 4	6.7 (2.2) a-x	0.3 (0.3) a-y	0.0 (0.0) a-n-y	NA	NA	0.0 (0.0) a-n	NA	NA	0.0 (0.0) a-n

Table 2-10. Summary of fishes captured (species and total length noted) with experimental gill nets in two Missouri River backwaters in North Dakota [Erickson Island Slough (EIS) and the confluence backwater (CB)] in late April (Period 1), mid-May (Period 2), late June and early July (Period 3), and September (Period 4) of 1997-1999. Fish species abbreviations are defined in Appendix 1. For each period, year, and backwater, the catch per unit effort (number/hour), standard error (in parentheses), and results from statistical tests are noted. For each species, the letters a-d designate the among-period comparisons within each year and backwater. The letters n-p denote the among-year comparisons within each backwater and period. The letters x-y represent the pairwise comparison between the two backwaters within each year and period. Cells with the same letters were not statistically different (P>0.05).

	1997		1998		1999	
Species/Period	EIS	CB	EIS	CB	EIS	CB
BIB (≥25 cm)						
Period 1	0.5 (0 2) abn-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.0 (0.0) a-n-x
Period 2	2.0 (1.2) a-n-x	0.1 (0.1) a-n-y	0.2 (0.2) a-o-x	0.0 (0.0) b-n-x	1.0(0.7) a-no-x	0.0 (0.0) a-n-x
Period 3	0.5 (0.2) ab-n-x	0.0 (0.0) a-o-y	0.2 (0.1) a-n-x	0.8 (0.6) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-o-x
Period 4	0.1 (0.1) b-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
BUF (<25 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.2 (0.2) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 4	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.8 (0.2) a-n-x	0.0 (0.0) a-n-y	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x
BLB (≥15 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 4	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.4 (0.2) a-n-x	0.0 (0.0) a-n-y	0.8 (0.5) a-n-x	0.1 (0.1) a-n-x
BLB (<15 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.4 (0.2) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.1) b-n-x	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	2.6 (0.7) a-n-x	0.2 (0.2) a-n-y	0.2 (0.1) a-o-x	0.3 (0.3) a-n-x

Table 2-10. Continued.

Species/Period	1997		1998		1999	
	EIS	CB	EIS	CB	EIS	CB
CCF (≥28 cm)						
Period 1	1.6 (0.8) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) b-o-x	0.0 (0.0) a-n-x	0.1 (0.1) a-o-x	0.0 (0.0) b-n-x
Period 2	1.0 (0.3) ab-n-x	0.1 (0.1) a-n-x	0.4 (0.2) a-n-x	0.0 (0.0) a-n-y	0.3 (0.1) a-n-x	0.0 (0.0) b-n-y
Period 3	0.4 (0.2) b-n-x	0.1 (0.1) a-n-y	0.2 (0.1) a-n-x	0.3 (0.2) a-n-x	0.1 (0.1) a-n-x	0.4 (0.2) a-n-x
Period 4	0.2 (0.1) b-n-x	0.1 (0.1) a-n-x	0.1 (0.1) ab-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x
COC (≥28 cm)						
Period 1	1.0 (0.3) a-n-x	0.0 (0.0) b-n-y	0.3 (0.2) a-o-x	0.0 (0.0) a-n-x	0.6 (0.2) a-no-x	0.0 (0.0) b-n-y
Period 2	0.6 (0.3) ab-n-x	0.2 (0.1) b-n-x	0.0 (0 0) b-n-x	0.0 (0.0) a-n-x	0.4 (0.1) ab-n-x	0.3 (0.2) a-n-x
Period 3	0.4 (0.2) b-n-x	0.1 (0.1) b-n-x	0.9 (0.3) a-n-x	0.3 (0.2) a-n-y	0.4 (0.3) ab-n-x	0.2 (0.1) ab-n-x
Period 4	0.1 (0.1) b-n-y	1.2 (0.5) a-n-x	0.5 (0.2) a-n-x	0.0 (0.0) a-o-y	0.2 (0.1) b-n-y	0.7 (0.2) a-no-x
COC (<28 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.3 (0.2) a-n-x	0.0 (0.0) a-n-y
Period 2	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-o-x	0.2 (0.1) a-n-x	1.0 (0.3) a-n-x	0.0 (0.0) a-n-y	0.4 (0.3) a-no-x	0.4 (0.2) a-n-x
FRD (≥20 cm)						
Period 1	0.0 (0.0) ba-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) b-n-x	0.1 (0.1) ab-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 3	0.3 (0.2) a-n-x	0.0 (0.0) b-n-x	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 4	0.1 (0.1) ab-n-x	0.3 (0.1) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
GOE (≥10 cm)						
Period 1	20.6 (7.0) a-n-x	1.1 (0.7) ab-n-y	0.0 (0.0) b-o-x	0.0 (0.0) b-n-x	1.1 (0.4) b-o-x	0.0 (0.0) b-n-x

Table 2-10. Continued.

	1997		1998		1999	
Species/Period	EIS	CB	EIS	CB	EIS	CB
Period 2	7.1 (2.4) a-n-x	7.0 (1.7) a-n-x	2.9 (0.9) a-o-x	0.1 (0.1) b-o-x	10.6 (2.8) a-n-x	0.8 (0.6) b-o-y
Period 3	12.1 (5.2) a-n-x	15.2 (4.1) a-n-x	11.6 (2.6) a-n-x	3.4 (1.2) a-o-y	9.5 (2.2) a-n-x	16.7 (6.0) a-n-x
Period 4	0.4 (0.2) b-n-x	0.4 (0.2) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	1.0 (0.7) b-n-x	0.0 (0.0) b-n-x
NOP (≥35 cm)						
Period 1	1.1 (0.4) a-n-y	3.2 (1.5) a-n-x	0.5 (0.2) a-n-x	0.4 (0.2) a-o-x	0.4 (0.2) a-n-x	0.0 (0.0) b-o-y
Period 2	0.1 (0.1) b-n-x	1.1 (0.6) ab-n-x	0.7 (0.3) a-n-x	0.6 (0.4) a-n-x	0.3 (0.1) a-n-y	0.9 (0.4) a-n-x
Period 3	0.2 (0.1) b-n-x	0.2 (0.1) b-n-x	0.1 (0.1) b-n-x	0.3 (0.2) a-n-x	0.1 (0.1) a-n-x	0.2 (0.2) ab-n-x
Period 4	0.0 (0.0) b-o-y	2.5 (0.2) a-n-x	0.1 (0.1) b-o-x	0.0 (0.0) b-o-x	0.8 (0.8) a-n-x	0.1 (0.1) b-o-y
NOP (<35 cm)						
Period 1	0.0 (0.0) a-o-x	0.1 (0.1) b-n-x	0.4 (0.2) b-n-x	0.4 (0.3) a-n-x	0.0 (0.0) b-o-x	0.0 (0.0) b-n-x
Period 2	0.0 (0.0) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x	0.2 (0.2) ab-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-y	0.3 (0.2) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
Period 4	0.0 (0.0) a-o-y	0.4 (0.2) a-n-x	0.3 (0.1) a-n-x	0.4 (0.2) a-n-x	0.8 (0.2) a-n-x	0.6 (0.2) a-n-x
POM (≥13 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 2	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x	0.0 (0.0) a-n-x
POM (<13 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x

Table 2-10. Continued.

Species/Period	1997		1998		1999	
	EIS	CB	EIS	CB	EIS	CB
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
RIC (≥13 cm)						
Period 1	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.4 (0.2) a-n-x	0.0 (0.0) b-n-x
Period 2	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x
Period 3	0.4 (0.2) a-n-x	0.0 (0.0) b-n-x	0.5 (0.3) a-n-x	0.3 (0.2) a-n-x	0.2 (0.1) ab-n-x	0.4 (0.2) a-n-x
Period 4	0.1 (0.1) b-n-x	0.3 (0.2) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.1 (0 1) b-n-x	0.1 (0.1) b-n-x
RIC (<13 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
SAB (≥25 cm)						
Period 1	3.5 (1.1) a-n-x	0.0 (0.0) b-n-y	0.0 (0.0) b-o-x	0.0 (0.0) b-n-x	0.0 (0.0) b-o-x	0.0 (0.0) b-n-x
Period 2	6.1 (0.7) a-n-x	0.8 (0.3) a-n-y	2.3 (0.6) a-o-x	0.0 (0.0) b-o-y	3.9 (1.2) a-n-x	0.3 (0.2) a-n-y
Period 3	0.2 (0.1) b-n-x	0.1 (0.1) b-o-x	0.6 (0.3) ab-n-x	0.9 (0.5) a-n-x	0.2 (0.1) b-n-x	0.4 (0.2) a-no-x
Period 4	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
SAR (≥17 cm)						
Period 1	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
Period 2	0.0 (0.0) b-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.1 (0.1) a-n-x	0.4 (0.2) a-n-x
Period 3	0.3 (0.2) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.5 (0.2) a-n-x	0.0 (0.0) b-n-y

Table 2-10. Continued.

	1997		1998		1999	
Species/Period	EIS	CB	EIS	CB	EIS	CB
Period 4	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
SHG (≥18 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0 3 (0.2) a-n-x	0.0 (0.0) a-n-x	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x
SHR (≥10 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.1 (0 1) a-n-x	0.0 (0 0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.2 (0.1) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x
Period 4	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
WAE (≥17 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 3	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 4	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
WHS (≥13 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0 0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.1) a-n-x

Table 2-10. Continued.

	1997		1998		1999	
Species/Period	EIS	CB	EIS	CB	EIS	CB
YEB (≥15 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
YEP (≥13 cm)						
Period 1	0.2 (0.1) a-n-x	0.0 (0.0) a-n-y	0.2 (0.2) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-y	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
LAW (no length designation)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x

Table 2-11. Summary of fishes captured (species and total length noted) with trap nets in two Missouri River backwaters in North Dakota [Erickson Island Slough (EIS) and the confluence backwater (CB)] in late April (Period 1). mid-May (Period 2). late June and early July (Period 3). and September (Period 4) of 1997-1999. Fish species abbreviations are defined in Appendix 1. For each period. year. and backwater. the catch per unit effort (number/net night). standard error (in parentheses). and results from statistical tests are noted. For each species. the letters a-d designate the among-period comparisons within each year and backwater. The letters n-p denote the among-year comparisons within each backwater and period. The letters x-y represent the pairwise comparison between the two backwaters within each year and period. Cells with the same letters were not statistically different (P>0.05).

	1997		1998		1999	
Species/ Period	EIS	CB	EIS	CB	EIS	CB
BIB (≥25 cm)						
Period 1	0 1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 2	3.3 (1.0) a-n-x	0.1 (0.1) a-n-y	0.2 (0.1) a-o-x	0.0 (0.0) a-n-y	3.5 (0.0) a-n-x	0.1 (0.1) a-n-y
Period 3	0.1 (0.1) b-n-y	0.4 (0.3) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-o-y	0.1 (0.1) b-n-x	0.0 (0.0) a-o-x
Period 4	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-y	2.0 (1.2) a-n-x
BLB (<15 cm)						
Period 1	7.1 (2.6) b-o-x	0.2 (0.1) b-o-y	712.6 (437.0) a-n-x	33.3 (16.6) ab-n-y	4.8 (1.2) b-o-x	1.5 (0.9) b-o-y
Period 2	1.3 (0.0) c-o-x	0.0 (0.0) b-o-y	26 4 (8.2) b-n-x	18.8 (7.2) b-n-x	1.1 (0.7) c-o-x	0.2 (0.1) b-o-x
Period 3	4.9 (2.0) b-n-x	0.1 (0.1) b-n-y	2.3 (0.8) b-n-x	0.2 (0.1) c-n-x	0.2 (0.1) c-o-x	0.2 (0.1) b-n-x
Period 4	94.7 (53.9) a-o-x	145.2 (88.7) a-n-x	519.0 (201.7) a-n-x	100.2 (70.9) a-n-y	47.1 (15.7) a-o-y	120.2 (54.2) a-n-x
BLB (≥15 cm)						
Period 1	0.4 (0.2) b-n-x	0.0 (0.0) b-n-y	0.6 (0.1)b-n-x	0.3 (0.2) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) c-o-x	0.0 (0.0) b-o-x	4.8 (2.8) a-n-x	1.0 (0.8) a-n-y	0.1 (0.1) b-o-x	0 3 (0.1) a-n-x
Period 3	0.5 (0.2) b-n-x	0.1 (0.1) b-n-y	0.2 (0.1) b-n-x	0.1 (0.1) a-n-x	0.0 (0.0) b-o-x	0.1 (0.1) a-n-x
Period 4	3.1 (1.9) a-n-x	0.4 (0.2) a-n-y	2.4 (0.8) a-n-x	0.0 (0.0) a-n-y	1.3 (0.4) a-n-x	0.2 (0.1) a-n-y
BRS (no length designation)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.3) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	1.5 (0.7) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
BUF (<25 cm)						
Period 1	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.5 (0.1) c-n-x	0.0 (0.0) c-n-x
Period 2	0.0 (0.0) b-o-x	0.0 (0.0) b-n-x	1.3 (1.0) b-n-x	0.0 (0.0) b-n-y	0.0 (0.0) c-o-x	0.0 (0.0) c-n-x
Period 3	0.1 (0.1) b-o-y	20.8 (11.9) a-n-x	0.0 (0.0) b-o-x	0.0 (0.0) b-o-x	48.4 (35.7) a-n-x	10.8 (3.4) a-n-y
Period 4	0.7 (0.3) a-o-y	2.8 (1.2) ab-o-x	162.2 (14.3) b-n-x	62.8 (18.3) b-n-y	14.0 (1.3) b-o-x	3.4 (1.4) b-o-y

Table 2-11. Continued.

	1997		1998		1999	
Species/ Period	EIS	CB	EIS	CB	EIS	CB
BUR (<20 cm)						
Period 1	0.1 (0.1) b-o-x	0.0 (0.0) a-n-x	1.0 (0.4) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	2.6 (1.2) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) b-o-x	0.0 (0.0) a-n-x	0.1 (0.1) a-o-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0 0) a-n-x
BUR (≥20 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 4	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
CCF (<28 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 2	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.1 (0.1) a-o-x	0.0 (0.0) a-n-x	31.3 (15.3) a-n-x	0.0 (0.0) a-n-y	1.2 (0.4) a-o-x	0.0 (0.0) a-n-x
CCF (≥28 cm)						
Period 1	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 2	1.3 (0.5) a-n-x	0.3 (0.1) a-n-y	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.5 (0.4) a-no-x	0.1 (0.1) a-n-y
Period 3	0.2 (0.1) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) a-n-x
Period 4	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
COC (<28 cm)						
Period 1	0.2 (0.1) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.3 (0.1) b-n-x	0.0 (0.0) b-n-x
Period 2	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x
Period 3	1.4 (0.7) a-o-y	22.7 (12.7) a-n-x	0.1 (0.1) b-o-x	0.1 (0.1) b-o-x	9.3 (7.2) a-n-x	0.6 (0.2) a-o-y
Period 4	0.0 (0.0) b-o-x	1.6 (0.5) b-o-x	113.6 (29.8) a-n-x	193.7 (66.0) a-n-x	6.7 (1.9) a-o-x	1.5 (0.4) a-o-y
COC (≥28 cm)						
Period 1	0.5 (0.2) a-n-x	0.2 (0.1) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-x

Table 2-11. Continued.

	1997		1998		1999	
Species/ Period	EIS	CB	EIS	CB	EIS	CB
Period 2	2.2 (0.8) a-n-x	2.7 (0.7) a-n-x	1.4 (0.9) a-n-x	0.2 (0.2) a-n-x	2.1 (0.8) a-n-x	0.7 (0.2) a-n-x
Period 3	1.4 (0 6) a-n-x	1.2 (0.3) a-n-x	1.5 (0.5) a-n-x	0.9 (0.5) a-n-x	0.3 (0.2) a-n-x	0.2 (0.1) a-n-x
Period 4	0.5 (0.2) a-n-x	0.2 (0.1) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-x	0.3 (0.1) a-n-x	0.2 (0.2) a-n-x
CRC (no length designation)						
Period 1	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
EMS (no length designation)						
Period 1	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.1 (0.1) b-o-x	0.0 (0.0) b-n-x	3.1 (0.8) a-n-x	1.0 (0.5) a-n-y
Period 2	0.0 (0.0) a-o-x	0.0 (0.0) a-o-x	0.0 (0.0) b-o-x	0.2 (0.2) b-o-x	0.9 (0.6) b-y-x	2.1 (1.0) a-n-x
Period 3	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.4 (0.3) b-n-x	0.1 (0.1) b-n-x
Period 4	0.1 (0.1) a-o-x	0.0 (0.0) a-n-x	0.6 (0.2) a-n-y	1.8 (1.4) a-n-x	1.3 (0 4) a-n-x	0.0 (0.0) b-n-y
FHM (no length designation)						
Period 1	0.0 (0.0) a-n-x	0.1 (0.1) a-p-x	0.0 (0.0) a-n-y	6.2 (5.4) b-o-x	0.1 (0.1) a-n-y	36.7 (7.8) a-n-x
Period 2	0.1 (0.1) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) a-n-y	2.0 (1.0) c-n-x	0.0 (0.0) a-n-y	1.0 (0.4) b-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) c-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-o-x	0.1 (0.1) a-n-y	30.5 (9.8) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) b-o-x
FLC (no length designation)						
Period 1	0.2 (0.1) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.3 (0.1) a-n-x	0.3 (0.2) a-n-x
Period 2	0.0 (0.0) a-o-x	0.0 (0.0) a-o-x	0.1 (0.1) a-o-x	0.0 (0.0) a-o-x	0.6 (0.3) a-n-x	0.6 (0.2) a-n-x
Period 3	0.3 (0.2) a-n-x	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
FRD (<20 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-p-x	0.0 (0.0) a-n-x	2.8 (0.9) a-n-x	0.0 (0.0) a-n-y	0.5 (0.3) a-o-x	0.0 (0.0) a-n-y

Table 2-11. Continued.

	1997		1998		1999	
Species/ Period	EIS	CB	EIS	CB	EIS	CB
FRD (≥20 cm)						
Period 1	0.0 (0.0) b-n-x	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.5 (0.2) a-n-x	0.1 (0.1) a-n-y	0.1 (0.1) a-o-x	0.1 (0.1) a-n-x	0.1 (0.1) a-o-x	0.1 (0.1) a-n-x
Period 4	0.2 (0.1) a-n-x	0.0 (0.0) a-n-y	0.2 (0.2) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
GOE (<10 cm)						
Period 1	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.0 (0.0) b-o-x	0.0 (0.0) b-n-x	0.5 (0.3) a-n-x	0.0 (0.0) a-n-y
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.2 (0.2) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) a-n-x
Period 3	0.0 (0 0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.0 (0.0) a-n-x
Period 4	0.2 (0.1) a-o-x	0.2 (0.1) a-n-x	17.8 (4.7) a-n-x	0.8 (0.5) a-n-y	0.5 (0.3) a-o-x	0.0 (0.0) a-n-y
GOE (≥10 cm)						
Period 1	0.7 (0.5) c-o-x	0.0 (0.0) b-n-y	0.1 (0.1) b-o-x	0.0 (0.0) b-n-x	3.7 (1.3) a-n-x	0.2 (0.1) b-n-y
Period 2	0.8 (0.5) c-n-x	0.2 (0.1) b-o-x	0.4 (0.2) b-n-x	0.5 (0.3) a-o-x	1.0 (0.6) b-n-x	1.8 (0.8) a-n-x
Period 3	1.4 (0.5) b-o-x	0.7 (0.3) a-n-x	3.6 (0.8) a-n-x	0.3 (0.2) a-o-y	1.0 (0.3) b-o-x	0.7 (0.3) a-n-x
Period 4	2.1 (1.3) a-o-x	0.9 (0.4) a-n-y	5.4 (1.6) a-n-x	0.0 (0.0) b-o-y	1.2 (0.3) b-o-x	0.0 (0.0) b-o-y
GOS (no length designation)						
Period 1	0.0 (0.0) b-o-x	0.0 (0.0) a-o-x	0.6 (0.2) a-n-x	0.0 (0.0) b-o-y	0.0 (0.0) a-o-x	0.3 (0.3) a-n-x
Period 2	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x
Period 3	0.1 (0.1) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x
Period 4	0.3 (0.2) a-n-x	0.1 (0.1) a-n-y	0.1 (0.1) b-o-y	0.5 (0.3) a-n-x	0.0 (0.0) a-o-x	0.0 (0.0) b-n-x
HYB (no length designation)						
Period 1	0.1 (0.1) a-n-x	0.1 (0.1) a-o-x	0.0 (0.0) c-n-x	0.0 (0.0) c-o-x	0.3 (0.1) b-n-y	19.7 (12.3) a-n-x
Period 2	0.1 (0.1) a-o-x	0.0 (0.0) a-o-x	0.0 (0.0) c-o-x	0.0 (0.0) c-o-x	0.8 (0.4) a-n-y	2.1 (0.7) b-n-x
Period 3	0.0 (0.0) a-o-x	0.0 (0.0) a-o-x	0.7 (0.4) b-n-y	2.6 (0.9) a-n-x	0.3 (0.2) b-n-x	0.1 (0.1) c-o-x
Period 4	0.3 (0.2) a-o-x	0.2 (0.1) a-n-x	4.2 (1.3) a-n-x	0.7 (0.7) a-n-y	0.1 (0.1) b-o-y	0.8 (0.3) c-n-x
LEP (no length designation)						
Period 1	0.1 (0.1) a-o-x	0.0 (0.0) b-o-x	0.4 (0.2) a-n-x	0.0 (0.0) b-o-y	0.0 (0.0) b-o-y	0.5 (0.3) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) b-o-x	0.0 (0.0) a-n-y	0.5 (0.5) a-n-x	0.1 (0.1) b-n-x	0.2 (0.1) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.1 (0.1) b-n-x

Table 2-11. Continued.

	1997		1998		1999	
Species/ Period	EIS	CB	EIS	CB	EIS	CB
Period 4	0.2 (0.1) a-n-y	16.9 (6.7) a-n-x	0.1 (0.1) a-n-y	1.0 (0.4) a-o-x	0.4 (0.2) a-n-x	0.0 (0.0) b-o-y
LOD (no length designation)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
LOS (<13 cm)						
Period 1	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.1 (0.1) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x
NOP (<35 cm)						
Period 1	0.1 (0.1) a-n-x	0.0 (0.0) b-o-x	0.2 (0.1) b-n-y	1.7 (0.6) a-n-x	0.2 (0.1) b-n-x	0.0 (0.0) b-o-x
Period 2	0.1 (0.1) a-n-x	0.0 (0.0) b-o-x	0.0 (0.0) b-y-x	1.7 (0.8) a-n-x	0.2 (0.1) b-n-x	2.5 (1.3) a-o-x
Period 3	0.0 (0.0) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.3 (0.1) b-n-x	0.0 (0.0) b-n-y
Period 4	0.1 (0.1) a-o-y	0.5 (0.2) a-n-x	0.6 (0.2) a-o-x	0.3 (0.3) b-n-y	6.1 (1.3) a-n-x	0.2 (0.2) b-n-y
NOP (≥35 cm)						
Period 1	2.9 (0.9) a-n-x	3.4 (1.1) a-n-x	3.6 (1.2) a-n-x	0.5 (0.2) a-n-y	0.9 (0.3) a-o-x	0.2 (0.2) b-n-y
Period 2	0.6 (0.2) b-o-x	0.4 (0.2) b-n-x	5.9 (1.6) a-n-x	0.7 (0.3) a-n-y	0.4 (0.2) a-o-y	1.8 (0.4) a-n-x
Period 3	0.2 (0.1) b-o-x	0.0 (0.0) b-n-x	0.2 (0.1) b-o-x	0.0 (0.0) b-n-x	0.6 (0.2) a-n-x	0.2 (0.1) b-n-y
Period 4	1.0 (0.3) ab-n-x	0.4 (0.2) b-n-y	0.5 (0.3) b-no-x	0.0 (0.0) b-n-y	0.1 (0.1) b-o-x	0.3 (0.2) b-n-x
NRD (no length designation)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
POM (<13 cm)						
Period 1	0.3 (0.1) b-o-x	0.1 (0.1) b-o-x	0.2 (0.1) b-o-x	0.0 (0.0) b-o-x	11.1 (3.0) b-n-x	1.8 (1.2) b-n-y
Period 2	0.0 (0.0) b-o-x	0.0 (0.0) b-o-x	0.1 (0.1) b-o-x	0.0 (0.0) b-o-x	0.6 (0.3) c-n-x	0.6 (0.2) c-n-x

Table 2-11. Continued.

	1997		1998		1999	
Species/ Period	EIS	CB	EIS	CB	EIS	CB
Period 3	0.4 (0.2) b-o-x	0.0 (0.0) b-o-x	0.1 (0.1) b-o-x	0.0 (0.0) b-o-x	3.2 (1.2) b-n-x	0.8 (0.5) c-n-y
Period 4	86.9 (26.5) a-o-x	41.1 (16.3) a-n-y	285.1 (67.9) a-n-x	52.0 (21.2) a-n-y	53.6 (13.4) a-o-x	30.0 (12.8) a-n-y
POM (≥13 cm)						
Period 1	0.3 (0.2) d-n-x	0.0 (0.0) c-n-y	0.2 (0.1) c-n-x	0.0 (0.0) b-n-y	0.1 (0.1) c-n-x	0.3 (0.3) b-n-x
Period 2	3.3 (2.0) b-n-x	0.0 (0.0) c-o-y	1.8 (0.5) b-n-x	0.5 (0.3) a-n-y	0.1 (0.1) c-o-x	0.1 (0.1) c-o-x
Period 3	1.1 (0.3) c-n-x	0.1 (0.1) b-n-y	1.1 (0.4) b-n-x	0.1 (0.1) b-n-y	1.6 (0.5) b-n-x	0.1 (0.1) c-n-y
Period 4	5.2 (0.9) a-o-x	0.4 (0.2) a-o-y	3.8 (0.9) a-p-x	0.0 (0.0) b-o-y	7.7 (1.8) a-n-x	2.7 (0.8) a-n-y
RBS (no length designation)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
RIC (<13 cm)						
Period 1	0.0 (0.0) c-o-x	0.0 (0.0) b-o-x	0.0 (0.0) b-o-x	0.0 (0.0) b-o-x	0.9 (0.3) b-n-x	0.7 (0.4) a-n-x
Period 2	0.0 (0.0) c-o-x	0.0 (0.0) b-o-x	0.0 (0.0) b-o-x	0.2 (0.2) b-o-x	0.7 (0.2) b-n-x	0.4 (0.1) a-n-y
Period 3	0.3 (0.2) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-o-x	0.0 (0.0) b-n-x	0.3 (0.1) b-n-x	0.0 (0.0) b-n-x
Period 4	1.2 (0.3) a-o-y	8.1 (2.7) a-o-x	46.8 (11.1) a-n-x	38.5 (26.9) a-n-x	3.7 (1.1) a-o-x	0.7 (0.3) a-p-y
RIC (≥13 cm)						
Period 1	1.5 (0.7) b-n-x	0.2 (0.1) b-n-y	0.0 (0.0) b-o-x	0.0 (0.0) a-n-x	0.2 (0.2) b-o-x	0.2 (0.2) b-n-x
Period 2	0.2 (0.1) c-n-x	0.7 (0.7) a-o-x	0.3 (0.3) b-n-x	0.2 (0.2) a-o-x	0.2 (0.1) b-y-x	2.2 (1.3) a-n-x
Period 3	3.6 (1.1) a-n-x	0.3 (0.2) b-o-y	1.4 (0.4) a-p-x	0.2 (0.1) a-o-y	2.2 (0.7) a-o-x	1.2 (0.6) a-n-y
Period 4	0.3 (0.1) c-o-x	0.2 (0.1) b-n-x	0.1 (0.1) b-o-x	0.0 (0.0) a-o-x	1.2 (0.3) a-n-x	0.5 (0.3) b-n-y
SAB (≥25 cm)						
Period 1	2.2 (1.0) b-n-x	0.0 (0.0) a-n-y	0.1 (0.1) c-o-x	0.0 (0.0) a-n-y	0.1 (0.1) b-o-x	0.0 (0.0) a-n-x
Period 2	14.3 (4.4) a-n-x	0.0 (0.0) a-n-y	0.9 (0.7) a-o-x	0.0 (0.0) a-n-y	106 (3.8) a-n-x	0.0 (0.0) a-n-y
Period 3	0.3 (0.2) c-n-x	0.0 (0.0) a-n-y	0.5 (0.2) b-n-x	0.0 (0.0) a-n-y	0.2 (0.1) b-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) c-n-x	0.0 (0.0) a-n-x	0.0 (0.0) c-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
SAR (≥20 cm)						
Period 1	0.0 (0.0) c-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x

Table 2-11. Continued.

	1997		1998		1999	
Species/ Period	EIS	CB	EIS	CB	EIS	CB
Period 2	0.2 (0.1) b-n-x	0.1 (0.1) a-n-x	0.0(0.0) b-o-x	0.2 (0.2) a-n-x	0.3 (0.2) a-n-x	0.1 (0.1) a-n-x
Period 3	0.7 (0.2) a-n-x	0.2 (0.1) a-n-y	1.0 (0.5) a-n-x	0.1 (0.1) a-n-y	0.4 (0.2) a-n-x	0.1 (0.1) a-n-y
Period 4	0.2 (0.1) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-x
SHG (≥18 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 2	0.2 (0.2) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.2 (0.1) b-n-x	0.2 (0.2) a-n-x
Period 3	0.0 (0.0) a-o-x	0.0 (0.0) b-n-x	0.7 (0.5) a-n-x	0.1 (0.1) a-n-y	1.0 (0.6) a-n-x	0.1 (0.1) a-n-y
Period 4	0.2 (0.1) a-o-y	2.1 (0.7) a-n-x	0.3 (0.1) a-o-x	0.0 (0.0) a-o-y	1.2 (0.3) a-n-x	0.0 (0.0) a-o-y
SHR (<10 cm)						
Period 1	0.0 (0.0) a-n-y	0.6 (0.3) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) b-o-x	0.0 (0.0) a-n-y	0.8 (0.8) a-n-x	0.0 (0.0) a-n-x	0.2 (0.1) a-o-x
Period 3	0.1 (0.1) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.2 (0.1) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
SHR (≥10 cm)						
Period 1	0.1 (0.1) b-n-x	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x	0.1 (0.1) a-n-x	0.0 (0 0) b-n-x
Period 2	0.0 (0.0) b-n-x	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.2 (0.2) a-n-x	0.1 (0.1) a-n-x	0.2 (0.1) a-n-x
Period 3	0.3 (0.2) a-n-x	0.1 (0.1) a-o-y	0.0 (0.0) a-o-y	0.4 (0.1) a-n-x	0.2 (0.2) a-n-x	0.2 (0.1) a-n-x
Period 4	0.2 (0.1) a-n-x	0.0 (0.0) a-n-y	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x	0.2 (0.2) a-n-x	0.0 (0.0) b-n-x
SPS (no length designation)						
Period 1	0.0 (0.0) a-o-x	0.0 (0.0) b-n-x	0.0 (0.0) a-o-x	0.0 (0.0) b-n-x	0.6 (0.2) a-n-x	0.0 (0.0) b-n-x
Period 2	0.2 (0.1) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) a-o-x	0.0 (0.0) b-o-x	0.4 (0.1) a-n-x	0.4 (0.2) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.2 (0.1) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x
Period 4	0.1 (0.1) a-n-x	0.3 (0.2) a-n-x	0.1 (0.1) a-n-x	0.2 (0.2) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-o-x
STC (no length designation)						
Period 1	0.3 (0.2) a-n-x	0.1 (0.1) a-n-y	0.4 (0.3) a-n-x	0.0 (0.0) a-n-y	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x
Period 2	0.0 (0.0) b-o-x	0.0 (0.0) a-n-x	0.0 (0.0) b-o-x	0.0 (0.0) a-n-x	0.3 (0.2) a-n-x	0.2 (0.1) a-n-x
Period 3	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) b-n-x
Period 4	0.0 (0.0) b-o-x	0.0 (0.0) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-y	0.0 (0.0) b-o-x	0.0 (0.0) b-n-x
STZ (<17 cm)						
Period 1	0.0 (0.0) b-o-x	0.0 (0.0) b-n-x	0.0 (0.0) b-o-x	0.0 (0.0) a-n-x	0.3 (0.1) b-n-x	0.0 (0.0) b-n-y

Table 2-11. Continued.

	1997		1998		1999	
Species/ Period	EIS	CB	EIS	CB	EIS	CB
Period 2	0.0 (0.0) b-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.1 (0.1) b-n-x
Period 3	0.5 (0.3) a-o-y	1.9 (0.6) a-n-x	1.5 (1.0) a-n-x	0.1 (0.1) a-o-y	1.8 (0.4) a-n-x	1.5 (0.7) a-n-x
Period 4	0.0 (0.0) b-o-x	0.1 (0.1) b-n-x	1.3 (0.6) a-n-x	0.0 (0.0) a-n-y	0.1 (0.1) b-o-x	0.2 (0.2) b-n-x
TAM (no length designation)						
Period 1	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.7 (0.4) b-n-x	0.0 (0.0) a-n-y	0.7 (0.3) b-n-x	0.0 (0.0) a-n-y
Period 2	0.0 (0.0) a-o-x	0.0 (0.0) a-n-x	0.5 (0.2) b-n-x	0.0 (0.0) a-n-y	0.4 (0.3) b-n-x	0.0 (0.0) a-n-y
Period 3	0.2 (0.1) a-n-x	0.0 (0.0) a-n-y	0.1 (0.1) c-n-x	0.0 (0.0) a-n-x	0.0 (0.0) c-n-x	0.0 (0.0) a-n-x
Period 4	0.1 (0.1) a-o-x	0.0 (0.0) a-n-x	4.6 (1.4) a-n-x	0.0 (0.0) a-n-y	1.7 (0.5) a-n-x	0.0 (0.0) a-n-y
WAE (≥20 cm)						
Period 1	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.3 (0.2) a-n-x
Period 3	0.2 (0.1) a-n-x	0.1 (0.1) a-n-x	0.2 (0.1) a-n-x	0.1 (0.1) a-n-x	0.3 (0.1) a-n-x	0.2 (0.1) a-n-x
Period 4	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.2) a-n-x
WHB (<15 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x
WHS (<13 cm)						
Period 1	0.0 (0.0) b-o-x	0.0 (0.0) b-o-x	0.3 (0.2) a-n-x	0.8 (0.7) b-n-x	0.0 (0.0) a-o-x	0.5 (0.2) a-n-x
Period 2	0.0 (0.0) b-n-x	0.0 (0.0) b-o-x	0.0 (0.0) b-n-x	0.7 (0.5) b-n-x	0.0 (0.0) a-n-x	0.3 (0.2) b-n-x
Period 3	0.4 (0.2) a-n-x	0.2 (0.1) a-n-x	0.2 (0.1) a-n-x	0.2 (0.1) c-n-x	0.1 (0.1) a-o-x	0.1 (0.1) b-n-x
Period 4	0.0 (0.0) b-n-x	0.1 (0.1) b-o-x	0.2 (0.1) a-n-x	1.2 (0.3) a-n-x	0.1 (0.1) a-n-x	0.7 (0.3) a-n-x
WHS (≥13)						
Period 1	0.1 (0.1) a-o-x	0.0 (0.0) a-n-x	0.3 (0.2) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-o-x	0.2 (0.2) a-n-x
Period 2	0.2 (0.1) a-o-x	0.0 (0.0) a-n-x	0.6 (0.3) a-n-x	0.3 (0.3) a-n-x	0.6 (0.2) a-n-x	0.0 (0.0) a-n-x
Period 3	0.1 (0.1) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.1 (0.1) b-n-x	0.0 (0.0) a-n-x
Period 4	0.2 (0.1) a-n-x	0.0 (0.0) a-n-x	0.4 (0.1) a-n-x	0.0 (0.0) a-n-x	0.3 (0.1) a-n-x	0.0 (0.0) a-n-x
YEB (<15 cm)						
Period 1	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x

Table 2-11. Continued.

	1997		1998		1999	
Species/ Period	EIS	CB	EIS	CB	EIS	CB
Period 2	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.2 (0.1) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
YEB (≥15 cm)						
Period 1	0.2 (0.1) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x
Period 2	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
Period 4	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.1 (0.1) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x	0.0 (0.0) a-n-x
YEP (<13 cm)						
Period 1	1.6 (0.6) a-o-x	0.0 (0.0) b-o-y	25.1 (11.5) a-n-x	0.2 (0.2) b-o-y	0.9 (0.2) a-o-y	5.2 (2.6) a-n-x
Period 2	0.0 (0.0) b-o-x	0.0 (0.0) b-o-x	1.8 (1.2) c-n-x	0.5 (0.5) a-n-y	0.0 (0.0) c-o-x	0.2 (0.1) b-n-x
Period 3	0.2 (0.1) b-n-x	0.2 (0.1) b-n-x	0.3 (0.2) c-n-x	0.0 (0.0) b-n-x	0.3 (0.2) b-n-x	0.0 (0.0) b-n-y
Period 4	0.1 (0.1) b-o-x	0.0 (0.0) b-n-x	4.4 (1.3) b-n-x	0.0 (0.0) b-n-y	0.2 (0.2) b-o-x	0.0 (0.0) b-n-x
YEP (≥13 cm)						
Period 1	0.5 (0.2) a-o-x	0.0 (0.0) a-n-y	4.1 (0.9) a-n-x	0.0 (0.0) a-n-y	0.3 (0.1) a-o-x	0.0 (0.0) a-n-y
Period 2	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.1 (0.1) c-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 3	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x	0.0 (0.0) c-n-x	0.0 (0.0) a-n-x	0.0 (0.0) b-n-x	0.0 (0.0) a-n-x
Period 4	0.1 (0.1) b-o-x	0.0 (0.0) a-n-x	2.6 (1.1) b-n-x	0.0 (0.0) a-n-y	0.1 (0.1) b-o-x	0.0 (0.0) a-n-x

Bodensteiner and Lewis (1992) noted that age-0 freshwater drum sought refuge in off-channel areas to survive the winters. Channel catfish were present at some level during nearly all sample periods in EIS. In 1998, large numbers of juveniles were present during period 4, but relatively few were sampled in 1997 and 1999. Production of age-0 fishes was statistically greater in 1998 for several fishes, including freshwater drum, *Pomoxis* spp., *Ictiobus* spp., and black bullhead. Unfortunately, I was unable to obtain comparable CPUE data for many of these species in the Missouri River main channel. Therefore, I can highlight the relative changes within each backwater, but it is impossible to determine if the relative abundance observations represent a concentration of these species in backwaters or depict their visits as casual or occasional.

Several fish species that tend to be lentic-oriented, such as northern pike, white crappie, yellow perch, black bullhead, and two nonindigenous fishes (tadpole madtom and common carp), appeared to rely on the backwater habitats to provide spawning, rearing, and foraging needs throughout their life history. Several of these species appeared to fluctuate in abundance across seasons; however, I suspect that the inundation of preferred habitats with high densities of structure lured species such as yellow perch and white crappies away from easily sampled areas. Several "resident" species have taken advantage of EIS, but with the exception of common carp, do not appear to be well established in the more erratic CB. Approximately 50% of all fishes captured during my study were black bullhead (>40,500 fish) and for fishes sampled in EIS, black bullhead exceeded 60% of the total catch. In EIS, an additional 12% were *Pomoxis* spp. and 11% were either river carpsuckers or *Ictiobus* spp. The tadpole madtom population appears to be established with multiple year classes now present and abundance apparently is increasing (Wilson et al. In press). The white crappie population in EIS also is substantial and Sheik et al. (1998) noted that the population might provide a potential sport fishery and be a major regulatory species in the backwater community.

Although an entire chapter could be devoted to each fish species, I attempted to summarize the fish movements into and out of the backwater habitats by identifying fish assemblages based on the above-stated criteria. Gelwicks (1995) and Hynes (1970) also discuss functional group classifications based on fish relationships with the floodplain. In those studies, three basic groups were identified, including channel spawners-channel users, channel spawners-backwater users, and backwater spawners-backwater users. In my assessment, I identified seven assemblage types; however, some differ in subtle degrees. The assemblages included age-0 drifters, backwater spawners, two groups of transients, two groups of residents, and a small group of lotic obligates. Some subjectivity had to be applied during this assessment because insufficient data were available inhibited reliable responses to all of the criteria questions listed previously. Table 2-12 summarizes the results of the criteria questions for each species, or in some cases genera. Several species that were infrequently sampled or that involved a single specimen, including lake whitefish *Coregonus clupeaformis*, northern redbelly dace *Chrosomus eos*, longnose dace *Rhinichthys cataractae*, and rainbow smelt were not included in the assemblage analysis.

The first assemblage of fishes was classified as main channel or lotic obligates and these fishes did not appear to utilize backwater habitats during any life stage. This

Table 2-12. Summary of assemblage criteria for fish taxa captured from 1997 to 1999 in two upper Missouri River backwaters and adjacent sandbar habitats. Fish abbreviations are defined in Appendix 1. The questions are noted in the methods and results are summarized in the table. Responses include Y=yes, N=no. 1-4 designate sample periods. V=variable influx period. R=residential probability, I=immigrant probability. O=lotic oriented. E=lentic oriented, and N=no strong preference to lentic or lotic habitats. The assemblage assignments, including backwater (BW) spawners, residents (subdivisions A and B), drifters, main channel (MC) obligates, and transients (subdivisions A and B) are discussed in the text.

	Question designation											
Taxon	1	1A	1B	2	3	3A	3B	4	4A	4B	5	Assemblage
BIB	Y	2	Y	N	Y	4	R	Y	3	Y	O	BW spawners
BLB	N	-	-	Y	Y	4	R	N	-	-	E	Residents-A
BRS	N	-	-	N	N	-	-	N	-	-	N	Transients-A
BSR	N	-	-	N	N	-	-	Y	3	Y	O	Drifters
BUR	N	-	-	N	Y	3	R	Y	1	N	N	Drifters
CCF	Y	2	Y	Y	Y	4	R	N	-	-	O	BW spawners
COC	N	-	-	Y	Y	4	R	Y	3	Y	N	Residents-A
CRC	N	-	-	N	N	-	-	N	-	-	O	Transients-A
EMS	N	-	-	Y	Y	4	I	N	-	-	N	Residents-B
FHM	N	-	-	Y	N	-	-	N	-	-	E	Residents-A
FLC	N	-	-	N	Y	2	I	N	-	-	O	Drifters
FRD	Y	3	Y	N	Y	4	R	N	-	-	N	BW spawners
GOE	Y	V	N	Y	Y	4	I	N	-	-	N	Transient-B
GOS	N	-	-	Y	N	-	-	N	-	-	N	Residents-B
HYB	Y	V	N	Y	N	-	-	N	-	-	N	Residents-B
LAH	N	-	-	N	N	-	-	Y	2	N	E	Drifters
LEP	N	-	-	Y	Y	4	R	N	-	-	E	Residents-A
LOS	N	-	-	N	N	-	-	N	-	-	O	Drifters
NOP	Y	1	Y	Y	Y	V	R	N	-	-	E	Residents-A
POM	Y	V	Y	Y	Y	4	R	Y	3	Y	E	Residents-A
RIC	Y	3	Y	N	Y	4	R	Y	3	Y	N	BW spawners
SAB	Y	2	Y	N	Y	4	R	Y	3	Y	O	BW spawners
SAR	Y	3	N	N	Y	3	I	N	-	-	O	Transients-B
SHG	Y	3	N	N	N	-	-	N	-	-	N	Transients-A
SHR	N	-	-	Y	N	-	-	N	-	-	O	Transients-B
SHS	N	-	-	N	N	-	-	N	-	-	O	MC obligates
SIC	N	-	-	N	N	-	-	N	-	-	O	MC obligates
SNC	N	-	-	N	N	-	-	N	-	-	O	MC obligates
SPS	Y	V	Y	Y	N	-	-	N	-	-	N	Residents-B
STC	Y	V	N	Y	N	-	-	N	-	-	O	Transients-A
TAM	N	-	-	Y	Y	V	R	N	-	-	E	Residents-A
WAE	N	-	-	N	Y	3	I	N	-	-	N	Transients-B
WHB	N	-	-	N	N	-	-	N	-	-	E	Drifters
WHS	Y	V	N	Y	Y	3	R	Y	3	N	O	Transients-B
YEB	N	-	-	Y	N	-	-	N	-	-	E	Residents-B
YEP	Y	1	Y	Y	Y	V	R	Y	2	Y	N	Residents-A

assemblage is included because adult and juvenile members of three species, including shovelnose sturgeon, sicklefin chub, and sturgeon chub were captured in the main channel at locations adjacent to backwater inlet and outlet connections. Although these species were found near the backwater connections, no evidence suggested direct use of the backwater habitats. In Chapter 5, I discuss the concentration of lotic fishes in the channel near backwater outlets and how backwater production may be important.

There were a number of species that apparently dwell in backwater habitats throughout their life history. Analysis of this data set, combined with species life history documentation in the literature, provided sufficient information to classify one assemblage of fishes as primary residents (Residents-A; Table 2-12). The primary residents included black bullhead, *Pomoxis* spp., common carp, northern pike, tadpole madtoms, and yellow perch. Adults and juveniles of these species were present in all sample periods, ripe spawners were observed, and for some species, both larval and juvenile stages could be tracked from the time of spawning. These species were rarely captured near the connection areas, but were typically found in the backwater interior. The length-frequency information for *Pomoxis* spp. (Figure 2-9) and black bullhead (Figure 2-10) depict the general dynamics of the Residents-A assemblage, with adults and juveniles present throughout the sample periods and notable onsets of age-0 recruitment after what is presumed to be within-backwater spawning.

A secondary group of residential fishes (Residents-B) were also present in the backwaters during nearly all sample periods; however, the relationship that these species maintain with the backwaters appears to be more variable. The species classified as

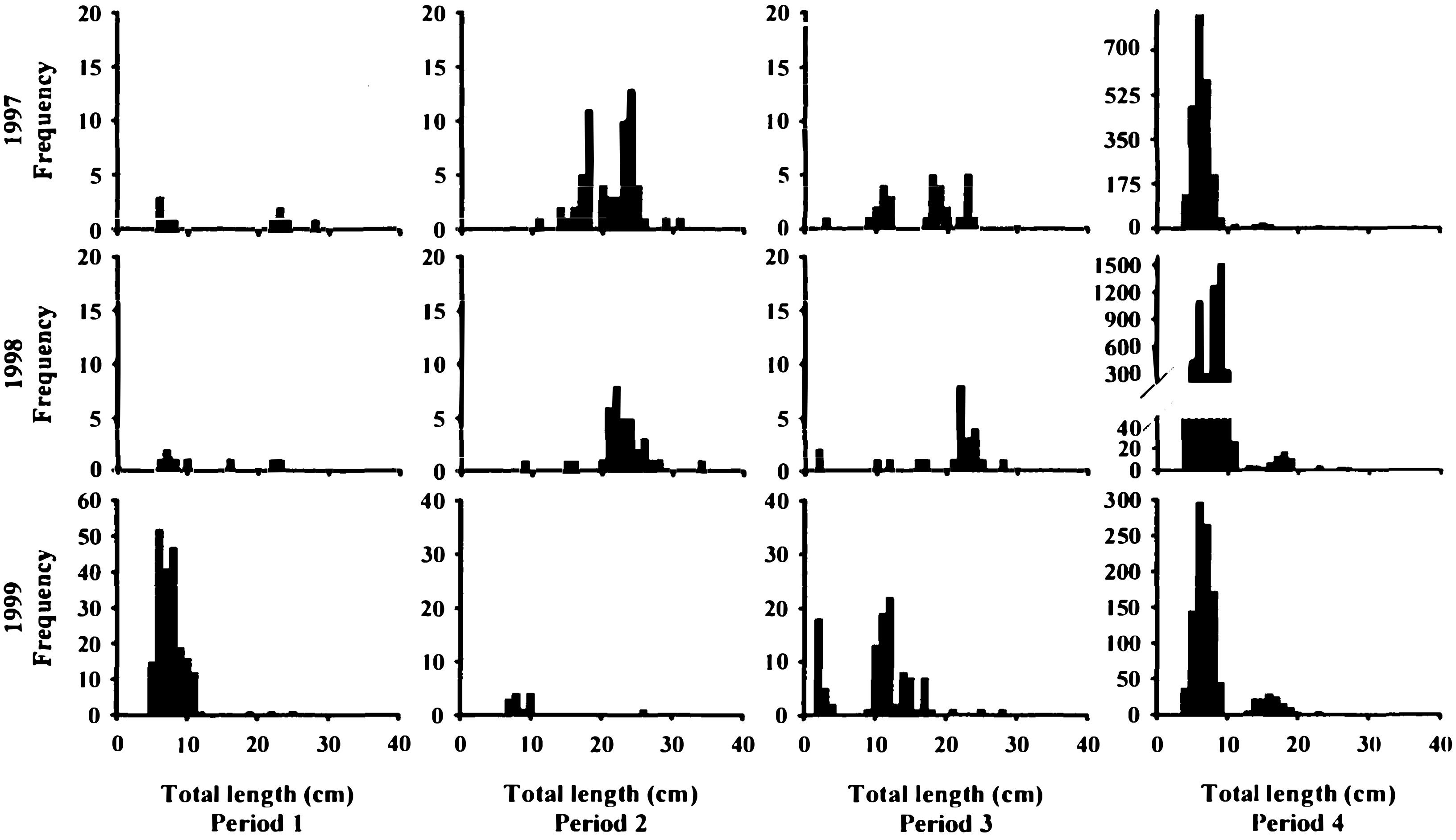

Figure 2-9. Length-frequency histograms of *Pomoxis* spp. from Erickson Island Slough, North Dakota, sampled during late April (Period 1), mid- to late May (Period 2), late June and early July (Period 3), and early September (Period 4) in 1997-1999. The frequencies represent the total catches during each period from 18 trap net nights.

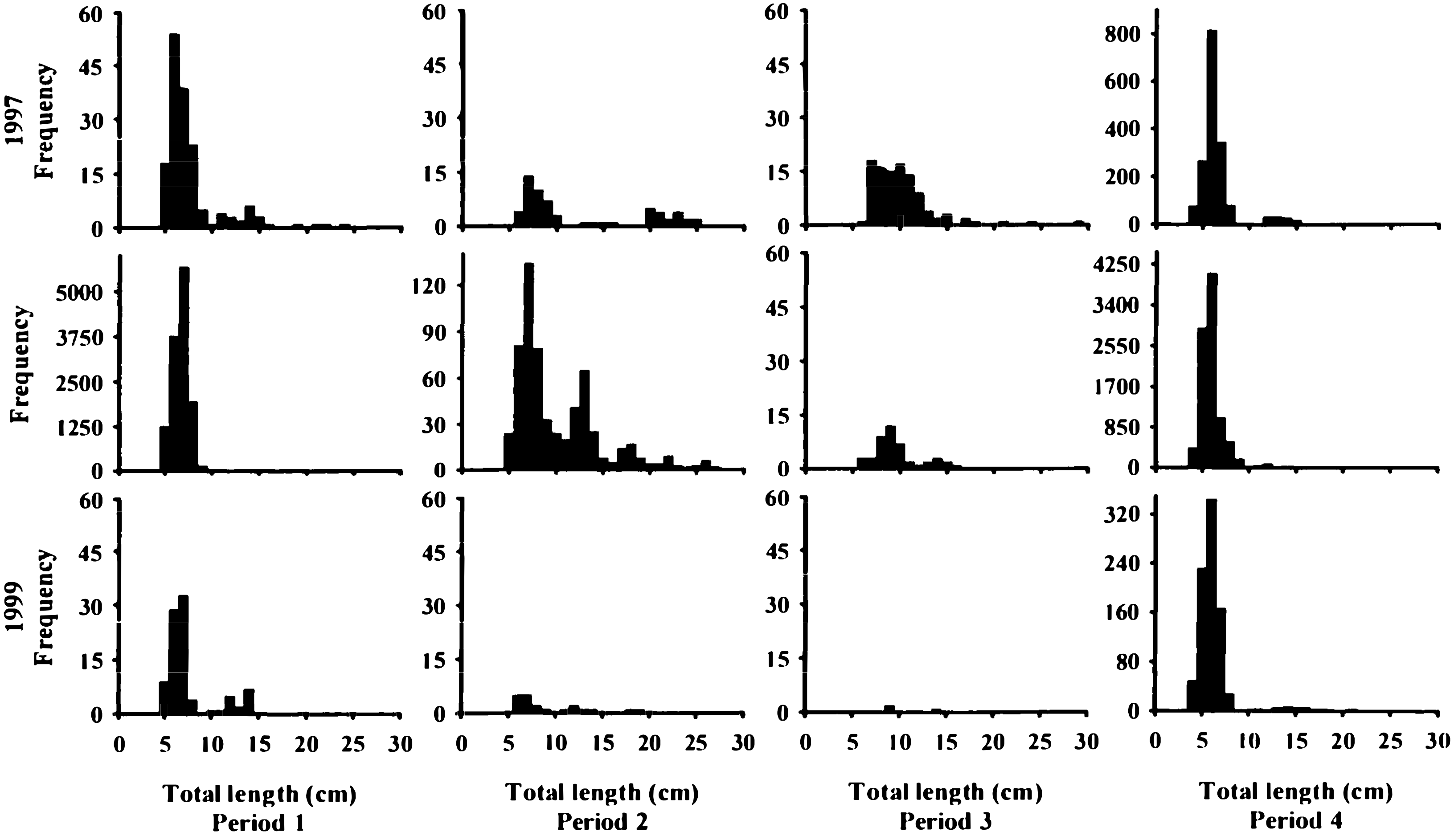

Figure 2-10. Length-frequency histograms of black bullheads from Erickson Island Slough, North Dakota, sampled during late April (Period 1), mid- to late May (Period 2), late June and early July (Period 3), and early September (Period 4) in 1997-1999. The frequencies represent the total catches during each period from 18 trap net nights.

Residents-B included fathead minnow, *Lepomis* spp., emerald shiner, golden shiner *Notemigonus crysoleucus*, spottail shiner, and yellow bullhead. Multiple life history stages of these species were captured during one or more sample periods during this study; however, abundance, irregularity of capture across years, and/or lack of strong support from the literature did not suggest that these species were obligated to the backwater habitats within this geographic region, but rather may set up residency when the opportunity was available. Fishes in the Residents-B category were suspected of spawning in the backwater habitats, but direct evidence was not secured. The adults and juveniles for each species were present, but demonstrate stochastic patterns that suggested the absence of an intense migration into or out of the backwaters.

Other groups of fishes exhibited strong migrational patterns, such as the members of an assemblage I will refer to as backwater spawners. This assemblage demonstrated strong movements of mature adults into the backwaters during the May and June ascending flood pulse, where they were observed spawning or preparing to spawn. By mid- to late summer, the larvae and juveniles of these species were utilizing the backwaters as nursery and rearing habitat. The members of this assemblage included bigmouth buffalo, smallmouth buffalo, river carpsucker, and to a lesser degree channel catfish and freshwater drum. The length-frequency histograms for smallmouth buffalo demonstrate the movement of adults into the backwaters typically during period 2, the adults quick departure by period 3, the abundant *Ictiobus* spp. larvae, and the continued use of the backwater habitats by the now juvenile age-0 buffalo (Figure 2-11).

Two other groups of fish that demonstrated migrations of adults (Transients-A) or

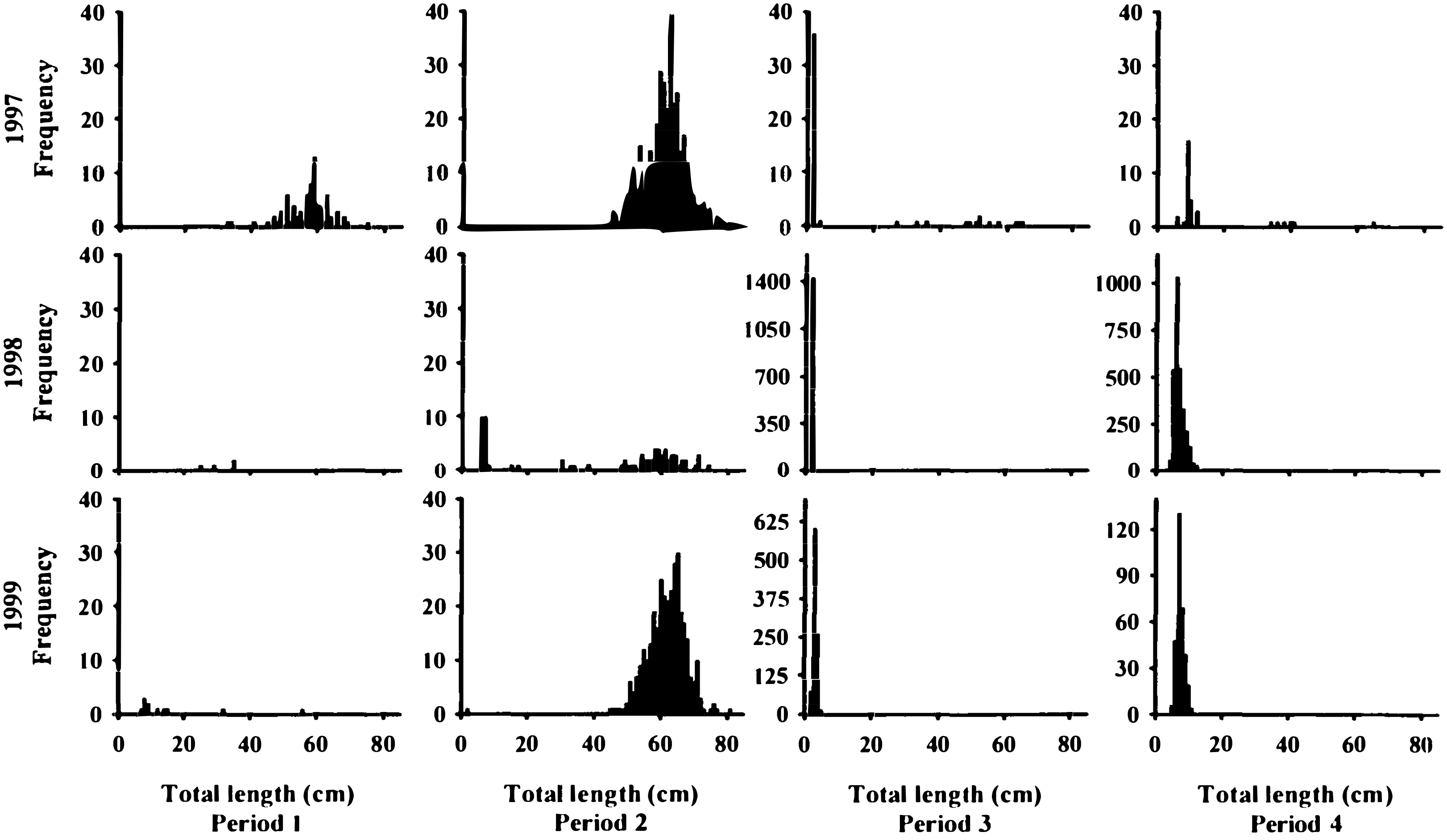

Figure 2-11. Length-frequency histograms of smallmouth buffalo from Erickson Island Slough, North Dakota, sampled during late April (Period 1), mid- to late May (Period 2), late June and early July (Period 3), and early September (Period 4) in 1997-1999. The frequencies represent the total catches during each period from 18 trap net nights.

adults and juveniles (Transients-B) were also identified. These two assemblages were set apart from the backwater spawners because they did not exhibit strong migrational patterns in and out of the backwater habitats (with the exception of goldeye), showed no indication of spawning, and their relative abundance tended to fluctuate irregularly across seasons and years. I suspect that the movement of these species between the backwaters and main channel may have been related to backwater food production, habitat refuge, or simply by chance. A small group of fishes periodically present in the backwaters as adults only were classified as members of the Transient-A assemblage and included brook stickleback, creek chub *Semotilus atromaculatus*, shortnose gar, and stonecats. No evidence supported the use of backwater habitats by larval or juvenile members of these species. A larger group of migratory fishes that were present as adults, juveniles and, in limited numbers as larvae but were not believed to spawn in the backwaters proper, were classified as Transients-B; these included goldeye, sauger, shorthead redhorse, walleye, and white sucker. As the length-frequency histograms for *Stizostedion* spp. demonstrates, a substantial influx of juvenile members during high connection periods and sporadic movements of adults does occur (Figure 2-12). A large migration of adult and juvenile goldeye can also be detected from the length-frequency histogram (Figure 2-13); however, the timing of these migrations varies and there was no evidence that the species was entering the backwaters to spawn.

The last assemblage was labeled the drifters and includes channel-spawned larvae and juveniles that appeared to enter the backwaters during periods of moderate to high connectivity, but not necessarily during peak flood-pulse flows. This assemblage

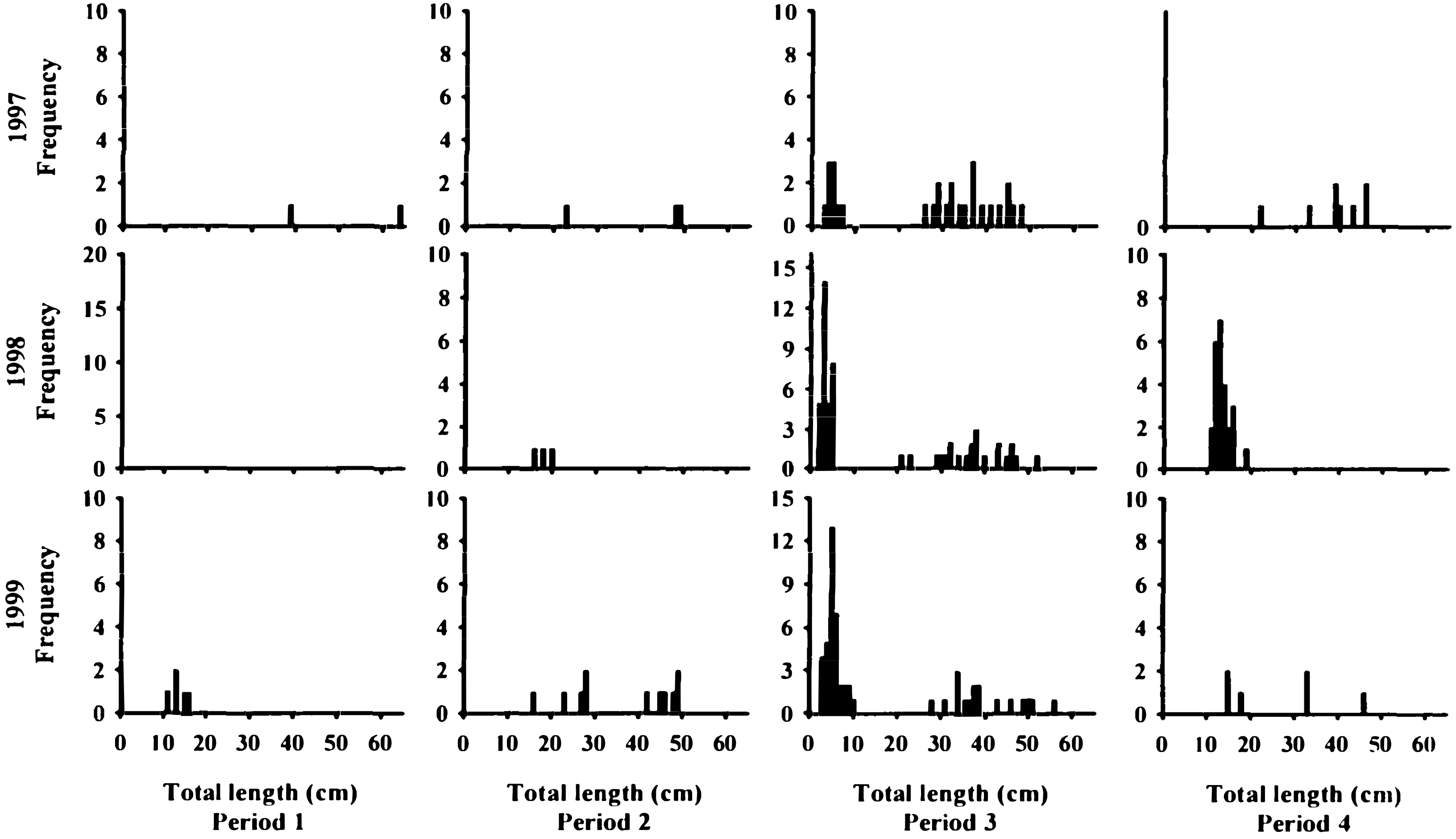

Figure 2-12. Length-frequency histograms of *Stizostedion* spp. from Erickson Island Slough, North Dakota, sampled during late April (Period 1), mid- to late May (Period 2), late June and early July (Period 3), and early September (Period 4) in 1997-1999. The frequencies represent the total catches during each period from 18 trap net nights.

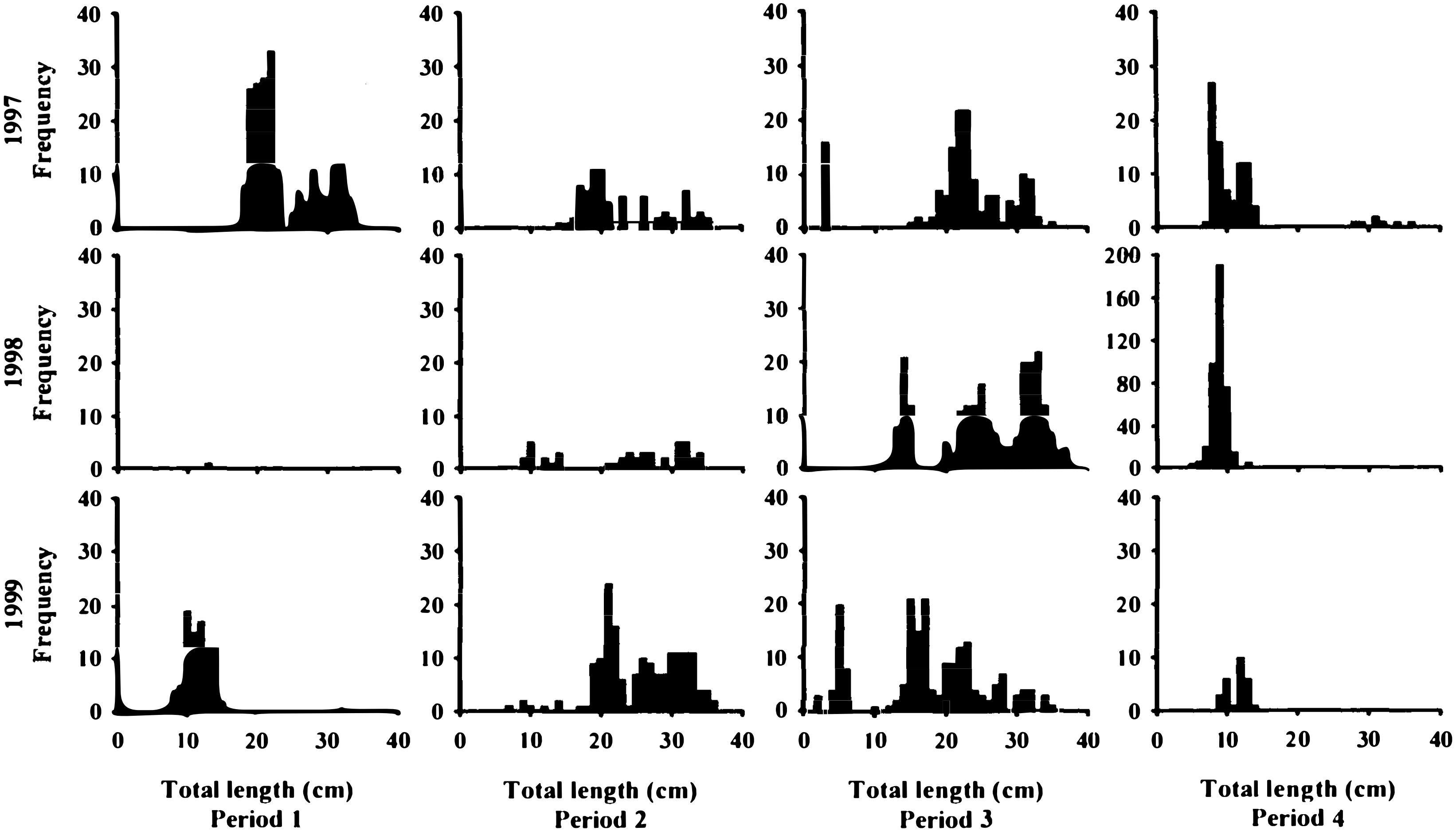

Figure 2-13. Length-frequency histograms of goldeye from Erickson Island Slough, North Dakota, sampled during late April (Period 1), mid- to late May (Period 2), late June and early July (Period 3), and early September (Period 4) in 1997-1999. The frequencies represent the total catches during each period from 18 trap net nights.

includes species such as blue sucker, burbot, lake herring, flathead chub, longnose sucker, and white bass *Morone chrysops*. Although the presence of blue sucker and burbot larvae is an important observation, it is difficult to assess how important the backwaters are to these species without comparative data for other habitat types in the same river segment. Researchers, as stated earlier, have struggled to capture age-0 members of these species.

Of the assemblages listed above, the drifters, backwater spawners, and residential fishes appear to rely most heavily on continued backwater connectivity. The reliance of transients on backwaters is unclear; however, food-habits information discussed in Chapters 4-6 reveal that numerous species directly and a few indirectly benefit from backwater invertebrate and larval fish production.

Chapter Summary

A number of apparent changes occured in backwater habitats during changes in connectivity with the river during a historical flood-pulse pattern. Chapter 2 is a large collection of habitat, water quality, zooplankton, macroinvertebrate, and fish community assessments. In terms of the fish community, seven fish assemblages were identified. The assemblages included two groups of residents, two groups of transients, and single groups representing lotic obligates, age-0 drifters, and backwater spawners. Although the differences among some of the identified assemblages are quite subtle, I believe that these groups of fishes are in fact behaving differently and are worthy of separation. Regardless of the assemblages, however, the funding agencies continued to be particularly interested in the backwater relationships between backwaters and native fishes of concern, particularly the sturgeons (pallid and shovelnose), blue sucker, the chubs (sicklefin, sturgeon, and flathead), paddlefish, and burbot. In general, there was no direct evidence of physical inhabitance of backwaters during any life stage by the sturgeons and sicklefin and sturgeon chubs. However, some evidence was noted for each of the other species was present.

Paddlefish have not been discussed in this chapter because they were not collected within the protocol of my study. According to this investigation, there was no evidence of paddlefish inhabiting either the CB or EIS; however, during a sample collection to assess goldeye predation during the second week of August 1998, a single paddlefish (35 cm in length from the eye to the fork of the tail) was captured and documented. During no other sample periods did I note any paddlefish activity. Of greater interest in regard to the paddlefish relationship with the backwaters were observations during period 3 of my 1998 sampling. On two separate afternoons, five paddlefish were observed holding in the mouth of the EIS outlet. Judged by the open mouths of these paddlefish, they appeared to be feeding on items flushed from the backwater.

Flathead chubs were found sparingly in both backwaters; however, given the species high abundance in the channel, a few individuals are probably going to enter backwater habitats. Compared with catches of flathead chubs on sandbar habitats, I believe that the backwater use by juvenile flathead chubs could be classified as quite low. The use of backwater-produced organisms by flathead chubs in the main river channel may be more noteworthy. In Chapter 5, I discuss the food habits of flathead chubs in greater detail. Although the flathead chubs and the other two chub species (sicklefin and sturgeon) appear to use different habitats during a majority of their life histories, it stands to reason that numerous species may be benefitting from backwater-produced prey as were the flathead chubs.

The larval burbot and blue suckers, although present in the backwaters during different periods, both appeared to seek refuge in the backwaters during portions of their early life history. Whether the larvae of these species actively sought backwater habitats or if they passively entered in the drift remains unclear. Either way, during 1997 and 1999, when the flows were similar to the mean hydrograph pattern (not intensity), the two species found their way into the backwaters. The blue sucker larvae were all sampled in the CB and nearly all of the burbot larvae were sampled in EIS. The habitat characteristics that make a backwater suitable for one species over another is intriguing, but difficult to answer without appropriate replications.

Chapter 3.

Dynamics of a Perched Missouri River Wetland

Large river ecosystems around the world have been substantially altered by human activity and the Missouri River floodplain is no exception (Amoros 1991; Hesse and Mestl 1993). Knowlton and Jones (1997) noted that natural wetlands were once numerous in the Missouri River floodplain, but most have been lost through draining, impoundment, or channelization. The loss of floodplain wetlands may be a critical factor in declining populations of some native species, as off-channel aquatic habitats are generally more productive than the river channels they border (Amoros 1991). During the flood-pulse phenomenon (Junk et al. 1989), backwaters can also be an important contributor of nutrients and organisms (Bayley 1995).

The loss of flood-pulse processes to artificial hydrographs has nearly eliminated opportunities to assess the importance of floodplain habitats under historical conditions. The Yellowstone River flows freely from the eastern slopes of the Rocky Mountains through the Montana plains to a confluence with the Missouri River in North Dakota. The natural flood pulse of the Yellowstone River strongly influences the Missouri River hydrograph for several kilometers until reaching the headwaters of Lake Sakakawea, a Missouri River mainstem reservoir. In this Yellowstone River influenced segment of the Missouri River, floodplain wetlands and backwaters with varying degrees of connectivity maintain historical structure and function. Some of these wetlands are perched at elevations several meters higher than the channel and free-flowing connection may be restricted to peak seasonal flow periods. Therefore, my objective was to survey aquatic fauna and habitat parameters in a perched backwater within the historical flood-pulse zone before, during, and after a period of channel connection to help assess the importance of this wetland type to the Missouri River ecosystem.

Study Site and Hydrologic Conditions

For this ecological study, I monitored a perched wetland located 15 river km downstream of the Yellowstone River and Missouri River confluence in North Dakota. The wetland has an approximate surface area of 10 ha, but can increase to more than 30 ha during peak flow periods. The water body lies to the south of the main Missouri River channel and is bordered by high bluffs to the east and a mix of agricultural land and riparian forest to the south and west. It remains separated from the main channel during most of the year by a clay bank that is relatively stable due to rooted terrestrial vegetation. Some horizontal groundwater penetration probably occurs; however, it is likely limited due to the heavy clay soils that underlay the wetland. Therefore, the backwater and channel appear to primarily exchange nutrients and organisms during high water periods.

Flow volume near the study site was indexed using cumulative flow (m^3/sec) data (USGS 1999) from an upstream Missouri River gauging station near Culbertson, Montana (69 km from study site) and a Yellowstone River gauging station near Sidney, Montana (48 km upstream). The cumulative 1997 hydrograph indicated that the annual water cycle was particularly wet and flow rates exceeded mean daily values by more than 50% during most of the open water season (Figure 3-1). On 18 May 1997 (day 138), cumulative flow surpassed 920 m^3/sec and I observed the initial period when water

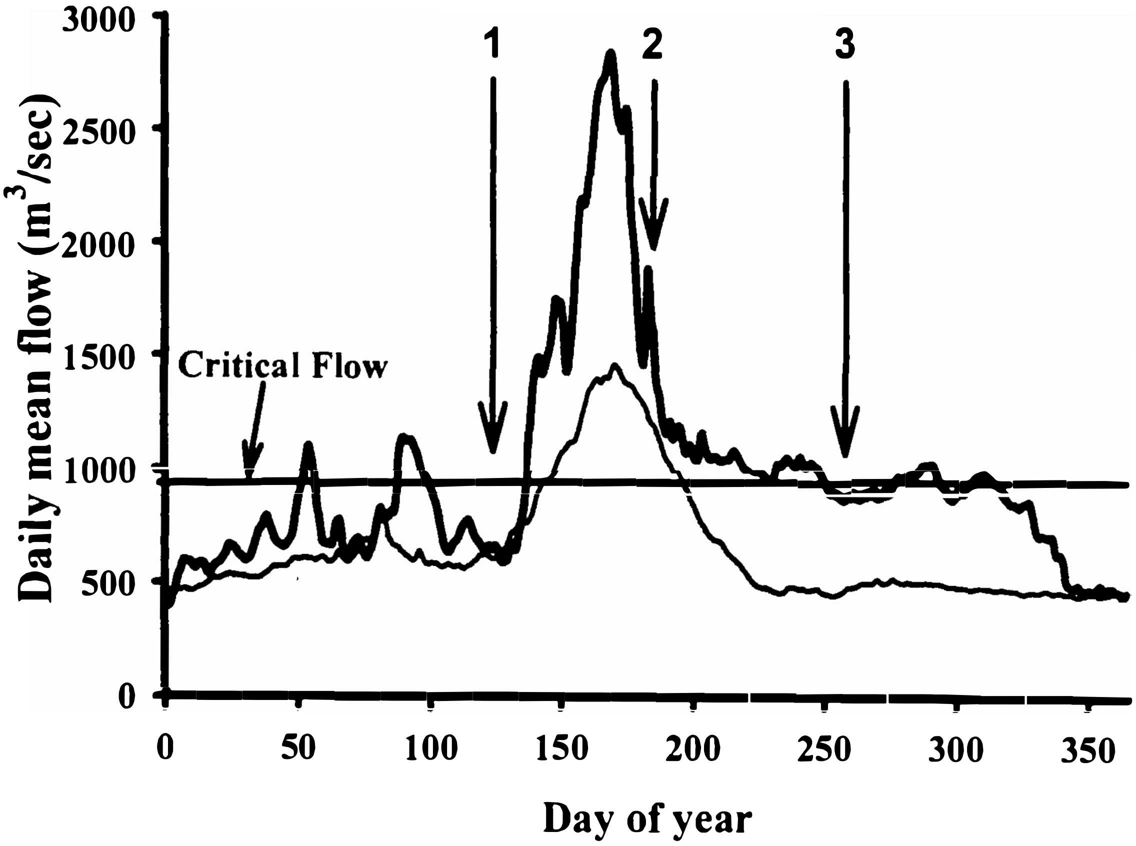

Figure 3-1. Cumulative daily mean flow (m^3/sec) for 1997 (solid black line) and the cumulative daily mean flow for all years combined from 1959 to 1997 (shaded area) of the Yellowstone River gauging station near Sidney, Montana and the Missouri River gauging station near Culbertson, Montana. The three 1997 sample periods are denoted by numerals (1=May, 2=July, and 3=September). The critical flow level at which water flowed into the perched wetland study site is designated.

overflowed the clay bank and freely entered the perched wetland. On 7 September 1997 (day 250), cumulative flow was 950 m^3/sec and a peripheral examination of the perched wetland revealed several free-flowing connection points. However, by 20 September (day 263), cumulative flow had dropped to 900 m^3/sec and another peripheral search disclosed no connections. Therefore, I hypothesized that a critical flow of approximately 910 m^3/sec was required to create and maintain a channel connection with this particular perched wetland in 1997.

Methods

Data collection

Sampling was completed in the wetland before (period 1), during (period 2), and after (period 3) peak flow connection in 1997 (Figure 3-1). I collected data on several habitat parameters, all life stages of fishes, benthic and limnetic macroinvertebrates, and zooplankton. Habitat information was collected along five transects during each sample period. Along each transect, 25 randomly selected locations were assessed for depth, substrate type, and the presence of woody debris, submergent vegetation, and emergent vegetation. Five randomly selected locations along each transect were also selected to assess conductivity and turbidity and complete DO, temperature, and pH profiles of the water column at 0.5-m increments. Substrates were collected with a petite ponar grab at each location, assessed, and categorized into one of three types, including detritus (decaying vegetation with limited soils), mud (particles held by a No. 10 sieve), and silt (particles flowed through a No. 10 sieve).

During each sample period, adult and juvenile fishes were sampled with six 2-hr gill-net sets (38 x 1.8 m with 7.6-m panels of 19-, 25-, 38-, 51-, and 76-mm bar measure monofilament mesh) and six trap-net nights (0.6- x 0.9-m frames, 3-mm mesh on hoops, and 7.6-m leads). Larval fishes and limnetic macroinvertebrates were sampled with quatrefoil light traps (25 x 30 cm with 2- to 4-mm slots, 12-h chemical stick light source). Benthic invertebrates were collected with a petite ponar grab and zooplankton were sampled with a 1-m tube sampler (75-mm diameter; DeVries and Stein 1991). All invertebrate samples were preserved in 5% sucrose-formalin and returned to the laboratory for enumeration and identification. Adult and juvenile fish were identified, measured, and released.

Statistical analyses

Depth, DO, temperature, conductivity, pH, and turbidity data were tested for normality with a Shapiro-Wilkes test (UNIVARIATE procedure; SAS 1990). With the exception of depth, none of the data sets were normal; however, visual inspection of the data plots suggested that normality would be achieved given sufficient sample size. Schlotzhauer and Littell (1987) also noted that if evidence exists to support the reasonable contention that the sample data parameter would be normally distributed in the overall population, parametric tests should still be used to retain analytical power. Therefore, parametric tests were utilized for these analyses. Depth, conductivity, and turbidity data were each analyzed with an ANOVA (ANOVA procedure; SAS 1990) to detect significant differences among sample periods. Statistical significance for all tests was set at $P<0.05$. When a significant difference was indicated, I used a Tukey's multiple range test to further assess difference among individual mean values (TUKEY command; SAS 1990).

DO, pH, and temperature data were each analyzed with a two-way ANOVA for unbalanced data sets (GLM procedure; SAS 1990) with the main effects of depth and sample period. The interaction terms between depth and sample period were not significant ($P>0.15$) for all three tests. Therefore, when a main effect was statistically significant, I again utilized the Tukey's test for each depth among sample periods and each sample period among depths to determine where those significant differences existed. During each sample period, I determined the proportion of the wetland that contained submergent vegetation, emergent vegetation, woody debris and each substrate type. The proportion data for all of these parameters were analyzed with a Chi-square test for homogeneity (Daniel 1990) to determine if the proportional coverage of each parameter differed significantly among sample periods.

The data for benthic invertebrate density (number/m^2), limnetic macroinvertebrate catch per unit effort (CPUE; number/light trap night), zooplankton density (number/L), and fish CPUE (number/trap net night) were tested for normality and visually inspected as described above. The zooplankton data were ascertained to be normally distributed and were analyzed with an ANOVA and Tukey's multiple range test. The macroinvertebrate and fish data did not appear to be normally distributed. Therefore, I altered the data with a $\log_{10}(n+1)$ transformation and reassessed the potential for normality; however, the data were still skewed. Thus, I used a Kruskal-Wallis ANOVA by ranks to detect significant differences among sample periods for each variable. When a significant difference was detected, I used a Mann-Whitney U test among all data pairs to determine which months were significantly different.

Results and Discussion

Using the 910 m^3/sec critical flow guideline, the wetland was connected to the main river channel during six different periods for a total of 181 days in 1997. Using mean daily flow data for the same gauging stations from 1959 to 1997, this wetland would typically connect once during the peak flow period and remain connected for approximately 58 days (Figure 3-1). Therefore, the results of this study may be somewhat different than what would be expected in a typical year; however, the opportunity to monitor changes in faunal densities and species composition before, during, and after the peak period connection was still available.

Habitat parameters, as expected, were considerably different during connection than they were before and after. During connection, the mean total depth of the perched wetland significantly increased ($P=0.004$) by more than 40% (Table 3-1). As a result of flow-through conditions and rising water, surrounding terrestrial habitats were inundated and the proportional area containing woody debris also significantly increased ($P<0.01$) by more than 35%. Limited aquatic vegetation of any type was present in this wetland. The substrate, dominated by a thick silt layer during most of the year, likely inhibited macrophyte establishment. During the high-flow period, silt deposits appeared to degrade and mud and detritus became notable substrate components (Table 3-1). The detritus

Table 3-1. Habitat parameters assessed in May, July, and September of 1997 in a perched wetland along the Missouri River in North Dakota. For mean values, the standard errors are in parentheses. Means with the same superscript letter were not significantly different (P>0.05) among months and with the same numerals were not significantly different (P>0.05) among depths . Due to limited depths during some sample periods, some habitat measurements were limited or not available (NA). The number of measurements collected during each sample period is also noted (N).

Habitat parameter	N	May	July	September
Mean total depth (cm)	25	^{a}81.2 (10.1)	^{b}119.4 (11.1)	^{a}70.1 (10.2)
Mean dissolved oxygen (ppm)	5			
0.1 m subsurface		^{a1}11.44 (0.54)	^{b1}5.04 (0.34)	^{ab1}8.52 (0.08)
0.5 m subsurface		^{a1}11.22 (0.34)	^{c1}4.40 (0.50)	^{b1}8.20 (0.10)
1.0 m subsurface		^{a1}10.60 (0.10)	^{c2}1.43 (0.96)	^{b2}7.30 (NA)
1.5 m subsurface		NA	^{3}0.50 (NA)	^{2}7.00 (NA)
Temperature (°C)	5			
0.1 m subsurface		^{a1}20.68 (0.77)	^{a1}22.76 (0.06)	^{b1}15.3 (0.19)
0.5 m subsurface		^{a1}20.36 (0.75)	^{a1}22.40 (0.15)	^{b2}12.7 (0.30)
1.0 m subsurface		^{a1}18.60 (0.70)	^{a1}20.83 (0.66)	^{b2}11.1 (NA)
1.5 m subsurface		NA	^{2}17.20 (NA)	^{2}11.2 (NA)
pH	5			
0.1 m subsurface		^{a1}6.10 (0.03)	^{b1}7.56 (0.08)	^{c1}8.38 (0.06)
0.5 m subsurface		^{a2}6.18 (0.02)	^{b1}7.36 (0.43)	^{c1}8.35 (0.15)
1.0 m subsurface		^{a2}6.25 (0.05)	^{b2}7.08 (0.17)	^{c1}8.40 (NA)
1.5 m subsurface		NA	^{2}6.90 (NA)	^{1}8.30 (NA)
Conductivity (μS/cm)	5	^{a}671 (5)	^{b}432 (9)	^{a}578 (2)
Turbidity (NTU)	5	^{a}0.4 (<0.1)	^{b}13.8 (0.7)	^{b}21.2 (2.1)
Submergent Vegetation (% cover)	25	^{a}12	^{a}16	^{a}0
Emergent Vegetation (% cover)	25	^{a}16	^{a}20	^{a}0
Woody debris (% area presence)	25	^{a}40	^{b}76	^{a}36
Substrate (% present)	25			
silt		^{a}100	^{b}24	^{a}100
mud		^{a}0	^{b}48	^{a}0
detritus		^{a}0	^{b}28	^{a}0

accumulated from both inundated terrestrial grasses and deposits of coarse particulate organic matter from the river channel. As water levels decreased, siltation increased and the substrate again became relatively homogenous.

Detrital accumulation, the subsequent decay process, and the continuous flushing which limits algal establishment and productivity, may alter DO concentrations. Barton and Taylor (1996) suggested that rivers with slow-moving waters, like those found in off-channel areas, can become critically low in DO due to turbidity, lack of rooted macrophytes, and decomposition from detrital deposition. July DO levels were significantly lower ($P<0.001$) than other sample periods and the lower water column became nearly anoxic (Table 3-1). Partial water column anoxia may result in the development of internal hypoxia in fish. Hypoxia, or the lack of sufficient oxygen at the cellular level, can cause fish to alter behaviors or cause death (Suthers and Gee 1986). Kramer (1987) noted that fish will use upper water columns and increase surface breathing activity when DO is limited in bottom waters, increasing their risk of avian predation. This may have been particularly true during my study, as American white pelicans *Pelecanus erythrorhynchos*, western grebes *Aechmophorus occidentalis*, double-crested cormorants *Phalacrocorax auritus*, great blue herons *Ardea herodias*, and common terns *Sterna hirundo* were observed feeding and nesting in and near the study site.

The lack of DO in lower water levels combined with the thick detrital deposit on the sediment-water interface likely created nearly anoxic sediments. Barton and Taylor (1996) noted that benthic invertebrate communities can be structured by the availability of DO. Nebeker (1972) suggested that DO levels <4 mg/L can initiate lethal responses in nearly half of all benthic invertebrate species and Jacob et al. (1984) recognized that the lower tolerance limit for nearly all benthic invertebrates was above 10% of saturation. Our benthic invertebrate densities, although not significantly different among sample periods, declined during July with Diptera (excluding Chironomidae) and Trichoptera completely absent from the samples (Table 3-2). Benthic invertebrates, similar to fishes, may also attempt to utilize the upper water column with higher DO levels; however, I did not locate any documentation of such activity.

Although not identified to species, benthic invertebrate richness appeared to be low, with Chironomidae and Oligochaeta being the only two taxonomic groups represented in appreciable quantities. The Oligochaeta densities did not exceed 42/m^2 and were substantially lower than densities reported for other water bodies. Canfield et al. (1996) reported Oligochaeta densities ranging from 300 to over 100,000/m^2 in the Saginaw River and Indiana Harbor areas of Lake Michigan. Chironomidae densities in the perched wetland were between 125 and 450/m^2 and comparable to those reported elsewhere. Rosemond et al. (1992) documented Chironomidae densities ranging from 125 to 1,650/m^2 and Canfield et al. (1996) also noted densities ranging from 10 to nearly 400/m^2 in the Buffalo River of New York. All of these sites have substrates dominated by fine particles. With larger substrate particle size, Chironomidae abundance can regularly surpass 30,000/m^2, as was reported by Barber and Kevern (1973) for the Pine River in Michigan. Although the decline in Chironomidae density during channel connection appeared to be modest, there had been a nearly 60-d recovery time between

Table 3-2. Benthic and limnetic macroinvertebrate density estimates for May, July, and September of 1997 from a perched wetland along the Missouri River in North Dakota. Mean benthic invertebrate density (number/m^2) and limnetic invertebrate catch per unit effort (CPUE; number/trap night) are listed with standard errors in parentheses. The number of samples collected during each sample period is noted (N). No significant differences ($P>0.05$) among macroinvertebrate density or CPUE estimates were detected.

Taxon category	N	May	July	September
Benthic samples:	4			
Chironomidae		420.2 (165.4)	126.1 (100.0)	367.6 (120.2)
Other Diptera		10.5 (10.5)	0	0
Oligochaeta		10.5 (10.5)	10.5 (10.5)	42.0 (42.0)
Trichoptera		10.5 (10.5)	0	0
Limnetic samples:	4			
Amphipoda		0.5 (0.5)	0.5 (0.5)	12.0 (11.7)
Chironomidae		0	2.8 (1.6)	0.5 (0.3)
Coleoptera		2.0 (0.8)	0.5 (0.5)	0
Corixidae		2.3 (0.5)	51.0 (49.7)	25.8 (10.5)
Ephemeroptera		0	0.8 (0.3)	0.5 (0.3)
Hydracarina		191.8 (109.0)	2.0 (1.2)	6.0 (3.2)
Odonata		0	0	0.25 (0.25)
Other Diptera		1,252.8 (563.4)	117.3 (78.6)	51.0 (17.1)
Plecoptera		0.5 (0.3)	0	0
Trichoptera		0	0.25 (0.25)	0

initial connection and the July sample period. Stock and Schlosser (1991) noted that during a sudden flushing event, as much as 95% of all macroinvertebrates can be lost, but within 60 d a 50% recovery of predisturbance abundance can be achieved.

With the exception of Hydracarina, limnetic macroinvertebrate densities did not appear to be highly influenced by flushing. CPUE of limnetic macroinvertebrates did not significantly differ among months for any designated taxon (Table 3-2). Although a substantial decline in relative Diptera abundance occurred in mid-summer, it may have been a combination of emergence and flow-through export. Other limnetic taxa, particularly the Corixidae, appeared to find refuge and suitable foraging conditions in the inundated vegetation and actually increased in relative abundance during the connection period. Although the CPUE change was subtle, Chironomidae presence in the upper water column increased in July, possibly supporting speculation that anoxic sediments may force normally benthic invertebrates to use limnetic habitats. The use of light traps to monitor limnetic macroinvertebrates is an uncommon practice and comparative data are thus difficult to locate.

Zooplankton density estimates for Copepoda nauplii, calanoid Copepoda, and *Bosmina* spp. significantly differed among months ($P<0.02$; Table 3-3). However, no distinct pattern relating to connection period could be identified. Cyclopoid Copepoda abundance declined during the connected and post-connection periods, but was not significantly different ($P=0.115$) among sample periods. Total zooplankton density during all sample periods exceeded 3,200 organisms/L. The total zooplankton densities substantially exceeded those reported by Power and Owen (1984) for nearby Lake

Table 3-3. Mean zooplankton density (number/L) and standard error (in parentheses) for May, July, and September of 1997 from a perched wetland along the Missouri River in North Dakota. Four 3-m tube samples were collected during each month. Means with the same superscript letters were not significantly different (P>0.05) among months.

Taxon category	May	July	September
Copepoda nauplii	^{b}815.99 (345.10)	^{a}2,451.52 (349.61)	^{ab}1,572.54 (301.49)
Calanoid Copepoda	^{b}0.57 (0.20)	^{b}0	^{a}79.26 (14.07)
Cyclopoid Copepoda	^{a}2,122.72 (795.89)	^{a}837.65 (138.23)	^{a}634.11 (196.55)
Bosmina spp.	^{b}161.92 (55.20)	^{b}326.47 (68.47)	^{a}924.27 (145.42)
Daphnia spp.	^{a}112.59 (23.74)	^{a}90.52 (27.37)	^{a}70.77 (32.27)
Other Cladocera	^{a}1.42 (0.48)	^{a}0.64 (0.24)	^{a}0.14 (0.14)

Sakakawea headwaters where summer densities did not exceed 350/L. Even in a hypereutrophic glacial lake in South Dakota, total zooplankton density infrequently surpassed 1,000/L (Fisher 1996). The high production of zooplankton in this floodplain wetland and the periodic exchange of organisms with the main river channel adds supporting evidence that these habitats may play a critical role in providing prey items to the Missouri River invertebrate drift. Fishes may also be able to take advantage of this high productivity during periods of connection by migrating into these regions to forage and spawn.

Twenty-four fish species were found in the perched wetland during one or more of the three sample periods in 1997 (Table 3-4). The most prominent resident of the perched wetland, and one of the most environmentally tolerant species in the area, was the black bullhead. Northern pike, common carp, golden shiner, channel, green sunfish, creek chub, fathead minnow, shortnose gar, yellow bullhead, and goldeye, were also sampled in limited numbers during one or more sample periods (Table 3-4). Although no adult smallmouth buffalo or bigmouth buffalo were captured in the wetland, individuals were observed entering this habitat during the initial connection period. I observed more than 20 buffalo fishes attempting to enter the perched wetland by jumping onto the clay bank and laboriously working their way across the mud flats to enter water that was less than 10 cm in total depth. Likewise, common carp that were already inhabiting the closed wetland were escaping into the river channel during the initial connection.

The initial sample period in May revealed the presence of a few species not expected in the closed wetland, including flathead chub, burbot, western silvery minnow,

Table 3-4. Catch per unit effort from trap nets (TN; number per net night) and gill nets (GN; number/hr) and standard errors (in parentheses) for May, July, and September (Sept) of 1997 from a perched wetland along the Missouri River in North Dakota. Six trap nets and six gill net sets were completed during each sample. Stage designations include adult (A), juvenile (J), or no separation (NS) and the total length criteria for the separations, in addition to the species abbreviations definitions are noted in appendix 1. Means with the same superscript letters were not significantly different ($P>0.05$) in gill net samples among months and means with the same numerals were not significantly different among trap net samples.

Species	Stage	May TN	May GN	July TN	July GN	Sept TN	Sept GN
BIB	J	^{2}0	^{b}0	^{2}0	^{b}0	^{1}7.3 (3.9)	^{a}1.0 (0.3)
BLB	A	^{1}1.0 (0.4)	^{a}0	^{1}2.0 (0.6)	^{a}0	^{1}45.8	^{a}0.2 (0.1)
	J	^{1}1231.2	^{b}0	^{2}45.7	^{b}0	^{1}413.0	^{a}2.6 (0.6)
BUR	J	^{1}0.5 (0.2)	^{a}0	^{1}0.2 (0.2)	^{a}0	^{1}0	^{a}0
CCF	A	^{1}0.2 (0.2)	^{a}0.1 (0.1)	^{1}0.2 (0.2)	0.8 (0.5)	^{1}0	^{a}0
	J	^{1}0	^{a}0	^{1}0	^{a}0	^{1}0.5 (0.5)	^{a}0
COC	A	^{2}0	^{a}0	^{1}1.2 (0.4)	^{a}1.1 (0.7)	^{2}0	^{a}0.1 (0.1)
	J	^{2}0.1 (0.1)	^{a}0	^{1}18.3	^{a}0	^{2}1.3 (0.5)	^{a}0
POM	A	^{1}0	^{a}0	^{1}3.3 (1.3)	^{a}0	^{1}2.0 (1.6)	^{a}0
	J	^{2}0	^{a}0	^{2}0.2 (0.2)	^{a}0	^{1}14.5	^{a}0
CRC	NS	^{1}0.2 (0.2)	^{a}0	^{1}0	^{a}0	^{1}0	^{a}0
FHM	NS	^{1}0.2 (0.2)	^{a}0	^{1}0	^{a}0	^{1}0	^{a}0
FLC	NS	^{1}1.0 (0.6)	^{a}0	^{2}0	^{a}0	^{2}0	^{a}0
GOS	NS	^{1}0.2 (0.2)	^{a}0	^{1}0.2 (0.2)	^{a}0	^{1}0.2 (0.2)	^{a}0
GOE	A	^{2}0	^{a}0.9 (0.7)	^{2}0	^{a}0.2 (0.2)	^{1}1.8 (0.9)	^{a}0
	J	^{1}0	^{a}0	^{1}0	^{a}0	^{1}0.5 (0.5)	^{a}0
LEP	NS	^{1}0.2 (0.2)	^{a}0	^{1}0.2 (0.2)	^{a}0	^{1}0	^{a}0
HYB	NS	^{1}0.3 (0.2)	^{a}0	^{1}0	^{a}0	^{1}0.5 (0.5)	^{a}0
LOD	NS	^{1}0.2 (0.2)	^{a}0	^{1}0	^{a}0	^{1}0	^{a}0
NOP	A	^{1}0.2 (0.2)	^{a}2.2 (1.2)	^{1}0.2 (0.2)	^{b}0	^{1}0.7 (0.5)	^{a}2.7 (1.2)
	J	^{1}0	^{b}0.4 (0.4)	^{1}0.5 (0.5)	^{b}0.2 (0.2)	^{1}0.8 (0.5)	^{a}1.9 (0.5)
RIC	J	^{2}0	^{a}0	^{2}0	^{a}0	^{1}6.7 (3.6)	^{a}0.2 (0.2)
STZ	J	^{1}0	^{a}0	^{1}0	^{a}0	^{1}0.4 (0.2)	^{a}0
SHR	A	^{1}0	^{a}0	^{1}0	^{a}0	^{1}0.2 (0.2)	^{a}0
SHG	A	^{2}0	^{b}0	^{2}0	^{b}0	^{1}1.0 (0.4)	^{a}0.8 (0.4)
SAB	J	^{1}0	^{a}0	^{1}0	^{a}0	^{1}2.3 (1.7)	^{a}0.2 (0.1)
WHS	A	^{1}0	^{a}0	^{1}0.7 (0.3)	^{a}0	^{1}0.8 (0.5)	^{a}0
YEB	J	^{1}0.8 (0.8)	^{a}0	^{1}0	^{a}0	^{1}0	^{a}0
YEP	A	^{2}0	^{a}0	^{2}0	^{a}0.2 (0.2)	^{1}0.5 (0.2)	^{a}0
	J	^{1}0	^{a}0	^{1}0	^{a}0.2 (0.2)	^{1}0.3 (0.3)	^{a}0

and longnose dace. I suspect that these fishes entered the perched wetland during the early connections that occurred in February and March of 1997 (Figure 3-1) and became stranded. Other species that either moved into the wetland after connection or were hatched in the wetland proper included juvenile river carpsuckers, shorthead redhorse, sauger, and the buffalo fishes. Only four larval fishes were captured with the light traps, all during July, and included a single specimen of channel catfish, goldeye, common carp, and white sucker. The presence of large numbers of juvenile fishes (e.g., white crappie and yellow perch) during and after the connection period suggests that these off-channel habitats may be important rearing areas. Kwak (1988), Scott and Nielsen (1989), and Copp (1997) all suggested that access to backwater habitats may be a critical factor in the life history of many riverine fishes.

Unfortunately, it appears that the natural hydrographs of nearly all large rivers in the world have been or are in the process of being disrupted. Hesse and Mestl (1993) noted that the seven mainstem and some 75 tributary stream dams in the Missouri River basin have substantially altered historical structure and function. In the small Missouri River segments where natural hydrographs are still achieved, the use of floodplain wetlands by fishes appears to mimic historical processes. The existence of some 24 fish species and the substantial production of zooplankton implies that these small wetlands, even though small and inconspicuous, may be vital to the health of the ecosystem. The environmental conditions at times may be quite harsh and cause biological stress in benthic invertebrates and fish; however, the potential refuge, prey productivity, and contribution to the avian community outweigh those disadvantages when considered as one component of the larger ecosystem.

Chapter Summary

The Missouri River floodplain historically contained numerous wetlands; however, alterations to the corridor have resulted in the loss of flood-pulse processes. Small perched wetlands that only connected during peak flows on an annual basis were often discounted as unimportant and drained or filled. The objective of this study was to survey aquatic fauna and assess habitat parameters in a small perched wetland before, during, and after a period of connection within a naturally functioning section of the Missouri River in western North Dakota. Fishes, macroinvertebrates, zooplankton, and habitats were sampled during May, July, and September of 1997. No significant differences ($P>0.05$) in densities or catch per unit effort (CPUE) among sample periods could be detected for either benthic or limnetic macroinvertebrates. Zooplankton densities exhibited significant changes ($P <0.02$) and, regardless of sample period, surpassed 3,200 organisms/L. Zooplankton densities in the wetland exceeded other regional means by as much as 900%. Twenty-four fish species were documented in the wetland; however, the black bullhead dominated the fish community. Several other fishes utilized the wetland, particularly during their juvenile zooplanktivorous life history stage. Wetland depth and surface area increased during the connection period and inundated terrestrial grasses and woody debris. Decay of inundated organic matter, combined with the lack of rooted macrophytes, loss of algal communities to flushing, and higher turbidity, limited mid-summer DO levels. Avian feeding activity suggested that fishes were utilizing upper water column portions when nearly anoxic lower water column conditions existed. Although the wetland habitat may be harsh, the presence of juvenile fishes and dense zooplankton promotes the importance of these water bodies as refuge and production areas that contribute to the Missouri River ecosystem.

Chapter 4.

Backwater Ecology: Early Life History Observations of Burbot Utilizing Missouri River Backwater Habitats

Burbot are top-level predators in many northern latitude lakes and rivers and research assessing adult burbot population dynamics and ecology has been completed (e.g., Schram 1983; Carl 1992; Bernard et al. 1993). Historically, the burbot has been considered a nuisance because of its voracious appetite for commercially and ecologically important fish species (Branion 1930; Bailey 1972). In recent years, however, the value of burbot as a sport fish and aquatic community member has been re-evaluated as the species is declining in some modified river systems (Paragamian et al. 1998).

With a renewed interest in the burbot, questions regarding all segments of their life history have arisen. Although burbot larvae are often common in large lakes (Clady 1976; Mansfield et al. 1983), the age-0 members of the species are rarely captured and typically found in low numbers (Hanson and Qadri 1980). The gap of knowledge concerning burbot early life history appears to be particularly apparent for populations inhabiting large river systems. In 1997 and 1998, research conducted in two upper Missouri River backwaters revealed the existence of early life stage burbot. Given this unique opportunity, my objectives were to 1) determine age-0 burbot growth rates, 2) assess age-0 burbot food habits, and 3) qualitatively describe the backwater habitats utilized by the 1997 burbot year class during the first year of life.

Methods

Larval and juvenile burbot were captured in both EIS and the CB. A backwater, as described earlier, was defined as an off-channel habitat that contained water with limited flow and maintained a connection with the main river channel during all or a large portion of the year. In 1997, however, the backwaters maintained higher water levels and greater flow-through rates due to the unusually intense hydrograph peak (greater than 25,500 m^3/sec) in the Yellowstone River (Figure 1-1).

For this study, fish sampling was conducted in late April (Period 1), late May (Period 2), early July (Period 3), and early September (Period 4) of 1997 and then again in Period 1 of 1998. Larval fishes were sampled with quatrefoil light traps (25 cm high x 30 cm wide) with 2- to 4-mm slots and a 12-h photochemical stick was used as a light source. Ten light traps were set overnight in each backwater at randomly selected locations within a stratum where water depth was $\geq$30 cm. CPUE, defined as the number/trap net night, and the standard error (SE) of the mean were calculated for each sample period. Larval fishes were also sampled during daytime hours with an ichthyoplankton surface trawl (50-cm mouth; 500-μm bar-measure mesh) at random locations within a stratum where water was $\geq$50 cm. The surface trawl was pulled from the boat at approximately 1 m/sec for 1 to 4 min. Eight surface trawl samples were collected from each backwater during each sample period, except for Period 1 of 1998 when water levels were too low to deploy the gear. Mean CPUE, defined as the number/min, and SE were calculated for each sample period. Larval fish identification was completed using the Auer (1982) key and case specimens were verified by the Larval Fish Laboratory biologists at Colorado State University in Fort Collins, Colorado.

Juvenile fish were collected with a bag seine (30 x 1.8 m with 1.8-m^3 bag and 6-mm bar measure mesh) and trap nets (three nets with 0.9- x 1.8-m frames, 9.5-mm bar measure mesh, and 16-m leads; three nets with 0.6- x 0.9-m frames, 9.5-mm bar measure mesh on frames, 3-mm bar measure mesh on hoops, and 7.6-m leads). Six daytime seine hauls were completed along 20-m open shoreline sections during each sample period in each backwater in 1997. Bag seining was not completed in Period 1 of 1998 due to excessive mud and silt deposits. Mean CPUE, defined as the number/seine haul, and SE were calculated for each sample period. Eighteen trap net nights (nine nights with each net size) were completed in each backwater during each sample period and CPUE, defined as the number/net night, and SE were calculated.

Descriptive notes on sample locations, habitats, and water temperatures were recorded when burbot larvae or juveniles were captured. All sampled burbot larvae were measured to the nearest 0.1 mm TL and juveniles were measured to the nearest mm TL. Mean TL and SE were calculated for each of the sample periods where sample sizes were sufficient. Stomach contents of up to 15 randomly selected burbot from sample periods 1 and 3 in 1997 and during period 1 of 1998 were assessed. Stomachs were examined and percent by number and frequency of occurrence for each diet item were reported.

Results and Discussion

Age-0 collection summary

A total of 10 burbot larvae [CPUE of 0.50/trap night (SE=0.28)] were captured only in Period 1 of 1997 with the light traps. No larval burbot were collected during any other sample period with either larval collection gear. No age-0 burbot were captured in Period 2 of 1997 with either the seine or the trap nets; however, the trap net CPUE of juvenile burbot for Period 3 in 1997 was 2.8/net night (SE=1.2). In all sample periods combined, only two juvenile burbot were collected with the shoreline seine, suggesting that open-shore littoral areas were not commonly utilized by burbot juveniles during the day. The age-0 burbot were again absent from the fish collections in Period 4 of 1997, but age-1 burbot reappeared in Period 1 of 1998 with a trap net CPUE of 1.1 (SE=0.4). The absence of age-0 burbot in Period 2 of 1997 may have been due to gear selectivity and avoidance; however, the lack of juveniles in the September sample period raises challenging questions about overwinter habitat use.

Growth

The mean TL of the larval burbot captured in Period 1 of 1997 (N=10) was 4.9 mm (SE=0.1). The mean TL of the burbot larvae was slightly less than would have been expected considering that the specimens were near the end of yolk-sac stage and had initiated feeding. Burbot larvae of comparable developmental stages should be >6-mm TL (Auer 1982). The disparity between larval fish TL measurements may be explained by the shrinkage that often occurs due to preservation in formalin (e.g., Jennings 1991; Fisher et al. 1998). By early July, the mean TL of age-0 burbot had increased to 80.9 mm (SE=1.2) and by the following April, the now age-1 burbot had reached a mean TL of 152.6 mm (SE=3.8; Figure 4-1). The growth rate between April and July was approximately 0.99 mm/day. This is faster than the rate reported for burbot larvae in Shebandowan Lake, Ontario, where daily growth rates during the first 5 months of life were approximately 0.52 mm/day (Ryder and Pesendorfer 1992; Figure 4-1). By age-1, the remaining burbot in the two backwaters were considerably shorter than the mean TL reported for Lake Erie (Clemens 1951), but seemed to be similar with those collected from Lake Opeongo, Ontario (Martin 1940; Figure 4-1).

Food habits

Sufficient numbers of larval and juvenile burbot were collected to assess stomach contents in Periods 1 and 3 of 1997 and Period 1 of 1998. Although sample sizes were low, studies have often found limited variability in the diets of age-0 fishes (e.g., Siefert 1972; Fisher and Willis 1997); thus, the information collected is still of interest. In April of 1997, the larval burbot appeared to be in the early stages of exogenous feeding. Six of the 10 larvae contained food items, including *Bosmina* spp., Copepoda nauplii, and *Keratella* spp. (Table 4-1). Copepoda nauplii were the most numerous by number (62.5%) and were found in half of the total larval stomachs combined. Few other studies note the first food of burbot; however, Hartmann (1983) observed a strict diet of

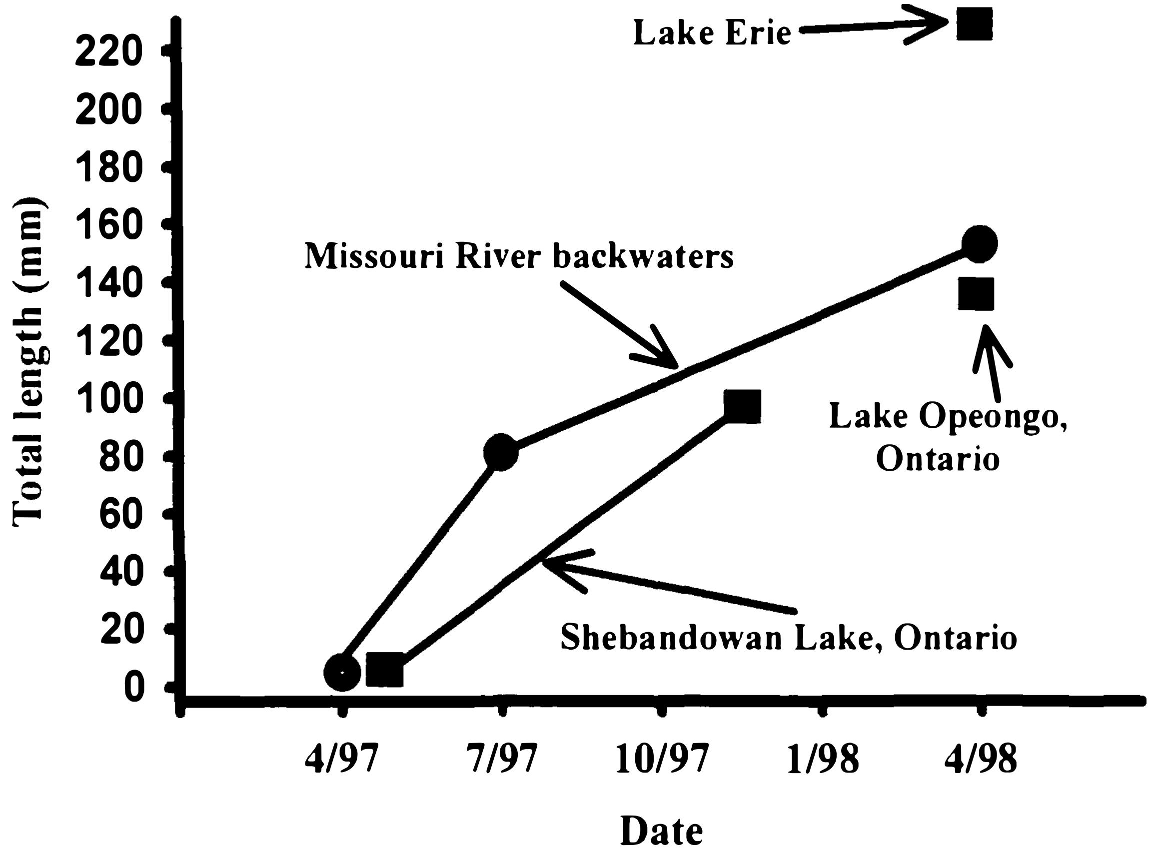

Figure 4-1. Mean length at time of capture in 1997 and 1998 of the 1997 burbot year class from two Missouri River backwaters in North Dakota. Also noted from years other than 1997 and 1998 are the observed growth rates for age-0 burbot in Shebandowan Lake, Ontario (Ryder and Pesendorfer 1992) and the mean back-calculated lengths for age-1 burbot collected in Lake Opeongo, Ontario (Martin 1940) and Lake Erie (Clemens 1951).

Table 4-1. Summary of stomach contents from larval burbot collected in April of 1997 and juvenile burbot collected in July of 1997 and April of 1998 from two Missouri River backwaters in northwestern North Dakota. For each sample period, the number of stomachs (N) and percent empty are indicated. For each sample period and taxon found in the stomachs, the percent by number of all diet items and frequency of occurrence in all stomachs is reported.

Period-Year	N	Taxon	Percent by number	Frequency of occurrence
1-97	10	*Bosmina* spp.	12.5	10.0
		Copepoda nauplii	62.5	50.0
		Keratella spp.	25.0	20.0
3-97	15	Amphipoda	22.8	53.3
		Chironomidae	10.4	20.0
		Corixidae	4.2	13.3
		Plecoptera	20.8	40.0
		Trichoptera	14.6	26.7
		Larval *Ictiobus* spp.	18.8	26.7
		Larval *Catostomus* spp.	4.2	13.3
		Larval goldeye	4.2	13.3
1-98	15	Amphipoda	20.0	46.7
		Chironomidae	27.7	20.0
		Coleoptera	3.1	13.3
		Corixidae	9.2	33.3
		Odonata	12.3	53.3
		Plecoptera	18.5	33.3
		Trichoptera	9.2	26.7

Copepoda nauplii through the first 6 weeks of life in Lake Constance, Switzerland, and Ghan and Sprules (1993) documented Copepoda nauplii and rotifers as burbot first foods in Oneida Lake, New York.

Ryder and Pesendorfer (1992) documented limnetic feeding of burbot on zooplankton until approximately 30-mm TL, after which they became exclusively benthic foragers, feeding at night and almost exclusively on Amphipoda. Other studies (e.g., Beeton 1956; Hanson and Qadri 1980) also noted that Amphipoda was an important diet taxon for burbot. The current study also supports the contention that Amphipoda may be an important food resource for juvenile burbot in Missouri River backwaters (Table 4-1). Unlike the other documented burbot food habits, however, the diets of the backwater-collected juveniles were not dominated by Amphipoda. Other important food items in the first growing season were Plecoptera, Trichoptera, and larval fishes (*Ictiobus* spp., *Catostomus* spp., and goldeye). Larval fish consumption, as observed in my study, by juvenile burbot is believed to be uncommon. Of the studies located, only Ryder and Pesendorfer (1992) documented any piscivorous feeding (a single smallmouth bass *Micropterus dolomieu* larvae). The opportunistic nature of the burbot appears to begin early in their life history. Larval fishes, especially catostomids, were plentiful in the backwater habitats from June through September. As was suggested by the lack of fishes in the April 1998 diets, the overwinter decline in larval fishes of the appropriate size for burbot predation appears to return the food habits to domination by invertebrates, particularly Amphipoda, Chironomidae, Odonata, and Plecoptera (Table 4-1).

Backwater habitat use

No distinguishable characteristics were noted about the larval burbot collection sites. Ryder and Pesendorfer (1992) reported that schools of swim-up fry could be located in the upper water column of littoral habitats. It could be hypothesized that burbot larvae are attracted to areas with high densities of Copepoda nauplii and rotifers; however, as Houde (1969) noted, larval fishes and zooplankton inhabiting upper portions of the water column are often at the mercy of prevailing winds and currents. Burbot will spawn in lotic habitats and have been known to migrate from lentic habitats into tributary rivers for spawning purposes (e.g., Schram 1983). Therefore, it is assumed that the burbot larvae captured in the two Missouri River backwaters likely were channel-spawned and then drifted into the backwaters during rises in early spring water levels.

Although not quantified, several habitat characteristics where burbot juveniles were collected appear to be noteworthy. During high water flows, old channels and chutes meander through the existing backwater habitats, leaving a series of small, deeper pools. More than 95% of the burbot juveniles sampled in July of 1997 were from trap nets set in water deeper than 1.5 m, with some flow, water temperatures not exceeding 20°C, and adjacent to habitat segments consisting of flooded terrestrial vegetation. These flooded vegetative habitats were highly productive zones for macroinvertebrates, particularly Amphipoda and Odonata (Chapter 2). Although no age-0 burbot were sampled in September of 1997, by April of 1998 the age-1 burbot were again found in the deeper portions of the backwaters and tended to be concentrated in the pools near the channel connections. Whether the burbot left in the late summer and returned in the spring or overwintered in the backwaters remains unclear. During rising water conditions initiated by mountain snowmelt in May of 1998, I again sampled the backwaters and found no remaining age-1 burbot. Thus, the juvenile burbot apparently evacuated the habitat prior to that sample period.

The preceding early life history observations stimulate questions concerning the importance of backwater habitats to burbot in large river systems. Burbot larvae are rarely sampled and definitive conclusions are elusive; however, the observed use of the two backwaters in 1997 suggests that such habitat may be important to the early life history of the species. Other observations in the upper Missouri River suggest that the juvenile burbot will use channel habitats. In July of 1994, juvenile burbot were captured at a rate of 6.5/trap net night in a partially disconnected secondary channel; however, these juveniles had only attained a mean TL of 68 mm and were experiencing considerable avian predation (Steven Krentz, U.S. Fish and Wildlife Service, Bismarck, North Dakota, personal communication). Although reports about decreasing burbot abundance in channelized and impounded river segments have been increasing, the burbot population in the portion of the Missouri River still influenced by the natural Yellowstone River hydrograph appears to be stable, if not flourishing. One conspicuous difference between the Yellowstone River influenced Missouri River segment and other channelized and impounded reaches is the existence of historically functioning backwater habitats. Backwater presence combined with the observations discussed here begins to suggest a case for the importance of backwater habitat to burbot populations.

Chapter Summary

Research conducted in two Missouri River backwaters in northwestern North Dakota in 1997 and 1998 revealed that these habitats were utilized by age-0 and age-1 burbot. Observations concerning growth rates, food habits, and backwater microhabitat use were recorded. The 1997 year class of burbot attained a mean total length of 80.9 mm (SE = 1.2) by early July of 1997 and 152.6 mm (SE = 3.8) by April of 1998. Stomachs of larval burbot (N=10) primarily contained Copepoda nauplii and *Keratella* spp. Juvenile burbot (N=30) consumed macroinvertebrates, including Odonata, Amphipoda, and Plecoptera, but also preyed upon catostomid larvae when available. The burbot juveniles appeared to select microhabitats characterized by depths greater than 1.5 m, with some notable flow, water temperatures not exceeding 20°C, and adjacent areas of flooded vegetation. The presence of burbot larvae and juveniles in functioning backwaters suggests that off-channel habitats may be important to the early life history of large river burbot populations. Questions surrounding burbot life history need to be addressed because several large river systems that have been impounded or channelized have declining, or nearly extirpated burbot populations.

Chapter 5.

Backwater Ecology: Importance of Backwater Habitats to Flathead Chubs Inhabiting Sandbar Complexes in the Missouri River

Cross et al. (1986) and Pfleiger and Grace (1987) reported that flathead chub populations have decreased by as much as 98% over portions of their historical range. The causes of these declines are not well understood; however degraded habitats are a suspected possibility (Lee et al. 1980). In the channelized and impounded segments of the Missouri River, Grady and Milligan (1998) noted pronounced flathead chub declines over the past few decades. Several researchers have suggested that the substantial loss of floodplain connections have occurred due to channel modifications and flow regulation (e.g., Hesse et al. 1989); however, there have been identified relationships between the conspicuous backwater absences and declines in flathead chub populations.

As noted by Scott and Nielsen (1989) and Sabo and Kelso (1991), backwater habitats are important rearing and nursery areas for a number of native fish species. However, as discussed in Chapter 2, juvenile flathead chub use of EIS and the CB was limited and no larval specimens were captured in the backwaters. Although no direct use of backwater habitats was indicated, indirect benefits may exist. Amoros (1991) suggested that floodplain flushing transports large numbers of invertebrates from backwaters to the main channel, providing an important food resource for many native fishes obligated to flowing water habitats. Eckblad et al. (1984) and Cellot and Bournard (1987) observed substantial increases in channel invertebrate densities below connection points with floodplain wetlands; however, Kennedy (1979) noted that excessive backwater flushing rates tended to remove too much production and limited flushing removed too little production from the floodplain - both having a detrimental impact on prey availability in channel habitats. Therefore, the objective of this study was to assess the food habits of flathead chubs collected below a major backwater outlet during two different hydrograph cycles and determine if the diets differed in backwater-produced prey composition.

Methods

To provide a distinct comparison, I wanted to sample flathead chubs in the Missouri River channel during one hydrograph cycle that approximated mean flows and during another hydrograph cycle that included flows substantially higher or lower than the mean flow rates. In 1997, nearly record flows were recorded in the study area and in 1999, a nearly mean hydrograph was observed (Figure 1-1). Therefore, during these years, flathead chubs were collected from sandbar complexes with a bag seine (methods and gear described in Chapter 2) every 4-6 weeks; however, due to high flows, the sandbars became inundated during a portion of the sample period in May and June of 1997. To better facilitate a pairwise comparison and avoid euthanizing flathead chubs unnecessarily, I did not collect specimens for analysis in May and June of 1999. Therefore fish were collected in April, July, August, and September of 1997 and 1999 from sandbar habitats below EIS, North Dakota.

Up to 30 flathead chubs from each of the following total length groups were euthanized and returned to the laboratory for stomach content analysis. The total length groups included, <60, 60-99, 100-139, 140-179, and >179 mm. To provide additional samples in the large length groups, a gill net (21-m long x 2-m high with one 7-m panel each of 1-, 2-, and 3-cm bar measure mesh) was drifted for short distances on channel-sandbar margins and deeper pools in sandbar complexes. Although few flathead chubs were sampled with the gill nets relative to the seine, the largest length group (>179-mm TL) would have been absent from nearly all of the samples without the gill net contributions. The flathead chubs that I collected and intended to use for this study were measured to the nearest mm. For future research needs and to maximize the benefits from these flathead chub collections, basic biological data, including weight, sex, maturity, and age (from scale samples) were also collected, but not reported here. The stomachs were removed from the flathead chubs and contents examined under a dissecting scope.

The food habits were assessed for feeding uniformity by determining the frequency of occurrence, while feeding intensity on each prey type was investigated by determining the percent by number for each prey item within each flathead chub length group. Frequency of occurrence was the proportion of individuals in each flathead chub length group that contained the prey item. The percent by number for each prey item was determined for stomach contents for each fish that contained food and the mean values for each length group were reported. Bowen (1996) noted that proportional diet data are not normally distributed; therefore, a Mann-Whitney test (NPAR1WAY procedure; SAS 1990) was used to detect significant proportional differences between sample years within each sample period and flathead chub length group. No assessment was completed for differences among flathead chub length-group differences.

Results and Discussion

The food habits assessment provided nearly irrefutable evidence that the diets of flathead chubs in the high water year of 1997 were substantially different than those observed in the typical water year of 1999. In 1997, the most frequently consumed prey across all length groups of flathead chubs during the April and July samples were Ostracoda, Copepoda, Hemiptera (dominated by Corixidae), and Diptera, with a few larger chubs also consuming Orthoptera (Table 5-1). During the late summer and into autumn, Ostracoda, Hemiptera, and Copepoda continued to demonstrate frequent presence in the stomach contents; however, Ephemeroptera and Trichoptera became more prevalent in the diets. The 1999 frequency of occurrence data indicated that fewer flathead chubs were consuming Copepoda, and Hemiptera and Ostracoda were nearly absent from the diets. Alternatively, flathead chub feeding strategies were more focused on Coleoptera in the spring and early summer and Hymenoptera and macrophytic plant seeds in the late summer and autumn.

Numerically, the Ostracoda dominated the flathead chub diets in 1997, with Copepoda, Hemiptera, Trichoptera, and Diptera also substantially contributing to the diets (Table 5-2). In 1999, Ostracoda (Figure 5-1), Hemiptera, and Copepoda (Figure 5-2) were significantly less abundant in the flathead chub diets ($P<0.05$) during numerous sample periods and among most length groups. However, the significant decline in several prey taxa was offset by highly significant increases in the numeric proportions of

Table 5-1. Frequency of occurrence (%) of various diet items found in the stomachs of flathead chubs collected in April, July, August, and September of 1997 and 1999 from sandbar habitats below Erickson Island Slough in the Missouri River, North Dakota. Sample month and year, the total number sampled (N), and percent empty are noted. Food item abbreviations are defined in Appendix 3. Total length groups, referred to as length in the table, include: 1=<60 mm, 2=60-99 mm, 3=100-139 mm, 4=140-179 mm, and 5=>179 mm.

Month	Year	Length	N	% empty	AMPH	OSTR	DIPT	EPHM	HEMI	HYME	LEPI
April	97	1	8	0.0	0.0	100.0	12.5	0.0	25.0	0.0	0.0
April	99	1	13	0.0	0.0	16.4	23.1	0.0	0.0	7.7	0.0
April	97	2	30	46.7	3.3	36.7	26.7	0.0	20.0	0.0	0.0
April	99	2	30	13.3	0.0	3.3	40.0	3.3	9.9	0.0	0.0
April	97	3	13	0.0	7.7	69.2	30.8	0.0	30.8	0.0	0.0
April	99	3	29	10.3	0.0	6.9	55.2	3.4	10.3	17.2	0.0
April	97	4	4	0	25.0	25.0	50.0	0.0	0.0	0.0	0.0
April	99	4	10	0.0	0.0	0.0	20.0	20.0	40.0	10.0	0.0
April	97	5	0	No fish							
April	99	5	0	No fish							
July	97	1	17	17.6	0.0	52.9	5.9	0.0	29.4	0.0	0.0
July	99	1	30	30.0	0.0	0.0	13.3	0.0	0.0	0.0	0.0
July	97	2	30	50.0	0.0	36.7	13.3	0.0	20.0	20.0	0.0
July	99	2	29	13.8	0.0	0.0	6.9	0.0	0.0	0.0	0.0
July	97	3	10	0.0	0.0	50.0	50.0	10.0	30.0	0.0	0.0
July	99	3	30	0.0	0.0	0.0	16.7	0.0	0.0	0.0	0.0
July	97	4	3	0.0	0.0	66.6	0.0	33.3	33.3	0.0	0.0
July	99	4	14	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
July	97	5	2	0.0	0.0	50.0	50.0	0.0	50.0	0.0	0.0
July	99	5	3	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
August	97	1	9	0.0	0.0	55.6	33.3	0.0	44.4	0.0	0.0
August	99	1	1	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
August	97	2	30	53.3	0.0	33.3	3.3	13.2	19.8	0.0	0.0
August	99	2	30	6.7	0.0	0.0	50.0	46.7	0.0	0.0	0.0
August	97	3	13	0.0	0.0	53.8	7.7	23.1	53.8	0.0	0.0
August	99	3	27	11.1	0.0	0.0	40.7	85.2	0.0	0.0	0.0
August	97	4	4	0.0	0.0	75.0	0.0	50.0	50.0	0.0	0.0
August	99	4	30	6.7	0.0	0.0	40.0	73.3	0.0	3.3	0.0
August	97	5	0	No fish							
August	99	5	4	0.0	0.0	0.0	50.0	100.0	0.0	0.0	0.0
Sept	97	1	30	16.7	0.0	50.0	30.0	0.0	46.7	0.0	0.0
Sept	99	1	13	30.8	0.0	0.0	15.4	0.0	0.0	53.8	0.0
Sept	97	2	30	6.7	0.0	56.7	33.3	53.3	53.3	6.7	6.7
Sept	99	2	30	46.7	0.0	0.0	16.7	0.0	0.0	43.3	0.0
Sept	97	3	20	0.0	0.0	70.0	25.0	35.0	50.0	10.0	10.0
Sept	99	3	28	60.7	0.0	0.0	7.1	0.0	0.0	17.9	0.0
Sept	97	4	13	0.0	0.0	46.1	53.8	15.4	30.8	0.0	23.1
Sept	99	4	23	34.8	0.0	0.0	17.4	0.0	4.3	39.1	0.0
Sept	97	5	12	0.0	0.0	33.3	41.7	50.0	25.0	8.3	16.7
Sept	99	5	10	70.0	0.0	0.0	10.0	0.0	0.0	10.0	0.0

Table 5-1. Continued

Period	Year	Length	ODON	ORTH	PLEC	TRIC	COPE	CLAD	EGGS	COLE	MACR
April	97	1	0.0	0.0	0.0	12.5	50.0	0.0	0.0	0.0	0.0
April	99	1	0.0	0.0	0.0	0.0	15.4	0.0	0.0	92.3	0.0
April	97	2	3.3	0.0	0.0	16.7	26.7	3.3	0.0	0.0	0.0
April	99	2	0.0	0.0	13.3	3.3	3.3	3.3	0.0	76.7	0.0
April	97	3	30.8	0.0	0.0	53.8	38.5	0.0	0.0	0.0	0.0
April	99	3	17.2	0.0	13.8	27.6	3.4	3.4	0.0	72.4	0.0
April	97	4	25.0	25.0	0.0	75.0	75.0	0.0	0.0	0.0	0.0
April	99	4	10.0	0.0	50.0	30.0	0.0	0.0	10.0	80.0	0.0
April	97	5	No fish								
April	99	5	No fish								
July	97	1	0.0	0.0	0.0	11.8	41.2	0.0	0.0	0.0	0.0
July	99	1	0.0	0.0	0.0	43.3	3.3	6.7	0.0	26.7	0.0
July	97	2	0.0	0.00	0.0	6.7	16.7	0.0	0.0	0.0	0.0
July	99	2	0.0	0.0	79.3	3.4	0.0	0.0	13.8	0.0	0.0
July	97	3	0.0	50.0	0.0	10.0	30.0	0.0	0.0	0.0	0.0
July	99	3	0.0	0.0	6.7	93.3	3.3	6.7	0.0	6.7	0.0
July	97	4	0.0	66.6	0.0	66.6	33.3	0.0	0.0	0.0	0.0
July	99	4	0.0	0.0	0.0	78.6	14.3	7.1	0.0	7.1	0.0
July	97	5	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
July	99	5	0.0	0.0	0.0	33.3	33.3	0.0	0.0	0.0	0.0
August	97	1	0.0	0.0	0.0	33.3	33.3	0.0	0.0	0.0	0.0
August	99	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0
August	97	2	3.3	3.3	0.0	3.3	23.1	0.0	0.0	0.0	0.0
August	99	2	0.0	0.0	6.7	13.4	3.3	0.0	0.0	10.0	0.0
August	97	3	38.5	46.2	0.0	30.8	30.8	0.0	0.0	0.0	0.0
August	99	3	0.0	0.0	0.0	11.1	0.0	0.0	0.0	7.4	0.0
August	97	4	0.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0
August	99	4	3.3	0.0	6.7	30.0	0.0	0.0	0.0	10.0	0.0
August	97	5	No fish								
August	99	5	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0
Sept	97	1	0.0	0.0	0.0	20.0	30.0	0.0	0.0	0.0	0.0
Sept	99	1	0.0	0.0	0.0	7.7	0.0	0.0	0.0	15.4	0.0
Sept	97	2	29.7	6.7	3.3	19.8	26.4	0.0	0.0	0.0	0.0
Sept	99	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.3	3.3
Sept	97	3	20.0	25.0	5.0	20.0	40.0	0.0	0.0	0.0	0.0
Sept	99	3	0.0	0.0	0.0	10.7	0.0	0.0	0.0	0.0	3.6
Sept	97	4	0.0	46.1	0.0	46.1	23.1	0.0	15.4	0.0	0.0
Sept	99	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.4	13.0
Sept	97	5	0.0	41.7	8.3	25.0	16.7	0.0	50.0	0.0	0.0
Sept	99	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0

Table 5-2. Percent by number for various diet items found in the stomachs of flathead chubs collected in April, July, August, and September of 1997 and 1999 from sandbar habitats below Erickson Island Slough in the Missouri River, North Dakota. Sample month and year are listed. Refer to Table 5-1 for sample sizes and % empty stomach information. Food item abbreviations are defined in Appendix 3. Total length groups, referred to as length in the table, include: 1=<60 mm, 2=60-99 mm, 3=100-139 mm, 4=140-179 mm, and 5=>179 mm. Statistical comparisons between years were completed for each prey type within each sample period and total length group. Pairs of mean values that were significantly different (P<0.05) are denoted with superscript letters a and b.

Month	Year	Length	AMPH	OSTR	DIPT	EPHM	HEMI	HYME
April	97	1	0.0	66.8^{a} (12.9)	2.1^{b} (2.1)	0.0	12.5^{a} (8.2)	0.0
April	99	1	0.0	3.3^{b} (2.6)	10.8^{a} (7.8)	0.0	0.0^{b}	1.4 (1.4)
April	97	2	0.9 (0.9)	47.1^{a} (8.9)	14.3 (5.5)	0.0	9.9^{a} (4.2)	0.0
April	99	2	0.0	2.2^{b} (1.6)	20.3 (6.0)	1.3 (1.3)	1.5^{b} (0.9)	0.0
April	97	3	0.4 (0.4)	45.2^{a} (10.3)	5.4^{b} (2.8)	0.0	14.3 (7.4)	0.0
April	99	3	0.0	0.3^{b} (0.2)	20.6^{a} (5.8)	0.4 (0.4)	1.4 (0.8)	2.7 (1.4)
April	97	4	4.2 (4.2)	22.1 (22.1)	20.8 (12.5)	0.0	0.0	0.0
April	99	4	0.0	0.0	11.0 (9.9)	1.3 (0.9)	3.4 (2.0)	1.4 (1.4)
April	97	5	No fish					
April	99	5	No fish					
July	97	1	0.0	54.9^{a} (11.8)	1.8 (1.8)	0.0	22.3^{a} (10.3)	0.0
July	99	1	0.0	0.0^{b}	8.7 (4.1)	0.0	0.0^{b}	0.0
July	97	2	0.0	57.2^{a} (9.9)	6.7 (3.2)	0.0	16.2^{a} (7.9)	3.0 (1.5)
July	99	2	0.0	0.0^{b}	5.6 (4.3)	0.0	0.0^{b}	0.0
July	97	3	0.0	39.3^{a} (13.4)	14.5 (6.1)	2.5 (2.5)	12.9^{a} (8.5)	0.0
July	99	3	0.0	0.0^{b}	11.1 (4.8)	0.0	0.0^{b}	0.0
July	97	4	0.0	48.6^{a} (24.4)	0.0	22.2 (22.2)	2.6 (2.6)	0.0
July	99	4	0.0	0.0^{b}	0.0	0.0	0.0	0.0
July	97	5	0.0	12.5 (12.5)	37.5 (37.5)	0.0	25.0 (25.0)	0.0
July	99	5	0.0	0.0	0.0	0.0	0.0	0.0
August	97	1	0.0	36.3 (12.4)	14.4 (7.3)	0.0	24.6 (12.5)	0.0
August	99	1	0.0	0.0	100.0 (NA)	0.0	0.0	0.0
August	97	2	0.0	52.2^{a} (10.0)	2.4^{b} (2.4)	10.7^{b} (7.3)	15.0 (5.9)	0.0
August	99	2	0.0	0.0^{b}	46.9^{a} (8.8)	31.9^{a} (8.2)	0.0	0.0
August	97	3	0.0	37.0^{a} (10.8)	3.8^{b} (3.8)	4.7^{b} (2.5)	20.8^{a} (6.6)	0.0
August	99	3	0.0	0.0^{b}	24.9^{a} (5.9)	69.3^{a} (7.1)	0.0^{b}	0.0
August	97	4	0.0	50.4^{a} (17.9)	0.0	7.5^{b} (4.4)	$10\ 0^{a}$ (7.9)	0.0
August	99	4	0.0	0.0^{b}	19.9 (5.9)	58.1^{a} (7.3)	0.0^{b}	3 6 (3 6)
August	97	5	No fish					
August	99	5	0.0	0.0	13.3 (8.2)	68.0 (9.8)	0.0	0.0
Sept	97	1	0.0	47.7^{a} (8.6)	15.3 (5.0)	0.0	19.4^{a} (5.7)	0.0^{b}
Sept	99	1	0.0	0.0^{b}	13.3 (11.1)	0.0	0.0^{b}	74.4^{a} (14.4)
Sept	97	2	0.0	28.6^{a} (5.5)	8.1 (2.9)	13.2^{a} (3.1)	20.9^{a} (5.4)	1.1^{b} (0.8)
Sept	99	2	0.0	0.0^{b}	6.2 (3.1)	0.0^{b}	0.0^{b}	66.2^{a} (9.1)
Sept	97	3	0.0	49.1^{a} (8.2)	2.7 (1.2)	7.2^{a} (3.4)	6.8^{a} (2.0)	2.9^{b} (2.5)
Sept	99	3	0.0	0.0^{b}	18.2 (12.2)	0.0^{b}	0.0^{b}	45.5^{a} (15.7)
Sept	97	4	0.0	26.8^{a} (8.9)	19.2 (6.3)	1.8 (1.3)	10.7 (5.4)	0.0^{b}
Sept	99	4	0.0	0.0^{b}	20.0 (9.5)	0.0	1.7 (1.7)	46.1^{a} (11.6)
Sept	97	5	0.0	16.7 (8.1)	7.2 (3.5)	15.0 (5.4)	5.8 (3.2)	2.1^{b} (2.1)
Sept	99	5	0.0	0.0	22.2 (22.2)	0.0	0.0	33.3^{a} (3.3)

Table 5-2. Continued.

Period	Year	Length	LEPI	ODON	ORTH	PLEC	TRIC
April	97	1	0.0	0.0	0.0	0.0	3.1^{a} (3.1)
April	99	1	0.0	0.0	0.0	0.0	0.0
April	97	2	0.0	1.8 (1.8)	0.0	0.0	9.3^{a} (4.1)
April	99	2	0.0	0.0	0.0	2.9 (1.5)	0.5^{b} (0.5)
April	97	3	0.0	10.1 (5.0)	0.0	0.0	13.5 (5.5)
April	99	3	0.0	5.8 (3.9)	0.0	1.1 (0.6)	4.1 (2.0)
April	97	4	0.0	2.5 (2.5)	2.5 (2.5)	0.0	23.3 (11.3)
April	99	4	0.0	0.6 (0.6)	0.0	17.5 (10.1)	5.0 (3.3)
April	97	5	No fish				
April	99	5	No fish				
July	97	1	0.0	0.0	0.0	0.0	6.1^{b} (4.8)
July	99	1	0.0	0.0	0.0	0.0	48.4^{a} (9.8)
July	97	2	0.0	0.0	0.00	0.0	4.9^{b} (3.3)
July	99	2	0.0	0.0	0.0	4.2 (4.2)	79.5^{a} (7.1)
July	97	3	0.0	0.0	12.1^{a} (5.4)	0.0	5.0^{b} (5.0)
July	99	3	0.0	0.0	0.0^{b}	1.7 (1.2)	81.4^{a} (5.6)
July	97	4	0.0	0.0	13.7^{a} (10.1)	0.0	6.7^{b} (3.6)
July	99	4	0.0	0.0	0.0^{b}	0.0	77.8^{a} (10.1)
July	97	5	0.0	25.0 (NA)	0.0	0.0	0.0
July	99	5	0.0	0.0	0.0	0.0	50.0 (50.0)
August	97	1	0.0	0.0	0.0	0.0	14.7 (11.0)
August	99	1	0.0	100.0 (NA)	0.0	0.0	0.0
August	97	2	0.0	0.3 (0.3)	1.2 (1.2)	0.0	1.4 (1.4)
August	99	2	0.0	0.0	0.0	3.1 (2.5)	8.2 (5.0)
August	97	3	0.0	6.7^{a} (3.1)	14.0^{a} (5.9)	0.0	7.8 (3.6)
August	99	3	0.0	0.0^{b}	0.0^{b}	0.0	2.7 (1.8)
August	97	4	0.0	0.0	16.1^{a} (11.8)	0.0	16.1 (11.8)
August	99	4	0.0	1.8 (1.8)	0.0^{b}	4.2 (3.6)	7.4 (2.5)
August	97	5	No fish				
August	99	5	0.0	0.0	0.0	7.8 (5.2)	10.9 (6.6)
Sept	97	1	0.0	0.0	0.0	0.0	8.4 (4.7)
Sept	99	1	0.0	0.0	0.0	0.0	2.2 (2.2)
Sept	97	2	1.4 (1.0)	7.1^{a} (2.8)	1.0 (0.8)	0.2 (0.2)	5.0 (2.1)
Sept	99	2	0.0	0.0^{b}	0.0	0.0	0.0
Sept	97	3	0.4 (0.3)	3.6 (2.5)	7.1 (3.4)	0.1 (0.1)	7.6 (4.1)
Sept	99	3	0.0	0.0	0.0	0.0	27.3 (14.1)
Sept	97	4	4.2 (2.2)	0.0	9.9^{a} (3.3)	0.0	10.2 (4.1)
Sept	99	4	0.0	0.0	0.0^{b}	0.0	0.0
Sept	97	5	4.9 (4.2)	0.0	14.0 (6.0)	2.1 (2.1)	5.7 (3.2)
Sept	99	5	0.0	0.0	0.0	0.0	0.0

Table 5-2. Continued.

Period	Year	Length	COPE	CLAD	EGGS	COLE	MACR
April	97	1	15.5^{a} (9.8)	0.0	0.0	0.0^{b}	0.0
April	99	1	6.0^{b} (5.1)	0.0	0.0	78.6^{a} (9.1)	0.0
April	97	2	15.7^{a} (6.8)	1.0 (1.0)	0.0	0.0^{b}	0.0
April	99	2	0.4^{b} (0.4)	1.9 (1.9)	0.0	69.0^{a} (6.7)	0.0
April	97	3	11.0^{a} (4.8)	0.0	0.0	0.0^{b}	0.0
April	99	3	0.1^{b} (0.1)	0.1 (0.1)	0.0	63.4^{a} (6.7)	0.0
April	97	4	24.6^{a} (14.6)	0.0	0.0	0.0^{b}	0.0
April	99	4	0.0^{b}	0.0	8.3 (8.3)	51.5^{a} (10.9)	0.0
April	97	5	No fish				
April	99	5	No fish				
July	97	1	14.9^{a} (7.2)	0.0	0.0	0.0^{b}	0.0
July	99	1	1.6^{b} (1.6)	6.3 (4.9)	0.0	34.9^{a} (10.4)	0.0
July	97	2	12.0^{a} (7.0)	0.0	0.0	0.0	0.0
July	99	2	1.0^{b} (1.0)	0.0	9.7 (5.0)	0.0	0.0
July	97	3	13.8 (10.1)	0.0	0.0	0.0	0.0
July	99	3	0.8 (0.8)	2.8 (2.0)	0.0	2.2 (1.7)	0.0
July	97	4	6.3 (6.3)	0.0	0.0	0.0	0.0
July	99	4	8.3 (5.6)	8.3 (8.3)	0.0	5.6 (5.6)	0.0
July	97	5	0.0	0.0	0.0	0.0	0.0
July	99	5	50.0 (50.0)	0.0	0.0	0.0	0.0
August	97	1	9.9 (5.8)	0.0	0.0	0.0	0.0
August	99	1	0.0	0.0	0.0	0.0	0.0
August	97	2	16.8^{a} (6.0)	0.0	0.0	0.0	0.0
August	99	2	1.8^{b} (1.8)	0.0	0.0	8.0 (5.0)	0.0
August	97	3	5.2^{a} (3.1)	0.0	0.0	0.0	0.0
August	99	3	0.0^{b}	0.0	0.0	2.4 (1.7)	0.0
August	97	4	0.0	0.0	0.0	0.0	0.0
August	99	4	0.0	0.0	0.0	5.1 (3.7)	0.0
August	97	5	No fish				
August	99	5	0.0	0.0	0.0	0.0	0.0
Sept	97	1	9.2^{a} (3.3)	0.0	0.0	0.0	0.0
Sept	99	1	0.0^{b}	0.0	0.0	10.0^{a} (7.1)	0.0
Sept	97	2	13.5^{a} (4.9)	0.0	0.0	0.0^{b}	0.0
Sept	99	2	0.0^{b}	0.0	0.0	21.4^{a} (8.6)	6.3 (6.3)
Sept	97	3	12.6^{a} (5.5)	0.0	0.0	0.0^{b}	0.0
Sept	99	3	0.0^{b}	0.0	0.0	0.0	9.1 (9.1)
Sept	97	4	14.2 (8.6)	0.0	2.9 (2.3)	0.0	0.0
Sept	99	4	0.0	0.0	0.0	15.6 (7.7)	16.7 (9.3)
Sept	97	5	1.6 (1.1)	0.0	25.4 (9.8)	0.0	0.0^{b}
Sept	99	5	0.0	0.0	0.0	0.0	44.4^{a} (29.4)

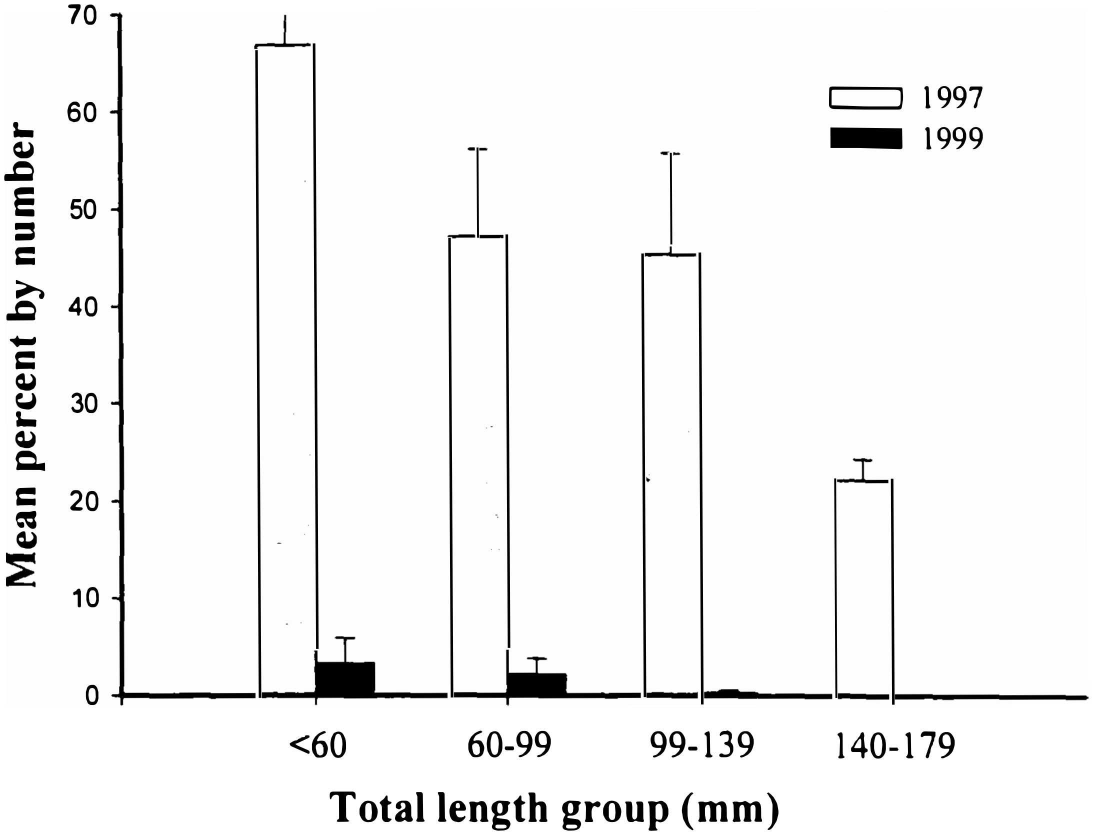

Figure 5-1. Mean percent by number for Ostracoda found in flathead chub stomachs collected in 1997 and 1999 from the Missouri River in North Dakota. Total length groups (mm) are noted. Significant differences are not listed because each pair of observations was significantly different ($P<0.05$). The vertical bars represent one standard error.

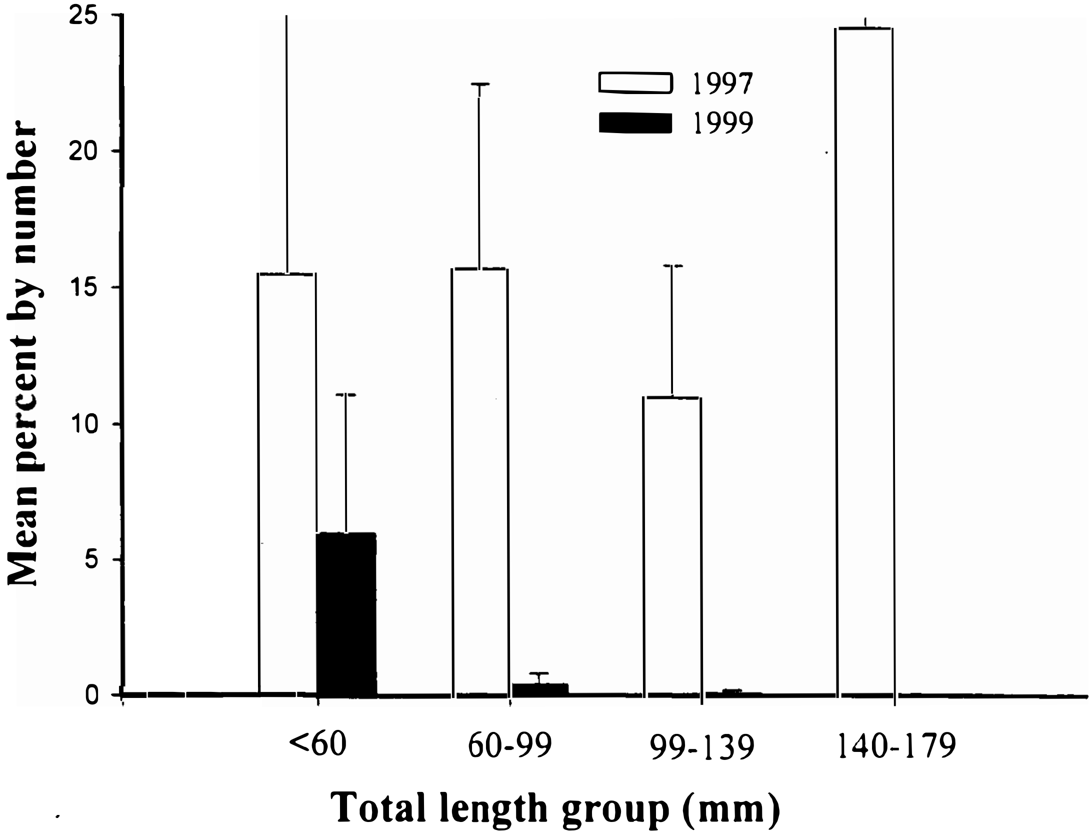

Figure 5-2. Mean percent by number for Copepoda found in flathead chub stomachs collected in April of 1997 and 1999 from the Missouri River in North Dakota. Total length groups (mm) are noted. Significant differences are not listed because each pair of observations was significantly different (P<0.05). The vertical bars represent one standard error.

Coleoptera, Diptera, Trichoptera (Figure 5-3), Ephemeroptera (Figure 5-4) and Hymenoptera during several seasons and length groups ($P<0.001$; Table 5-2).

As suggested in Chapter 2, the backwater habitats produce a number of invertebrates relatively uncommon in channel habitats, including primary taxa noted in the flathead chub diets in 1997, such as Copepoda zooplankton and Hemiptera. Although Ostracoda can be abundant in the backwater habitats, the origin of the numerous Ostracoda is less clear. Pennak (1989) noted that seed shrimps (Ostracoda) are well-equipped to survive and thrive in numerous habitat types, including lotic and lentic habitats. The Corixidae and Copepoda zooplankton, however, both tend to be obligated during large portions of their life history to calm waters and exhibit low densities in running water habitats (Merrit and Cummins 1984; Pennak 1989). Therefore, the evidence suggests that the high flows in 1997 were likely contributing to the altered diets by transporting prey taxa from the floodplain, making them available in the channel, and/or by eliminating typical food resources due to the high flows and depth that inundated sandbar habitats and evacuated in-channel food resources at a much greater rate than during a more typical flow year.

Of the taxa consumed in 1999, the Coleoptera presence during April and extending into the other sample months was pronounced and noteworthy. Although listed as Coleoptera, nearly all of the beetles observed in the flathead chub stomachs belonged to the family Cicindelidae (tiger beetles). Borror and White (1970) noted that tiger beetles, where present, tended to be very abundant and inhabited open shorelines and beaches. I observed numerous tiger beetles on the sandbars, and Borror and White (1970)

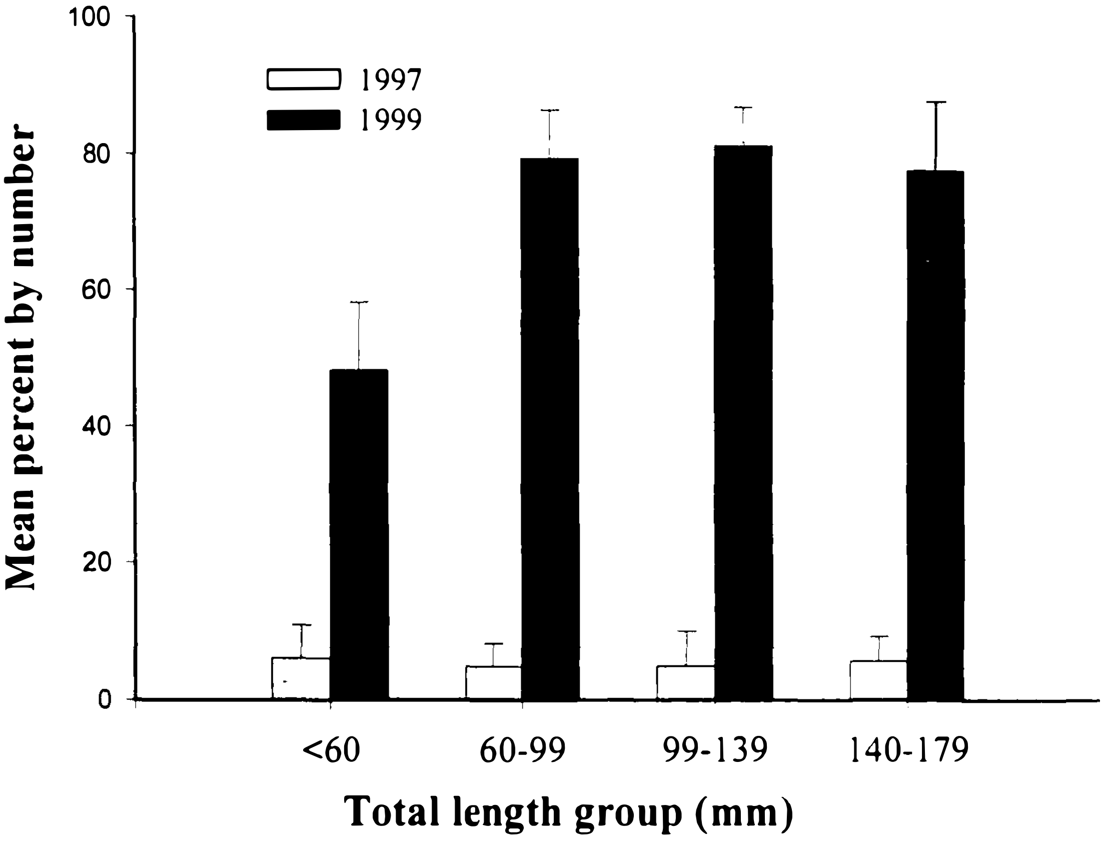

Figure 5-3. Mean percent by number for Trichoptera found in flathead chub stomachs collected in July of 1997 and 1999 from the Missouri River in North Dakota. Total length groups (mm) are noted. Significant differences are not listed because each pair of observations was significantly different (P<0.05). The vertical bars represent one standard error.

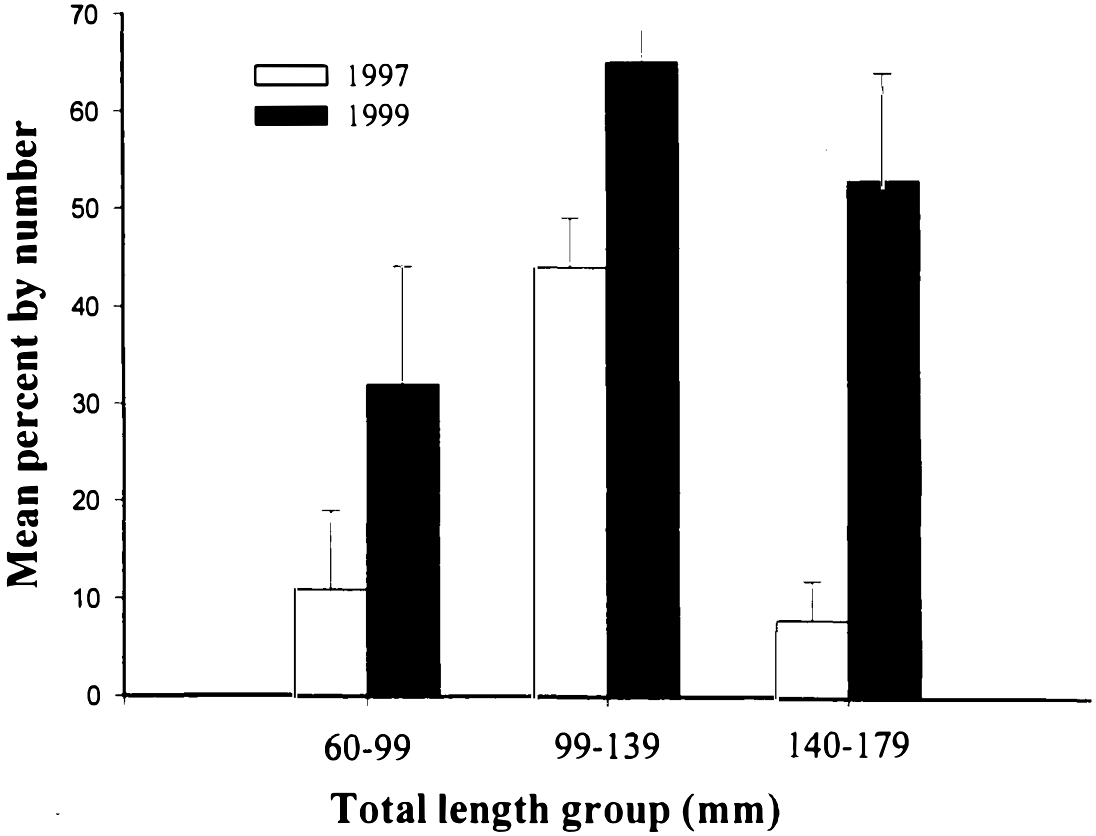

Figure 5-4. Mean percent by number for Ephemeroptera found in flathead chub stomachs collected in July of 1997 and 1999 from the Missouri River in North Dakota. Total length groups (mm) are noted. Significant differences are not listed because each pair of observations was significantly different (P<0.05). The vertical bars represent one standard error.

noted that the larvae tend to burrow into sandy areas during their juvenile stages. I can only speculate about the mechanisms that made tiger beetles available to flathead chubs; however, during the spring and summer of 1999, a number of tiger beetles were observed in the drift and it is possible that as sandbars shift, late-stage larvae and possibly adults are expunged from their burrows and become available to fish predation. In 1997, the absence of tiger beetles from the diet was conspicuous. It is possible that the inundation of sandbar habitats, which occurred earlier than normal in 1997, removed the staging substrates, either repelling the beetles away from the river bottom in search of better habitats or transporting the organisms out of the feeding area.

The consumption of backwater-originated prey resources by flathead chubs during 1999, and more extensively in 1997 suggests that backwater prey production is important to flathead chubs in the Missouri River, particularly during periods or annual cycles with above-average flows. In 1997, it appears that the high flow rates washed much of the more typical flathead chub prey into unusable areas and the increased consumption of backwater-oriented food resources was a compensatory effort to obtain nutrition. Unfortunately, it remains unclear if the backwater prey availability was sufficient to provide adequate rations for the flathead chub population. As indicated by Kennedy (1979) and discussed earlier, too much flow excessively transporting food resources and nutrients from one habitat to another can be equally as detrimental as too little flow that does not transport any materials.

Chapter Summary

The biology of flathead chubs, including food habits, is often referred to in general, but seldom supported with documentation (e.g., McCLane 1978; Baxter and Stone 1995). Lee et al. (1980) did note that researchers found flathead chub food habits to be greatly dominated by terrestrial insects, with additional prey including small aquatic invertebrates. Brown (1971) noted that biologists in Montana believe the flathead chubs feed on aquatic invertebrates, but extensively utilize abundant terrestrial insects that periodically fall into the water and become part of the drift, and are sufficiently omnivorous to feed on vegetative matter. My results support these assumptions, including some sporadic feeding on plant tissues, primarily seeds. These data also indicate that diets can vary substantially during differential hydrograph cycles. The backwater-produced prey appear to be especially utilized when flushed from the floodplain, but I could not determine if flathead chubs prefer the backwater organisms or are using their availability to compensate for absent channel resources during high flow periods, given my study design.

Chapter 6.

Backwater Ecology: Assessment of Community Interactions and Energy Flow

The previous chapters provided a description of seasonal native fish dynamics in two upper Missouri River backwaters and yielded insight about the importance of backwater habitats to the life stages of a variety of native fishes. However, it is difficult to draw inferences about community interactions and energy flow from relative abundance data. Winemiller and Polis (1996) generalized that food webs provide valuable information regarding community regulation and structure, productivity gradients, assemblage identification, and energy flow - concepts lacking from the discussions in previous chapters. To better understand the flow of energy and nutrients through biological communities, Lasenby et al. (1986) and Kaufman (1992) suggested that food web analyses be included in community assessment. Graphically portraying community structure and interactions can facilitate comprehension and predictions about energy flow pathways and community responses to environmental change.

Food web construction requires considerable thought and planning, particularly in a dynamic riverine ecosystem. Strong (1986) and Dunson and Travis (1991) cautioned that ecological equilibrium is rare; therefore, it is inappropriate to develop food webs that represent static interactions or neglect changes in time and species life history. Werner and Gilliam (1984) also supported this concept, arguing that seasonal variation in fish diets and other ecosystem components are substantial and need to be addressed during various dynamic stages. Other food web issues that may affect model validity include diagram development based solely on empirical food habits data, neglect of detrital energy source contributions, and "ignorance" concerning temporal shifts. Polis (1991) and Paine (1992) both suggested that food webs are often constructed with limited or inappropriate data and therefore cannot adequately demonstrate the flow of energy or identify critical community interactions.

The use of empirical food habits data, although important, tends to limit the ecological value of many food-web depictions, and interactions appearing to be predominant are often misleading (Glasser 1983; Yodzis 1993). Power et al. (1996) suggested that a food web assessment utilizing multiple techniques, such as descriptive bottom-up transfer observations and isotopic fractionation, might be a better strategy. Stable isotope analyses (e.g., $\delta^{13}C$ and $\delta^{15}N$) have proven to be a valuable ecological assessment tool facilitating diverse evaluations including impacts of introduced species, determination of energy origination points, and stock density assessments (Angradi 1994; Yoshioka et al. 1994; Sierszen et al. 1996). The use of multiple techniques has been recommended when assessing simple food webs and is imperative for the evaluation of complex ecosystems. Lajtha and Michener (1994) provide a discussion and collection of chapters from various researchers on how stable isotope analysis was developed, has been utilized, and the principles that are foundational to the assessment tool assumptions.

Winemiller (1996) suggested that riverine food webs, including those found in floodplain habitats (i.e., backwaters) are equally or more complex than other webs and are seasonally dynamic with massive and swift shifts between microbial-based and photosynthetic energy resources. Pimm (1991) suggested that these shifts, or disturbances, in aquatic communities catalyze the establishment of short food chains.

However, Power et al. (1996) found that food chain length tended to increase directly with an increase in disturbance frequency and intensity. Winemiller (1996) further suggested that facultative feeding (i.e., omnivory) helps maintain longer food chains in riverine communities, allowing for dietary flexibility when environmental changes occur. Therefore, one could hypothesize that changes in energy resource origination tend to have limited effects on community structure and composition.

Although food web assessments can be difficult, our understanding of backwater community interactions is limited. Therefore, the goal of this chapter was to secure data that would help improve understanding about community interactions in an upper Missouri River backwater, particularly under natural inundation cycles. The objectives of this chapter were to 1) seasonally categorize fishes into functional consumer classifications using empirical food habits data and stable isotope ratios, 2) construct simplified seasonal food web diagrams utilizing a combination of observed community interactions and stable isotopic signatures, 3) identify the primary seasonal energy flow pathways, and 4) discuss how invertebrates, flora, sediments and various fish life stages contribute to the community during different temporal periods.

Methods

Field data collection

Fishes, macroinvertebrates, zooplankton, aquatic and terrestrial flora, detritus, and sediments were collected in May, July, and September of 1998 in EIS, North Dakota (refer to site description in Chapter 1). For this study, fishes were collected with gill nets when possible; however, fishes captured in overnight trap net sets were also used (see Chapter 4 for gear specifications). Benthic invertebrates were collected with a petite ponar grab and by hand when possible. Limnetic macroinvertebrates were collected with surface trawls and light traps (see Chapter 3 for gear specifications). Zooplankton were filtered from water samples using a centrifugal pump and a multi-tier sieve (500-, 355-, and 150-μm bar measure meshes) to separate the zooplankton by size group. The 500-μm mesh retained large Cladocera and Copepoda, the 355-μm mesh concentrated adult Copepoda and some intermediate-sized Cladocera, and the 150-μm mesh held the Copepoda nauplii and small Cladocera (primarily *Bosmina* spp.).

Detritus and sediment samples were obtained with a core sampler (75-mm diameter, 30-cm high) during each sample period. The detrital layer, distinguishable in core samples due to its rich brown color, was separated from the sediment layer and frozen. Course particulate organic matter (CPOM) was collected with a surface trawl and by hand along wind-blown shorelines. Periphyton was scraped from available substrates, typically terrestrial woody debris, and stored. Efforts were made to avoid contaminating the samples with substrate tissues; however, some contamination may have occurred. Phytoplankton samples were obtained by filtering water samples through 1-μm pore glass filters. Dominant macrophytes (both aquatic and immediately adjacent terrestrial taxa) were collected by hand to obtain samples for stable isotope analyses. All of the above-described samples were frozen and returned to the laboratory for subsequent analyses.

Food habits analysis

Fish were identified and measured for total length (TL). The length-frequency histograms for fishes collected in EIS during 1997 were assessed to determine the number of length modes present in the backwater for each species. After determining modes, each species was divided into TL subgroups. During each collection period, up to 10 individuals per species and TL subgroup were euthanized and frozen for laboratory analyses. More than 10 specimens of smaller fishes (e.g., most Cyprinidae and age-0 fishes) were collected to provide sufficient tissue for stable isotope analyses.

In the laboratory, stomachs of all fish were removed and the contents were assessed. Stomach contents were counted and wet biomass estimates were assigned to each diet item. When possible, the actual wet weight of each stomach content was determined; however, weights were difficult to obtain because of substantial digestion and the presence of numerous invertebrate taxa. To determine the wet weights of digested fishes that could be identified to species, the TL was estimated using the vertebral column and then weight-length regressions from various literature sources were applied. The biomass of fishes that could not be identified were recorded as actual values. Zooplankton biomass was estimated using weight-length equations from Dumont et al. (1975). Macroinvertebrate (e.g., insects, Hydracarina, and Amphipoda) wet weights were estimated by collecting a composite sample of each taxon from the stomach samples and determining a mean wet weight per individual during each sample period. These means were then applied to the numerical stomach contents data to establish an estimated weight for each taxon.

After weights were assigned to all diet items, the dietary proportions, by biomass, were determined (Appendix 4). The top three diet items based on biomass proportions that also exceeded 1% of the total biomass were summarized and consumer classifications based on the empirical diet data were assigned. The classifications, including detritivore, herbivore, planktivore, insectivore, and piscivore were arbitrarily assigned when appropriate diet items exceeded 75% of the total dietary biomass. When single dietary categories (e.g., insects or detritus) did not exceed 75%, the group of fishes was classified as omnivores.

Stable isotope analyses

Frozen samples described above, including sediment, detritus, phytoplankton, periphyton, macrophytes, zooplankton, and macroinvertebrates were thawed, rinsed with deionized water and dried at 60°C until no net water loss could be recorded. Samples were then homogenized with a mortar and pestle and stored in scintillation vials at -18°C until $\delta^{13}C$ and $\delta^{15}N$ isotope assessments could be completed. Plant tissue samples, including all macrophytes, phytoplankton, and periphyton, were subdivided into two samples. One set of tissue samples was treated with a dilute HCl (0.01 M) solution to remove carbonates. Several test sets of HCl-treated and untreated plant tissues were analyzed and the untreated HCl tissues provided more consistent isotopic signatures; therefore, the subsequent discussions include untreated plant tissue samples only.

Fish collected for food habits assessment above were also used for the stable isotope analyses. For each individual fish, a muscle tissue sample was collected from a region above the lateral line and adjacent to the dorsal fin. Muscle tissue samples were processed using the same techniques described above. Whole body analyses, except for stomachs and digestive tracts, were conducted on larval and early juvenile fishes because muscle tissue alone provided insufficient sample volumes.

For each taxonomic or food item group, including all flora, fauna, sediment and detritus, three samples were selected at random and a composite sample, utilizing equal amounts of tissue from each original sample, was created. From these composite samples, duplicate isotopic assessments were completed. A Europa 20-20 ratio mass spectrometer (Europa Scientific, Ltd., United Kingdom) equipped with a dual-ion collection beam was used for $^{13}C/^{12}C$ and $^{15}N/^{14}N$ isotope ratio measurement. When the two $\delta^{13}C$ and $\delta^{15}N$ values for each subsample were within 10% of each other, the samples were considered valid for the tissue and the mean and standard error were recorded. When greater than 10% discrepancies occurred, a third sample was tested from the original composite tissue. If the third sample was within 2% of one of the original duplicate samples, contamination possibilities were addressed and the questionable samples were eliminated. If the third sample was not similar to one of the other samples, a mean of the three samples was used as our predicted isotopic signature. Isotopic signatures for fishes are summarized in Appendix 5 and isotope values for all non-fish samples are listed in Appendix 6.

Isotopic signatures were plotted to help fish assemblages, energy flow, and community interactions. To provide a clearer visual presentation of the isotopic data, isotopic fish data were condensed utilizing several strategies. During each sample period, relative fish abundance was assessed and similar to Winemiller (1996), subjective criteria helped eliminate species from the discussion that were likely contributing minimally to the overall community structure. Initially, attempts to eliminate species with numerical proportions of less than 10% and 1% during each sample period failed due to the numerically high proportion of a few species. The reductions were too great and some species believed to have substantial influence on the backwater communities were being eliminated. To lessen the effect of numerically abundant species and to retain apparently important species, such as black bullhead and age-0 *Pomoxis* spp., I ranked the numerical data and excluded the species with numerical values greater than or equal to the 95% quantile (UNIVARIATE procedure, SAS 1990). After the numerically predominant species were removed, a second ranking was completed and those species falling below the median (i.e., the 50% quantile) were eliminated from further discussion. The species above the median, including the species removed during the 95% quantile assessment, were then included in subsequent analyses.

The second reduction strategy was to combine some of the length subgroups within each species. Subgroups of each species during the same sample period were assessed with similar criteria discussed above. That is, subgroups with isotopic signatures that diverged by less than 10% were combined. Therefore, all of the subgroups for some omnivorous species were condensed to a single species entry during some sample periods. Stable isotope data for the condensed fishes list, all invertebrates, flora, and sediment and detritus then were plotted to allow inspection of C and N enrichment patterns and aid in the assessment of energy flow and seasonal food web construction.

Using the isotope signatures and assuming that enrichment was constant and identifiable on the plots, consumer classifications, including primary, secondary, tertiary, and quaternary levels were assigned.

Food web construction

Seasonal food webs representing hypothesized primary community interactions were developed in a five-stage process. The initial step was to determine which taxonomical groups should be included on the food web diagram. To accomplish this, I used the reduction approaches described under the isotope analysis methods above. Therefore, the fishes, invertebrates, flora, and sediments represented on the seasonal food webs were similar to those used in the isotope signature plots. Once it was determined which groups would be included, they were arranged by isotopic consumer classifications on the new figure. Although there is considerable variance in trophic level classifications, for clarity purposes, the food webs were synthesized in a four-tier format including levels for producers/energy sources, primary consumers, secondary consumers, and tertiary and quaternary consumers. After the groups were arranged, a three-step overlay of potential interactions was completed. The first overlay was to establish the primary observed dietary interactions, the second overlay was applied to denote the interactions based on isotopic enrichment patterns, and finally primary interactions were highlighted that were supported by both empirical diet and isotopic data.

Results and Discussion

Spring food web of EIS

Fifty-seven subgroups of fish were assessed in May and of these, the dietary assessments indicated that 19.3% were omnivorous, implying that greater than 80% exhibited some type of specialized or selective feeding habits (Table 6-1). Based on the stable isotope values (Figure 6-1), nearly 60% of the 57 fish subgroups were secondary consumers. Isotopic and food habits data suggest that Chironomidae and Corixidae were the two primary consumers most frequently used as an energy resource by the secondary consumers (Figure 6-2).

In May, the stable isotope values suggest that the CPOM in the backwater food web originated from marsh smartweed *Polygonum coccineum* and sedges. The CPOM along with the phytoplankton appear to be contributing to the energy resources of medium to large zooplankton and large invertebrate scavengers and parasites such as Hydracarina and leeches (Hirudinea). Isotopic evidence suggests that this food chain continues into some fishes, including *Pomoxis* spp. and goldeye; however, when considering both isotopic and empirical dietary data, the food chains originating with periphyton and continuing onto Chironomidae and Corixidae appear to be more important (Figure 6-2).

Evidence supports the contention that some species, such as common carp, river carpsucker, and juvenile white sucker may be receiving some energy resources directly from sediments and detritus. However, more apparent was that species such as *Hybognathus* spp. were directly utilizing periphyton resources and energy assimilation was predominantly transferred from Chironomidae and Corixidae, both of which were

Table 6-1. Summary of fishes collected in Erickson Island Slough, North Dakota during May of 1998. total length (TL) groups, primary food habits biomass proportions based on stomach analyses. and suggested trophic level classifications. Trophic classifications based on stomach contents include several functional feeding categories. The consumer classifications were based on isotopic signatures (δN^{15}‰ and δC^{13}‰) that indicate the ecological consumer level assuming that nitrogen and carbon enrichment is occurring Refer to the abbreviations and acronyms list for definitions.

		Dietary biomass proportions			Consumer classification	
Taxon	TL (mm)	Primary	Secondary	Tertiary	Dietary	Isotopic
BIB	100-249	LZOO (99.9)	--	--	Planktivore	Secondary
	250-599	MZOO (74.8)	CORX (19.2)	SZOO (3.7)	Planktivore	Secondary
	>599	CHIR (93.9)	MZOO (4.1)	SZOO (1.4)	Insectivore	Secondary
BLB	<100	COLE (35.2)	TRIC (33.6)	CHIR (18.0)	Insectivore	Secondary
	100-159	CORX (25.6)	UFI (25.5)	CHIR (23.1)	Omnivore	Secondary
	160-199	YEP (33.9)	CHIR (29.9)	CORX (12.8)	Omnivore	Secondary
	>199	YEP (64.7)	CYP (10.6)	BLB (10.3)	Piscivore	Secondary
BUR	<200	ODON (75.1)	EPHE (12.6)	TRIC (6.3)	Insectivore	Tertiary
CCF	400-549	DECA (41.6)	BLB (37.4)	CHIR (10.8)	Omnivore	Quaternary
	>549	CAT (97.0)	BLB (2.1)	--	Piscivore	Quaternary
COC	<100	CORX (98.8)	MZOO (1.2)	--	Insectivore	Secondary
	300-599	DETR (56.5)	SEDI (18.2)	PERI (11.6)	Detritivore	Secondary
	>599	SEDI (41.8)	DETR (23.9)	MACR (14.1)	Detritivore	Secondary
EMS	<70	CORX (93.2)	MZOO (5.7)	SZOO (1.1)	Insectivore	Secondary
	>69	CORX (49.5)	TRIC (20.8)	CHIR (19.5)	Insectivore	Secondary
FLC	<70	CHIR (55.7)	FEL (29.6)	CORX (14.1)	Omnivore	Secondary
	>69	CORX (94.2)	FEL (4.2)	AMPH (1.5)	Insectivore	Secondary
FRD	125-299	DETR (52.3)	CHIR (28.8)	CORX (16.4)	Omnivore	Tertiary
	>299	CHIR (47.8)	MACR (46.8)	TRIC (4.9)	Omnivore	Tertiary
GOE	<100	CHIR (51.3)	TRIC (32.9)	CORX (15.7)	Insectivore	Secondary
	100-174	CHIR (41.4)	TRIC (30.2)	COLE (13.9)	Insectivore	Secondary
	175-274	CORX (67.5)	COLE (9.9)	TRIC (9.4)	Insectivore	Tertiary
	>274	COLE (64.9)	CORX (28.1)	PLEC (3.0)	Insectivore	Tertiary
GOS	<125	COLE (72.4)	DETR (22.9)	CORX (4.7)	Insectivore	Secondary
HYB	<60	PERI (32.7)	DETR (32.7)	CHIR (26.5)	Omnivore	Primary
	>59	PERI (98.2)	FEL (1.8)	--	Herbivore	Primary
LEP	<125	PLEC (61.1)	CHIR (38.4)	--	Insectivore	Secondary
NOP	200-399	GOE (57.2)	CAT (22.4)	POM (10.7)	Piscivore	Tertiary
	400-599	GOE (80.9)	CYP (11.3)	YEP (7.8)	Piscivore	Tertiary
POM	<100	CHIR (37.8)	CORX (24.0)	MZOO (18.3)	Omnivore	Secondary

Table 6-1. Continued.

		Dietary biomass proportions			Consumer classification	
Taxon	TL (mm)	Primary	Secondary	Tertiary	Dietary	Isotopic
POM	150-199	CHIR (28.2)	AMPH (23.9)	COLE (23.9)	Omnivore	Secondary
	200-249	CHIR (38.9)	CORX (21.6)	TRIC (18.6)	Insectivore	Secondary
	>249	CHIR (40.9)	DIPT (24.1)	CORX (14.3)	Insectivore	Tertiary
RIC	<100	SEDI (91.9)	CHIR (7.4)	--	Detritivore	Secondary
	225-374	DETR (52.9)	SEDI (43.9)	CHIR (3.1)	Detritivore	Secondary
	>374	CHIR (80.5)	SEDI (9.1)	DETR (7.9)	Insectivore	Secondary
SAB	400-599	SEDI (64.5)	CHIR (24.7)	DETR (10.7)	Detritivore	Secondary
	>599	SEDI (92.4)	DETR (3.9)	CHIR (3.1)	Detritivore	Tertiary
SAR	250-399	CORX (100.0)	--	--	Insectivore	Tertiary
SHR	150-199	CHIR (79.0)	TRIC (17.9)	CORX (3.1)	Insectivore	Secondary
	>199	DETR (39.9)	CHIR (19.4)	COLE (16.8)	Omnivore	Secondary
SPS	<80	CHIR (98.0)	HYDR (1.2)	--	Insectivore	Secondary
	>79	CHIR (89.3)	TRIC (7.8)	CORX (2.5)	Insectivore	Tertiary
STC	100-199	BLB (85.5)	UFI (12.9)	CHIR (1.0)	Piscivore	Tertiary
	>199	CYP (64.3)	UFI (22.5)	DETR (6.6)	Piscivore	Tertiary
STZ	<170	CYP (69.3)	CHIR (15.7)	UFI (13.2)	Piscivore	Quaternary
TAM	<60	PLEC (69.3)	CHIR (14.4)	TRIC (9.6)	Insectivore	Secondary
	60-99	TRIC (72.5)	CHIR (15.4)	PLEC (7.9)	Insectivore	Secondary
WAE	170-249	UFI (91.5)	CHIR (8.5)	--	Piscivore	Quaternary
	250-399	PLEC (74.9)	TRIC (25.1)	--	Insectivore	Tertiary
WHS	<150	CHIR (61.5)	DETR (24.0)	SEDI (14.4)	Omnivore	Secondary
	150-374	CHIR (61.8)	TRIC (22.0)	DETR (11.8)	Insectivore	Tertiary
	>374	SEDI (53.2)	DETR (36.8)	PERI (7.7)	Detritivore	Quaternary(?)
YEB	<100	CHIR (69.6)	ODON (10.3)	COLE (6.3)	Insectivore	Secondary
	>199	YEP (93.8)	UFI (3.5)	DECA (2.2)	Piscivore	Tertiary
YEP	<100	DIPT (62.9)	CHIR (30.8)	CORX (3.6)	Insectivore	Secondary
	100-199	TRIC (29.6)	CHIR (25.8)	CORX (23.2)	Insectivore	Secondary

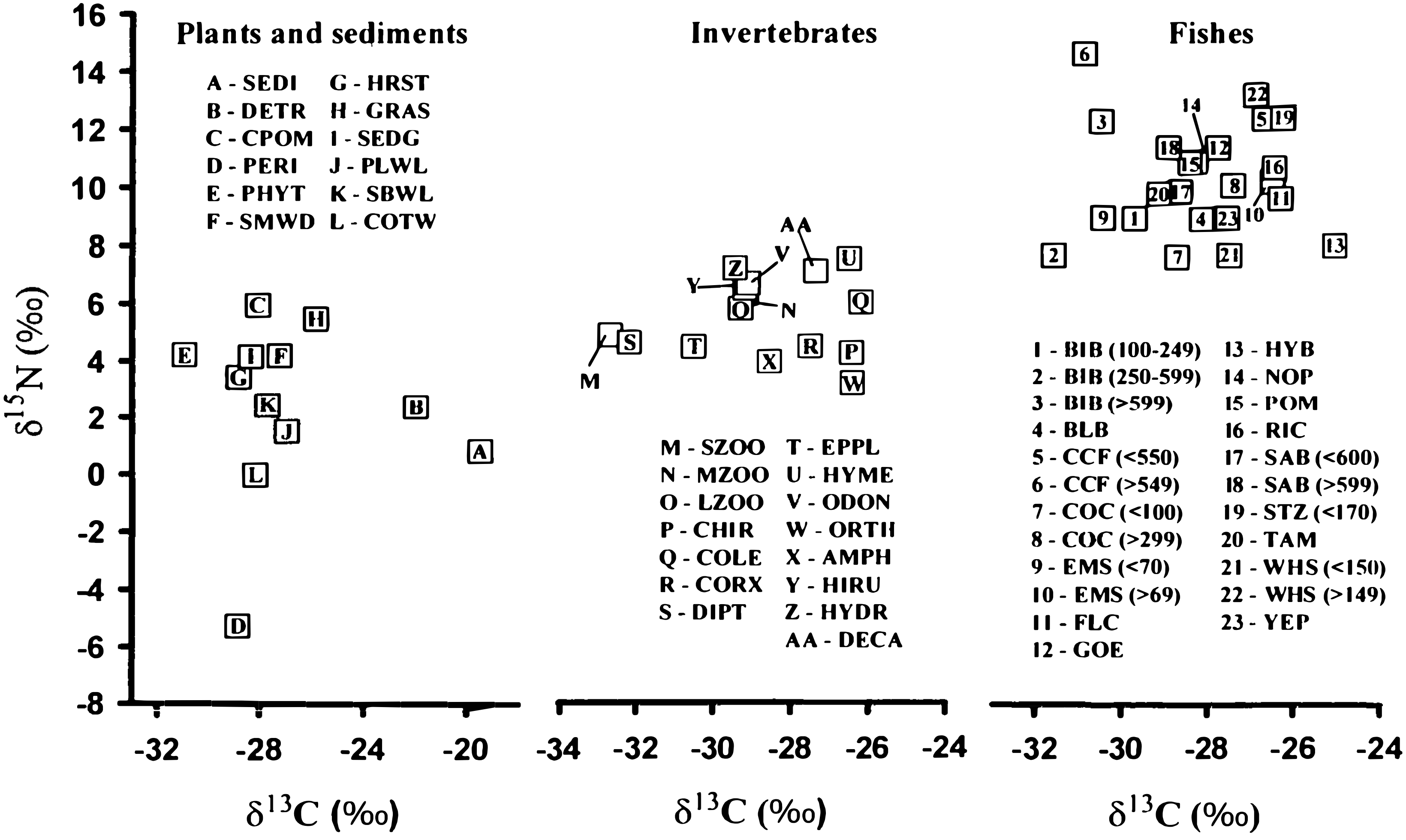

Figure 6-1. Dual isotope values for $\delta^{13}C$ and $\delta^{15}N$ of plants, sediments, invertebrates, and fishes collected in Erickson Island Slough during May of 1998. Refer to the abbreviations and acronyms list for definitions. Fish lengths are total length in mm.

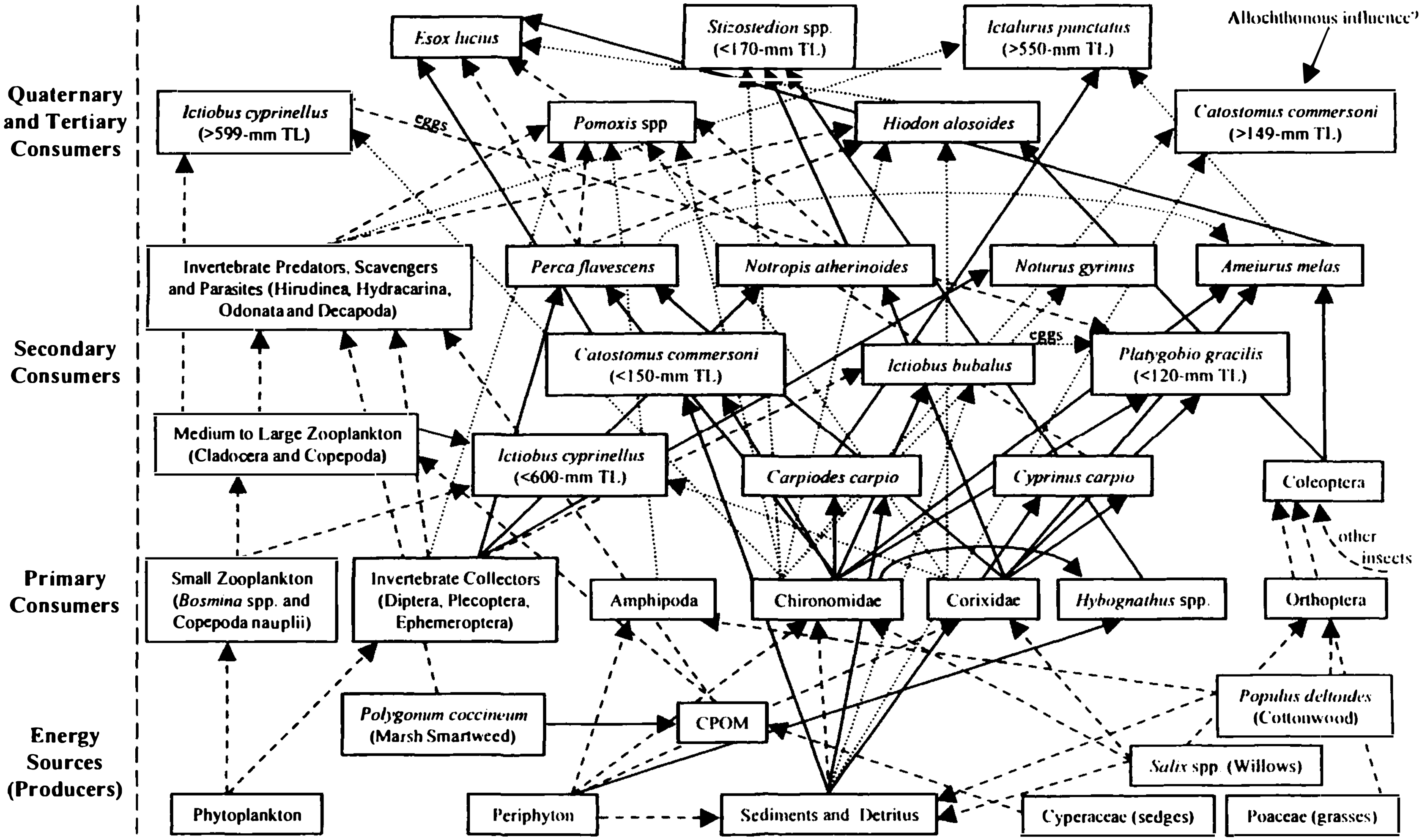

Figure 6-2. A food web formulated from empirical diet data and stable isotope data collected from the Erickson Island Slough community, North Dakota in May of 1998. The dotted lines represent interactions based on food habit analyses, but lack isotopic support. The dashed lines indicate isotopic relationships without diet data support. The solid lines signify interactions supported by both the food habit analyses and stable isotope analyses. Total length (TL) designations are noted where applicable.

commonly consumed by numerous fish species in May. Chironomidae and Corixidae appear to play a substantial role in the transfer of energy from the detritus and periphyton to the secondary consumers, including river carpsucker, yellow perch, black bullhead, flathead chub, emerald shiner, and white sucker. Other primary consumers, such as the zooplankton and Amphipoda exhibited some isotopic relationships with higher trophic levels; however, dietary data for bigmouth buffalo indicated the only instances of substantial consumption. Tertiary consumption was present and both food habits and isotopic evaluation supported piscivory by northern pike, channel catfish, and *Stizostedion* spp.; however, secondary consumption appeared to dominate the energy transfers to the overall piscivorous community. The isotopic values for some species and length subgroups, such as the white sucker exceeding 149-mm TL, suggest that the individuals are quaternary piscivores. Logically, the white sucker is not a piscivore, and the subgroup likely established its isotopic signature outside of the backwater proper, as is indicated by its disjunction from the EIS backwater enrichment pattern.

Mid-summer food web

Fifty subgroups of fishes were assessed in July. Of those 50 subgroups, the dietary assessments indicated that 40% should be classified as omnivores (Table 6-2). Therefore, fish exhibited a more variable diet in July and utilized opportunities to take advantage of the community composition shift and feed on the more abundant Coleoptera, zooplankton, larval fishes, and both allochthonous and autochthonous floral production. Polyphagous feeding strategies predominated; however, isotopic data suggest

Table 6-2. Summary of fishes collected in Erickson Island Slough, North Dakota during July of 1998, total length (TL) groups, primary food habits biomass proportions based on stomach analyses, and suggested trophic level classifications. Trophic classifications based on stomach contents include several functional feeding categories. The consumer classifications were based on isotopic signatures (δN^{15}‰ and δC^{13}‰) that indicate the ecological consumer level assuming that nitrogen and carbon enrichment is occurring Refer to the abbreviations and acronyms list for definitions.

		Dietary biomass proportions			Consumer classification	
Taxon	TL (mm)	Primary	Secondary	Tertiary	Dietary	Isotopic
BIB	250-599	PERI (54.0)	CHIR (31.5)	CORX (14.2)	Omnivore	Secondary
	>599	DETR (45.4)	MACR (30.3)	PERI (21.7)	Detritivore	Tertiary
BLB	<100	MACR (30.4)	CHIR (27.1)	SEDI (22.8)	Omnivore	Secondary
	100-159	SEDI (43.4)	MACR (36.2)	CHIR (8.6)	Omnivore	Secondary
	160-199	MACR (24.9)	BLB (22.3)	TRIC (21.7)	Omnivore	Secondary
	>199	UFI (35.7)	SEDI (26.4)	MACR (19.8)	Omnivore	Secondary
CCF	400-549	COLE (44.0)	CHIR (28.0)	CORX (8.3)	Insectivore	Tertiary
	>549	CAT (47.1)	UFI (39.0)	DETR (9.7)	Piscivore	Quaternary
COC	<100	MACR (81.4)	CHIR (13.2)	MZOO (4.6)	Herbivore	Secondary
	300-599	MACR (41.9)	DETR (25.8)	CHIR (19.1)	Omnivore	Secondary
	>599	SEDI (60.0)	DETR (40.0)	--	Detritivore	Secondary
EMS	>69	CORX (47.4)	MACR (31.9)	LZOO (10.3)	Omnivore	Tertiary
FLC	<70	MZOO (100.0)	--	--	Planktivore	Primary
	>69	MZOO (100.0)	--	--	Planktivore	Primary
FRD	125-299	CHIR (36.1)	DECA (32.1)	TRIC (19.3)	Omnivore	Tertiary
	>299	CHIR (58.0)	DIPT (23.1)	TRIC (10.6)	Insectivore	Tertiary
GOE	<100	LZOO (88.9)	MZOO (11.1)	--	Planktivore	Secondary
	100-174	CORX (54.0)	COLE (12.9)	FEL (12.2)	Omnivore	Tertiary
	175-274	COLE (37.3)	CORX (26.9)	MACR (16.4)	Omnivore	Tertiary
	>274	COLE (37.8)	CORX (33.7)	PERI (7.2)	Omnivore	Quaternary
HYB	<60	PERI (99.0)	MZOO (1.0)	--	Herbivore	Primary
	>59	PERI (94.5)	MACR (5.2)	--	Herbivore	Primary
NOP	400-599	CAT (62.8)	CYP (20.9)	YEP (16.3)	Piscivore	Tertiary
	>599	GOE (97.6)	CYP (2.4)	--	Piscivore	Quaternary
POM	100-149	CORX (51.8)	CHIR (34.0)	LZOO (8.9)	Insectivore	Tertiary
	150-199	CORX (45.8)	CHIR (42.4)	DIPT (10.6)	Insectivore	Tertiary
	200-249	YEP (35.6)	UFI (33.8)	CORX (19.0)	Piscivore	Tertiary
	>249	CORX (66.7)	CHIR (14.6)	DIPT (14.6)	Insectivore	Tertiary
RIC	<100	DETR (80.6)	SEDI (8.1)	CHIR (6.5)	Detritivore	Primary
	225-374	CHIR (75.3)	DETR (11.7)	SEDI (6.0)	Insectivore	Secondary

Table 6-2. Continued

		Dietary biomass proportions			Consumer classification	
Taxon	TL (mm)	Primary	Secondary	Tertiary	Dietary	Isotopic
RIC	>374	DETR (41.0)	SEDI (29.4)	CHIR (11.0)	Omnivore	Secondary
SAB	200-399	DETR (75.2)	CHIR (24.4)	--	Detritivore	Secondary
	400-599	MACR (26.7)	SEDI (23.6)	DETR (14.4)	Omnivore	Tertiary
	>599	SEDI (37.6)	DETR (35.7)	CHIR (14.3)	Omnivore	Tertiary
SAR	250-399	BLB (49.1)	CYP (15.1)	ACB (14.5)	Piscivore	Quaternary
	>399	UFI (100.0)	--	--	Piscivore	Quaternary
SHG	500-624	UFI (54.8)	YEP (10.5)	COLE (10.2)	Omnivore	Tertiary
	>624	MACR (100.0)	--	--	Herbivore	Tertiary
SHR	150-199	CHIR (62.2)	MACR (31.2)	DETR (4.0)	Omnivore	Tertiary
SPS	<80	DIPT (44.8)	CHIR (22.4)	LZOO (21.3)	Omnivore	Tertiary
STC	<100	DETR (94.8)	CHIR (5.1)	--	Detritivore	Tertiary
	100-199	CHIR (27.1)	UFI (22.7)	CAT (19.1)	Omnivore	Tertiary
STZ	<170	CHIR (61.0)	DIPT (24.4)	FEL (6.1)	Insectivore	Tertiary
TAM	60-99	CHIR (37.8)	MACR (32.4)	PLEC (12.9)	Omnivore	Secondary
WAE	170-249	CAT (82.2)	CHIR (16.5)	CORX (1.3)	Piscivore	Tertiary
	>399	BLB (97.8)	DETR (2.2)	--	Piscivore	Quaternary
WHS	<150	CHIR (60.0)	SEDI (16.3)	COLE (13.8)	Omnivore	Secondary
	150-374	CHIR (93.4)	PLEC (4.0)	CORX (1.3)	Insectivore	Tertiary
YEP	<100	CHIR (50.9)	CORX (25.8)	FEL (13.5)	Insectivore	Secondary
	100-199	CHIR (90.0)	LZOO (8.3)	MZOO (1.7)	Insectivore	Tertiary

that 48% of the fish subgroups were tertiary consumers, obtaining a majority of their assimilated energy through piscine or predacious insect consumption (Table 6-2; Figure 6-3).

In the July food web, the isotopic values indicate that the CPOM originated from a combination of sedges and willows, both of which were inundated during the high water period from late May through July. Marginally supported isotopic trends indicated the transfer of detrital-based energy resources to *Hybognathus* spp., juvenile common carp, and juvenile white sucker (Figure 6-3). Although grazing on sediments and detritus was a relatively common practice among benthic and other fishes in the backwater, isotopic evidence suggests that a majority of the energy assimilation came from the organisms within the sediment and detritus, not the substrate itself. Based on the hypothesized enrichment patterns, Chironomidae were receiving their energy resources from the CPOM and settled phytoplankton (Figure 6-4). Chironomidae also appeared to be the major dietary pathway for energy transfer to nearly all of the secondary consumers and a portion of the classified tertiary consumers. The food web in July was highly variable; however, the primary energy transfer pathways appeared to be driven by primary production more than microbial-based activity.

Fall food web

Fifty-two subgroups of fishes were assessed in September. Of those 52 subgroups, the food habits analysis suggested that only 15% exhibited omnivorous feeding strategies (Table 6-3). Therefore, the remaining 85% of the subgroups were

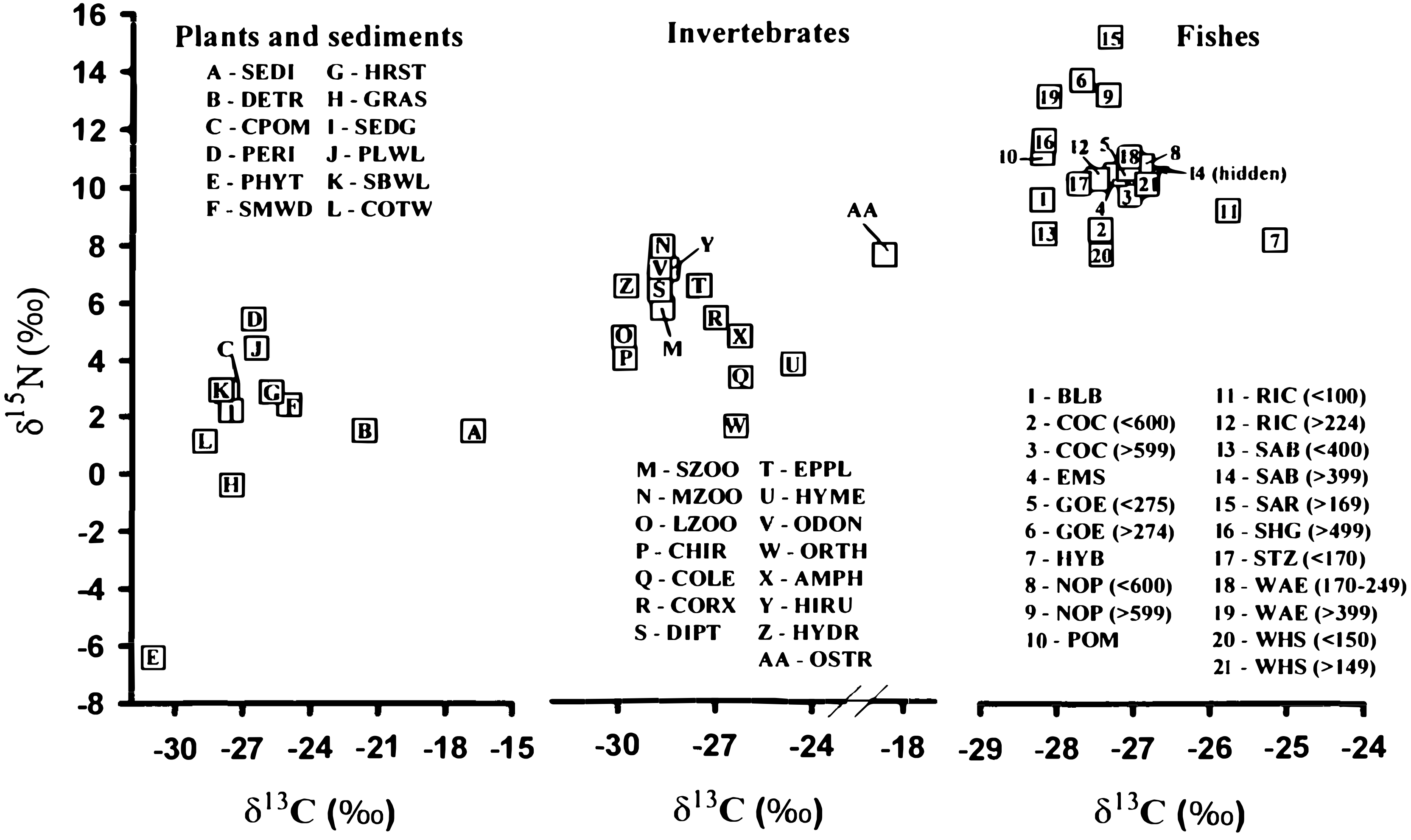

Figure 6-3. Dual isotope values for $\delta^{13}C$ and $\delta^{15}N$ of plants, sediments, invertebrates, and fishes collected in Erickson Island Slough during July of 1998. Refer to the abbreviations and acronyms list for definitions. Fish lengths are total length in mm.

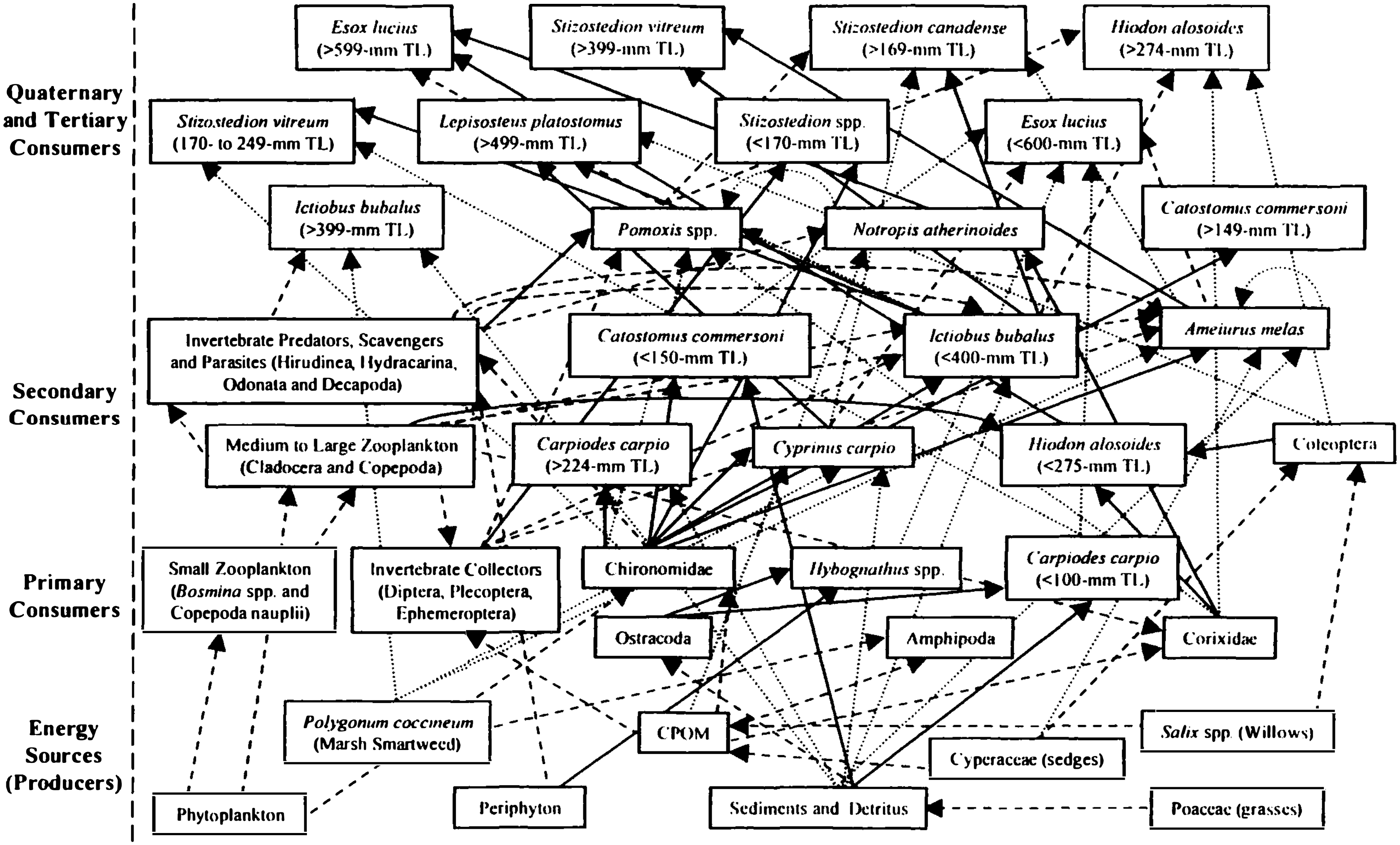

Figure 6-4. A food web formulated from empirical diet data and stable isotope data collected from the Erickson Island Slough community, North Dakota in July of 1998. The dotted lines represent interactions based on food habit analyses, but lack isotopic support. The dashed lines indicate isotopic relationships without diet data support. The solid lines signify interactions supported by both the food habit analyses and stable isotope analyses. Total length (TL) designations are noted where applicable.

Table 6-3. Summary of fishes collected in Erickson Island Slough, North Dakota during September of 1998, total length (TL) groups, primary food habits biomass proportions based on stomach analyses, and suggested trophic level classifications. Trophic classifications based on stomach contents include several functional feeding categories. The consumer classifications were based on isotopic signatures (δN^{15}‰ and δC^{13}‰) that indicate the ecological consumer level assuming that nitrogen and carbon enrichment is occurring Refer to the abbreviations and acronyms list for definitions.

		Dietary biomass proportions			Consumer classification	
Taxon	TL (mm)	Primary	Secondary	Tertiary	Dietary	Isotopic
BIB	<100	LZOO (91.4)	MZOO (8.6)	--	Planktivore	Secondary
	100-249	LZOO (42.2)	SZOO (28.7)	MZOO (16.0)	Planktivore	Secondary
BLB	<100	CHIR (56.0)	DIPT (17.7)	MACR (13.5)	Omnivore	Secondary
	100-159	UFI (83.1)	CHIR (6.5)	ACB (4.6)	Piscivore	Secondary
	160-199	ACB (68.4)	POM (8.8)	MACR (6.3)	Piscivore	Tertiary
	>199	ACB (48.3)	POM (29.0)	CAT (9.7)	Piscivore	Tertiary
CCF	<100	CHIR (55.6)	MACR (37.6)	DIPT (3.7)	Omnivore	Secondary
COC	<100	CHIR (100.0)	--	--	Insectivore	Secondary
	100-299	DETR (55.8)	SEDI (32.3)	MACR (7.6)	Detritivore	Secondary
	300-599	DETR (58.9)	CHIR (19.1)	SEDI (19.1)	Detritivore	Secondary
	>599	CHIR (54.4)	DETR (21.5)	MACR (10.7)	Omnivore	Secondary
EMS	<70	CHIR (98.8)	--	--	Insectivore	Secondary
	>69	CHIR (94.7)	MZOO (5.3)	--	Insectivore	Tertiary
FLC	<70	CHIR (100.0)	--	--	Insectivore	Secondary
	>69	DIPT (99.4)	--	--	Insectivore	Tertiary
FRD	<125	PERI (50.7)	CHIR (29.1)	DETR (12.1)	Omnivore	Primary
	>299	BLB (54.7)	UFI (45.1)	--	Piscivore	Quaternary
GOE	<100	HYME (90.7)	CHIR (3.4)	MZOO (3.2)	Insectivore	Secondary
	100-174	ORTH (63.9)	CHIR (16.7)	CORX (14.9)	Insectivore	Secondary
HYB	<60	PERI (91.1)	DETR (7.6)	CHIR (1.2)	Herbivore	Primary
	>59	PERI (95.8)	CHIR (4.2)	--	Herbivore	Primary
LEP	<125	CHIR (82.8)	LZOO (17.2)	--	Insectivore	Secondary
NOP	200-399	UFI (47.7)	ACB (27.1)	YEP (16.9)	Piscivore	Tertiary
	400-599	ACB (48.0)	UFI (44.9)	POM (7.0)	Piscivore	Tertiary
	>599	POM (87.9)	UFI (12.1)	--	Piscivore	Quaternary
POM	<100	MZOO (54.5)	OSTR (14.6)	CHIR (11.2)	Omnivore	Secondary
	100-149	MZOO (54.7)	LZOO (23.3)	TRIC (14.4)	Planktivore	Secondary
	150-199	ACB (58.8)	UFI (40.6)	--	Piscivore	Tertiary
	200-249	ACB (60.2)	UFI (30.7)	ORTH (4.4)	Piscivore	Tertiary
	>249	UFI (99.5)	--	--	Piscivore	Tertiary

Table 6-3. Continued.

		Dietary biomass proportions			Consumer classification	
Taxon	TL (mm)	Primary	Secondary	Tertiary	Dietary	Isotopic
RIC	<100	PERI (97.4)	DETR (1.7)	--	Herbivore	Primary
	100-224	CHIR (46.7)	DETR (37.8)	SEDI (14.6)	Omnivore	Secondary
SAB	<100	MZOO (56.5)	LZOO (31.6)	CHIR (11.7)	Planktivore	Secondary
SHG	<300	UFI (100.0)	--	--	Piscivore	Tertiary
	300-499	UFI (100.0)	--	--	Piscivore	Tertiary
SHR	<150	OSTR (100.0)	--	--	Planktivore	Secondary
SPS	<80	CHIR (100.0)	--	--	Insectivore	Secondary
STC	<100	MACR (93.5)	CORX (6.5)	--	Herbivore	Secondary
	100-199	CAT (72.0)	UFI (28.0)	--	Piscivore	Tertiary
	>199	UFI (96.7)	DETR (3.3)	--	Piscivore	Tertiary
STZ	<170	UFI (73.0)	ACB (25.6)	CHIR (1.1)	Piscivore	Tertiary
TAM	<60	CHIR (61.9)	MACR (24.0)	DIPT (11.3)	Omnivore	Secondary
	>99	CHIR (86.6)	ODON (13.4)	--	Insectivore	Tertiary
WHS	<150	OSTR (100.0)	--	--	Planktivore	Primary
	150-374	DETR (49.6)	CHIR (37.2)	LZOO (6.1)	Omnivore	Secondary
	>374	CHIR (86.1)	MZOO (7.4)	DETR (4.7)	Insectivore	Tertiary
YEB	<100	ODON (44.1)	CHIR (20.9)	CORX (12.4)	Insectivore	Secondary
	100-199	UFI (71.0)	CYP (16.9)	COLE (6.4)	Piscivore	Secondary
	>199	ACB (42.8)	POM (35.5)	UFI (20.9)	Piscivore	Tertiary
YEP	<100	UFI (86.6)	CHIR (10.4)	CORX (2.6)	Piscivore	Secondary
	100-199	ACB (66.0)	UFI (34.0)	--	Piscivore	Tertiary
	>199	UFI (100.0)	--	--	Piscivore	Tertiary

targeting specific organismal groups and the isotopic patterns support this shift to specialized feeding. Most noteworthy was that 38% of the fish subgroups were classified as piscivores, as compared with only 15% in May and 16% in July (Figure 6-5). The catalyst for the increased levels of piscivory, even in some previously classified secondary consumers, such as *Pomoxis* spp. and yellow perch, was due to the high relative abundance of age-0 common carp, smallmouth buffalo and bigmouth buffalo.

The organic source for the detritus in September appeared to primarily be the grasses (Family Poaceae), probably a residual effect from the mid-summer period of inundation. Isotopic signatures suggest, however, that detritus contributions to the overall food web were limited. Although several species, such as common carp, river carpsucker, and age-0 freshwater drum grazed on the detritus, no isotopic evidence supported the transfer of nutrients from detrital resources to the fish or invertebrate species. Primary production, predominantly from periphyton and phytoplankton, appeared to be driving the September food web. The overall food web can be summarized quite succinctly into four "supercategories" including the primary energy producers mentioned above, followed by two primary pathways leading to the zooplankton and Chironomidae, then to the extensive age-0 fish community (e.g., age-0 *Ictiobus* spp., goldeye, *Pomoxis* spp., and black bullhead), and eventually to the now extended piscivorous assemblage, including yellow perch, adult *Pomoxis* spp., black bullhead, and northern pike (Figure 6-6; Figure 6-7).

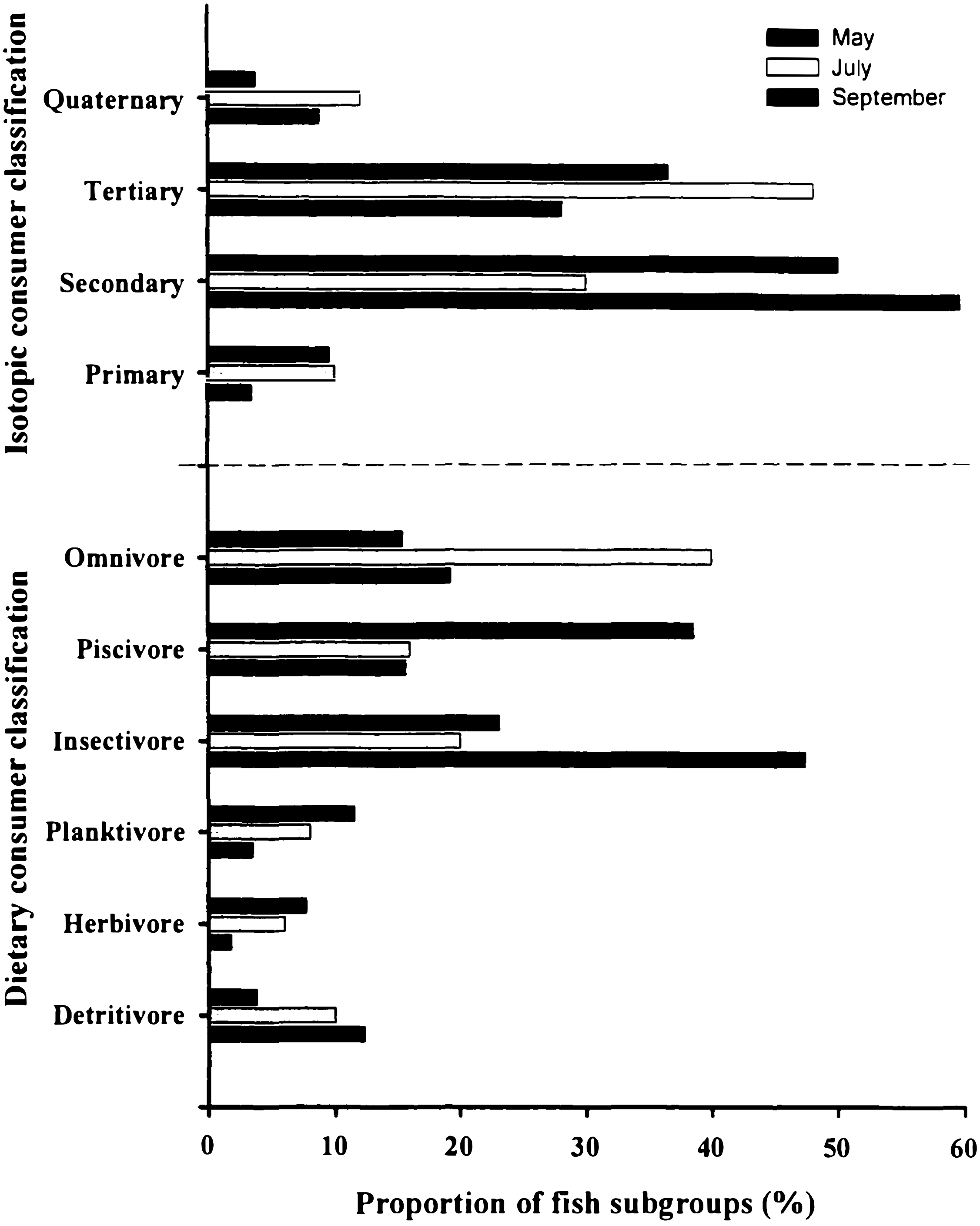

Figure 6-5. Proportional consumer classifications for fish subgroups collected in May, July, and September of 1998 in Erickson Island Slough, North Dakota. The subgroups were categorized based on the food habits observations (lower section) and N and C isotopic signatures (upper section).

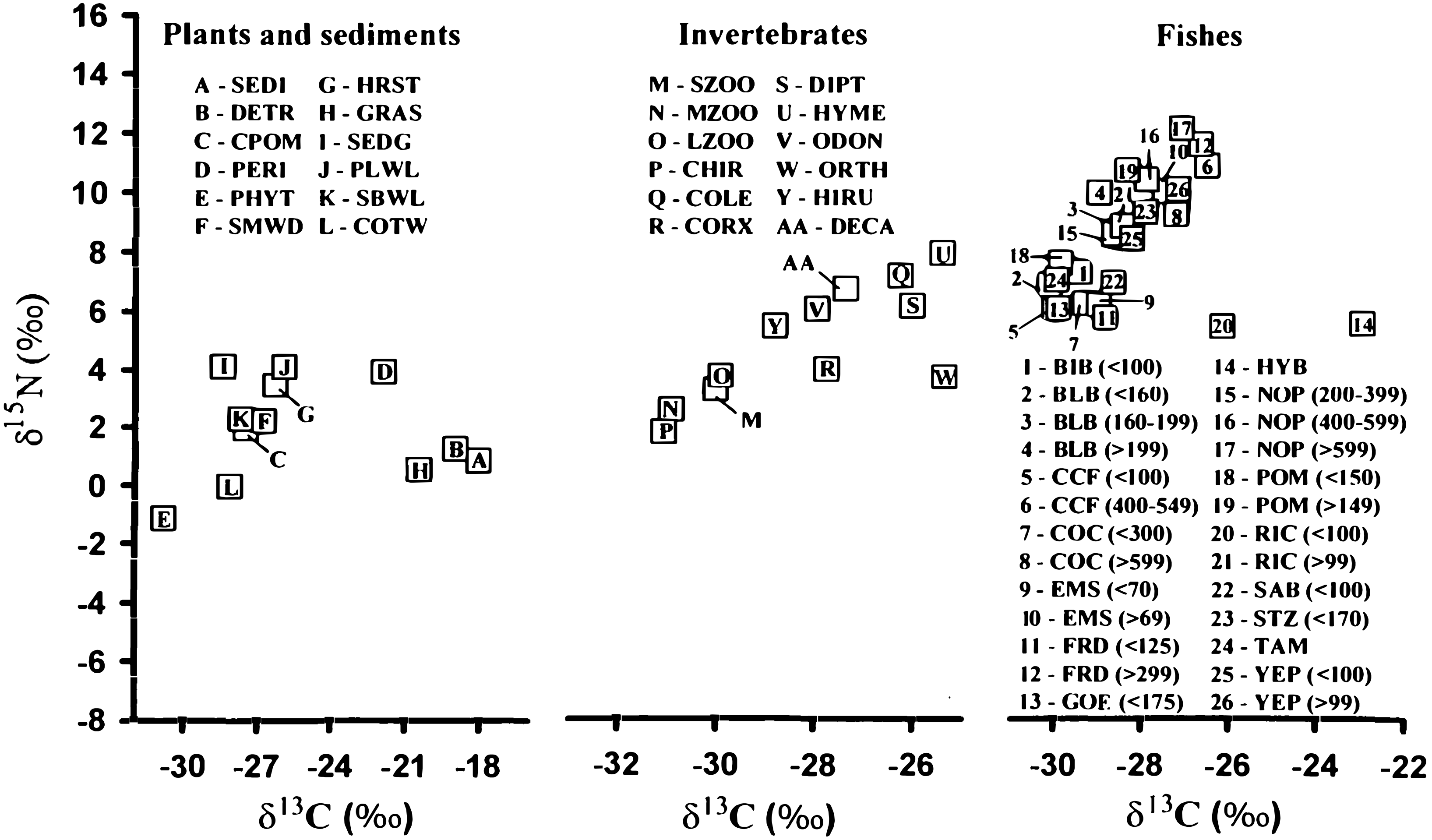

Figure 6-6. Dual isotope values for $\delta^{13}C$ and $\delta^{15}N$ of plants, sediments, invertebrates, and fishes collected in Erickson Island Slough during September of 1998. Refer to the abbreviations and acronyms list for definitions. Fish lengths are total lengt in mm.

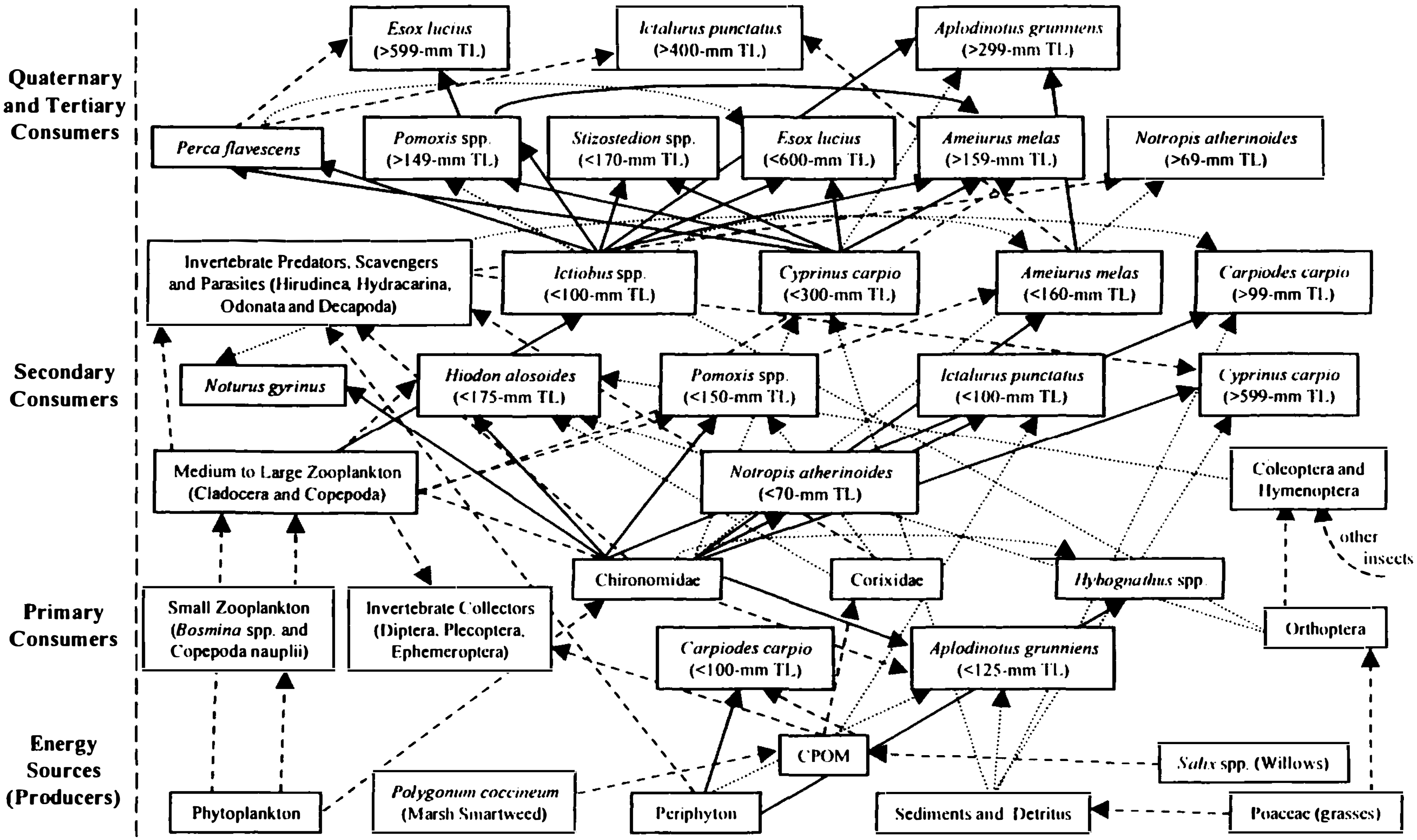

Figure 6-7. A food web formulated from empirical diet data and stable isotope data collected from the Erickson Island Slough community, North Dakota in early September of 1998. The dotted lines represent interactions based on food habit analyses, but lack isotopic support. The dashed lines indicate isotopic relationships without diet data support. The solid lines signify interactions supported by both the food habit analyses and stable isotope analyses. Total length (TL) designations are noted where applicable.

Chapter Summary

Polis and Hurd (1996) suggested that allochthonous inputs can play important roles in shaping the dynamics of primary consumers, thus influencing the overall community. The data presented here lend support to this concept. The CPOM, although not a substantial portion of fish food habits, isotopically appeared to be a major contributor to the backwater food web via the macroinvertebrates, especially Chironomidae and Corixidae during the terrestrial inundation period of July. During a typical year, the flood-pulse inundates a substantial area of terrestrial biomass that contributes extensively to the CPOM and detritus. Differing during the other periods, periphyton (also including other aufwuchs) appeared to be the critical producer in May, whereas in September the system was driven by phytoplankton production. Detrital energy production, although evidenced as important to a few species, did not appear to play a major role in supporting the overall backwater food web. Across all seasons, the Chironomidae were the predominant primary consumer providing nourishment to the remainder of the food web; however, in September, zooplankton also played an important role and Corixidae shared critical energy transfer duties in May.

The level of omnivory was evidenced by the variability among the isotopic signatures for both fish and invertebrate taxonomical groups. Yoshioka et al. (1994) stated that the carbon isotope ratio tends to indicate the organic source and the nitrogen isotope ratio reflects the trophic level of the organism. In May and July, the wide distributions of $\delta^{13}C$ values indicate that the organic sources were varied, whereas in September the enrichment pattern was considerably more linear and appeared to originate from the phytoplankton. The wide array in $\delta^{15}N$ values in July and to an extent in May, also supports my contention that specialized feeding was less prevalent in those sample periods than it was in September. The isotopic signatures for the fishes in September demonstrated four identifiable assemblages (Figure 6-5). The first group, consisting of juvenile river carpsucker and *Hybognathus* spp., appeared to be primary consumers drawing their energy resources from periphyton and possibly detrital sources. The second group of fishes, all of which could be classified as secondary consumers, targeted the zooplankton and Chironomidae and included nearly all age-0 fishes. The third and fourth groups appeared to represent the piscivorous community that was actively preying on secondary and lower tertiary consumers; however, of those secondary consumers, both isotopic and empirical diet data suggest that the age-0 common carp and buffalo (bigmouth and smallmouth) were the vital dietary connection to higher trophic levels.

This assessment was actually more complex than described in this chapter. For future reference, several TL subgroups of nearly all fish species present have been classified using a dual dietary and isotopic approach. These classifications allowed me to create a sequence of proposed food webs and indicate which energy transfer interactions can be supported with both biological observations and chemical assessments. Riverine researchers have often suggested that microbial energy production tends to be more important than primary production to aquatic food webs (Junk 1984; Mann 1988; Ward 1989); however, other research has concluded that detrital energy reserves play a small role in lotic production. Hamilton et al. (1992) and Schlacher and Wooldridge (1996) found that in saline estuaries and large river floodplains, detrital-based energy resources were secondary to primary production. My study also suggests that in EIS, autochthonous energy resources predominated during much of the year. However, allochthonous resources and detritus are important during the periods of inundation.

Chapter 7.

Summary, Conservation Recommendation, and Research Needs

Closing summary

Researchers, including Sedell et al. (1990), have suggested that the only way to maintain biotic diversity on riverine corridors is to preserve the many unique habitats, including backwaters. Without the lateral dimension, river structure and function is degraded and many species that have evolved with a flood pulse as part of their annual cycle cannot survive (Welcomme 1979; Bouvert et al. 1985). My data suggest that backwaters in the upper Missouri River are a highly dynamic, but important component of species life history strategies and community stability; however, as the habitat information suggests, backwater habitats can at times be a stressful environment for fishes, invertebrates, and researchers.

The seasonal flood pulse is obviously an important event for species such as smallmouth buffalo and river carpsucker. These long-lived species, however, may not require the availability of a flood-pulse every year, as a missing year class would not likely be detrimental to the overall population. In regulated rivers, though, a series of congruent years could miss any type of flood pulse, resulting in multiple missing year classes and causing serious detriment to the breeding populations. Short-lived species, such as flathead chubs, may be more vulnerable to missed flood pulses because of their short life span.

As suggested by the observations of numerous larval and juvenile fishes that were likely hatched in the channel, such as blue sucker, sauger, and burbot, backwater availability may be an important factor during their early life history. Other species, including residential fishes and backwater spawners, intentionally place their gametes in areas suitable for proper development and growth and have over time evolved to place those reproductive efforts in the backwaters. Species such as white crappie, smallmouth buffalo, and northern pike appear to be obligated to the backwaters for successful completion of reproductive efforts.

Although the backwaters can serve as important physical habitat, indirect benefits should also be considered. The Missouri River, given its turbid water conditions, has limited photosynthetic activity and the biotic community likely relies on allocthonous energy resources produced in the floodplain. Backwater habitats, having an inherent ability to filter sediments and CPOM, tend to maintain a much higher degree of primary productivity and also increase the amount of land-water interchange area. Therefore, the backwaters are an active energy producing supplier of organic resources. In response to phytoplankton production and CPOM filtration, zooplankton and macroinvertebrates, particularly the Chironomidae and Corixidae, thrive and serve as critical links between upper and lowed trophic levels in the backwaters and facilitate considerable transport of energy resources to the main channel during periods of connection. I believe that my data support previous contentions that backwater habitats are ecologically important; however, it is difficult to draw species-specific conclusions. Therefore, numerous studies approaching species, fish assemblages, and habitat dynamics should be completed to better define the mechanisms that regulate backwater structure and function and correlate with population dynamics.

Conservation recommendation

The historical flood pulse was an important driving force behind the evolutionary process in large-river ecosystems. The simulation of a natural hydrograph, based on my observations, appears to facilitate the life cycles of several native fishes. However, water volume must be adequate to allow access to the floodplain and must endure for sufficient time to allow fish to fulfill their required or minimum needs. Long-lived species may not require an annual strong flood pulse; however, shorted-lived species that use the backwaters directly (e.g., western silvery minnow) and those that inhabit the channel but feed on backwater-produced prey resources (e.g., flathead chub) may require a more consistent flood pulse cycle to ensure population stability. Although it would be nice to suggest specific time periods when floodplain connections would be most beneficial, my data are insufficient to provide a valid set of highly specific recommendations. In 1997 and 1999, I noted relatively similar hydrographs and biotic parameters, while 1998 had a quite different hydrograph. Therefore, the following research suggestions may help address some of these dilemmas.

Research needs

The following list of research suggestions is a partial summary of topics that would clarify the ecological importance of backwater habitats to several native fishes. In addition, such research would provide a sound basis on which to recommend specific flow requirements and patterns that would best benefit the local flora and fauna, while still maintaining some socioeconomic utility of aquatic resource.

1. Although my study assessed seasonal dynamics during four specific hydrograph periods, many subtleties may have been missed. Therefore, it would be beneficial to monitor the fish and invertebrate communities more frequently across temporal periods. This type of research effort would be quite costly, but would also provide some very specific information regarding the fish and invertebrate dynamics in the backwaters and help describe the relationships that different species have with the backwaters in regard to connectivity timing and intensity. In addition, it would be essential to collect long-term data sets when possible.

2. Some studies have assessed the influence of flushing rates on backwater habitat productivity, but little research has been conducted on turbid systems. Although the observations are somewhat incongruent, there appears to be an interesting relationship among flushing rates, turbidity levels, primary production, and primary consumer dynamics. Food webs in large river systems have historically been assumed to be detrital driven; however, my observations suggest more photosynthetic productivity than previously suspected. Therefore, research on primary production and organic-source utilization by primary consumers may provide important data concerning the foundation of food webs and energy contributions to the river channel.

3. Floodplain connectivity duration may be a critical factor. Research assessing connection and disconnection intervals may help assess the dynamics of biotic communities in the backwaters and the channel. Connectivity period research may help

provide the needed data to determine the necessary length of a simulated flood pulse. Flows that inundate the floodplain, but last for a short time, will be insufficient for the completion of fish life stages that are linked to off-channel habitats.

4. The most beneficial research suggestion that I can provide is to increase the number of backwaters in any associated study to allow the identification of gradients that make some backwater habitats more suitable than others. The two backwaters and the perched wetland used in this study differed substantially and each supported a different biotic assemblage with highly varied abiotic parameters. Correlating abiotic and biotic parameters across a wide range of floodplain wetlands and backwaters would probably prove very important when determining how to approach backwater restorations in regulated lotic systems.

5. The flathead chub population in the upper Missouri River and Yellowstone River appears to be stable and abundant. Continued monitoring of this species, including an assessment of habitat-specific preferences and early life history documentation in the channel would provide valuable information for research assessing declining flathead chubs populations elsewhere. Also, annual monitoring of the species should be completed so agencies can be prepared in the event that populations decline. Autumn appears to be the best time to sample this species on sandbar habitats, as the greatest length range, including age-0 juveniles can be sampled at that time.

6. Several species-specific assessments may prove to be useful. For example, western silvery minnow is a species with questionable population status throughout its range. This species appeared to be a relatively consistent member of the backwater community; therefore, its relationship to backwaters may be worthy of future study. Other species of greater interest to managing agencies, such as sauger and walleye, also utilize the backwater habitats, but the importance of off-channel habitats to the overall sauger and walleye community needs to be assessed by comparing the abundance, condition, and food habits of those utilizing backwaters with those remaining in channel habitats.

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Appendix 1. Summary of fish abbreviations, including definitions and length designations used to separate adults from juveniles. Individuals were classified as juveniles if they were less than the cm length listed. Some species were not seperated and classified as no designation (ND) or only combined for use in food habits analyses.

Abbreviation	Fish common name/group defintion	Adult-juvenile length split (cm TL)
ACB	Age-0 common carp and *Ictiobus* spp.	ND-food habits only
BIB	Bigmouth buffalo	25
BLB	Black bullhead	15
BRS	Brook stickleback	ND
BSR	Blue sucker	ND
BUF	*Ictiobus* spp.	Included juveniles <6
BUR	Burbot	20
CAT	*Catostomus* spp.	ND-food habits only
CCF	Channel catfish	28
COC	Common carp	28
CRC	Creek chub	ND
CYP	Cyprinidae	NA
EMS	Emerald shiner	ND
FEL	Fish eggs and larvae	NA
FHM	Fathead minow	ND
FLC	Flathead chub	ND
FRD	Freshwater drum	20
GOE	Goldeye	10
GOS	Golden shiner	ND
HYB	*Hybognathus* spp.	ND
LAH	Lake herring	13
LAW	Lake whitefish	ND
LEP	*Lepomis* spp.	ND
LOD	Longnose dace	ND
LOS	Longnose sucker	13
NOP	Northern pike	35
NRD	Northern redbelly dace	ND
POM	*Pomoxis* spp.	13
RBS	Rainbow smelt	ND
RIC	River carpsucker	13
SAB	Smallmouth buffalo	23
SAR	Sauger	17
SHG	Shortnose gar	18
SHR	Shorthead redhorse	10
SHS	Shovelnose sturgeon	25

Appendix 1. Continued.

Abbreviation	Fish common name/group defintion	Adult-juvenile length split (cm TL)
SIC	Sicklefin chub	ND
SNC	Sturgeon chub	ND
SPS	Spottail shiner	ND
STC	Stonecat	ND
STZ	*Stizostedion* spp.	Included juveniles <17
TAM	Tadpole madtom	ND
UFI	Unidentified fishes	ND-food habits only
WAE	Walleye	17
WHB	White bass	ND
WHS	White sucker	13
YEB	Yellow bullhead	15
YEP	Yellow perch	13

Appendix 2. Summary of presence-absence fish data for all species captured in Erickson Island Slough (EIS), the confluence backwater (CB), and sandbar habitats in the main channel (MC) of the Missouri River in northwestern North Dakota from 1997 to 1999. Sample periods include late April (1), mid- to late May (2), late June and early July (3), and early September (4). The fish species abbreviations are listed in Appendix 1. An 'X' designation means that the species, or genus in some cases, was sampled during that sample period and site during the study.

	EIS				CB				MC			
Taxon	1	2	3	4	1	2	3	4	1	2	3	4
BIB	X	X	X	X		X	X	X				
BLB	X	X	X	X	X	X	X	X				
BRS					X	X						
BSR												
BUF		X	X	X			X	X				
BUR	X	X	X	X	X		X				X	
CCF	X	X	X	X		X	X	X	X		X	X
COC	X	X	X	X	X	X	X	X			X	X
CRC	X				X	X		X				
EMS	X	X	X	X	X	X	X	X	X		X	X
FHM	X	X		X	X	X		X	X		X	
FLC	X	X	X	X	X	X	X		X	X	X	X
FRD		X	X	X	X	X	X	X				
GOE	X	X	X	X	X	X	X	X	X	X	X	X
GOS	X	X	X	X	X		X	X				
HYB	X	X	X	X	X	X	X	X	X	X	X	X
LAH		X				X						X
LAW	X											
LEP	X	X	X	X	X	X	X	X				
LOD			X									
LOS	X		X				X	X	X			
NOP	X	X	X	X	X	X	X	X	X	X	X	

Appendix 2. Continued.

	EIS				CB				MC			
Taxon	1	2	3	4	1	2	3	4	1	2	3	4
NRD							X					
POM	X	X	X	X	X	X	X	X	X	X	X	
RBS		X		X					X			
RIC	X	X	X	X	X	X	X	X	X		X	X
SAB	X	X	X	X		X	X	X				
SAR		X	X	X		X	X		X	X		X
SHG		X	X	X		X	X	X				
SHR	X	X	X	X	X	X	X	X	X		X	X
SHS									X	X	X	X
SIC												X
SNC										X	X	X
SPS	X	X	X	X	X	X	X	X			X	
STC	X	X	X	X	X	X						
STZ	X	X	X	X	X	X	X	X	X		X	X
TAM	X	X	X	X								
WAE	X	X	X	X	X	X	X	X		X		X
WHB	X		X	X								
WHS	X	X	X	X	X	X	X	X	X			
YEB	X	X		X								
YEP	X	X	X	X	X	X	X	X				

Appendix 3. Definitions of abbreviations used to denote food items and invertebrates.

AMPH	Amphipoda
CHIR	Chironomidae
COLE	Coleoptera
CORX	Corixidae
DECA	Decapoda
DETR	Detritus
DIPT	Diptera
EPHE	Ephemeroptera
HIRU	Hirudineae (leeches)
HYDR	Hydracarina
HYME	Hymenoptera
LZOO	Large zooplankton (primarily Cladocera)
MACR	Macrophytes
MZOO	Medium zooplankton (mostly Copepoda)
ODON	Odonata
ORTH	Orthoptera
OSTR	Ostrcoda
PERI	Periphyton
PLEC	Plecoptera
SEDI	Sediments
SZOO	Small zooplankton (mostly nauplii)
TRIC	Trichoptera

Appendix 4. Total biomass and proportions of food items found in the stomachs of fishes collected in Erickson Island Slough, ND during May, July and September (Sept) of 1998. Total length (TL) groups and sample size (N) are noted. Fish species abbreviations are defined in Appendix 1 and other abbreviations are in Appendix 3.

Month		May	May	May	July	July	Sept	Sept	May
Species		BIB	BIB	BIB	BIB	BIB	BIB	BIB	BLB
TL group (mm)		100-249	250-599	>599	250-599	>599	<100	100-249	<100
N		1	3	5	2	4	4	6	4
Mean TL (mm)		122.0	334.7	708.8	341.5	705.5	92.0	112.7	76.3
TL SE		NA	2.9	43.0	16.5	41.4	1.4	4.9	7.3
Diet category									
SEDI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DETR	(mg)	--	--	--	--	15000.0	--	--	--
	%	--	--	--	--	45.4	--	--	--
PERI	(mg)	--	--	--	500.0	7175.0	--	--	20.0
	%	--	--	--	54.0	21.7	--	--	2.8
MACR	(mg)	--	--	--	--	10000.0	--	--	--
	%	--	--	--	--	30.3	--	--	--
LZOO	(mg)	0.1	4.2	0.2	--	512.8	111.9	77.2	--
	%	99.9	1.6	<0.1	--	1.6	91.4	42.2	--
MZOO	(mg)	<0.1	192.9	1333.7	1.9	330.3	10.5	29.2	1.3
	%	<0.1	74.8	4.1	0.2	1.0	8.6	16.0	0.2
SZOO	(mg)	<0.1	9.6	453.3	--	33.6	--	52.5	<0.1
	%	<0.1	3.7	1.4	--	0.1	--	28.7	<0.1
OSTR	(mg)	--	1.7	--	--	5.4	--	24.1	0.1
	%	--	0.7	--	--	<0.1	--	13.2	<0.1
CHIR	(mg)	--	--	30488.4	291.6	--	--	--	129.6
	%	--	--	93.9	31.5	--	--	--	18.0
DIPT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
TRIC	(mg)	--	--	--	--	--	--	--	242.2
	%	--	--	--	--	--	--	--	33.6
PLEC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	--	49.4	189.5	131.8	--	--	--	74.2
	%	--	19.2	0.6	14.2	--	--	--	10.3
AMPH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYDR	(mg)	--	--	20.4	--	--	--	--	--
	%	--	--	0.1	--	--	--	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	--	--	--	--	--	253.4
	%	--	--	--	--	--	--	--	35.2
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--

Appendix 4. Continued.

Month		May	May	May	July	July	July	July	Sept
Species		BLB	BLB	BLB	BLB	BLB	BLB	BLB	BLB
TL group (mm)		100-159	160-199	>199	<100	100-159	160-199	>199	<100
N		7	9	10	9	5	4	1	10
Mean TL (mm)		133.4	176.2	249.1	83.8	134.6	172.0	235.0	58.9
TL SE		3.7	3.0	8.7	3.4	11.9	4.3	NA	2.5
Diet category									
SEDI	(mg)	--	--	--	600.0	3600.0	--	2000.0	--
	%	--	--	--	22.8	43.4	--	26.4	--
DETR	(mg)	--	3000.0	--	200.0	400.0	850.0	--	--
	%	--	10.7	--	7.6	4.8	15.9	--	--
PERI	(mg)	--	--	400.0	--	--	--	--	--
	%	--	--	0.8	--	--	--	--	--
MACR	(mg)	--	--	1400.0	800.0	3000.0	1329.0	1500.0	74.0
	%	--	--	2.7	30.4	36.2	24.9	19.8	13.5
LZOO	(mg)	0.5	--	--	2.3	--	12.3	--	7.5
	%	--	--	--	0.1	--	0.2	--	1.4
MZOO	(mg)	<0.1	0.3	--	20.2	0.4	--	--	29.3
	%	<0.1	--	--	0.8	<0.1	--	--	5.3
SZOO	(mg)	0.1	<0.1	--	--	--	2.5	--	2.6
	%	<0.1	<0.1	--	--	--	<0.1	--	0.5
OSTR	(mg)	--	<0.1	--	--	1.3	--	--	--
	%	--	<0.1	--	--	<0.1	--	--	--
CHIR	(mg)	988.2	8407.8	1263.6	712.8	712.8	567.0	745.2	307.8
	%	23.1	29.9	2.4	27.1	8.6	10.6	9.8	56.0
DIPT	(mg)	307.8	--	16.2	97.2	32.4	97.2	162.0	97.2
	%	7.2	--	<0.1	3.7	0.4	1.8	2.1	17.7
TRIC	(mg)	778.5	2179.8	484.4	--	34.6	1159.1	--	--
	%	18.2	7.8	0.9	--	0.4	21.7	--	--
PLEC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	1095.9	3600.9	1919.9	8.2	379.0	24.7	131.8	--
	%	25.6	12.8	3.6	0.3	4.6	0.5	1.7	--
AMPH	(mg)	--	--	--	--	--	--	--	30.8
	%	--	--	--	--	--	--	--	5.6
HYDR	(mg)	4.8	89.4	30.0	--	2.4	--	--	--
	%	0.1	0.3	0.1	--	<0.1	--	--	--
ODON	(mg)	--	--	--	--	--	102.6	205.2	--
	%	--	--	--	--	--	1.9	2.7	--
COLE	(mg)	--	1140.3	380.1	--	126.7	--	126.7	--
	%	--	4.1	0.7	--	1.5	--	1.7	--
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	387.4	193.7	--	--	--	--
	%	--	--	0.7	7.4	--	--	--	--
HIRU	(mg)	--	156.0	--	--	--	--	--	--
	%	--	0.6	--	--	--	--	--	--
DECA	(mg)	--	--	1300.0	--	--	--	--	--
	%	--	--	2.5	--	--	--	--	--
FEL	(mg)	8.6	4.3	8.6	--	5.4	--	--	--
	%	0.2	<0.1	--	--	0.1	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	5600.0	--	--	--	--	--
	%	--	--	10.6	--	--	--	--	--
BLB	(mg)	--	--	5450.0	--	--	1189.0	--	--
	%	--	--	10.3	--	--	22.3	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	9520.0	34150.0	--	--	--	--	--
	%	--	33.9	64.7	--	--	--	--	--
UFI	(mg)	1090.0	--	--	--	--	--	2700.0	--
	%	25.5	--	--	--	--	--	35.7	--

Appendix 4. Continued.

Month		Sept	Sept	Sept	May	May	May	July	July
Species		BLB	BLB	BLB	BUR	CCF	CCF	CCF	CCF
TL group (mm)		100-159	160-199	>199	<200	400-549	>549	400-549	>549
N		9	13	4	2	1	1	6	2
Mean TL (mm)		133.8	185.5	210.8	162.5	528.0	673.0	470.3	614.0
TL SE		7.3	3.6	3.9	4.5	NA	NA	20.2	14.0
Diet category									
SEDI	(mg)	--	2000.0	--	--	--	--	--	--
	%	--	2.3	--	--	--	--	--	--
DETR	(mg)	--	--	--	--	--	--	10300.0	3983.0
	%	--	--	--	--	--	--	7.3	9.7
PERI	(mg)	--	--	--	--	--	--	400.0	90.0
	%	--	--	--	--	--	--	0.3	0.2
MACR	(mg)	212.0	5500.0	--	--	--	--	4328.0	110.0
	%	2.4	6.3	--	--	--	--	3.1	0.3
LZOO	(mg)	15.4	5.0	--	--	--	--	--	--
	%	0.2	<0.1	--	--	--	--	--	--
MZOO	(mg)	15.4	3.3	0.4	--	--	--	--	--
	%	0.2	<0.1	<0.1	--	--	--	--	--
SZOO	(mg)	2.5	--	--	--	--	--	13.2	--
	%	<0.1	--	--	--	--	--	<0.1	--
OSTR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CHIR	(mg)	567.0	1328.4	1377.0	--	259.2	--	39463.2	65.8
	%	6.5	1.5	4.4	--	10.8	--	28.0	0.2
DIPT	(mg)	64.8	81.0	--	16.2	--	--	2154.6	--
	%	0.7	0.1	--	2.0	--	--	1.5	--
TRIC	(mg)	51.9	--	--	51.9	--	--	--	--
	%	0.6	--	--	6.3	--	--	--	--
PLEC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
EPHE	(mg)	--	--	--	103.1	--	--	--	--
	%	--	--	--	12.6	--	--	--	--
CORX	(mg)	49.4	33.0	--	33.0	--	--	11651.4	16.5
	%	0.6	<0.1	--	4.0	--	--	8.3	<0.1
AMPH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYDR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ODON	(mg)	102.6	--	--	615.6	--	--	102.6	--
	%	1.2	--	--	75.1	--	--	0.1	--
COLE	(mg)	--	253.4	--	--	--	--	61956.3	633.5
	%	--	0.3	--	--	--	--	44.0	1.5
ORTH	(mg)	--	--	--	--	--	--	2231.1	--
	%	--	--	--	--	--	--	1.6	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	400.0	--	247.0	--	289.0	222.0
	%	--	--	1.3	--	10.3	--	0.2	0.5
DECA	(mg)	--	--	--	--	1000.0	500.0	--	560.0
	%	--	--	--	--	41.6	0.9	--	1.4
FEL	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ACB	(mg)	400.0	60100.0	15000.0	--	--	--	3080.0	--
	%	4.6	68.4	48.3	--	--	--	2.2	--
CAT	(mg)	--	4000.0	3000.0	--	--	54300.0	--	19300.0
	%	--	4.6	9.7	--	--	97.0	--	47.1
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	900.0	1200.0	--	--
	%	--	--	--	--	37.4	2.1	--	--
GOE	(mg)	--	2000.0	2300.0	--	--	--	--	--
	%	--	2.3	7.4	--	--	--	--	--
POM	(mg)	--	7700.0	9000.0	--	--	--	--	--
	%	--	8.8	29.0	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	7300.0	4800.0	--	--	--	--	4800.0	16000.0
	%	83.1	5.5	--	--	--	--	3.4	39.0

Appendix 4. Continued.

Month		Sept	May	May	May	July	July	July	Sept
Species		CCF	COC	COC	COC	COC	COC	COC	COC
TL group (mm)		<100	<100	300-599	>599	<100	300-599	>599	<100
N		20	1	10	3	4	16	2	5
Mean TL (mm)		68.1	97.0	465.6	633.0	33.0	454.7	687.0	76.4
TL SE		1.1	NA	28.8	9.2	1.2	24.3	20.0	4.9
Diet category									
SEDI	(mg)	--	--	16000.0	21300.0	--	21700.0	12000.0	--
	%	--	--	18.2	41.8	--	7.6	60.0	--
DETR	(mg)	--	--	49700.0	12200.0	--	73890.0	8000.0	--
	%	--	--	56.5	23.9	--	25.8	40.0	--
PERI	(mg)	--	--	10220.0	90.0	--	--	--	--
	%	--	--	11.6	0.2	--	--	--	--
MACR	(mg)	822.0	--	1300.0	7200.0	100.0	119862.0	--	--
	%	37.6	--	1.5	14.1	81.4	41.9	--	--
LZOO	(mg)	4.5	--	--	--	0.8	0.8	--	--
	%	0.2	--	--	--	0.7	<0.1	--	--
MZOO	(mg)	5.6	0.1	0.1	--	5.6	0.8	--	<0.1
	%	0.3	1.2	<0.1	--	4.6	<0.1	--	<0.1
SZOO	(mg)	0.1	--	--	--	0.3	--	--	<0.1
	%	<0.1	--	--	--	0.2	--	--	<0.1
OSTR	(mg)	--	--	--	--	<0.1	0.9	--	--
	%	--	--	--	--	<0.1	<0.1	--	--
CHIR	(mg)	1215.0	--	7727.4	5977.8	16.2	54756.0	--	48.6
	%	55.6	--	8.8	11.7	13.2	19.1	--	100.0
DIPT	(mg)	81.0	--	--	--	--	--	--	--
	%	3.7	--	--	--	--	--	--	--
TRIC	(mg)	--	--	2612.3	3823.3	--	865.0	--	--
	%	--	--	3.0	7.5	--	0.3	--	--
PLEC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	57.7	8.2	329.6	379.1	--	420.2	--	--
	%	2.6	98.8	0.4	0.7	--	0.1	--	--
AMPH	(mg)	--	--	7.7	30.8	--	--	--	--
	%	--	--	<0.1	0.1	--	--	--	--
HYDR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	--	--	--	14697.2	--	--
	%	--	--	--	--	--	5.1	--	--
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--

Appendix 4. Continued.

Month		Sept	Sept	Sept	May	May	July	Sept	Sept
Species		COC	COC	COC	EMS	EMS	EMS	EMS	EMS
TL group (mm)		100-299	300-599	>599	<70	>69	>69	<70	>69
N		7	4	8	3	5	2	5	2
Mean TL (mm)		158.4	509.5	644.1	62.7	82.4	100.0	45.0	73.0
TL SE		29.7	65.7	14.8	2.6	2.3	4.0	6.2	0.0
Diet category									
SEDI	(mg)	5500.0	12000.0	20900.0	--	--	--	--	--
	%	32.3	19.1	7.2	--	--	--	--	--
DETR	(mg)	9500.0	37000.0	62000.0	--	--	--	--	--
	%	55.8	58.9	21.5	--	--	--	--	--
PERI	(mg)	--	--	5000.0	--	--	--	--	--
	%	--	--	1.7	--	--	--	--	--
MACR	(mg)	1300.0	--	31000.0	--	--	100.0	--	--
	%	7.6	--	10.7	--	--	31.9	--	--
LZOO	(mg)	0.5	1.3	--	--	--	32.4	--	--
	%	<0.1	<0.1	--	--	--	10.3	--	--
MZOO	(mg)	2.9	8.2	26.3	0.5	0.8	--	0.1	2.7
	%	<0.1	<0.1	<0.1	5.7	0.5	--	0.3	5.3
SZOO	(mg)	4.2	--	--	0.1	0.2	--	0.3	--
	%	<0.1	--	--	1.1	0.1	--	0.9	--
OSTR	(mg)	26.7	--	89.5	--	--	--	--	--
	%	0.2	--	<0.1	--	--	--	--	--
CHIR	(mg)	696.6	12020.4	157204.8	--	32.4	--	32.4	48.6
	%	4.1	19.1	54.4	--	19.5	--	98.8	94.7
DIPT	(mg)	--	356.4	--	--	--	32.4	--	--
	%	--	0.6	--	--	--	10.3	--	--
TRIC	(mg)	--	--	2439.3	--	34.6	--	--	--
	%	--	--	0.8	--	20.8	--	--	--
PLEC	(mg)	--	103.1	--	--	--	--	--	--
	%	--	0.2	--	--	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	--	206.0	7498.4	8.2	82.4	148.3	--	--
	%	--	0.3	2.6	93.2	49.5	47.4	--	--
AMPH	(mg)	--	--	608.3	--	15.4	--	--	--
	%	--	--	0.2	--	9.3	--	--	--
HYDR	(mg)	--	--	--	--	0.6	--	--	--
	%	--	--	--	--	0.4	--	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	2153.9	--	--	--	--	--
	%	--	--	0.7	--	--	--	--	--
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	1162.2	--	--	--	--	--	--
	%	--	1.8	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--

Appendix 4. Continued.

Month		May	May	July	July	Sept	Sept	May	May
Species		FLC	FLC	FLC	FLC	FLC	FLC	FRD	FRD
TL group (mm)		<70	>69	<70	>69	<70	>69	125-299	>299
N		4	4	1	1	2	1	4	2
Mean TL (mm)		60.0	106.8	62.0	100.0	49.0	85.0	257.0	376.6
TL SE		1.9	6.2	NA	NA	3.0	NA	14.1	8.0
Diet category									
SEDI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DETR	(mg)	--	--	--	--	--	--	2500.0	--
	%	--	--	--	--	--	--	52.3	--
PERI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
MACR	(mg)	--	--	--	--	--	--	--	2000.0
	%	--	--	--	--	--	--	--	46.8
LZOO	(mg)	--	--	--	--	<0.1	--	--	--
	%	--	--	--	--	<0.1	--	--	--
MZOO	(mg)	0.4	<0.1	0.1	0.1	--	0.1	--	--
	%	0.7	<0.1	100.0	100.0	--	0.6	--	--
SZOO	(mg)	--	<0.1	--	--	--	--	--	--
	%	--	<0.1	--	--	--	--	--	--
OSTR	(mg)	--	--	<0.1	--	--	--	--	--
	%	--	--	<0.1	--	--	--	--	--
CHIR	(mg)	32.4	--	--	--	16.2	--	1377.0	2041.2
	%	55.7	--	--	--	100.0	--	28.8	47.8
DIPT	(mg)	--	--	--	--	--	16.2	--	--
	%	--	--	--	--	--	99.4	--	--
TRIC	(mg)	--	--	--	--	--	--	121.1	207.6
	%	--	--	--	--	--	--	2.5	4.9
PLEC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	8.2	477.9	--	--	--	--	782.8	24.7
	%	14.1	94.2	--	--	--	--	16.4	0.6
AMPH	(mg)	--	7.7	--	--	--	--	--	--
	%	--	1.5	--	--	--	--	--	--
HYDR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	17.2	21.5	--	--	--	--	--	--
	%	29.6	4.2	--	--	--	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--

Appendix 4. Continued.

Month		July	July	Sept	Sept	May	May	May	May
Species		FRD	FRD	FRD	FRD	GOE	GOE	GOE	GOE
TL group (mm)		125-299	>299	<125	>299	<100	100-174	175-274	>274
N		2	3	12	3	1	7	7	6
Mean TL (mm)		241.5	346.3	81.1	339.7	72.0	125.7	252.0	329.2
TL SE		1.5	13.7	2.3	26.3	NA	4.5	5.8	7.6
Diet category									
SEDI	(mg)	--	1000.0	--	--	--	--	--	--
	%	--	7.4	--	--	--	--	--	--
DETR	(mg)	--	--	270.0	--	--	400.0	--	--
	%	--	--	12.1	--	--	4.4	--	--
PERI	(mg)	--	--	1130.0	--	--	--	150.0	--
	%	--	--	50.7	--	--	--	1.9	--
MACR	(mg)	--	--	12.0	--	--	--	--	300.0
	%	--	--	0.5	--	--	--	--	0.6
LZOO	(mg)	1.5	--	--	--	--	0.3	0.1	--
	%	0.1	--	--	--	--	<0.1	<0.1	--
MZOO	(mg)	--	--	<0.1	--	0.2	0.5	0.1	--
	%	--	--	<0.1	--	0.1	<0.1	<0.1	--
SZOO	(mg)	--	--	--	--	<0.1	<0.1	--	--
	%	--	--	--	--	<0.1	<0.1	--	--
OSTR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CHIR	(mg)	842.4	7857.0	648.0	16.2	81.0	3774.6	259.2	437.4
	%	36.1	58.0	29.1	0.2	51.3	41.4	3.4	0.9
DIPT	(mg)	226.8	3126.6	16.2	--	--	16.2	--	388.8
	%	9.7	23.1	0.7	--	--	0.2	--	0.8
TRIC	(mg)	449.8	1435.9	--	--	51.9	2750.7	726.6	34.6
	%	19.3	10.6	--	--	32.9	30.2	9.4	0.1
PLEC	(mg)	--	--	103.1	--	--	--	206.2	1443.4
	%	--	--	4.6	--	--	--	2.7	3.0
EPHE	(mg)	--	--	--	--	--	103.1	--	618.6
	%	--	--	--	--	--	1.1	--	1.3
CORX	(mg)	65.9	24.7	49.4	--	24.7	1161.8	5199.4	13521.8
	%	2.8	0.2	2.2	--	15.7	12.8	67.5	28.1
AMPH	(mg)	--	--	--	--	--	--	--	15.4
	%	--	--	--	--	--	--	--	<0.1
HYDR	(mg)	--	0.6	--	--	--	--	0.6	3.6
	%	--	<0.1	--	--	--	--	<0.1	<0.1
ODON	(mg)	--	102.6	--	--	--	--	--	102.6
	%	--	0.8	--	--	--	--	--	0.2
COLE	(mg)	--	--	--	--	--	1267.0	760.2	31168.2
	%	--	--	--	--	--	13.9	9.9	64.9
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	393.0	--
	%	--	--	--	--	--	--	5.1	--
DECA	(mg)	750.0	--	--	--	--	--	--	--
	%	32.1	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	--	34.4	8.6	8.6
	%	--	--	--	--	--	0.4	0.1	<0.1
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	3600.0	--	--	--	--
	%	--	--	--	54.7	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	--	--	--	2970.0	--	--	--	--
	%	--	--	--	45.1	--	--	--	--

Appendix 4. Continued.

Month		July	July	July	July	Sept	Sept	May	May
Species		GOE	GOE	GOE	GOE	GOE	GOE	GOS	HYB
TL group (mm)		<100	100-174	175-274	>274	<100	100-174	<125	<60
N		1	4	10	6	10	9	1	3
Mean TL (mm)		32.0	144.0	241.1	332.7	92.3	103.8	118.0	46.7
TL SE		NA	3.3	5.8	12.0	1.9	0.6	NA	1.7
Diet category									
SEDI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DETR	(mg)	--	--	560.0	--	--	--	40.0	100.0
	%	--	--	2.8	--	--	--	22.9	32.7
PERI	(mg)	--	--	20.0	460.0	--	--	--	100.0
	%	--	--	0.1	7.2	--	--	--	32.7
MACR	(mg)	--	71.0	3295.0	210.0	--	--	--	--
	%	--	1.4	16.4	3.3	--	--	--	--
LZOO	(mg)	0.8	104.9	28.5	0.8	--	--	--	--
	%	88.9	2.1	0.1	<0.1	--	--	--	--
MZOO	(mg)	0.1	3.1	0.9	0.1	62.3	--	--	0.2
	%	11.1	0.1	<0.1	<0.1	3.2	--	--	0.1
SZOO	(mg)	--	0.1	4.1	0.2	<0.1	--	--	<0.1
	%	--	<0.1	<0.1	<0.1	<0.1	--	--	<0.1
OSTR	(mg)	--	--	<0.1	--	2.3	0.3	--	<0.1
	%	--	--	<0.1	--	0.1	0.1	--	<0.1
CHIR	(mg)	--	210.6	243.0	243.0	64.8	64.8	--	81.0
	%	--	4.3	1.2	3.8	3.4	16.7	--	26.5
DIPT	(mg)	--	129.6	194.4	145.8	--	--	--	--
	%	--	2.6	1.0	2.3	--	--	--	--
TRIC	(mg)	--	--	86.5	259.5	--	17.3	--	--
	%	--	--	0.4	4.1	--	4.5	--	--
PLEC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	--	2645.0	5397.2	2142.4	49.4	57.7	8.2	24.7
	%	--	54.0	26.9	33.7	2.6	14.9	4.7	8.1
AMPH	(mg)	--	--	7.7	--	--	--	--	--
	%	--	--	<0.1	--	--	--	--	--
HYDR	(mg)	--	--	--	1.8	--	--	--	--
	%	--	--	--	<0.1	--	--	--	--
ODON	(mg)	--	307.8	--	102.6	--	--	--	--
	%	--	6.3	--	1.6	--	--	--	--
COLE	(mg)	--	633.5	7475.3	2407.3	--	--	126.7	--
	%	--	12.9	37.3	37.8	--	--	72.4	--
ORTH	(mg)	--	--	--	--	--	247.9	--	--
	%	--	--	--	--	--	63.9	--	--
HYME	(mg)	--	193.7	193.7	--	1743.3	--	--	--
	%	--	4.0	1.0	--	90.7	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	597.7	2551.0	391.3	--	--	--	--
	%	--	12.2	12.8	6.1	--	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--

Appendix 4. Continued.

Month		May	July	July	Sept	Sept	May	Sept	May
Species		HYB	HYB	HYB	HYB	HYB	LEP	LEP	NOP
TL group (mm)		>59	<60	>59	<60	>59	<125	<125	200-399
N		3	4	6	28	10	2	2	11
Mean TL (mm)		74.3	54.0	70.2	50.6	62.0	58.5	79.0	274.5
TL SE		1.3	0.9	4.3	0.9	0.8	6.5	4.0	13.6
Diet category									
SEDI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DETR	(mg)	--	--	--	200.0	--	--	--	--
	%	--	--	--	7.6	--	--	--	--
PERI	(mg)	300.0	67.0	476.0	2406.0	372.0	--	--	--
	%	98.2	99.0	94.5	91.1	95.8	--	--	--
MACR	(mg)	--	--	26.0	--	--	--	--	--
	%	--	--	5.2	--	--	--	--	--
LZOO	(mg)	--	--	0.8	--	--	--	10.1	--
	%	--	--	0.2	--	--	--	17.2	--
MZOO	(mg)	0.1	0.7	0.9	0.4	0.1	2.5	--	--
	%	<0.1	1.0	0.2	<0.1	<0.1	0.5	--	--
SZOO	(mg)	--	--	--	1.0	--	0.1	--	--
	%	--	--	--	<0.1	--	<0.1	--	--
OSTR	(mg)	--	--	--	0.1	0.1	0.1	--	--
	%	--	--	--	<0.1	<0.1	<0.1	--	--
CHIR	(mg)	--	--	--	32.4	16.2	194.4	48.6	--
	%	--	--	--	1.2	4.2	38.4	82.8	--
DIPT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
TRIC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
PLEC	(mg)	--	--	--	--	--	309.3	--	--
	%	--	--	--	--	--	61.1	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	--	--	--	--	--	--	--	8.2
	%	--	--	--	--	--	--	--	<0.1
AMPH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYDR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	5.4	--	--	--	--	--	--	--
	%	1.8	--	--	--	--	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	12240.0
	%	--	--	--	--	--	--	--	22.4
CYP	(mg)	--	--	--	--	--	--	--	4600.0
	%	--	--	--	--	--	--	--	8.4
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	31280.0
	%	--	--	--	--	--	--	--	57.2
POM	(mg)	--	--	--	--	--	--	--	5850.0
	%	--	--	--	--	--	--	--	10.7
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	--	--	--	--	--	--	--	720.0
	%	--	--	--	--	--	--	--	1.3

Appendix 4. Continued.

Month		May	July	July	Sept	Sept	Sept	May	May
Species		NOP	NOP	NOP	NOP	NOP	NOP	POM	POM
TL group (mm)		400-599	400-599	>599	200-399	400-599	>599	<100	150-199
N		9	1	5	13	7	1	3	3
Mean TL (mm)		496.6	494.0	754.0	307.5	472.6	691.0	88.0	158.0
TL SE		24.4	NA	42.4	11.4	16.8	NA	2.5	2.3
Diet category									
SEDI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DETR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
PERI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
MACR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
LZOO	(mg)	--	--	--	--	--	--	--	0.4
	%	--	--	--	--	--	--	--	<0.1
MZOO	(mg)	--	--	--	--	--	--	31.4	10.0
	%	--	--	--	--	--	--	18.3	0.4
SZOO	(mg)	--	--	--	--	--	--	1.3	--
	%	--	--	--	--	--	--	0.8	--
OSTR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CHIR	(mg)	--	--	--	--	--	--	64.8	745.2
	%	--	--	--	--	--	--	37.8	28.2
DIPT	(mg)	--	--	--	--	--	--	--	16.2
	%	--	--	--	--	--	--	--	0.6
TRIC	(mg)	--	--	--	--	--	--	17.3	--
	%	--	--	--	--	--	--	10.1	--
PLEC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	--	--	--	--	--	--	41.2	173.0
	%	--	--	--	--	--	--	24.0	6.5
AMPH	(mg)	--	--	--	--	--	--	15.4	708.4
	%	--	--	--	--	--	--	9.0	26.8
HYDR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	--	--	--	--	--	633.5
	%	--	--	--	--	--	--	--	23.9
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ACB	(mg)	--	--	--	11200.0	24600.0	--	--	--
	%	--	--	--	27.1	48.0	--	--	--
CAT	(mg)	--	18900.0	--	--	--	--	--	--
	%	--	62.8	--	--	--	--	--	--
CYP	(mg)	9280.0	6300.0	8700.0	3400.0	--	--	--	--
	%	11.3	20.9	2.4	8.2	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	66400.0	--	352600.0	--	--	--	--	--
	%	80.9	--	97.6	--	--	--	--	--
POM	(mg)	--	--	--	--	3600.0	8700.0	--	--
	%	--	--	--	--	7.0	87.9	--	--
YEP	(mg)	6400.0	4900.0	--	7000.0	--	--	--	--
	%	7.8	16.3	--	16.9	--	--	--	--
UFI	(mg)	--	--	--	19720.0	23000.0	1200.0	--	360.0
	%	--	--	--	47.7	44.9	12.1	--	13.6

Appendix 4. Continued.

Month		May	May	July	July	July	July	Sept	Sept
Species		POM	POM	POM	POM	POM	POM	POM	POM
TL group (mm)		200-249	>249	100-149	150-199	200-249	>249	<100	100-149
N		15	3	2	3	15	1	9	3
Mean TL (mm)		223.3	270.0	113.5	170.0	228.9	281.0	80.7	102.7
TL SE		3.0	7.5	9.5	1.5	3.0	NA	5.8	0.7
Diet category									
SEDI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DETR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
PERI	(mg)	--	100.0	--	--	--	--	--	--
	%	--	1.5	--	--	--	--	--	--
MACR	(mg)	--	--	--	--	500.0	--	--	--
	%	--	--	--	--	3.6	--	--	--
LZOO	(mg)	0.1	--	8.5	6.9	5.4	4.6	12.1	27.9
	%	<0.1	--	8.9	1.1	<0.1	4.1	8.3	23.3
MZOO	(mg)	0.2	0.4	5.1	0.1	2.2	--	79.0	65.5
	%	<0.1	<0.1	5.3	<0.1	<0.1	--	54.5	54.7
SZOO	(mg)	--	--	--	--	0.1	--	0.4	0.9
	%	--	--	--	--	<0.1	--	0.3	0.8
OSTR	(mg)	--	--	--	--	--	--	21.1	--
	%	--	--	--	--	--	--	14.6	--
CHIR	(mg)	11696.4	2689.2	32.4	259.2	178.2	16.2	16.2	--
	%	38.9	40.9	34.0	42.4	1.3	14.6	11.2	--
DIPT	(mg)	64.8	1587.6	--	64.8	486.0	16.2	16.2	--
	%	0.2	24.1	--	10.6	3.5	14.6	11.2	--
TRIC	(mg)	5587.9	190.3	--	--	155.7	--	--	17.3
	%	18.6	2.9	--	--	1.1	--	--	14.4
PLEC	(mg)	103.1	--	--	--	--	--	--	--
	%	0.3	--	--	--	--	--	--	--
EPHE	(mg)	2474.2	309.3	--	--	103.1	--	--	--
	%	8.2	4.7	--	--	0.7	--	--	--
CORX	(mg)	6493.1	939.4	49.4	280.2	2612.1	74.2	--	8.2
	%	21.6	14.3	51.8	45.8	19.0	66.7	--	6.8
AMPH	(mg)	23.1	--	--	--	--	--	--	--
	%	0.1	--	--	--	--	--	--	--
HYDR	(mg)	1.2	--	--	--	--	--	--	--
	%	<0.1	--	--	--	--	--	--	--
ODON	(mg)	--	--	--	--	102.6	--	--	--
	%	--	--	--	--	0.7	--	--	--
COLE	(mg)	1647.1	760.2	--	--	--	--	--	--
	%	5.5	11.6	--	--	--	--	--	--
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	387.4	--	--	--	--	--	--	--
	%	1.3	--	--	--	--	--	--	--
HIRU	(mg)	198.0	--	--	--	--	--	--	--
	%	0.7	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	68.8	--	--	--
	%	--	--	--	--	0.5	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	1380.0	--	--	--	--	--	--	--
	%	4.6	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	4900.0	--	--	--
	%	--	--	--	--	35.6	--	--	--
UFI	(mg)	--	--	--	--	4650.0	--	--	--
	%	--	--	--	--	33.8	--	--	--

Appendix 4. Continued.

Month		Sept	Sept	Sept	May	May	May	July	July
Species		POM	POM	POM	RIC	RIC	RIC	RIC	RIC
TL group (mm)		150-199	200-249	>249	<100	225-374	>374	<100	225-375
N		9	4	7	1	2	5	2	10
Mean TL (mm)		178.9	235.3	266.7	68.0	274.5	413.2	62.5	300.1
TL SE		3.2	0.5	3.1	NA	5.5	10.8	10.5	6.4
Diet category									
SEDI	(mg)	--	--	--	400.0	2490.0	30900.0	100.0	3000.0
	%	--	--	--	91.9	43.9	9.1	8.1	6.0
DETR	(mg)	--	--	--	--	3000.0	26900.0	1000.0	5800.0
	%	--	--	--	--	52.9	7.9	80.6	11.7
PERI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
MACR	(mg)	--	15.0	--	--	--	--	--	1000.0
	%	--	0.3	--	--	--	--	--	2.0
LZOO	(mg)	0.1	--	--	--	--	--	--	--
	%	<0.1	--	--	--	--	--	--	--
MZOO	(mg)	0.1	--	--	2.9	--	0.3	0.1	1888.9
	%	<0.1	--	--	0.7	--	<0.1	<0.1	3.8
SZOO	(mg)	--	--	--	--	--	--	--	575.5
	%	--	--	--	--	--	--	--	1.2
OSTR	(mg)	--	--	--	0.1	0.3	270.0	--	15.3
	%	--	--	--	<0.1	<0.1	0.1	--	<0.1
CHIR	(mg)	64.8	243.0	32.4	32.4	178.2	273213.0	81.0	37470.0
	%	0.4	4.3	0.2	7.4	3.1	80.5	6.5	75.3
DIPT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
TRIC	(mg)	--	--	--	--	--	8217.5	51.9	--
	%	--	--	--	--	--	2.4	4.2	--
PLEC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	--	8.2	49.4	--	--	--	--	16.5
	%	--	0.1	0.3	--	--	--	--	<0.1
AMPH	(mg)	33.0	--	--	--	--	--	7.7	--
	%	0.2	--	--	--	--	--	0.6	--
HYDR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ORTH	(mg)	--	247.9	--	--	--	--	--	--
	%	--	4.4	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	--	12.9	--	--
	%	--	--	--	--	--	<0.1	--	--
ACB	(mg)	10850.0	3400.0	--	--	--	--	--	--
	%	58.8	60.2	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	7490.0	1730.0	15050.0	--	--	--	--	--
	%	40.6	30.7	99.5	--	--	--	--	--

Appendix 4. Continued.

Month		July	Sept	Sept	May	May	July	July	July
Species		RIC	RIC	RIC	SAB	SAB	SAB	SAB	SAB
TL group (mm)		>374	<100	100-224	400-599	>599	200-399	400-599	>599
N		9	22	2	3	2	1	6	7
Mean TL (mm)		440.3	51.4	171.5	500.7	637.0	305.0	525.0	654.4
TL SE		10.9	2.4	22.5	51.0	17.0	NA	14.6	6.9
Diet category									
SEDI	(mg)	10050.0	100.0	500.0	16200.0	6700.0	--	21200.0	45072.0
	%	29.4	0.1	14.6	64.5	92.4	--	23.6	37.6
DETR	(mg)	14000.0	1150.0	1300.0	2700.0	280.0	3700.0	12950.0	42800.0
	%	41.0	1.7	37.8	10.7	3.9	75.2	14.4	35.7
PERI	(mg)	--	66300.0	--	--	--	--	--	--
	%	--	97.4	--	--	--	--	--	--
MACR	(mg)	800.0	--	--	--	40.0	--	23999.0	11036.0
	%	2.3	--	--	--	0.6	--	26.7	9.2
LZOO	(mg)	--	--	--	--	--	--	--	0.8
	%	--	--	--	--	--	--	--	<0.1
MZOO	(mg)	2105.6	346.1	32.2	0.5	--	9.1	374.7	49.2
	%	6.2	0.5	0.9	<0.1	--	0.2	0.4	<0.1
SZOO	(mg)	5.7	79.7	--	--	--	--	--	--
	%	<0.1	0.1	--	--	--	--	--	--
OSTR	(mg)	0.2	61.2	0.1	0.3	--	11.1	588.3	23.8
	%	<0.1	0.1	<0.1	<0.1	--	0.2	0.7	<0.1
CHIR	(mg)	3758.4	--	1603.8	6204.6	226.8	1198.8	27702.0	17074.8
	%	11.0	--	46.7	24.7	3.1	24.4	30.8	14.3
DIPT	(mg)	--	--	--	--	--	--	243.0	--
	%	--	--	--	--	--	--	0.3	--
TRIC	(mg)	3390.8	--	--	--	--	--	--	17.3
	%	9.9	--	--	--	--	--	--	<0.1
PLEC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	57.7	--	--	16.5	8.2	--	659.2	115.4
	%	0.2	--	--	0.1	0.1	--	0.7	0.1
AMPH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYDR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	--	--	--	--	2153.9	3547.6
	%	--	--	--	--	--	--	2.4	3.0
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--

Appendix 4. Continued.

Month		Sept	May	July	July	July	July	Sept	Sept
Species		SAB	SAR	SAR	SAR	SHG	SHG	SHG	SHG
TL group (mm)		<100	250-399	250-399	>399	500-624	>624	<300	300-499
N		19	1	13	3	8	2	5	5
Mean TL (mm)		69.4	376.0	341.7	468.7	601.5	697.0	289.8	311.0
TL SE		1.4	NA	NA	5.9	6.8	52.0	4.9	4.5
Diet category									
SEDI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DETR	(mg)	--	--	950.0	--	500.0	--	--	--
	%	--	--	10.2	--	10.1	--	--	--
PERI	(mg)	--	--	--	--	500.0	--	--	--
	%	--	--	--	--	10.1	--	--	--
MACR	(mg)	--	--	--	--	--	350.0	--	--
	%	--	--	--	--	--	100.0	--	--
LZOO	(mg)	218.6	--	--	--	--	--	--	--
	%	31.6	--	--	--	--	--	--	--
MZOO	(mg)	391.1	--	0.4	--	--	--	--	--
	%	56.5	--	<0.1	--	--	--	--	--
SZOO	(mg)	1.6	--	--	--	--	--	--	--
	%	0.2	--	--	--	--	--	--	--
OSTR	(mg)	0.1	--	--	--	--	--	--	--
	%	<0.1	--	--	--	--	--	--	--
CHIR	(mg)	81.0	--	243.0	--	16.2	--	--	--
	%	11.7	--	2.6	--	0.3	--	--	--
DIPT	(mg)	--	--	162.0	--	--	--	--	--
	%	--	--	1.7	--	--	--	--	--
TRIC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
PLEC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
EPHE	(mg)	--	--	206.2	--	--	--	--	--
	%	--	--	2.2	--	--	--	--	--
CORX	(mg)	--	16.5	16.5	--	--	--	--	--
	%	--	100.0	0.2	--	--	--	--	--
AMPH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYDR	(mg)	--	--	0.6	--	--	--	--	--
	%	--	--	<0.1	--	--	--	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	--	--	506.8	--	--	--
	%	--	--	--	--	10.2	--	--	--
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	193.7	--	--	--
	%	--	--	--	--	3.9	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ACB	(mg)	--	--	1350.0	--	--	--	--	--
	%	--	--	14.5	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	1400.0	--	--	--	--	--
	%	--	--	15.1	--	--	--	--	--
BLB	(mg)	--	--	4570.0	--	--	--	--	--
	%	--	--	49.1	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	520.0	--	--	--
	%	--	--	--	--	10.5	--	--	--
UFI	(mg)	--	--	400.0	4900.0	2710.0	--	10190.0	5900.0
	%	--	--	4.3	100.0	54.8	--	100.0	100.0

Appendix 4. Continued.

Month		May	May	July	Sept	May	May	July	Sept
Species		SHR	SHR	SHR	SHR	SPS	SPS	SPS	SPS
TL group (mm)		150-199	>199	150-199	<150	<80	>79	<80	<80
N		3	2	2	1	4	8	4	1
Mean TL (mm)		170.7	232.5	324.0	115.0	60.3	94.9	75.5	58.0
TL SE		11.0	32.5	2.0	NA	9.5	3.2	0.5	NA
Diet category									
SEDI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DETR	(mg)	--	300.0	50.0	--	--	--	--	--
	%	--	39.9	4.0	--	--	--	--	--
PERI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
MACR	(mg)	--	--	390.0	--	--	--	--	--
	%	--	--	31.2	--	--	--	--	--
LZOO	(mg)	--	--	--	--	--	0.1	15.4	--
	%	--	--	--	--	--	<0.1	21.3	--
MZOO	(mg)	--	0.5	1.1	--	0.2	0.6	0.2	--
	%	--	0.1	0.1	--	0.4	<0.1	0.3	--
SZOO	(mg)	<0.1	0.1	--	--	0.2	--	<0.1	--
	%	<0.1	<0.1	--	--	0.4	--	<0.1	--
OSTR	(mg)	--	<0.1	--	0.6	<0.1	<0.1	<0.1	--
	%	--	<0.1	--	100.0	<0.1	<0.1	<0.1	--
CHIR	(mg)	842.4	145.8	777.6	--	48.6	1782.0	16.2	16.2
	%	79.0	19.4	62.2	--	98.0	89.3	22.4	100.0
DIPT	(mg)	--	16.2	32.4	--	--	--	32.4	--
	%	--	2.2	2.6	--	--	--	44.8	--
TRIC	(mg)	190.3	51.9	--	--	--	155.7	--	--
	%	17.9	6.9	--	--	--	7.8	--	--
PLEC	(mg)	--	103.1	--	--	--	--	--	--
	%	--	13.7	--	--	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	33.0	8.2	--	--	--	49.4	8.2	--
	%	3.1	1.1	--	--	--	2.5	11.3	--
AMPH	(mg)	--	--	--	--	--	7.7	--	--
	%	--	--	--	--	--	0.4	--	--
HYDR	(mg)	--	--	--	--	0.6	0.6	--	--
	%	--	--	--	--	1.2	<0.1	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	126.7	--	--	--	--	--	--
	%	--	16.8	--	--	--	--	--	--
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--

Appendix 4. Continued.

Month		May	May	July	July	Sept	Sept	Sept	May
Species		STC	STC	STC	STC	STC	STC	STC	STZ
TL group (mm)		100-199	>199	<100	100-199	<100	100-199	>199	<170
N		3	2	1	3	1	1	1	6
Mean TL (mm)		190.3	218.0	48.0	169.0	98.0	198.0	209.0	155.2
TL SE		3.3	8.0	NA	8.9	NA	NA	NA	4.9
Diet category									
SEDI	(mg)	--	500.0	--	--	--	--	--	--
	%	--	6.6	--	--	--	--	--	--
DETR	(mg)	--	500.0	300.0	--	--	--	50.0	--
	%	--	6.6	94.8	--	--	--	3.3	--
PERI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
MACR	(mg)	--	--	--	--	117.0	--	--	--
	%	--	--	--	--	93.5	--	--	--
LZOO	(mg)	0.1	--	--	20.1	--	--	--	--
	%	<0.1	--	--	0.2	--	--	--	--
MZOO	(mg)	--	--	0.3	0.9	--	--	--	0.1
	%	--	--	0.1	<0.1	--	--	--	<0.1
SZOO	(mg)	--	--	--	--	--	--	--	0.1
	%	--	--	--	--	--	--	--	<0.1
OSTR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CHIR	(mg)	48.6	--	16.2	2268.0	--	--	--	486.0
	%	1.0	--	5.1	27.1	--	--	--	15.7
DIPT	(mg)	--	--	--	955.8	--	--	--	--
	%	--	--	--	11.4	--	--	--	--
TRIC	(mg)	--	--	--	380.6	--	--	--	--
	%	--	--	--	4.6	--	--	--	--
PLEC	(mg)	--	--	--	103.1	--	--	--	--
	%	--	--	--	1.2	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	16.5	--	--	--	8.2	--	--	57.7
	%	0.3	--	--	--	6.5	--	--	1.9
AMPH	(mg)	7.7	--	--	--	--	--	--	--
	%	0.2	--	--	--	--	--	--	--
HYDR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	--	126.7	--	--	--	--
	%	--	--	--	1.5	--	--	--	--
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	1600.0	--	3600.0	--	--
	%	--	--	--	19.1	--	72.0	--	--
CYP	(mg)	--	4860.0	--	--	--	--	--	2150.0
	%	--	64.3	--	--	--	--	--	69.3
BLB	(mg)	4100.0	--	--	1000.0	--	--	--	--
	%	85.5	--	--	12.0	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	620.0	1700.0	--	1900.0	--	1400.0	1470.0	410.0
	%	12.9	22.5	--	22.7	--	28.0	96.7	13.2

Appendix 4. Continued.

Month		July	Sept	May	May	July	Sept	Sept	May
Species		STZ	STZ	TAM	TAM	TAM	TAM	TAM	WAE
TL group (mm)		<170	<170	<60	60-99	60-99	<60	>99	170-249
N		27	10	8	2	15	3	2	3
Mean TL (mm)		41.8	138.9	48.6	73.0	85.1	51.7	101.5	192.3
TL SE		1.6	6.5	2.0	12.0	2.0	0.9	0.5	6.1
Diet category									
SEDI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DETR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
PERI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
MACR	(mg)	--	--	--	--	3110.0	69.0	--	--
	%	--	--	--	--	32.4	24.0	--	--
LZOO	(mg)	9.3	--	--	--	1.7	<0.1	--	--
	%	3.5	--	--	--	<0.1	<0.1	--	--
MZOO	(mg)	4.9	--	2.8	0.9	1.6	0.7	--	0.4
	%	1.8	--	<0.1	<0.1	<0.1	0.2	--	<0.1
SZOO	(mg)	0.1	--	--	--	--	--	--	--
	%	<0.1	--	--	--	--	--	--	--
OSTR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CHIR	(mg)	162.0	48.6	858.6	405.0	3628.8	178.2	664.2	97.2
	%	61.0	1.1	14.4	15.4	37.8	61.9	86.6	8.5
DIPT	(mg)	64.8	--	--	--	113.4	32.4	--	--
	%	24.4	--	--	--	1.2	11.3	--	--
TRIC	(mg)	--	--	570.9	1903.0	138.4	--	--	--
	%	--	--	9.6	72.5	1.4	--	--	--
PLEC	(mg)	--	--	4124.0	206.2	1237.2	--	--	--
	%	--	--	69.3	7.9	12.9	--	--	--
EPHE	(mg)	--	--	206.2	--	--	--	--	--
	%	--	--	3.5	--	--	--	--	--
CORX	(mg)	8.2	--	82.4	--	107.1	--	--	--
	%	3.1	--	1.4	--	1.1	--	--	--
AMPH	(mg)	--	--	--	15.4	53.9	7.7	--	--
	%	--	--	--	0.6	0.6	2.7	--	--
HYDR	(mg)	--	--	--	0.6	1.2	--	--	--
	%	--	--	--	<0.1	<0.1	--	--	--
ODON	(mg)	--	--	102.6	--	102.6	--	102.6	--
	%	--	--	1.7	--	1.1	--	13.4	--
COLE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	16.2	16.2	--	94.6	--	--	--	--
	%	6.1	0.4	--	3.6	--	--	--	--
ACB	(mg)	--	1140.0	--	--	1100.0	--	--	--
	%	--	25.6	--	--	11.5	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	--	3250.0	--	--	--	--	--	1050.0
	%	--	73.0	--	--	--	--	--	91.5

Appendix 4. Continued.

Month		May	July	July	July	May	May	May	July
Species		WAE	WAE	WAE	WAE	WHS	WHS	WHS	WHS
TL group (mm)		250-399	170-249	250-399	>399	<150	150-374	>374	<150
N		2	2	1	6	2	7	3	3
Mean TL (mm)		314.5	207.5	371.0	444.7	95.0	351.4	394.3	92.3
TL SE		40.5	26.5	NA	9.3	6.0	13.0	6.7	8.4
Diet category									
SEDI	(mg)	--	--	--	--	300.0	15500.0	5500.0	300.0
	%	--	--	--	--	14.4	4.0	53.2	16.3
DETR	(mg)	--	--	--	250.0	500.0	45400.0	3800.0	--
	%	--	--	--	2.2	24.0	11.8	36.8	--
PERI	(mg)	--	--	--	--	--	--	800.0	--
	%	--	--	--	--	--	--	7.7	--
MACR	(mg)	--	--	--	--	--	10.0	--	--
	%	--	--	--	--	--	<0.1	--	--
LZOO	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
MZOO	(mg)	--	--	--	--	2.2	0.5	--	0.4
	%	--	--	--	--	0.1	<0.1	--	<0.1
SZOO	(mg)	--	--	--	--	0.1	<0.1	--	--
	%	--	--	--	--	<0.1	<0.1	--	--
OSTR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CHIR	(mg)	--	210.6	16.2	--	1279.8	238690.8	64.8	1101.6
	%	--	16.5	100.0	--	61.5	61.8	0.6	60.0
DIPT	(mg)	--	--	--	--	--	145.8	--	--
	%	--	--	--	--	--	<0.1	--	--
TRIC	(mg)	34.6	--	--	--	--	84960.3	173.0	69.2
	%	25.1	--	--	--	--	22.0	1.7	3.8
PLEC	(mg)	103.1	--	--	--	--	412.4	--	--
	%	74.9	--	--	--	--	0.1	--	--
EPHE	(mg)	--	--	--	--	--	--	--	103.1
	%	--	--	--	--	--	--	--	5.6
CORX	(mg)	--	16.5	--	8.2	--	57.7	--	8.2
	%	--	1.3	--	0.1	--	<0.1	--	0.4
AMPH	(mg)	--	--	--	--	--	100.1	--	--
	%	--	--	--	--	--	<0.1	--	--
HYDR	(mg)	--	--	--	--	--	4.8	--	0.6
	%	--	--	--	--	--	<0.1	--	<0.1
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	--	--	--	506.8	--	253.4
	%	--	--	--	--	--	0.1	--	13.8
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	193.7	--	--
	%	--	--	--	--	--	0.1	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	1050.0	--	--	--	--	--	--
	%	--	82.2	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	11312.0	--	--	--	--
	%	--	--	--	97.8	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--

Appendix 4. Continued.

Month		July	Sept	Sept	Sept	May	May	Sept	Sept
Species		WHS	WHS	WHS	WHS	YEB	YEB	YEB	YEB
TL group (mm)		150-374	<150	150-374	>374	<100	>199	<100	100-199
N		1	1	5	3	2	2	2	4
Mean TL (mm)		345.0	69.0	268.6	407.7	68.0	215.0	64.0	137.5
TL SE		NA	NA	43.9	7.7	5.0	15.0	7.0	2.1
Diet category									
SEDI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DETR	(mg)	--	--	800.0	250.0	--	--	--	--
	%	--	--	49.6	4.7	--	--	--	--
PERI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
MACR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
LZOO	(mg)	--	--	97.9	81.7	0.4	--	1.7	--
	%	--	--	6.1	1.5	<0.1	--	0.4	--
MZOO	(mg)	273.7	--	86.0	392.6	2.0	--	3.4	--
	%	1.3	--	5.3	7.4	0.1	--	0.7	--
SZOO	(mg)	--	--	3.5	--	--	--	--	--
	%	--	--	0.2	--	--	--	--	--
OSTR	(mg)	--	0.1	8.0	11.8	--	--	--	--
	%	--	100.0	0.5	0.2	--	--	--	--
CHIR	(mg)	19440.0	--	599.4	4552.2	1393.2	--	97.2	16.2
	%	93.4	--	37.2	86.1	69.6	--	20.9	0.1
DIPT	(mg)	--	--	--	--	--	--	48.6	16.2
	%	--	--	--	--	--	--	10.4	0.1
TRIC	(mg)	--	--	--	--	121.1	--	51.9	--
	%	--	--	--	--	6.1	--	11.1	--
PLEC	(mg)	824.8	--	--	--	103.1	--	--	--
	%	4.0	--	--	--	5.2	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	271.9	--	16.5	--	41.2	65.9	57.7	148.3
	%	1.3	--	1.0	--	2.1	0.5	12.4	1.3
AMPH	(mg)	--	--	--	--	7.7	--	--	--
	%	--	--	--	--	0.4	--	--	--
HYDR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ODON	(mg)	--	--	--	--	205.2	--	205.2	--
	%	--	--	--	--	10.3	--	44.1	--
COLE	(mg)	--	--	--	--	126.7	--	--	760.2
	%	--	--	--	--	6.3	--	--	6.4
ORTH	(mg)	--	--	--	--	--	--	--	495.8
	%	--	--	--	--	--	--	--	4.2
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	280.0	--	--
	%	--	--	--	--	--	2.2	--	--
FEL	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
ACB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	2000.0
	%	--	--	--	--	--	--	--	16.9
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	12130.0	--	--
	%	--	--	--	--	--	93.8	--	--
UFI	(mg)	--	--	--	--	--	450.0	--	8400.0
	%	--	--	--	--	--	3.5	--	71.0

Appendix 4. Continued.

Month		Sept	May	May	July	July	Sept	Sept	Sept
Species		YEB	YEP	YEP	YEP	YEP	YEP	YEP	YEP
TL group (mm)		>199	<100	100-199	<100	100-199	<100	100-199	>199
N		1	10	2	5	1	9	13	2
Mean TL (mm)		271.0	90.9	139.5	38.8	100.0	78.0	158.5	213.5
TL SE		NA	1.2	1.5	1.3	NA	1.6	6.3	4.5
Diet category									
SEDI	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DETR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
PERI	(mg)	70.0	--	--	--	--	--	--	--
	%	0.7	--	--	--	--	--	--	--
MACR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
LZOO	(mg)	--	0.2	--	--	1.5	0.3	0.1	--
	%	--	<0.1	--	--	8.3	<0.1	<0.1	--
MZOO	(mg)	--	2.4	--	3.0	0.3	0.3	0.3	--
	%	--	<0.1	--	9.4	1.7	<0.1	<0.1	--
SZOO	(mg)	--	0.1	--	0.1	--	--	--	--
	%	--	<0.1	--	0.3	--	--	--	--
OSTR	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CHIR	(mg)	--	2786.4	210.6	16.2	16.2	194.4	--	--
	%	--	30.8	25.8	50.9	90.0	10.4	--	--
DIPT	(mg)	--	5686.2	48.6	--	--	--	--	--
	%	--	62.9	5.9	--	--	--	--	--
TRIC	(mg)	--	17.3	242.2	--	--	--	--	--
	%	--	0.2	29.6	--	--	--	--	--
PLEC	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
EPHE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CORX	(mg)	--	321.4	189.5	8.2	--	49.4	8.2	--
	%	--	3.6	23.2	25.8	--	2.6	0.1	--
AMPH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYDR	(mg)	--	6.0	--	--	--	--	--	--
	%	--	0.1	--	--	--	--	--	--
ODON	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
COLE	(mg)	--	--	126.7	--	--	--	--	--
	%	--	--	15.5	--	--	--	--	--
ORTH	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HYME	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
HIRU	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
DECA	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
FEL	(mg)	--	219.3	--	4.3	--	5.4	--	--
	%	--	2.4	--	13.5	--	0.3	--	--
ACB	(mg)	4100.0	--	--	--	--	--	10190.0	--
	%	42.8	--	--	--	--	--	66.0	--
CAT	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
CYP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
BLB	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
GOE	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
POM	(mg)	3400.0	--	--	--	--	--	--	--
	%	35.5	--	--	--	--	--	--	--
YEP	(mg)	--	--	--	--	--	--	--	--
	%	--	--	--	--	--	--	--	--
UFI	(mg)	2000.0	--	--	--	--	1620.0	5250.0	4200.0
	%	20.9	--	--	--	--	86.6	34.0	100.0

Appendix 5. Summary of mean isotopic signatures (δN^{15}‰ and δC^{13}‰) and standard errors (in parentheses) for fishes collected in Erickson Island Slough, North Dakota during May, July and September (Sept) of 1998. Refer to the abbreviations and acronyms list for definitions.

			δN^{15}‰			δC^{13}‰	
Taxon	TL (mm)	May	July	Sept	May	July	Sept
BIB	<100	--	--	7.07 (0.05)	--	--	-29.34 (0.01)
	100-249	7.58 (0.13)	--	7.53 (0.06)	-31.60 (0.13)	--	-29.58 (0.05)
	250-599	8.85 (0.04)	9.44 (0.07)	--	-29.72 (0.01)	-27.80 (0.15)	--
	>599	12.20 (0.01)	12.38 (0.26)	--	-30.48 (0.20)	-30.83 (0.08)	--
BLB	<100	8.95 (0.05)	9.51 (0.36)	6.77 (0.22)	-29.77 (0.04)	-28.44 (0.17)	-30.23 (0.06)
	100-159	8.98 (0.17)	9.45 (0.21)	6.95 (0.01)	-27.70 (0.10)	-28.04 (0 08)	-30.09 (0.02)
	160-199	8.41 (0.22)	9.53 (0.01)	8.69 (0.12)	-27.93 (0.61)	-28.17 (0.08)	-28.66 (0.24)
	>199	8.88 (0.02)	--	10.00 (0.04)	-27.25 (0.01)	--	-29.03 (0.03)
BUR	<200	9.93 (0.24)	--	--	-27.81 (0.13)	--	--
CCF	<100	--	--	6.01 (0.07)	--	--	-30.04 (0.04)
	400-549	12.26 (0.21)	11.91 (0.05)	10.92 (0.04)	-26.71 (0.21)	-27.47 (0.02)	-26.55 (0.02)
	>549	14.52 (0.07)	13.01 (0.03)	--	-30.88 (0.03)	-28.50 (0.12)	--
COC	<100	7.52 (0.22)	8.49 (0.19)	5.86 (0.09)	-28.72 (0.59)	-27.56 (0.10)	-29.27 (0.12)
	100-299	--	--	6.61 (0.04)	--	--	-29.42 (0.09)
	300-599	10.68 (0.25)	8.50 (0.28)	--	-27.83 (0.06)	-27.35 (0.28)	--
	>599	9.27 (0.09)	9.66 (0.09)	9.28 (0.15)	-27.05 (0.11)	-27.07 (0.28)	-27.26 (0.14)
EMS	<70	8.87 (0.34)	--	6.18 (0.06)	-30.46 (0.39)	--	-29.02 (0.11)
	>69	10.10 (0.26)	10.41 (0.13)	10.06 (0.19)	-26.53 (1.09)	-27.06 (0.07)	-27.52 (0.24)
FLC	<70	9.79 (0.08)	8.64 (0.18)	6.25 (0.06)	-26.75 (0.74)	-26.10 (0.02)	-27.68 (0.11)
	>69	9.26 (0.12)	8.12 (0.03)	8.75 (0.19)	-25.93 (0.05)	-24.41 (0.06)	-23.08 (0.24)
FRD	<125	--	--	5.75 (0.04)	--	--	-28.86 (0.06)
	125-299	11.90 (0.20)	11.36 (0.14)	--	-26.89 (0.30)	-25.61 (0.02)	--
	>299	11.60 (0.14)	12.03 (0.07)	11.65 (0.18)	-28.11 (0.07)	-26.45 (0.14)	-26.70 (0.00)
GOE	<100	10.43 (0.40)	9.77 (0.40)	6.18 (0.01)	-27.95 (0.06)	-27.54 (0.10)	-29.68 (0.05)
	100-174	10.97 (0.28)	10.63 (0.16)	5.94 (0.13)	-28.40 (0.06)	-27.09 (0.12)	-30.21 (0.15)
	175-274	12.08 (0.15)	10.71 (0.08)	--	-27.36 (0.04)	-27.15 (0.11)	--
	>274	11.75 (0.30)	13.62 (0.16)	--	-27.12 (0.18)	-27.70 (0.02)	--
GOS	<125	9.53 (0.13)	--	--	-29.80 (0.09)	--	--
HYB	<60	8.76 (0.36)	8.37 (0.06)	5.43 (0.25)	-25.18 (0.02)	-26.05 (0.07)	-23.35 (0.17)
	>59	7.08 (0.11)	7.86 (0.01)	5.79 (0.02)	-24.97 (0.03)	-24.31 (0.01)	-22.47 (0 34)
LEP	<125	9.21 (0.32)	--	9.10 (0.02)	-28.91 (0.02)	--	-28.01 (0.05)
NOP	200-399	10.67 (0.33)	--	8.60 (0.03)	-28.23 (0.03)	--	-28.69 (0.06)
	400-599	10.21 (0.46)	10.67 (0.28)	10.46 (0.08)	-28.79 (0.15)	-26.92 (0.71)	-27.94 (0.10)
	>599	11.52 (0.10)	13.11 (0.28)	12.18 (0.08)	-27.93 (0.08)	-27.35 (0.04)	-27.14 (0.11)
POM	<100	10.99 (0.08)	--	7.73 (0.17)	-31.54 (0.05)	--	-29.65 (0.06)
	100-149	--	10.57 (0.29)	7.47 (0.06)	--	-28.90 (0.29)	-30.16 (0.05)

Appendix 5. Continued.

		δN^{15}‰			δC^{13}‰		
Taxon	TL (mm)	May	July	Sept	May	July	Sept
POM	150-199	10.04 (0.17)	10.99 (0.10)	10.57 (0.01)	-27.55 (0.13)	-27.67 (0.11)	-29.29 (0.05)
	200-249	10.91 (0.09)	11.10 (0.24)	10.83 (0.05)	-28.06 (0.09)	-27.37 (0.01)	-27.83 (0.03)
POM	>249	11.60 (0.16)	11.81 (0.18)	10.91 (0.09)	-27.86 (0.14)	-28.22 (0.07)	-28.04 (0.06)
RIC	<100	10.18 (0.03)	9.13 (0.08)	5.48 (0.11)	-26.72 (0.17)	-25.79 (0.06)	-26.17 (0.09)
	100-224	--	--	8.89 (0.17)	--	--	-28.49 (0.21)
	225-374	10.85 (0.10)	9.69 (0.11)	--	-25.79 (0.02)	-27.71 (0.15)	--
	>374	10.74 (0.25)	10.72 (0.30)	--	-26.96 (0.07)	-27.29 (0.17)	--
SAB	<100	--	--	6.95 (0.10)	--	--	-28.69 (0.13)
	200-399	9.62 (0.09)	8.33 (0.03)	--	-29.37 (0.14)	-28.18 (0.13)	--
	400-599	9.94 (0.16)	10.20 (0.28)	--	-27.98 (0.14)	-27.17 (0.25)	--
	>599	11.28 (0.06)	10.90 (0.08)	--	-28.94 (0.04)	-27.01 (0.46)	--
SAR	250-399	11.97 (0.15)	14.27 (0.11)	--	-26.82 (0.07)	-26.99 (0.08)	--
	>399	--	15.99 (0.16)	--	--	-27.67 (0.25)	--
SHG	<300	--	--	9.57 (0.36)	--	--	-28.60 (0.10)
	300-499	--	--	9.37 (0.21)	--	--	-28.34 (1.57)
	500-624	--	11.17 (0.04)	--	--	-28.40 (0.03)	--
	>624	--	11.96 (0.12)	--	--	-27.98 (0.12)	--
SHR	<150	9.51 (0.22)	--	6.03 (0.27)	-26.42 (0.05)	--	-30.05 (0.05)
	150-199	8.74 (0.21)	10.09 (0.01)	--	-28.86 (0.24)	-27.29 (0.06)	--
	>199	9.87 (0.09)	--	--	-26.85 (0.06)	--	--
SPS	<80	10.46 (0.06)	10.28 (0.20)	6.71 (0.20)	-28.28 (0.06)	-28.06 (0.22)	-29.82 (0.14)
	>79	11.46 (0.49)	--	--	-28.31 (0.02)	--	--
STC	<100	--	11.79 (0.02)	6.56 (0.10)	--	-25.20 (0.02)	-29.55 (0.04)
	100-199	11.39 (0.21)	11.34 (0.04)	--	-26.55 (0.17)	-26.58 (0.10)	--
	>199	11.50 (0.12)	--	10.77 (0.06)	-26.83 (0.13)	--	-26.40 (0.12)
STZ	<170	12.28 (0.06)	10.06 (0.21)	9.36 (0.24)	-26.28 (0.05)	-27.74 (0.18)	-27.96 (0.19)
TAM	<60	9.38 (0.14)	--	6.21 (0.04)	-29.14 (0.07)	--	-30.44 (0.06)
	60-99	10.00 (0.15)	9.16 (0.47)	7.13 (0.06)	-29.18 (0.06)	-27.09 (0.86)	-30.15 (0.00)
	>99	--	--	7.75 (0.15)	--	--	-29.39 (0.09)
WAE	170-249	13.76 (0.15)	10.97 (0.03)	--	-27.03 (0.03)	-27.08 (0.01)	--
	250-399	10.84 (0.09)	--	--	-28.83 (0.23)	--	--
	>399	--	13.04 (0.16)	--	--	-28.13 (0.06)	--
WHS	<150	7.58 (0.14)	7.64 (0.14)	5.81 (0.04)	-27.52 (0.19)	-27.44 (0.03)	-28.59 (0.06)
	150-374	13.05 (0.13)	10.03 (0.30)	8.48 (0.20)	-26.59 (0.09)	-26.85 (0.16)	-27.15 (0.10)
	>374	13.17 (0.09)	--	9.25 (0.05)	-27.26 (0.09)	--	-27.68 (0.44)

Appendix 5. Continued.

			δN^{15}‰			δC^{13}‰	
Taxon	TL (mm)	May	July	Sept	May	July	Sept
YEB	<100	8.95 (0.03)	--	6.18 (0.19)	-27.92 (0.04)	--	-29.28 (0.09)
	100-199	--	--	8.49 (0.06)	--	--	-28.23 (0.06)
	>199	10.50 (0.35)	--	11.10 (0.15)	-26.24 (0.15)	--	-28.26 (0.03)
YEP	<100	8.75 (0.05)	8.94 (0.06)	8.46 (0.15)	-27.74 (0.04)	-25.70 (0.09)	-28.27 (0.11)
	100-199	8.95 (0.05)	9 68 (0.08)	9.68 (0.02)	-27.40 (0.07)	-27.43 (0.91)	-27.50 (0.10)
	>199	--	--	10.43 (0.39)	--	--	-27.04(0.04)

Appendix 6. Summary of mean isotopic signatures (δN^{15}‰ and δC^{13}‰) and standard errors (in parentheses) for sediments, detritus, plants, invertebrates, and larval fish collected in and adjacent to Erickson Island Slough, North Dakota during May, July and September (Sept) of 1998. Refer to the abbreviations and acronyms list for definitions.

		δN^{15}‰			δC^{13}‰	
Taxon or category	May	July	Sept	May	July	Sept
SEDI	0.78 (0.41)	1.49 (0.24)	0.83 (0.57)	-19.49 (1.48)	-16.83 (0.76)	-18.04 (2.23)
DETR	2.36 (0.31)	1.50 (0.51)	1.24 (0.50)	-21.99 (0.40)	-21.65 (0.48)	-18.98 (0.94)
CPOM	5.95 (1.54)	2.86 (0.28)	1.94 (0.36)	-28.09 (0.60)	-27.74 (0.05)	-27.48 (0.11)
PERI	-5.28 (0.33)	5.46 (0.35)	3.92 (0.80)	-28.82 (0.06)	-26.57 (0.16)	-21.87 (1.08)
PHYT	4.23 (0.78)	-6.41 (1.86)	-1.13 (2.68)	-30.94 (0.58)	-31.01 (0.36)	-30.82 (1.24)
Macrophytes						
SMWD	4.20 (0.46)	2.41 (0.03)	2.19 (1.42)	-27.26 (0.03)	-24.98 (0.00)	-26.75 (0.22)
HRST	3.45 (0.51)	2.86 (0.00)	3.45 (0.97)	-28.82 (0.06)	-25.76 (0.14)	-26.27 (0.24)
BROM	--	2.11 (0.29)	-2.74 (1.88)	--	-26.19 (0.07)	-26.68 (0.03)
REED	--	5.24 (0.16)	1.64 (0.21)	--	-25.70 (0.01)	-26.79 (0.02)
GRAS	5.47 (0.26)	-0.40 (0.32)	0.53 (0.50)	-25.87 (0.05)	-27.53 (0.11)	-20.45 (2.90)
SEDG	4.17 (0.15)	2.19 (0.33)	4.09 (0.41)	-28.36 (0.03)	-27.56 (0.08)	-28.40 (0.01)
FOXT	--	6.73 (0.01)	-0.26 (0.83)	--	-26.27 (0.03)	-25.47 (0.08)
ALFA	--	-1.56 (0.02)	1.94 (0.06)	--	-28.88 (0.08)	-26.60 (0.04)
SBWL	2.43 (0.09)	2.92 (0.11)	2.26 (0.20)	-27.73 (0.08)	-27.99 (0.02)	-27.68 (0.08)
PLWL	1.49 (0.04)	4.43 (0.22)	4.09 (0.27)	-26.99 (0.05)	-26.44 (0.10)	-25.91 (0.05)
ROLV	--	-2.18 (0.43)	-1.76 (0.24)	--	-27.65 (0.09)	-27.25 (0.14)
GASH	--	1.48 (0.08)	0.29 (0.42)	--	-26.19 (0.05)	-25.60 (0.10)
COTW	-0.02 (0.14)	1.12 (0.08)	-0.04 (0.32)	-28.18 (0.02)	-28.72 (0.04)	-28.14 (0.08)
Invertebrates						
SZOO	4.88 (0.44)	5.80 (0.18)	3.28 (0.01)	-32.71 (0.04)	-28.66 (0.28)	-30.03 (0.36)
MZOO	6.28 (0.23)	7.95 (0.44)	2.55 (0.05)	-29.18 (0.12)	-28.67 (0.14)	-30.93 (0.03)
LZOO	5.79 (0.34)	4.79 (0.29)	3.75 (0.25)	-29.32 (0.11)	-29.87 (0.26)	-29.93 (0.04)
OSTR	--	7.65 (0.13)	--	--	-18.63 (0.97)	--
CHIR	4.24 (0.24)	4.04 (0.01)	1.79 (0.04)	-26.47 (0.91)	-29.83 (0.01)	-31.08 (0.07)
COLE	6.00 (0.14)	3.35 (0.29)	7.18 (0.19)	-26.22 (0.04)	-26.25 (0.07)	-26.28 (0.30)
CORX	4.48 (0.11)	5.46 (0.13)	3.99 (0.15)	-27.53 (0.02)	-27.04 (0.04)	-27.77 (0.21)
DIPT	4.62 (0.10)	6.58 (0.02)	6.15 (0.02)	-32.21 (0.08)	-29.80 (0.30)	-26.04 (0.01)
EPPL	4.47 (0.10)	6.58 (0.19)	--	-30.54 (0.13)	-27.55 (0.05)	--
HYME	7.51 (0.20)	3.84 (0.40)	7.94 (0.11)	-26.53 (0.49)	-24.64 (0.17)	-25.43 (0.06)
ODON	6.49 (0.08)	7.17 (0.31)	6.05 (0.02)	-29.20 (0.23)	-28.54 (0.05)	-27.97 (0.10)
ORTH	3.18 (0.12)	1.60 (0.16)	3.71 (0.19)	-26.45 (0.07)	-26.40 (0.10)	-25.38 (0.05)
AMPH	3.93 (NA)	4.81 (0.03)	--	-28.58 (NA)	-26.28 (0.10)	--
DECA	7.09 (0.15)	--	6.73 (0.23)	-27.40 (0.43)	--	-27.39 (0.11)
HIRU	6.66 (0.09)	7.17 (0.18)	5.46 (0.21)	-29.13 (0.07)	-27.74 (0.66)	-28.82 (0.02)
HYDR	7.19 (0.03)	6.43 (NA)	--	-29.46 (0.30)	-28.76 (NA)	--
LVF	--	7.83 (1.92)	--	--	-28.75 (0.36)	--