Relations of Fish Community Composition to Environmental Variables in Streams of Central Nebraska, USA

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ABSTRACT / Nine sites on streams in the Platte River Basin in central Nebraska were sampled as part of the US Geological Survey's National Water-Quality Assessment Program during 1993–1994. A combination of canonical correspondence analysis and an index of biotic integrity determined from fish community data produced complementary evaluations of water-quality conditions. Results of the canonical correspondence analysis were useful in showing which environmental variables were significant in differentiating fish communities at the nine sites. Five environmental variables were statistically significant in the analysis. Median specific conductance of water samples collected at a site accounted for the largest amount of variability in the species data. Although the percentage of the basin as cropland was not the first variable chosen in a forward selection process, it was the most strongly correlated with the first ordination axis. A rangeland-dominated site was distinguished from all others along that axis. Median orthophosphate concentration of samples collected in the year up to the time of fish sampling was most strongly correlated with the second ordination axis. The index of biotic integrity produced results that could be interpreted in terms of the relative water quality between sites. Sites draining nearly 100% cropland had the lowest scores for two individual metrics of the index of biotic integrity that were related to species tolerance. Effective monitoring of water quality could be achieved by coupling methods that address both the ecological components of fish communities and their statistical relationships to environmental factors.

Water quality is an integration of physical, chemical, and biological components. Nationally, various methods have been used in assessing streamwater quality at a large scale ranging from purely chemical approaches such as the National Stream Quality Accounting Network of the US Geological Survey (USGS) to those incorporating various components of the resident biological communities (Karr and others 1986, Plafkin and others 1989, Fausch and others 1990, Karr 1991, Resh and Jackson 1993, Barbour and others 1995). Attempts to integrate chemical and biological assessments of water quality have been recommended (Lenat 1988) but generally have been conducted at spatially small scales. A notable exception is the use of invertebrate communities together with physical and chemical measures to evaluate water quality in Great Britain (Wright and others 1984). An integrated approach to the assessment of water quality in the United States is being conducted by the USGS. This National Water-Quality Assessment (NAWQA) Program uses physical, chemical, and biological data to determine the major factors affecting observed water-quality conditions (Hirsch and others 1988, Leahy and others 1990).

The composition of resident fish communities from stream sites representing selected environmental settings is one component measured as part of each NAWQA study (Meador and others 1993a). Although fish communities may have a high degree of natural variability, they may still be useful monitors of ecosystem health (Moyle 1994). Berkman and others (1986) recommend "Fish should be given greater consideration in biological water quality monitoring of streams because they are generally perceived to be more ecologically significant, and they are more directly related to legislative mandates." This approach of measuring biological integrity has been used by many investigators to relate fish community composition to water-quality conditions (Karr 1981, 1991, Fausch and others 1984, Karr and others 1986). Warm-water species such as are found in central Nebraska likely are affected by stream morphology, environmental setting of the drainage, instream habitat features, riparian habitat features, and water chemistry (Karr and others 1987, Schlosser 1990).

KEY WORDS: Canonical correspondence analysis; Fish communities; Environmental variables; Index of biotic integrity; National Water-Quality Assessment Program; Nebraska

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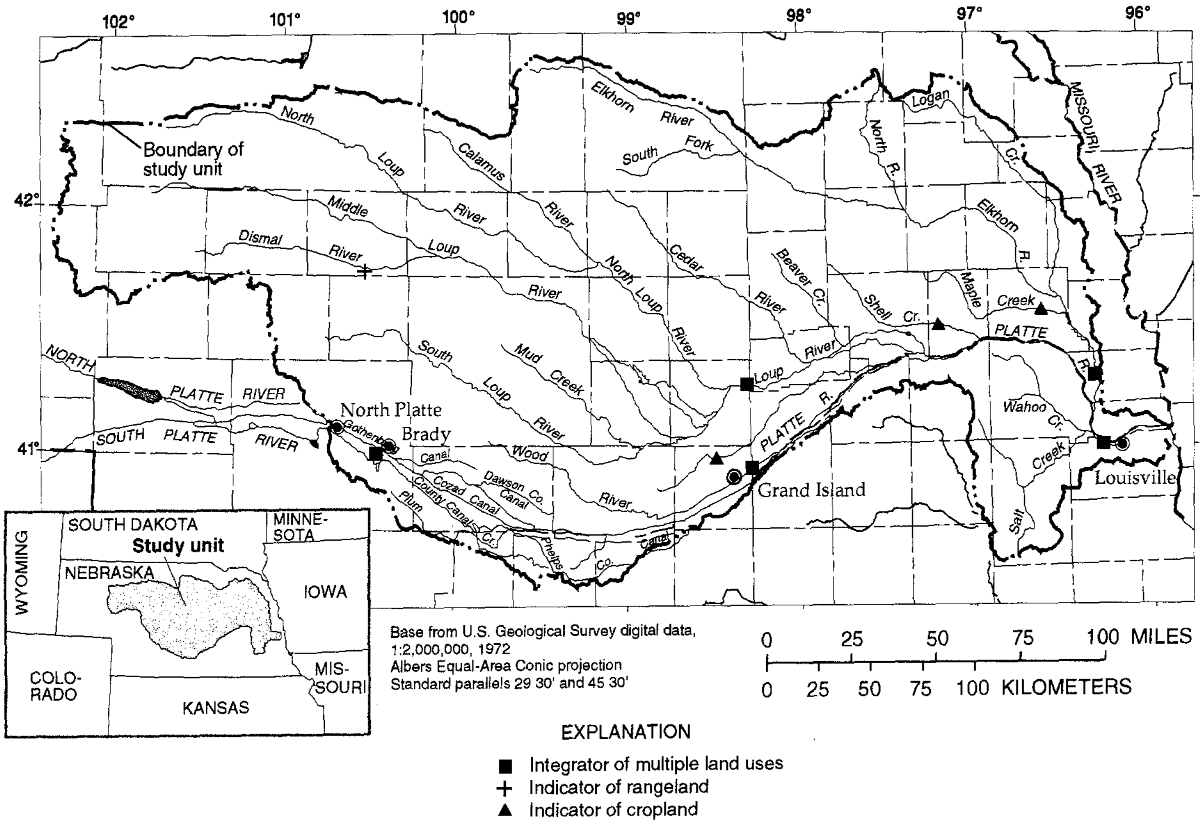

Figure 1. Location of sampling sites in the central Nebraska Basins NAWQA study unit.

In the Platte River drainage, the relative importance of these factors in determining fish community composition has not been documented. Our purpose in writing this paper was to describe the relations of fish community composition to water chemistry, land-use features, and habitat characteristics of central Nebraska streams. The scope of this paper was limited to analysis of data collected at nine stream sites in the Central Nebraska Basins NAWQA study unit during 1993–1994.

Methods

The Platte River drainage from North Platte, Nebraska, to Louisville, Nebraska (Figure 1) is one of 20 NAWQA study units that began collecting data in 1992. Initial data collection was for reconnaissance, and in 1993 intensive water chemistry and ecological data collection began. These intensive data collections were made at nine stream sampling sites that were either indicative of a single land use (environmental setting) or that integrated multiple settings (Figure 1). All of these sites were located where existing streamflow gauging stations provided historical information on streamflow and basic water chemistry. Three sites are on the main stem of the Platte River, which typically is shallow and braided. In addition, two large tributaries to the Platte River were sampled. The Loup River and Elkhorn River sampling sites and the Platte River sites integrate multiple land uses and environmental settings. In particular, the Platte River sites integrate land uses in the North and South Platte River basins that are upstream of the Central Nebraska Basins NAWQA study unit. Four sites on smaller streams were chosen for indicators of particular land uses. The Dismal River drains mostly rangeland, and Prairie, Shell, and Maple creeks drain predominantly cropland. Details of the Central Nebraska Basins NAWQA study unit's environmental settings are described by Huntzinger and Ellis (1993).

Ideally, stream reaches to be sampled as part of the NAWQA Program are selected on the basis of geomorphic features of the channel (Meador and others 1993b). However, sites sampled in the Central Nebraska Basins study unit are not characterized by consistent occurrences of riffles and pools. Woody debris provided the most stable substrates for invertebrate colonization and cover for fish in the unstable sand-channel streams and thus was the primary factor affecting reach selection. The only other habitat characteristics that provided fish cover in those streams were overhanging vegetation and a few undercut banks. Stream reaches, therefore, were selected as near to the streamflow gauge as possible and where instream habitat for invertebrates and fish was maximized.

Fish were collected during September 1993 and September 1994 by electrofishing stream reaches between 150 and 300 m in length. A reach length equivalent to 20 times the channel width was sampled if that value was within the 150- to 300-m criterion. During 1994, three reaches were sampled at the Dismal River, Platte River near Grand Island, and at Maple Creek to verify whether the single reaches sampled in 1993 were representative of local conditions. At Dismal River and Maple Creek, all sampled reaches were separated by a distance approximately equal to the reach length. Because of the extreme width and braided channel of the Platte River near Grand Island, the single reach sampled in 1993 was the left one third of the channel. The multiple reaches sampled in 1994 were the left one third, center one third, and right one third of the channel. These reaches were separated by islands. The fish community at the Platte River near Louisville was sampled only in 1993.

Comparisons of fish community composition at the multiple reaches were made using the Jaccard coefficient [as described by Plafkin and others (1989)]. This coefficient measures the taxonomic similarity of the communities but does not consider the abundance of individuals in the samples. Values for the Jaccard coefficient range from 0, where there are no species in common between two samples, to 1, where all species are present in both samples.

Techniques used for fish collection and processing were those described by Meador and others (1993a). Fish were collected by making two passes through the sampling reach using pulsed direct current electrofishing equipment. Because over 6000 individuals were collected during the first pass at the Platte River near Brady in each year, only one pass was made at that site. Fish were identified to species on site by fisheries biologists from the US Fish and Wildlife Service, and if identification was uncertain, specimens were preserved for later identification. The species abundance data were summarized by site (Appendix 1) for inclusion with environmental data in canonical correspondence analysis.

Environmental variables measured during this study include physical (i.e., water temperature, and habitat features) and chemical characteristics (i.e., nutrient and pesticide concentrations) of the stream that were generally indicative of conditions of that stream reach (Meador and others 1993b). Water-chemistry samples were collected and analyzed according to standard procedures used by the USGS (Edwards and Glysson 1988, Wells and others 1990, Shelton 1994). Minimum frequency for sample collection was at monthly intervals plus at six additional flow regimes during a water year to ensure adequate representation of hydrologic conditions. Habitat measurements were made from August to October of 1993 and of 1994.

Water-sample analysis was done at the USGS National Water-Quality Laboratory in Arvada, Colorado, and the USGS laboratory in Lawrence, Kansas. Water-chemistry variables were expressed as the median value of all samples collected during the 12 months prior to collection of a fish sample. Median values were used to reduce the bias in a sampling design that targets all hydrologic conditions but with emphasis placed on high-flow sampling likely to detect larger concentrations of agricultural chemicals. Streamflow records were obtained at each site using stage-discharge relations applied to continuous water-stage data.

Habitat features of each reach were measured along six equally spaced transects perpendicular to the flow and according to guidelines described by Meador and others (1993b). Measured habitat features included channel width, depth, and bed material; stability and amount of cover on banks; and canopy angle. Canopy angle was determined at each transect by measuring the angles from the center of the stream to the top of the tallest feature on each bank and subtracting those angles from 180°. Some habitat features, such as channel slope and width-to-depth ratio, were determined from topographic surveys made of each reach. Channel slope in the study unit was fairly stable from year to year and was measured only once for the two years of sampling. High streamflows can cause disturbance that alters the fish community composition (Resh and others 1988). To address this concern, the number of days from the peak streamflow for the year until the time of fish sampling was included as one of the environmental variables. A lower number of days since the peak streamflow increases the likelihood that the community compositions is affected by disturbance.

Because land use within the study unit is generally either cropland or rangeland, only one land-use category was considered for this analysis. The percentage of cropland in each basin was determined for the area below the confluence of the North and South Platte Rivers using USGS land-use data from 1979 to 1984 (US Geological Survey 1986).

Fish community composition also was evaluated independently from the environmental data using an index of biotic integrity (IBI) adjusted for fish communities and flow conditions in Nebraska (Karr 1981, modified by Nebraska Department of Environmental Control

1991). Three metrics used by the Nebraska Department of Environmental Control were not used in this analysis; one was the number of individuals per sample, the second was the percentage of individuals as insectivores, and the the third was the presence of anomalies. The total area sampled varied greatly between sampling sites, and therefore, a measure of numbers per sample would not be appropriate. The percent of individuals as insectivores was thought to decrease as water quality and habitat conditions become deteriorated. In contrast, the number of taxa tolerant to physical or chemical perturbation should increase given the same situation. In the Central Nebraska Basins study unit, less than 1% of the individuals collected were both insectivores and considered intolerant, while more than 30% were insectivores and tolerant. Therefore, the metric related to insectivores is not sensitive to poor water quality in the study unit and was not used. The metric regarding the presence of anomalies was not used because these data were not recorded during sampling. Each individual metric is scored as either 5 (when the measure is comparable to a relatively undisturbed reference), 3 (when comparable to a fair community), or 1 (when the measure strongly deviates from the expected range for fair communities) (Nebraska Department of Environmental control 1991). Because six metrics were used, possible scores for the IBI range from 6 (worst score) to 30 (best score).

Composition of the fish community was related to environmental conditions at a site by using canonical correspondence analysis (CCA) (Ter Braak 1986). This analytical technique is a form of direct gradient analysis in that ordination axes are chosen on the basis of both species and environmental data. CCA was applied using the computer program canonical community ordination (CANOCO) (Ter Braak 1988). CCA determines locations for samples (sites) and species in ecological space by assuming that species exhibit a Gaussian-type response to environmental gradients (Ter Braak 1985). In other words, species tolerate a range of values for each environmental variable and exhibit their peak abundance at some optimum value within that range. Species locations in the ordination diagram approximate the optima for that species' response to all measured environmental gradients. Therefore, the likelihood of a species occurrence decreases with increasing distance from its location in the diagram (Ter Braak 1986). Sample locations in the ordination diagrams are based on the species that comprise the sample, and samples with the most similar species composition will be located closest to each other in the ordination diagrams.

A natural log transformation was used to make species-abundance data more normally distributed. Species that occurred in only one sample and with an abundance of less than five were considered rare and deemed passive in the analysis, so they did not influence sample location in the ordination (Ter Braak 1988).

Eleven variables were used with fish-abundance data to determine important environmental gradients. Environmental variables were standardized [as described by Zar (1984)] so that direct comparisons of canonical coefficients could be made. The CANOCO computer program provided several diagnostics during an interactive session. One diagnostic was the variable inflation factor that suggested the degree a variable independently contributed to explaining variance in the species data. Inflation factors greater than 20 suggest that the variable was highly correlated with other variables and that it contributed no unique information in the regression (Ter Braak 1988). Environmental variables remaining after consideration of their inflation factors were subjected to a forward selection process in CANOCO. A Monte Carlo test with 99 random permutations computed the significance of each variable as it was added to the analysis. Variables with $P \leq 0.05$ were retained in the analysis.

Environmental gradients were displayed as vectors in the ordination diagram of sample locations. Vectors show the direction in which a variable is increasing in magnitude. Longer vectors generally relate to greater influence of that environmental variable in structuring the community composition. However, when viewed on a two-dimensional ordination diagram, the relative importance of minor environmental gradients may not be portrayed accurately. Because only relative length is important, vectors are shown at twice their actual length to improve clarity.

Canonical coefficients are analogous to regression coefficients. Greater absolute values of canonical coefficients indicate stronger correlation between a variable and the ordination axis tested. The variable with the greatest canonical coefficient on the first ordination axis has the greatest effect on species composition of the samples. The significance of each canonical coefficient may be examined with a *t* test. Generally, *t*s of absolute value greater than 2 are significant.

Results

Fish communities in central Nebraska streams were dominated by minnows (Cyprinidae, Appendix 1). During the two periods of data collection, 47 fish species and one hybrid were identified from the 23 samples collected at nine sites. Sixteen species were not found in more than one sample, and of those species only the

Table 1. IBI scores for samples from central Nebraska streams

Sampling site (Figure 1)	IBI scores[a]						
	Metric 1	Metric 2	Metric 3	Metric 4	Metric 5	Metric 6	Total score
1993							
Dismal River	3	5	5	3	1	1	18
Platte River near Brady	5	5	3	3	3	3	22
Platte River near Grand Island	5	5	1	5	3	5	24
Prairie Creek	3	3	1	1	1	1	10
Loup River	5	3	1	5	3	3	20
Shell Creek	1	1	1	3	3	1	10
Maple Creek	3	3	1	3	1	1	12
Elkhorn River	5	3	3	3	1	1	16
Platte River near Louisville	5	5	1	5	3	3	22
1994							
Dismal River							
reach 1	5	5	5	5	1	3	24
reach 2	3	5	5	5	1	1	20
reach 3	3	5	5	5	1	3	22
Platte River near Brady	5	5	3	5	3	3	24
Prairie Creek	5	5	1	3	1	1	16
Loup River	5	5	3	3	1	5	22
Platte River near Grand Island							
reach 1	5	5	1	5	3	3	22
reach 2	5	5	1	5	3	5	24
reach 3	5	3	3	5	3	3	22
Shell Creek	1	1	1	1	1	1	6
Maple Creek							
reach 1	5	5	1	3	3	1	18
reach 2	5	5	1	3	5	1	20
reach 3	5	5	1	3	3	3	20
Elkhorn River	3	5	1	3	3	1	16

[a]IBI, index of biotic integrity [modified from Nebraska Department of Environmental Control (1991) and Karr (1981)]. Metric 1, number of native fish species; metric 2, number of native cyprinid species; metric 3, number of intolerant species; metric 4, percentage of tolerant species; metric 5, percentage of individuals as omnivores; metric 6, percentage of individuals as carnivores.

quillback (*Carpiodes cyprinus*) and the central stoneroller (*Campostoma anomalum*) were abundant enough to be included in this analysis. Samples contained as few as two (Shell Creek, 1994) to as many as 21 species (Platte River near Brady in 1994). Total fish abundance in a sample ranged from 41 (Shell Creek, 1993) to 7611 at the Platte River near Brady (1993). The IBI scores [modified from Nebraska Department of Environmental Control (1991) and Karr (1981)], which are used as a comparative water-quality measure rather than an absolute measure, ranged from 6 at Shell Creek in 1994 to 24 at several locations (Table 1). The lowest IBI scores resulted from only a few tolerant species comprising a sample. Higher scores generally came from samples collected at the Dismal River and at main stem Platte River sites, which have a greater degree of habitat complexity than do the smaller streams. IBI scores related to species tolerance suggested that sites with greater percentages of cropland in the basin had fish communities indicative of poor water quality (Figure 2).

Several environmental variables were strongly correlated to other variables and therefore provided redundant information. Measures of individual variables related to bank conditions were dropped from the CCA because of strong correlations with stream width and canopy angle. Median herbicide concentration was eliminated because of strong correlation with the percent of cropland in the basin. All sites had sand as the dominant streambed substrate material, and therefore this variable provided no discriminatory power and was not included in the CCA. Two environmental variables (percentage of cropland in the 4000 sq km immediately upstream of the gauging station and median total suspended-solids concentration) were eliminated from the CCA on the basis of their inflation factors. Nine remaining variables were tested for their significance dur-

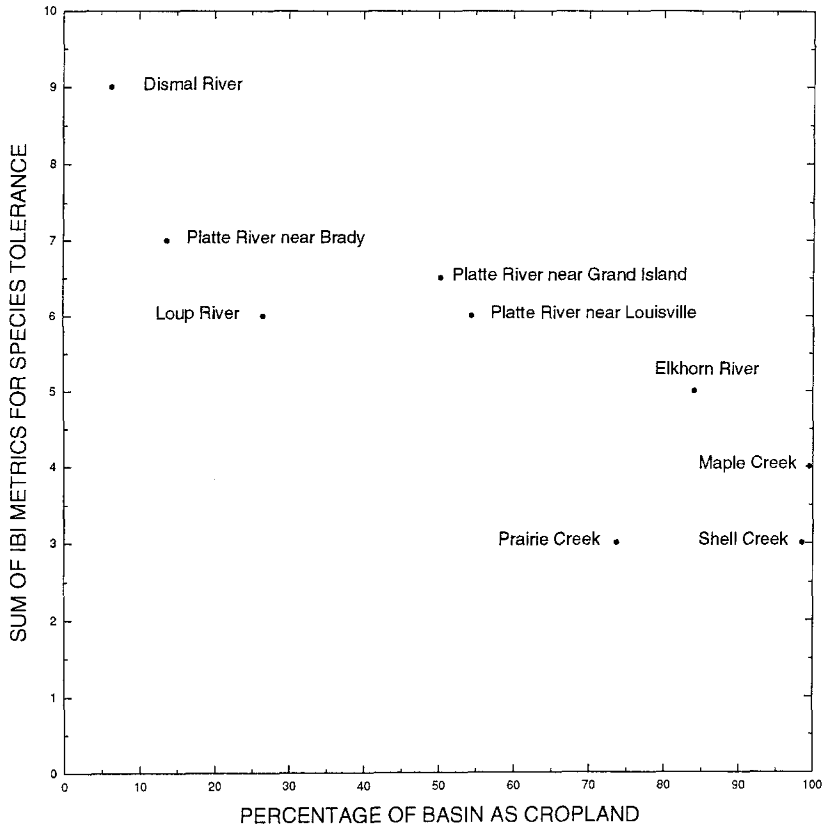

Figure 2. Relation of species tolerance expressed by the sum of IBI metrics 3 and 4 to the percentage of the basin as cropland. IBI metric scores are averages from 1993 and 1994 samples; lower values for the IBI metric scores suggest poorer water quality.

Table 2. Results of canonical correspondence analysis including eigenvalues, canonical coefficients, and t values of canonical coefficients

Environmental variable[a]	Eigenvalue	Canonical coefficient		t value of canonical coefficient	
		Axis 1	Axis 2	Axis 1	Axis 2
Specific conductance	0.25	−0.21	−0.20	−2.60	−5.98
Orthophosphate	0.21	0.02	0.52	0.29	17.2
Cropland	0.19	−0.55	−0.31	−5.44	−7.41
Canopy angle	0.13	−0.23	−0.24	−2.30	−5.94
Time since peak flow	0.08	−0.15	0.05	−2.13	1.87

[a]Environmental variables with $p < 0.05$.

ing forward selection of the variables in the CANOCO program. Five of those variables had $P < 0.05$ and were retained for analysis (Table 2). Stream slope, ratio of stream width to depth, instantaneous streamflow per unit width, and median nitrate concentration all had $P > 0.05$ and were not used.

Samples of the fish community collected during the two years separated into three groups in the ordination diagram, with the Dismal River and Prairie Creek samples dissimilar to the remaining samples (Figure 3). An example of how a site location in the ordination diagram relates to the species found at the sites is shown in Figure 4. In this example, Prairie Creek is characterized by a community of relatively tolerant species and the Dismal River by less tolerant species. The Dismal River was chosen as a site indicative of rangeland, and samples from this site were separated from the other samples primarily on the environmental gradient of cropland.

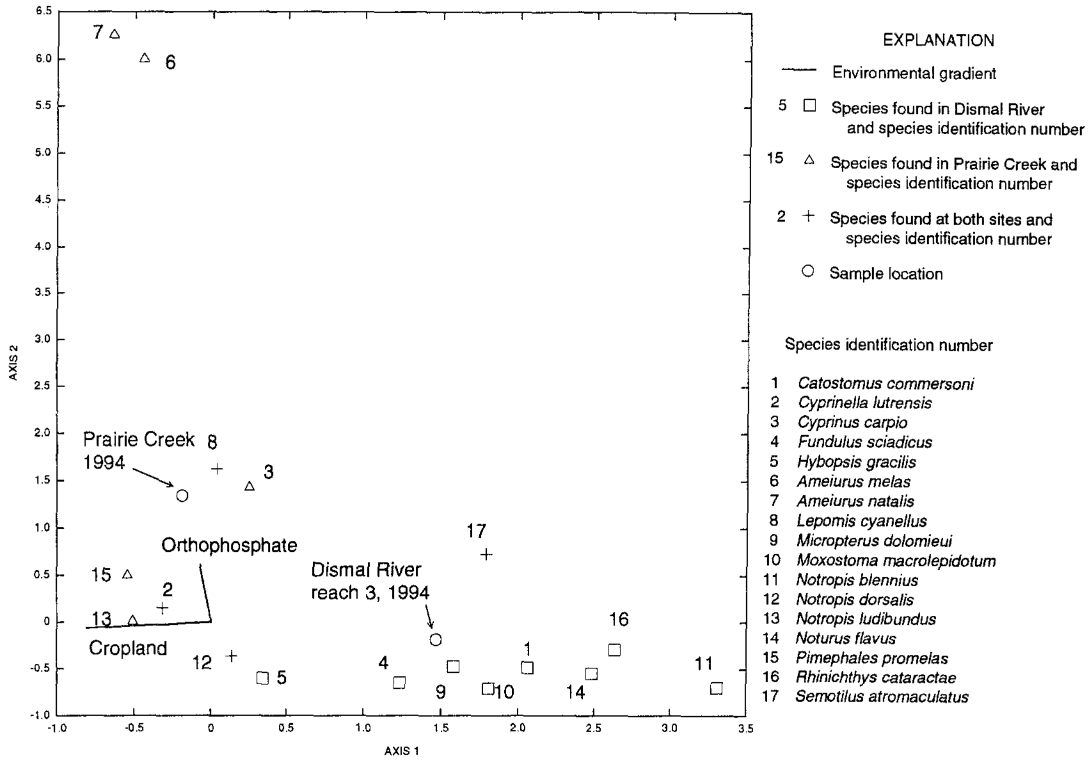

Figure 3. Results of canonical correspondence analysis showing sample locations based on species composition, environmental gradients, and separation of Dismal River and Prairie Creek samples along gradients of percentage of the basin as cropland and median orthophosphate concentration, respectively.

Median concentrations of nitrate and orthophosphate were included in the forward selection of environmental variables in the CCA to address possible concerns about nutrient enrichment. Nitrate concentration was not significant, but orthophosphate concentration was the second environmental variable chosen and was the variable most strongly correlated to the second ordination axis (Table 2). The canonical coefficient of 0.52 for median orthophosphate concentration on the second ordination axis was highly significant as demonstrated by the *t* value of 17.2. Prairie Creek samples were separated from the majority of sites along the environmental gradient of orthophosphate concentration. Shell Creek, which had the fewest species of fish in each of the two years, was not clearly discriminated in Figure 3.

Specific conductance of water samples collected during the year prior to fish sampling had the largest eigenvalue of the environmental variables analyzed. The strength of this variable indicates that the fish community compositions vary spatially across the study area, as do the geological and soil characteristics of the basins. Two other environmental gradients were significant in the sample ordination. However, the amount of variability accounted for by the canopy angle and the time since peak streamflow for the year was minor as indicated by the small eigenvalues (Table 2). Canopy angle described the degree of channel shading by high banks and vegetation. Because canopy angle distinguished large, open sites from small streams, this variable probably also was correlated to the relative influence of bank conditions on the overall stream condition. Sites with the smallest canopy angles were Prairie Creek, Shell Creek, and Maple Creek, and these sites all have unstable banks that contribute sediment to the stream during runoff. At large-river sites, bank conditions probably had little influence on fish communities inhabiting areas 100 m or more from the bank.

Multiple reaches sampled on the Dismal River, Platte River near Grand Island, and Maple Creek showed that there was little variability in fish community composition between reaches (Table 3 and Figure 3). Jaccard coefficients generally were larger between multiple reaches sampled in 1994 than between reaches sampled in 1993 and 1994 (Table 3). The similarity of the multiple reaches demonstrates two benefits of biomonitoring. First, these data indicate that the original reach sampled was representative and, therefore, conclusions regarding status of local conditions can be made with confi-

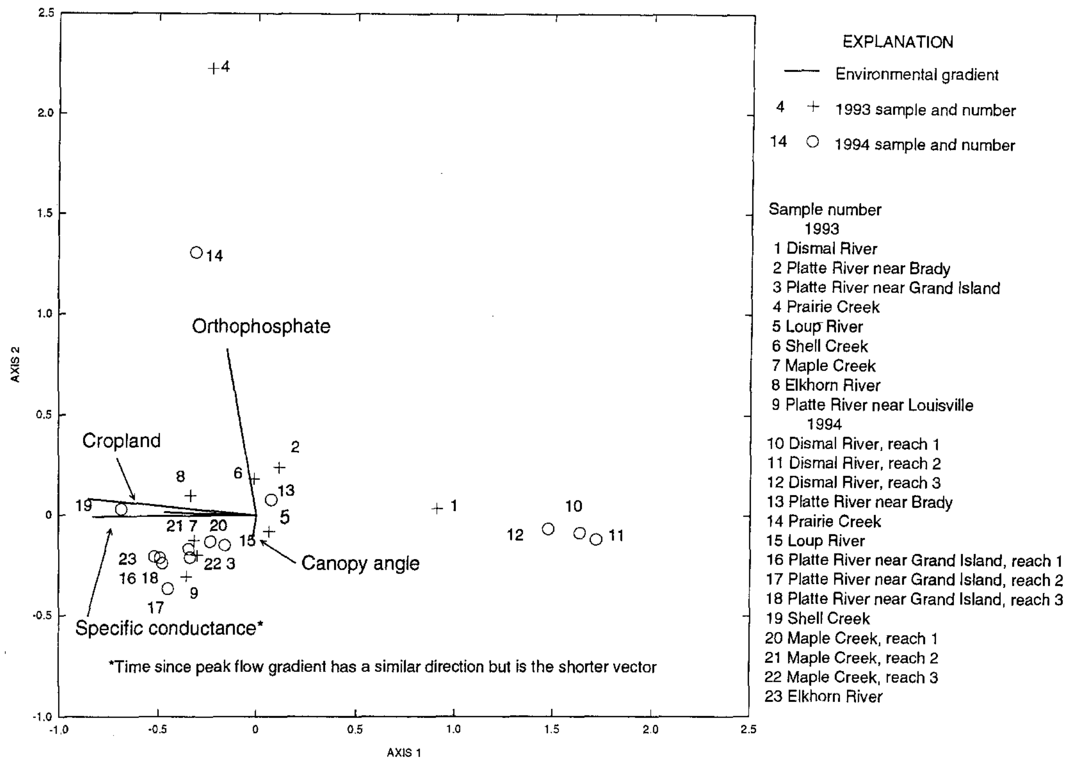

Figure 4. Ordination diagram showing species collected at Prairie Creek and reach 3 of the Dismal River in 1994. Species optima and species abundance in a sample define the sample location along the environmental gradients (only percentage of basin as cropland and median orthophosphate concentration gradients shown).

Table 3. Jaccard coefficients[a] for multiple reach sites

Reach comparison	Value
Dismal River	
Reach 1, 1993 and 1994	0.35
1994, reaches 1 and 2	0.69
1994, reaches 1 and 3	0.75
1994, reaches 2 and 3	0.64
Platte River near Grand Island	
Reach 1, 1993 and 1994	0.70
1994, reaches 1 and 2	0.71
1994, reaches 1 and 3	0.63
1994, reaches 2 and 3	0.59
Maple Creek	
Reach 1, 1993 and 1994	0.55
1994, reaches 1 and 2	0.73
1994, reaches 1 and 3	0.67
1994, reaches 2 and 3	0.75

[a]From Plafkin and others (1989).

dence. Secondly, the smaller degree of similarity of the communities sampled from the same reach in the two years suggested that fish community composition was more stable than environmental conditions between years. Higher streamflow during 1994 than during 1993 (Figure 5) may have accounted for some variability in the species composition at the sites.

Water-quality conditions varied considerably across the study unit and between 1993 and 1994 (Table 4). Median specific conductance ranged from 178 and 185 μS/cm (microsiemens per centimeter at 25°C) for 1993 and 1994, respectively, at the Dismal River site to 1040 and 950 μS/cm at the Platte River near Brady. The values are similar for 1993 and 1994 at large-river sampling sites (Dismal, Platte, Loup, and Elkhorn rivers) but varied at the small-basin sampling sites (Prairie, Shell, and Maple creeks). The differences are attributable to the proximity of agricultural runoff and the higher mean streamflow in 1993. Orthophosphate median concentrations ranged from 0.06 and 0.09 mg/liter for 1993 and 1994, respectively, at the Platte River near Brady to 3.99 and 2.33 mg/liter at the Prairie Creek sampling site. Orthophosphate median concentrations were higher in 1993 than in 1994 with the exceptions of Maple Creek, which was equal for both years, and Shell Creek and the Platte River near Louisville, which were slightly higher in 1994. This observation is generally consistent with the higher mean streamflows in 1993.

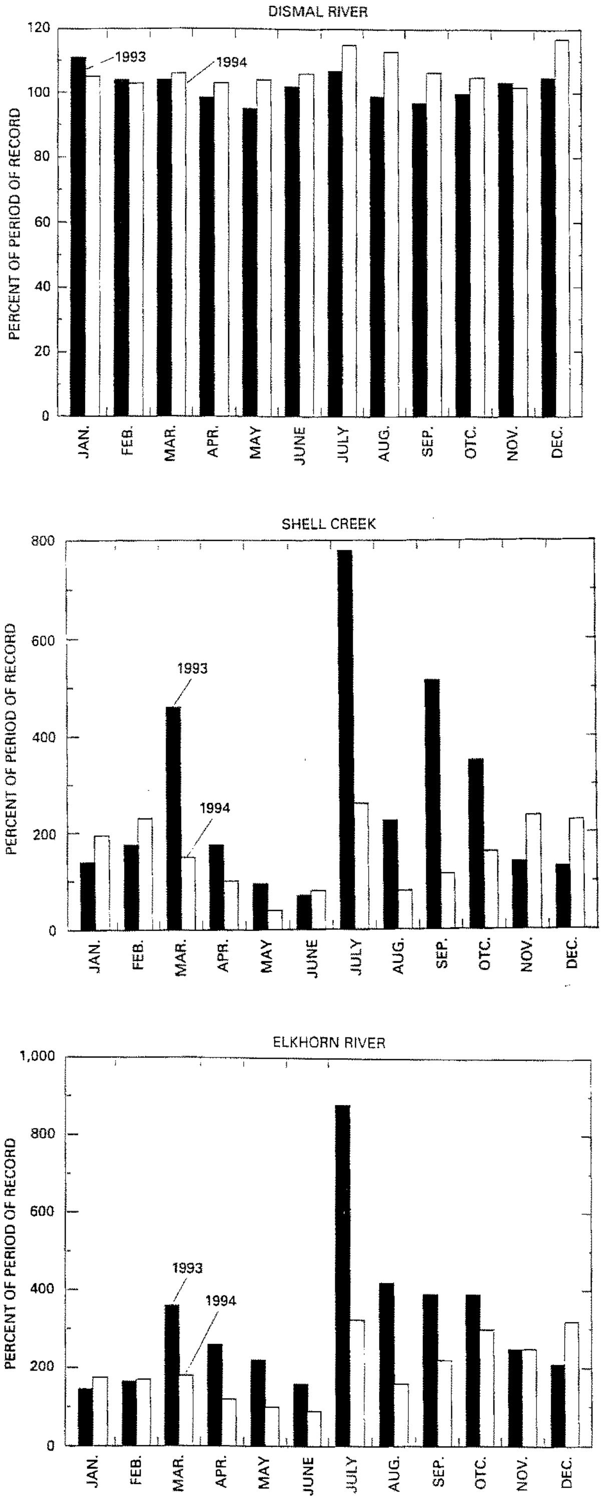

Figure 5. **(A)** Comparison of 1993 and 1994 monthly mean streamflows to monthly means for the period of record (1966–1994) at the Dismal River site. **(B)** Comparison of 1993 and 1994 monthly mean streamflows to monthly means for the period of record (1947–1975, 1977–1994) at the Shell Creek site. **(C)** Comparison of 1993 and 1994 monthly mean streamflows to monthly means for the period of record (1928–1994) at the Elkhorn River site.

Discussion

Correspondence between fish distributions and environmental variables has been documented by several researchers (e.g., Hawkes and others 1986, Matthews and others 1992, Ruhl 1995). Multivariate methods have been shown to effectively demonstrate such correspondence (Rohm and others 1987, Whittier and others 1988). We agree with Hawkes and others (1986) that "environmental variables operate in concert with each other and not as isolated univariate variables." Within that context, the results of this study also show a correspondence between fish distribution and environmental variables.

Environmental variability between the two periods sampled was most dramatic in terms of hydrologic conditions. In general, streamflow in both 1993 and 1994 was above the mean for the period of record (Figure 5). Hydrologic conditions at the Dismal River site (Figure 5A) are reflective of high soil permeability in this basin. Very little runoff contributes to total flow at the sampling site, and streamflow contribution is predominantly from groundwater. Uniformity of monthly mean streamflow is characteristic of the site. Even so, mean annual streamflow during 1994 was the highest for the period of record. Annual mean discharge for 1993 was the highest for the period of record at the Shell Creek site (Figure 5B) and the Elkhorn River site (Figure 5C) (Boohar and others 1994). Spring and summer rains in 1993 resulted in much higher than normal streamflow. Late summer rains led to flooding in the lower part of the study unit, with mean monthly streamflow nearly equal to or exceeding 800% of normal during July and remaining more than 300% of normal through October at both sites. Streamflow in 1994, although still above normal, was less than 1993 and was much more representative of normal conditions. Fish community composition may have been altered by flooding, but as is evident from the ordination results, there was a strong similarity of communities between 1993 and 1994 at each site.

Strong correlations between hydrological regimes and stream fish assemblages were documented by Poff and Allan (1995). Their findings showed that hydrologically variable sites typically were characterized by assemblages of trophic generalists, while stable sites included more specialists. The Dismal and Platte river sites were the more hydrologically stable sites sampled during this study and supported the richest fish assemblages. In contrast, the other sampled sites showed greater hydrologic variability, and the fish communities tended to have fewer species and larger percentages of trophic generalists.

Fish community composition probably was affected

Table 4. Summary of medians for selected water-quality and habitat characteristics at nine sites during 1993 and 1994.

	Specific conductance, µS/cm		Orthophosphate mg/L		Percentage of basin as cropland		Canopy angle, degrees		Number of days between peak flow and fish collection	
Site	1993	1994	1993	1994	1993	1994	1993	1994	1993	1994
Dismal	178	185	0.43	0.40	6.3		150		61	
Reach 1						6.3		150		49
Reach 2						6.3		156		49
Reach 3						6.3		157		49
Platte River nr Brady	1040	950	0.09	0.06	13.6	13.6	162	162	200	67
Platte River nr Grand Island	753	872	0.80	0.22	50.3		160		50	
Platte R. nr Grand Isl.										
Reach 1						50.3		160		175
Reach 2						50.3		176		176
Reach 3						50.3		173		177
Prairie Creek	451	827	3.99	2.33	73.7	73.7	151	151	51	187
Loup River	271	280	0.77	0.43	26.5	73.0	160	160	197	190
Shell Creek	336	657	0.43	0.49	98.5	98.5	102	102	71	55
Maple Creek	476	706	0.46	0.46	99.5		126		72	
Maple Creek										
Reach 1						99.5		126		54
Reach 2						99.5		122		54
Reach 3						99.5		121		54
Elkhorn River	565	542	0.77	0.64	84.1	84.1	136	136	62	189
Platte River at Louisville	594	735	0.60	0.61	54.5	54.5	173	173	58	—

by variability in environmental conditions between years as demonstrated by the smaller similarity coefficients measured between years than between reaches within a year. Our findings of more temporal variability than spatial variability in fish communities, however, were contrary to those of Fausch and Bramblett (1991). Changes in fish community composition in response to between-year variability in streamflow have been documented (Ross and others 1985), yet where the timing and extent of peak streamflow is within the range commonly experienced by that community, similarity may remain strong (Sousa 1984, Schlosser 1985, Poff and Ward 1989). The potential influence of disturbance from high streamflows was represented by the variable of time between the peak streamflow and the collection of fish. The more extreme the peak streamflow for the year relative to a typical year, the longer the recovery process for establishing a fish community similar to what existed prior to the disturbance. Because time from the annual peak flow to collection of fish was a significant variable in the analysis, streamflow or disturbance variability between sites appears to be a factor to which fish communities in Nebraska respond. However, similarity of community composition at sites between years suggest that the magnitude of disturbance in these streams during the course of this study was within the range that was commonly experienced.

The percentage of the basin as cropland was the third variable chosen during the forward selection process, yet it had the largest canonical coefficient on the first axis. The greatest separation of sites in the ordination is, by definition, along the first axis, and the variable most strongly correlated with the first axis is that which provides the greatest distinction between sites. The Dismal River drainage has little cropland and is separated from the majority of the sites in the ordination diagram along the first axis. Cropland exists in the Central Nebraska Basins study unit where the physical characteristics of soils and precipitation are suitable for crop production. Although cropland does not directly affect a fish community, factors related to the existence of cropland, as well as the impact of cropland on water chemistry and the physical habitat in the stream, likely are responsible for the correlation between cropland and fish community composition. Because one purpose of multivariate analysis is to reduce the number of variables by eliminating highly correlated variables, the percentage of cropland in a basin is considered to represent the effect of crop production on water quality.

Because median specific conductance had the largest eigenvalue of the environmental variables analyzed, more of the variability in the species data was associated with variability in the specific conductance than with any other variable. Specific conductance tends to reflect differences in geology and soils of the basins rather than degraded water quality from human activities. Extremely sandy soils characterize the drainages of the Dismal and Loup rivers (Huntzinger and Ellis 1993), and these sites had much smaller values for specific conductance than the other sites (Table 4).

Prairie Creek samples were separated from the main group of samples on the second ordination axis (sample numbers 4 and 14, Figure 3). Median orthophosphate concentrations in the Prairie Creek samples collected in 1993 and 1994 were 3.99 and 2.33 mg/liter, respectively. Median orthophosphate concentrations were 0.80 mg/liter or less at all other sites during the two years of sampling. Although elevated concentrations such as orthophosphate can affect communities by increasing primary productivity, in mid-western streams high turbidity limits the light available to benthic algae (Richards and others 1993). The same processes that elevated orthophosphate concentrations in these streams probably were responsible for increased turbidity. Prairie Creek water samples were collected from a site adjacent to a small cattle-feeding operation. Use of the stream by cattle upstream from the sampling site was evident by trampled banks and lack of suitable instream habitat for intolerant fish species. Local runoff and damaged banks may have contributed to the elevated orthophosphate concentrations and high turbidity in Prairie Creek. Shell Creek also had actively slumping banks within the sampling reach that contributed to the high tubidity during runoff. Samples from these two streams, which are indicative of streams draining areas of intense row crop production, had the fewest species and lowest IBI scores in the study. Maple Creek, another indicator basin for cropland, had a similarly low IBI score in 1993, but the multiple reaches of Maple Creek sampled in 1994 had higher IBI scores (Table 1). Data that we collected did not allow us to identify the particular processes or variables that contribute to orthophosphate's significance in this analysis. However, the measured and observed characteristics of Prairie Creek, Shell Creek, and Maple Creek suggest that local storm runoff from areas of intense agricultural activities adversely affected fish communities.

The species composition of samples reveals information about local environmental conditions. If tolerant species dominate the community to the exclusion of less tolerant species, then the implication is that water quality is degraded. Mean IBI scores for 1993 and 1994 for the three groups of samples identified in Figure 3 are Dismal River, 21; Prairie Creek, 13; and the rest of the samples, 18.8. Prairie Creek's lower IBI score suggests that this site has degraded water quality relative to the other sites. The fish community at Prairie Creek is characterized by tolerant species such as green sunfish, *Lepomis cyanellus;* common carp, *Cyprinus carpio;* and fathead minnow, *Pimephales promelas;* and the lack of intolerant species (Figure 4). The Dismal River, in contrast, has a community with a mix of tolerant species (i.e., white sucker, *Catostomus commersoni*), species with intermediate tolerance, and intolerant species (i.e., longnose dace, *Rhinichthys cataractae*). Samples from other sites have communities of tolerant and intermediately tolerant species, with intolerant species rarely represented. Shell Creek, which had the lowest IBI scores, was located with the majority of other sites in the ordination diagram because the few species collected at Shell Creek were among the most commonly found species in the study unit.

Multiple metrics were used to calculate the IBI scores because each individual metric reflects different potential impacts and addresses affects at individual to ecosystem levels (Barbour and others 1995). Two metrics (3 and 4 in Table 1) addressed the tolerance of species to physical or chemical perturbation (Nebraska Department of Environmental Control 1991). If a community is indeed structured according to species tolerance of degraded water quality, then ordering sites by the average of metrics 3 and 4 ranks those sites by degree of perturbation. Because metrics are scored as either 1, 3, or 5, the range of scores for two metrics is from a low of 2 to a high of 10. Shell and Prairie creeks had the lowest ranking using either the two metrics specific to tolerance or the total IBI scores, indicating the poorest water quality at those sites. The Dismal and Platte river sites had the highest rankings, which suggests the best water quality of the nine sites sampled. The order of ranking seems reasonable based on on-site observations and water-chemistry data. Berkman and others (1986) also found that only IBI metrics related to species tolerance had a consistent relationship to habitat quality. The IBI was able to distinguish sites in our study unit along a water-quality gradient more successfully than did the ordination, where only two sites were identified as substantially different from the remaining seven sites.

Cropland was essentially a surrogate measure of both natural factors that create productive cropland and human factors that result from the agricultural activity on those lands. The response of the fish community to those factors was represented by the species composition. However, for these streams in Nebraska the specific factors associated with cropland that affect the fish community composition are unknown. "Because experimental manipulation of suites of water-quality variables across large regions is impossible or unethical, correlative evidence is the most persuasive demonstration of the relationship between overall water quality and the composition of fish faunas" (Matthews and others 1992). At the sites we sampled in Nebraska, there was an apparent correlation between larger percentages of cropland in drainage and fish communities tolerant of physical or chemical water-quality degradation. This observation was consistent with a shift to tolerant fish species following the expansion of agricultural areas in Iowa (Menzel and others 1984).

Conclusions

The combination of CCA and an IBI determined from fish community data provided a reasonable evaluation of water-quality conditions in central Nebraska streams. An IBI and two individual metrics that contribute to the overall IBI score were effective in ranking sites in terms of water quality based on their fish communities. The performance of the IBI suggests that this method alone would be effective in identifying degraded sites. However, the IBI does not identify possible factors that contribute to the degraded conditions. Although a purely statistical method (CCA) lacks the ecological interpretations allowed by an IBI, CCA showed the grouping of sites, the variability between reaches at a site, and potentially important environmental gradients that were correlated to changes in fish community composition. Effective monitoring of water quality could be achieved by coupling methods that address both the ecological components of fish communities and their statistical relationships to environmental factors.

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Appendix 1. Species abundance in samples from streams in the Platte River Basin, Nebraska

Family name (common name)	Species name (common name)	Trophic class[a]	Tolerance[b]	Sample number[c]								
				1	2	3	4	5	6	7	8	9
Atherinidae (silversides)	*Labidesthes sicculus* (brook silverside)	P	MT	0	0	0	0	0	0	0	0	0
Catostomidae (suckers)	*Carpiodes carpio* (river carpsucker)	O	T	0	0	14	0	1	0	4	32	17
Catostomidae	*Carpiodes cyprinus* (quillback)	O	T	0	0	0	0	0	0	0	0	0
Catostomidae	*Catostomus commersoni* (white sucker)	O	T	83	5	9	0	1	0	0	0	1
Catostomidae	*Cycleptus elongatus* (blue sucker)	I	MT	0	0	0	0	0	0	0	1	0
Catostomidae	*Ictiobus bubalus* (smallmouth buffalo)	O	T	0	0	0	0	0	0	0	0	1
Catostomidae	*Ictiobus cyprinellus* (bigmouth buffalo)	O	T	0	0	0	0	0	0	0	1	0
Catostomidae	*Moxostoma macrolepidotum* (shorthead redhorse)	I	MT	2	0	0	0	6	0	0	0	0
Centrarchidae (sunfishes and basses)	*Lepomis cyanellus* (green sunfish)	G	T	0	9	23	106	11	2	1	9	1
Centrarchidae	*Lepomis macrochirus* (bluegill)	I	MT	0	0	9	0	0	0	0	0	3
Centrarchidae	*Lepomis macrochirus Xgibbosus* (bluegill × pumpkinseed hybrid)	I	MT	0	0	0	0	0	0	0	0	1
Centrarchidae	*Micropterus dolomieui* (smallmouth bass)	C	Int	0	0	0	0	0	0	0	0	0
Centrarchidae	*Micropterus salmoides* (largemouth bass)	C	MT	0	3	20	0	0	0	0	0	1
Centrarchidae	*Pomoxis annularis* (white crappie)	G	MT	0	0	0	0	0	0	0	3	0
Centrarchidae	*Pomoxis nigromaculatus* (black crappie)	G	MT	0	5	9	0	0	0	1	0	0
Clupeidae (herrings and shads)	*Dorosoma cepedianum* (gizzard shad)	I	MT	0	0	23	0	0	0	0	2	31
Cyprinidae (minnows)	*Campostoma anomalum* (central stoneroller)	H	MT	0	22	0	0	0	0	0	0	0
Cyprinidae	*Cyprinus carpio* (common carp)	O	T	5	40	19	115	0	2	0	7	6
Cyprinidae	*Cyprinella lutrenis* (red shiner)	I	T	7	76	575	19	210	0	16	8	30
Cyprinidae	*Erimystax x-punctatus* (gravel chub)	I	MT	0	0	0	0	0	0	0	0	0
Cyprinidae	*Hybopsis aestivalis* (speckled chub)	I	MT	0	0	2	0	0	0	0	0	0
Cyprinidae	*Hybopsis gracilis* (flathead chub)	I	MT	17	0	1	0	12	0	4	9	72
Cyprinidae	*Hybopsis storeriana* (silver chub)	I	MT	0	0	0	0	0	0	0	0	1
Cyprinidae	*Notemigonus crysoleucas* (golden shiner)	O	MT	0	0	0	0	0	0	0	0	0
Cyprinidae	*Notropis atherinoides* (emerald shiner)	I	MT	0	0	0	0	0	0	0	0	0
Cyprinidae	*Notropis blennius* (river shiner)	I	MT	0	0	0	0	0	0	0	0	0

Sample number[c]													
10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	0	0	3	0	0	0	0	0	0	0	0	0	0
0	0	0	8	0	118	43	68	5	0	1	1	1	6
0	0	0	0	0	5	0	0	0	0	0	0	0	0
358	168	65	31	0	1	0	5	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	1	4	0	0	6	1	0	0	0	0	0	0	0
5	1	2	22	113	48	12	0	2	0	0	1	1	0
0	0	0	3	0	0	32	0	14	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	5	0	0	0	0	1	0	0	0	0	0
0	0	0	4	0	39	26	7	7	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	6	1	1	0	0	0	1	0
0	0	0	9	0	0	0	0	0	0	0	0	0	0
1	1	0	563	3	11	1	2	0	0	0	0	0	5
7	2	5	273	47	192	869	299	164	0	116	106	65	65
0	0	0	29	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	8	10	0	0	0	0	0	1
13	7	2	10	0	35	5	1	0	0	36	20	6	3
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0	0
0	0	0	4	0	316	87	41	9	5	5	3	5	23
30	17	7	0	0	0	0	0	0	0	0	0	0	0

(continued)

Appendix 1. *Continued*

Family name (common name)	Species name (common name)	Trophic class[a]	Tolerance[b]	Sample number[c]								
				1	2	3	4	5	6	7	8	9
Cyprinidae	*Notropis dorsalis* (bigmouth shiner)	I	MT	0	1969	99	0	2	35	60	25	389
Cyprinidae	*Notropis heterolepis* (blacknose shiner)	I	Int	0	0	0	0	0	0	0	0	0
Cyprinidae	*Notropis ludibundus* (sand shiner)	I	T	141	1610	126	0	31	0	0	17	654
Cyprinidae	*Pimephales promelas* (fathead minnow)	O	T	2	642	1	14	0	0	111	435	27
Cyprinidae	*Rhinichthys atratulus* (blacknose dace)	I	Int	0	0	0	0	0	0	0	0	0
Cyprinidae	*Rhinichthys cataractae* (longnose dace)	I	Inr	51	31	0	0	0	0	0	0	0
Cyprinidae	*Semotilus atromaculatus* (creek chub)	G	T	21	123	0	2	0	0	0	0	0
Fundulidae (top minnows and killifishes)	*Fundulus sciadicus* (plains topminnow)	I	MT	0	0	2	0	0	0	0	0	0
Fundulidae	*Fundulus zebrinus* (plains killifish)	I	MT	0	3072	69	0	0	0	0	0	0
Hiodontidae (mooneyes)	*Hiodon alosoides* (goldeye)	G	MT	0	0	0	0	0	0	0	1	1
Ictaluridae (bullhead catfishes)	*Ameiurus melas* (black bullhead)	I	T	0	1	0	9	0	0	0	0	0
Ictaluridae	*Ameiurus natalis* (yellow bullhead)	I	MT	0	0	0	11	0	0	0	0	0
Ictaluridae	*Ictalurus punctatus* (channel catfish)	G	MT	0	3	81	0	17	2	14	0	19
Ictaluridae	*Noturus flavus* (stonecat)	I	MT	0	0	0	0	1	0	0	0	0
Ictaluridae	*Pylodictis olivaris* (flathead catfish)	C	MT	0	0	1	0	1	0	0	0	0
Lepisoteidae (gars)	*Lepisosteus osseus* (longnose gar)	C	T	0	0	0	0	0	0	0	0	1
Moronidae (temperate basses)	*Morone americana* (white perch)	G	MT	0	0	0	0	0	0	0	0	0
Percidae (perches and darters)	*Etheostoma exile* (Iowa darter)	I	Int	0	0	0	0	0	0	0	0	0
Percidae	*Etheostoma nigrum* (Johnny darter)	I	MT	1	0	0	0	0	0	0	0	0
Poeciliidae (live-bearers)	*Gambusia affinis* (mosquitofish)	I	MT	1	0	22	0	0	0	0	0	9
Percidae	*Perca flavescens* (yellow perch)	I	MT	0	0	0	0	0	0	0	0	0
Sciaenidae (drums)	*Aplodinotus grunnien* (freshwater drum)	I	MT	0	0	83	0	3	0	0	0	35
Total				331	7611	1188	276	296	41	211	550	1300

[a][I, insectivore; H, herbivore; O, ominivore; G, generalist; P, planktivore; C, carnivore.
[b]Int, intolerant; MT, moderately tolerant; T, tolerant.
[c]Sample 1, Dismal R. 1993; 2, Platte R., Brady 1993; 3, Platte R., Grand Island 1993; 4, Prairie Cr. 1993; 5, Loup R. 1993; 6, Shell Cr. 1993; 7, Maple Cr., 1993; 8, Elkhorn R. 1993; 9, Platte R., Louisville 1993; 10, Dismal R., reach 1, 1994; 11, Dismal R., reach 2, 1994; 12, Dismal R., reach 3, 1994; 13, Platte R. Brady 1994; 14, Prairie Cr. 1994; 15, Loup R. 1994; 16, Platte R., Grand Island, reach 1, 1994; 17, Platte R., Grand Island, reach 2, 1994; 18, Platte R., Grand Island, reach 3, 1994; 19, Shell Cr. 1994; 20, Maple Cr., reach 1, 1994; 21, Maple Cr., reach 2, 1994; 22, Maple Cr., reach 3, 1994; 23, Elkhorn R. 1994]

Sample number[c]													
10	11	12	13	14	15	16	17	18	19	20	21	22	23
447	139	114	2491	4	3	180	332	57	0	47	79	96	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	81	228	16	667	1141	163	0	342	130	68	21
0	0	0	1160	367	81	185	225	46	74	54	16	29	6
34	28	0	0	0	0	0	0	0	0	0	0	0	0
66	26	24	0	0	1	0	0	0	0	0	0	0	0
53	17	26	265	5	0	0	0	0	0	0	1	0	0
3	0	1	0	0	0	0	0	1	0	0	0	0	0
0	0	0	1063	0	0	197	240	13	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	5
0	0	0	0	5	0	0	0	1	0	0	0	0	0
0	0	0	0	8	0	2	0	0	0	0	0	0	0
0	0	0	24	0	21	176	114	16	0	2	2	4	4
2	0	1	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	2	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	1	2	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	12	0	0	18	59	9	0	0	0	0	0
0	0	0	0	0	1	0	0	0	0	0	0	0	0
0	0	0	0	0	14	46	4	6	0	0	0	0	2
1029	407	252	6061	780	908	2561	2550	517	79	604	359	278	141