DEVELOPMENT OF A RAPID BIOASSESSMENT

PROTOCOL FOR SAMPLING FISHES

IN LARGE PRAIRIE RIVERS

By

NICHOLAS JOHN UTRUP

Bachelor of Science

The Ohio State University

Columbus, Ohio

2002

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 2005

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Thesis Approved:

William L. Fisher

Thesis Advisor

Joseph R. Bidwell

Anthony A. Echelle

A. Gordon Emslie

Dean of Graduate College

ACKNOWLEDGMENTS

I sincerely thank my major advisor, Dr. William L. Fisher, for not only giving me the opportunity to conduct this research but also for all his guidance, understanding, and insight into the complexities of this project. Dr. Fisher has been an outstanding role model to me both personally and professionally throughout my time at Oklahoma State University (OSU) and I am forever grateful for all his time and effort.

I thank my committee members, Dr. Joseph R. Bidwell and Dr. Anthony A. Echelle, whose input, advice, and friendship not only improved the quality of my work but also made my stay at OSU even more enjoyable. I would like to acknowledge Dr. Dana L. Winkelman who helped out immensely in the early stages of this project. I am also grateful to Judy Gray, Sheryl Lyon, and Helen Murray of the Oklahoma Cooperative Fish and Wildlife Research Unit (OCFWRU) and Gertie Mulder of the Department of Zoology for their assistance during my stay at OSU. They were pivotalto the successful completion of my project and were a crucial part of my daily life at OSU.

I thank the Oklahoma Water Resources Board (OWRB), Oklahoma Department of Wildlife Conservation (ODWC), U. S. Geological Survey (USGS), and OCFWRU for funding this project, as well as the Oklahoma Chapter of the American Fisheries Society for providing me with a Jimmie Pigg Memorial Travel

Scholarship. In particular, I would like to thank Chuck Potts of OWRB and Brent Gordon and Greg Summers of ODWC for their assistance and encouragement throughout this project. I also thank Neil Fobes, Redlands Community College, Bob Drew, Jim Nolen, Dolese Brothers Sand and Gravel Company, and countless other land owners for allowing me access to the river.

I especially thank my field and lab assistants. Without their help this project could not have been completed and would not have been as much fun. I sincerely thank Bullit Farris for all his hard work, comic relief, and most of all his friendship. Brian Collins, Greg Cummings, and Melissa Willis for helping me get this project off the ground and volunteers: Kevin Belt and Zack Thomas. I also thank my fellow fisheries graduate students in the OCFWRU: Dan Dauwalter, Matt Mauck, Jason Schaffler, and Maureen Walsh for their constant support and advice.

Most of all, I thank my friends (both old and new) and family for their support throughout my time at OSU. My brothers, Jay and Kurt Utrup, who have always been my role models; my sister, Pam Schulte, whose constant updates from home and insatiable interest in “what I’m up to” has helped me deal with being so far away; and especially my parents, Gerald Utrup and Nina Nuveman, who have been the source of all my ambition and have always been there to give me support and encouragement. Finally, and most sincerely, I thank my future wife Jill Sporrong who has been by my side throughout my experience at OSU. She has been an endless source of encouragement and love and is the reason for all of my success and happiness.

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ABSTRACT

We used seining and hoop netting to collect fishes at 15 sites in five large prairie rivers in Oklahoma to (1) determine the minimum amount of effort needed to detect the majority of fish species at a sample site and (2) examine the selectivity of fish species detected by the two gear types. Analysis of similarities of the fishes collected in six different habitat types identified two distinct habitat types based on fish species composition: shallow/backwater (SBW) habitat (depth ≤ 0.75 m) and deep/non-wadeable (DNW) habitat (depth > 0.75 m). We estimated that between 6 and 10 ($\bar{x}$ = 8) SBW habitats andbetween 1 and 6 ($\bar{x}$ = 4) DNW habitats at each sample site were needed to detect the majority of fish species during a sampling event. Minimum sampling distance needed to encounter the minimum number of habitats ranged from 400 m to 1600 m and averaged 887 m. Gear evaluation showed seining captured more species per unit effort than hoop netting (3.6 and 1.4 respectively); however, hoop netting captured significantly larger fish (527 mm; $P < 0.001$) than seining (42 mm). Based on these collections, we present recommendations for sampling fish assemblages in large prairie rivers in the southern Great Plains to aid in the rapid bioassessment and monitoring of fish assemblages in large prairie rivers.

Introduction

Rapid bioassessment protocols to assess the biotic integrity of riverine environments have become an important component of water resources management. Methods for rapidly sampling biological species assemblages in small wadeable streams and rivers have been widely investigated and successfully implemented by biomonitoring agencies across the U.S. (Barbour et al. 1999). However, there has been relatively little research into the development of methods for rapidly assessing large non-wadeable rivers, particularly large prairie rivers. The paucity of large river sampling protocols can be attributable to the difficulty in characterizing fish assemblages in these environments and the lack of relatively unimpaired reaches for estimating reference conditions (Lyons et al. 2001). Fish sampling protocols that have been developed for large rivers are generally designed for rivers in the midwestern and western U.S. (OhioEPA 1989; Emery et al. 2003; Yoder and Kulik 2003) or target specific species (USGS 1998). Standardized fish sampling protocols for large prairie rivers in the interior Great Plains of the U.S. have focused primarily on the assessment and monitoring of targeted fish populations (i.e., paddlefish *Polyodon spathula* and pallid sturgeon *Scaphirhynchus albus*) in impounded sections of the Missouri River (USGS 1998) and therefore are not necessarily applicable to other large prairie rivers within the Great Plains.

The Great Plains Ecoregion in the U.S. (Omernik 1987) is dissected by three major river systems that flow from west to east and drain into the Mississippi River: the Missouri, Arkansas, and Red rivers and their tributaries.

Because of the surficial geology and solution processes within the soil and groundwater of the Great Plains, prairie rivers vary widely in their physical and chemical properties. These rivers are typically silt-laden, turbid, and alkaline with large fluctuations in discharge ranging from flash flooding during rain events to temporary intermittent flow during drought periods (Matthews 1988; Poff and Ward 1989; Dodds et al. 2004). However, there are distinct differences between prairie rivers in the northern and southern Great Plains. Prairie rivers of the northern Great Plains generally have more consistent flow and cobble substrates, whereas prairie rivers of the southern Great plains are characterized by irregular flow, distinct wet and dry seasons, ad smaller-sized substrates (Matthews 1988). Furthermore, southern Great Plains rivers have much greater concentrations of dissolved ions (i.e. higher conductivity) than northern rivers because southern rivers flow over Permian salt deposits from which chloride ions are leached to the surface by numerous springs and small creeks (Matthews 1988).

Prairie rivers with headwaters in the Rocky Mountains, such as the Platte and Arkansas rivers, form wide, shallow channels as they cross the Great Plains. Habitats for prairie river fishes that occur within these channels are influenced by geomorphology and hydrology. As these rivers course through this region, they cut away erosible banks and re-deposit fine sand and coarse alluvium uniformly throughout their river channels (Cross and Moss 1987). Therefore, many prairie rivers, particularly those of the southern Great Plains, have a fairly uniform sand or clay substratum (Matthews 1988). Cross and Moss (1987)recognized three distinct habitat types in these rivers: channels of fluctuating flow and shifting sand beds, clear brooks and marshes sustained by springs and seeps, and residual pools (i.e., backwaters and side channels) that are dependent on water level. Hydrologic fluctuations in these rivers can be large resulting in harsh environmental conditions for fishes (Matthews 1998), causing some species to seek out pools where hydraulic stress is low (Statzner et al. 1988).

Prairie rivers pose unique challenges for sampling fishes because of their physical and chemical characteristics. Most fish sampling in prairie rivers has used some combination of seining, hoop netting, gillnetting,and electrofishing depending on the conductivity and turbidity of the water (Peters et al. 1989; Barfoot and White 1999; Milewski et al. 2001) Milewski et al. (2001)found that seining was most effective at sampling minnows, whereas trapnets and hoop nets were most effective at sampling larger bodiedbenthic fishes in prairie rivers of eastern South Dakota. They also found that gillnets often collected few or no fishes and electrofishing proved ineffectiveat sites with high turbidity.

Because of the high turbidity and conductivity of prairie rivers in the southern Great Plains, electrofishing is not feasible. Therefore, most fish sampling in this region has used a variety of seining and gillnetting methods. Pigg (1988), Pigg et al. (1992), Pigg et al. (1997) and Pigg et al. (1999) used standardized methods of seining for sampling fishes in the large prairie rivers of Oklahoma. Their methods included approximately 20 seine hauls of 10 m length, covering the same amount of surface area (approximately 200 m) and the same segment of the shoreline at each site. In addition to seining, Pigg (1988) and

Pigg et al. (1992) placed a gillnet across the site for two hours. Ostrand and Wilde (2002) used a standardized method of seining to sample fishes in the Brazos River, a large prairie river in central Texas. They established15 to 20 transects, set 25 m apart, and made a total of 25 seine hauls of 5 m length at each sample site. In contrast to standardized sampling, Taylor et al. (1993) and Taylor et al. (1996) used judgmental sampling to collect fishes in several prairie rivers of the upper Red River basin. Their method included seining for 45 minutes to 1 hour at each site, and they attempted to sample all available habitats. Although several methods have been used to sample fishes in prairie rivers of the southern Great Plains, there is no single protocol that is both standardized and statistically based for sampling fish assemblages in the large prairie rivers of this region.

Determining the most efficient sampling method with the appropriate gear types, habitats to sample, and number of samples can be challenging. Statistically-based methods for developing a sampling design ensure that the data collected are appropriate for subsequentstatistical analysis and interpretation in water quality assessments (Chapman 1996). Moreover, use of a rapid, statistically valid sampling protocol allows for sampling of multiple sites in a single field season and the comparison of biological data among impaired and reference sites (OhioEPA 1989; Barbour et al. 1999). A rapid bioassessment protocol is needed to monitor the integrity of fish assemblages in large prairie rivers.

We developed a standard protocol for seining and hoop netting fish assemblages in five large prairie rivers in Oklahoma. Our objectives were to (1) determine the minimum number of samples needed to detect the majority of fish species in different habitats at a sample site, and (2) examine catchability of fish species by the two gear types. We present recommendations for the rapid bioassessment of fish assemblages in the large prairie rivers of the southern Great Plains.

Study Area

All major rivers of the interior plains of the U.S. flow through the Great Plains ecoregion (Omernik 1987). Within this ecoregion, large prairie rivers of the northern Great Plains generally flow through the West-Central Semi-Arid Prairies and Temperate Prairies ecoregions and the prairie rivers of the southern Great Plains flow through the South-Central Semi-Arid Prairies ecoregion (Omernik 1987; Figure 1). These southern Great Plains rivers typically have shallow, braided channels with sandy substrate much of which is underlain by Permian salt beds and extensive areas of overlying gypsum (Cross and Moss 1987).

For this study, we defined large prairie rivers in Oklahoma based onthe following physico-chemical characteristics: (1) high average conductivity (>1,000 µS/cm), (2) predominately sand substrate, and (3) over half of the river channel is non-wadeable (i.e. > 1.5 m deep) and/or cannot be safely sampled using wadeable sampling procedures (Barbour et al. 1999; OWRB 1999)during normal flow periods.

Physico-chemical characteristics were compiled from U.S. Geological Survey (USGS) gaging station data near 15 sites on the five large prairie rivers we sampled in Oklahoma (Table 1). Physico-chemical parameters varied among sites: contributing drainage area ranged from 12,398.3 km^2 on the Washita River near Alex, Oklahoma, to 195,474.2 km^2 on the Arkansas River near Coweta, Oklahoma, mean discharge ranged from 10.5 m^3/s on the N. Canadian River near El Reno, Oklahoma, to 207.1 m^3/s on the Arkansas River near Ralston, Oklahoma, specific conductance ranged from 950.4 µS/cm on the Washita River near Durwood, Oklahoma, to 13,102.7 µS/cm on the Cimarron River near Dover, Oklahoma, and turbidity ranged from 13.7 JTU on the Washita River near Alex, Oklahoma, to 262.5 JTU on the N. Canadian River near Wetumka, Oklahoma (Table 1).

Methods

We measured habitat and collected fish at 15 different sample sites on five large prairie rivers in western and central Oklahoma, including three sites on each the Arkansas, Cimarron, North Canadian, Washita, and Red rivers (Figure 2). Fish were collected during periods of normal to low flow from May to October in 2003 and 2004. At each site we established 11 transects spaced 100 m apart and measured water depth and stream flow along each transect. Depth was measured using a 1.5 m x 12.7 mm PVC pipe with cm increments. Current velocity was estimated from the movement of the water about the pipe, which was calibrated with a Marsh-McBirney, Inc, Flo-Mate portable flow meter. In areas with a fast current velocity (> 0.20 m/s), the water formed a “V” pattern about the pipe whereas in areas with a slow current velocity (< 0.20 m/s), the water formed a “U” pattern about the pipe (Gorman and Karr 1978). Six different habitat types were identified based on these measurements and mapped along each transect. These habitat types were: shallow slow (SS), shallow fast (SF), deep slow (DS), deep fast (DF), non-wadeable (NW), and backwater (BW); Table 2).

We were unable to use electrofishing because of high conductivity (> 1000 μS/cm) at each sample site (Table 1), therefore, we used a seine (6.1 m x 1.2 m x 4.8 mm mesh) in shallow-water habitats (depth ≤ 0.75 m) and large (0.9 m x 3.7 m x 50.8 mm mesh) and small (0.6 m x 2.4 m x 25.4 mm mesh) hoop nets in deep-water habitats (depth > 0.75 m). Sampling at each site consisted of approximately 20 seine hauls and 12 hoop net sets. We seined twice in four randomly selected SS and SF habitats and all BW habitats encountered throughout each 1000 m reach. Seine hauls were made parallel to the shoreline, with the current, for a distance of 10 m. When possible we used the river bank to trap the fish, and we attempted to seine near discrete microhabitats (e.g. cobble, bedrock) and structures (e.g. woody debris, boulder, undercut bank). We set 6 large hoop nets and 6 small hoop nets near in-stream structure and vegetation in DS, DF, and NW habitats. All nets were unbaited and allowed to fish over night and were emptied after approximately 12 hours.

To test for redundancy in fish species collected in the six habitat types, we compared the similarity in fish assemblage composition among habitat types (analysis of similarities; ANOSIM; PRIMER 5.0, Plymouth Marine Laboratory, Plymouth, UK). The ANOSIM test compares species (e.g., fish) composition between two groups (e.g., habitats) and generates an *R*-value, which is a measure of similarity ranging from 0 to 1 with 0 being completely similar and 1 being completely dissimilar (Clarke and Gorley 2001). The ANOSIM test is based on a non-parametric permutation procedure applied to a Bray-Curtis similarity matrix (Clarke and Warwick 2001). Fish assemblages were compared between all six habitat types with the groupings either being well separated ($R > 0.75$), overlapping but clearly different ($R > 0.5$), or barely separable ($R < 0.25$) based on thresholds described by Clarke and Gorley (2001).

To determine amount of sampling effort needed to detect a majority of the fish species present at each site, we created species-accumulation curves showing the cumulative increase in number of species with each added habitat. We used number of species captured and number of habitats sampled (averaged over all sample locations) to calculate the mean number of habitats needed to detect a majority of fish species in each habitat type at each sample site. We used regression analysis (SAS Institute Inc., Cary, NC) to test relationships between mean number of habitats needed and wetted width, contributing drainage area, and mean discharge at each sample site. We used analysis of variance (ANOVA) to test for differences in number of habitats needed to detect a majority of fish species among rivers. We also calculated number of samples required to obtain a statistically valid sample size based on species-per-unit-effort (SPUE) estimates for the seine and two hoop net sizes. The equation for calculating number of samples (N) needed is:

$$N = \frac{t^2 s^2}{(\bar{x}L)^2}$$

where t^2 is the Student's statistic for the selected confidence level (P = 0.05), s^2 is the variance of the sample, $\bar{x}$ is the sample mean, and *L* is the allowable error of the mean (Snedecor and Cochran 1967; Fisher 1987). For our study, t^2 was 4, and we set *L* at 0.1, 0.25, and 0.5 for comparative purposes. As a general rule, precision of sample size estimates within 10% (0.1) of the population mean are used in research studies, 25% (0.25) of the mean in management studies, 50% (0.5) of the mean in preliminary surveys (Robson and Regier 1964; Wilde and Fisher 1996).

We determined minimum sampling distance needed at each site to detect a majority of fish species from each habitat type based on sampling effort. To determine this distance, we classified habitat types in a 10 km section of the river near each of the 15 sample sites by photointerpreting black and white digital orthophoto quad (DOQ) maps using ArcView 3.3 GIS software (Whited et al. 2002). Habitat types were distinguished on the photos by their relative darkness in the wetted portion of the river channel. Light-colored areas (i.e., pixel color ranging from white to gray) were identified as shallow water (includes SS and SF habitats) and dark-colored areas (i.e., pixel color ranging from dark gray to black) as deep water (includes DS, DF, and NW habitats). Backwater habitats were identified as water in the river channel separated from the main channel on three or more sides (Figure 3). We divided each 10-km-river-section into 100 m transects and calculated average wetted width and percentage of each habitat type for the entire section (Figure 3) and used this to estimate the minimum sampling distance needed for each sample site. We used a regression analysis to examine the relationship between the average percentages of habitat types and average wetted width at each sample site.

Species-per-unit-effort for seining was measured as number of species caught per seine haul (approximately 10 m) and for hoop nets as number of species caught per net night (approximately 12 hours, set over night). We used an ANOVA, on $\log_{10}(X+1)$ transformed data, to test for differences in mean length and weight of fish between gear types and net sizes. We used ANOSIM to test for similarities in fish assemblage composition detected by the different gear types and net sizes.

Results

<u>Habitat Classification</u>

The six initial habitat types showed distinct similarities in fish assemblage composition (Global $R = 0.452$). We found that SS and SF habitats were the most similar ($R = 0.026$), followed by DS and DF ($R = 0.080$), DS and NW ($R = 0.087$), DF and NW ($R = 0.118$), and SS and BW habitats ($R = 0.174$). Fish species composition differed slightly between SF and BW habitats but not enough to definitively separate these two habitats ($R = 0.283$). The other habitat combinations were either well separated or slightly overlapping (*R* > 0.700; Table 3). Based on these results, we reduced the six initial habitat types to two, shallow/backwater (SBW) and deep/non-wadeable (DNW). Shallow/backwater habitat was characterized by having a depth ≤ 0.75 m regardless of current velocity and DNW habitat was characterized by having a depth > 0.75 m regardless of current velocity. Based on fish species composition, SBW and DNW habitats were well separated with only moderate overlap (*R* = 0.719).

<u>Sampling Effort</u>

We sampled an average of 11.3 (SD = 1.80) SBW habitats at each site and collected an average of 13.6 (SD = 3.36) species from each. We sampled an average of 5.3 (SD = 1.54) DNW habitats at each sample site and collected an average of 5.2 (SD = 2.43) species from each. We detected a majority of fish species after sampling 6 to 10 SBW habitats ($\bar{x}$ = 8) and 1 to 6 DNW habitats ($\bar{x}$ = 4) at each site (Table 4). We found no significant relationship between the mean sampling effort and mean wetted width (R^2 = 0.1773; P = 0.118), contributing drainage area (R^2 = 0.228; P = 0.072), or mean discharge (R^2 = 0.225; P = 0.074) for each sample site. There was no significant difference in mean sampling effort among rivers (P = 0.296). We also found that BW habitats, on average, contained approximately 63% of the species detected in SBW habitat.

Number of samples required to estimate mean sample SPUE within 10%, 25%, and 50% of the mean population SPUE varied by gear type (Table 5). A minimum of 5 and a maximum of 126 seine hauls are needed to estimate SPUE within 50% and 10% of the mean population respectively. A minimum of 13 and a maximum of 319 large hoop nets are needed and a minimum of 13 and a maximum of 322 small hoop nets are needed to estimate SPUE within 50% and 10% of the mean population respectively.

Sample Distance

Average wetted width of the river at each sample site was 147.8 m (SD = 123.01; Table 6). On average, DNW habitat comprised 45.6% (SD = 9.7), SW comprised 43.2% (SD = 8.9), andBW comprised 11.2% (SD = 4.9) of each sample site (Table 6).

For each sample site we calculated the minimum sample distance as the distance needed to encounter at least eight SBW habitats and four DNW habitats, based on the average effort needed to detect a majority of fish species at each sample site. Minimum sampling distance ranged from 400 m to 1600 m and averaged 886.7 m (SD = 344.1; Table 7) over all the sample sites. Based on these results, within a 900 m reach of a large prairie river we would expect to encounter 9 to 15 SW habitats ($\bar{x}$ = 8.0; SD = 3.02), 0 to 6 BW habitats ($\bar{x}$ = 2.5; SD = 1.81), and 5 to 22 DW habitats ($\bar{x}$ = 10.0; SD = 4.83; Table 7).

Regression analysis between mean wetted width and average percentages of SW, DW, and BW habitats at each sample site indicated that 66.3% of the variation in wetted width could be explained by the occurrence of BW habitat ($P < 0.001$), whereas SW and DW habitat did not explain a significant portion of the variation (P = 0.320 and P = 0.415 respectively). Based on these results, occurrences of BW habitat in the river channel should increase as wetted width increases.

Gear Evaluation

We collected 45,586 individual fish representing 13 families and 46 species from the 15 sample sites. We had a combined effort of 334 seine hauls and collected 44 species representing 13 families with a SPUE of 3.6 (SD = 2.04) species per seine haul (Table 8). Fish collected with the seine had a mean length of 42.4 mm (SD = 37.13) and a mean weight of 3.7 g (SD = 50.32). With the large hoop nets, we had a combined effort of 51 net nights and collected 11 species representing 7 families with a SPUE of 1.4 (SD = 1.23) species per net night (Table 8). Fish collected with the large hoop net had a mean length of 527.2 mm (SD = 199.15) and a mean weight of 1904.5 g (SD = 1963.08). With the small hoop nets, we had a combined effort of 79 net nights and collected 16 species representing 8 families with a SPUE of 1.2 (SD = 1.04) species per net night (Table 8). Fish collected with the small hoop net had a mean length of 357.3 mm (SD = 200.75) and a mean weight of 718.8 g (SD = 917.38).

Significantly more species were collected per unit effort by seining than were captured by both the large hoop net (P < 0.001) and small hoop net (P < 0.001), when averaged over all sites. However, there was no significant difference in the SPUE between the two sizes of hoop nets (P = 0.565). Large hoop nets captured significantly larger fish than both the seine ($P < 0.001$) and the small hoop nets ($P < 0.001$).

Analysis of similarities of fish species captured by each gear type showed distinct differences between the fish assemblage collected by seining and those collected with both sizes of hoop nets ($R = 0.783$); however, we found no difference between the fish assemblages captured with the large and small hoop nets ($R = 0.022$). Seining captured species from all 13 families collected in this study. The majority of species collected by seining were minnows, including red shiner *Cyprinella lutrensis*, emerald shiner *Notropis atherinoides*, western mosquitofish *Gambusia affinis*, and bullhead minnow *Pimephales vigilax*, which made up over 90% of the total catch (Table 8). In contrast, the majority of fish species captured by hoop nets were catfish. Channel catfish *Ictalurus punctatus* and flathead catfish *Pylodictis olivaris* represented over 50% of the combined catch in large and small hoop nets whereas smallmouth buffalo *Ictiobus bubalus* and river carpsucker *Carpiodes carpio* represented 47% and 12% respectively (Table 8). Although there was no difference in the fishassemblages captured by large and small hoop nets ($R = 0.022$), small hoop nets captured more sunfish species ($N = 4$) than large hoop nets ($N = 1$; Table 8).

Sampling Recommendations

The following sampling recommendations and protocol are intended for sample sites that meet the criteria for large prairie rivers in the southern Great Plains region and are based on sampling conducted at 15 sites in five large prairie rivers in Oklahoma. Sampling in these rivers should proceed through three stages: (1) verification of sample site access and physical characteristics using maps and DOQs prior to leaving for the field, (2) habitat mapping and sample selection in the field, and (3) fish sampling (Figure 4).

Stage 1: site verification--Prior to going into the field, map sources (paper and digital topographic maps, and aerial photos including DOQs) should be consulted to determine site access and to assess river and riparian habitat features. Interpretation of habitat types on DOQs or other aerial photos will provide an initial estimate of the channel dimensions and proportion of shallow water, deep water, and backwater habitats, which can be used to allocate sampling effort (i.e., sample distance).

Stage 2: sample selection and allocation--Once in the field, map the sample reach by walking (or boating) transects perpendicular to the shoreline and spaced 100 m apart. Identify and map SBW and DNW habitat along each transect and number each habitat. After habitat types are mapped, randomly select eight shallow water habitats. Include (when present) at least three BW habitats in with the randomly selected SBW habitats. Deep non-wadeable habitats should be selected based on the presence of in-stream structure and vegetation.

Stage 3: fish sampling--A minimum of two hoop nets should be set in each selected DNW habitat throughout the sample reach, one large (~ 0.91 m diameter, 50.8 mm mesh) and one small (~ 0.61 m diameter, 25.4 mm mesh). Placement of hoop nets may be at the discretion of the biologist, but for best results they should be placed near in-stream structure (e.g. woody debris, boulders, and undercut banks) and vegetation. The opening of the net should be facing the center point of the structure and should extend parallel (or underneath if possible) to the structure. If possible, secure the front of the net to the structure and tie the cod end to a t post (or log if available). The opening of the net should always be facing downstream. Nets should be fished overnight and for a minimum of 12 hours.

After hoop nets are set, seine eight randomly selected SBW habitats throughout the reach using a 6.1 x 1.2 m seine with 4.8 mm mesh attached to 1.5 m PVC brails (~ 50.8 mm diameter). If present in the sample reach, include at least three BW habitats among the eight SBW habitats. Make two seine hauls at each selected habitat with each seine haul covering approximately 10 m. Use the river bank to trap the fish when possible and always seine with the current. Try to seine near unique microhabitat (e.g. cobble, bedrock) and structure (e.g. woody debris, boulder, undercut bank) but be careful not to hang up the seine. If an area is not safe to seine, do not proceed (e.g. water too fast, sharp metal debris, unstable substrate, barbed wire).

Discussion

Prairie streams in the Great Plains ecoregion have become increasingly degraded over the past century because of extensive agricultural activities, urbanization, and alteration of natural hydrologyas a result of ground water withdrawal and construction of impoundments (Cross and Moss 1987; Cashner and Matthews 1988; Echelle et al. 1995; Matthews 1998; Dodds et al. 2004). Because of marked changes in the physical, chemical, and hydrological characteristics of some of these prairie rivers (Pigg 1988; Pigg et al. 1992; Pigg et al. 1997), several species that were once widespread have declined in their distribution and abundance. Species such as the Arkansas River shiner *Notropis girardi* and the Topeka shiner *Notropis topeka* have beenreduced to critically low numbers and are presently listed as federally endangered species (Echelle et al. 1995; Pigg et al. 1999; Dodds et al. 2004). As more species in prairie rivers become imperiled, maintaining existing natural prairie streams and restoring impaired streams will become increasingly difficult (Dodds et al. 2004). It is, therefore, imperative to assess and monitor impacts of human disturbances on the fauna of prairie rivers in this region.

Rapid bioassessment protocols for sampling fishes vary widely among biomonitoring agencies throughout the U.S. depending on the physico-chemical conditions of theriver being sampled and the context in which the protocols are being employed. Standardized sampling protocols for fishes in the Ohio River are based solely on the use of electrofishing (OhioEPA 1989; Emery et al. 2003; Yoder and Kulik 2003), whereas standard operating procedures for sampling fishes in the Missouri River are based on the combined use of seining, gill netting, trammel netting, mini-fyke netting, benthic trawling, and electrofishing (USGS 1998). These studies illustrate that in most cases sampling methodologies are tailored for a specific area or species and are not necessarily applicable for areas outside their region. Perhaps the most widespread and well know rapid bioassessment protocols for sampling fishes were those developed by the U.S. EPA for use in wadeable (Barbour et al. 1999) and non-wadeable (Lazorchak et al. 2000) streams and rivers. Although these are widely applicable protocols, they rely solely on the use of electrofishing, which is not feasible in the highly conductive rivers of the southern Great Plains region.

Fish species in prairie rivers have been shown to be strongly associated with depth, current velocity, substrate type and the occurrence of in-stream structure and vegetation (O'Shea et al. 1990; Taylor et al. 1993; Ostrand and Wilde 2002). Because habitats act as filters determining the kind of fish that are present in a system (Poff 1997; Keddy and Weiher 1999) and are easily identified, it is appropriate to base fish sampling protocols on the occurrence of habitat types in a stream. We found distinct differences in fish species composition based on depth and flow in five large prairie rivers in Oklahoma. However, some of these differences may be an artifact of our sampling method. Nearly all SBW habitats were sampled using a seine and all DNW habitats were sampled using hoop nets. Seines and hoop nets each have their own sampling biases. Seines typically select for smaller bodied, slower moving fishes (Hayes et al. 1996; Bayley and Herendeen 2000), whereas hoop nets select for larger bodied, more elusive fishes (Holland and Peters 1992; Hubert 1996). Between these two methods, however, we are confident that all but the rarest fish species were detected in our samples based on historical collection records (Jester et al. 1992; Pigg et al. 1992; Miller and Robison 2004). For instance, a comparison of our fish collections with historical fish collections from the North Canadian (Pigg et al. 1992; Pigg et al. 1997) and Cimarron (Pigg 1988) rivers showed that our method of seining and hoop netting detected a majority (> 50%) of all the fish species collected at similar sites, and over 90% of the common species as described by Pigg et al. (1992).

Even though there are distinct physico-chemical differences among the rivers we sampled, there was no relationship between these properties and estimates of required sampling effort. We found that to capture a majority of species during a relatively rapid sampling event (24 hours) at a site on large prairie rivers in Oklahoma, we had to seine 6 to 10 ($\bar{x}$ = 8) SBW habitats and set hoop nets in 1 to 6 ($\bar{x}$ = 4) DNW habitats. We based our minimum sampling effort on the recommendation by Lyons (1992) that the most efficient sampling effort for estimating species richness is the point where the cumulative species richness first levels off. Because conclusions about community dynamics are reliant on a representative sample, a majority of the species should be accounted for in a sample reach. Lyons (1992) and Angermeier and Smogor (1995) suggest that number of fish species typically exhibits a cumulative pattern of diminishing increase with increasing effort and found that proportions of species increased asymptotically and became less variable with greater sampling effort.

Similarly, our estimates of sample size requirements (Table 5) showed that a larger number of samples are needed depending on the goals of the study. For research studies, it may be necessary to sample extensively in both shallow and deep water habitat to get within 10% of the true species richness at a site; however, fewer samples are needed for preliminary surveys (Robson and Regier 1964; Wilde and Fisher 1996) such as rapid bioassessment protocols (Barbour et al. 1999).

There was a strong positive relationship between river size (i.e., wetted width) and occurrence of BW habitat. Because of the hydrologic variability in prairie rivers, BW habitats form fairly quickly and tend to strand many different species in a relatively small area. Fish move into river margins (e.g., oxbows, isolated backwaters) during times of high flow and are often stranded as the water recedes (Starrett 1951). Althoughour analysis of species -habitat similarities did not differentiate fish assemblages in BW habitats from those inthe other shallow water habitats (SS and SF), collecting fish in these habitats increases sampling efficiency because they are easy to locate in the river channel, are typically easy to sample with a seine, and have a high speci es richness.

A common approach for determining the length of river to sample is to base distance on a multiple of the mean wetted width of the river section (Lyons 1992; Angermeier and Smoger 1995; Barbour et al. 1999). However, this approach will result in over-sampling in large prairie rivers because they typically have a wetted width > 100 m. Our method of determining sampling distance was based on the average occurrence of habitat in the river channel by interpreting habitat types on aerial photographs using GIS. More importantly, since aerial photos (e.g. DOQs) have become more readily accessible, this approach would allow someone to customize sampling distance based on occurrence of habitat at particular sample site of interest without being bound by a channel morphology relationship.

We found that large and small hoop nets differ in size of fish and number of species collected. Overall, small hoop nets collected more species and smaller sized fish. This is a problem only if the management objective requires a representative sample from all size classes. We recommend using a combination of large and small hoop nets to ensure that all size classes have an equal opportunity to be detected. Our findings corroborate those by Holland and Peters (1992) who investigated the difference in detectability and fish size among hoop nets of three mesh sizes in the lower Platte River. They found that smaller-mesh hoop nets (25 mm) detected 82% of the fish species compared to only 18% in the larger mesh hoop nets (32 mm and 38 mm). They also found that the larger-mesh hoop nets detected bigger fish on average (316 mm) than smaller mesh hoop nets (266 mm). Hoop nets also are effective for capturing species such as channel catfish (Vokoun and Rabeni 2001; Vokoun and Rabeni 2002) and paddlefish (Dieterman et al. 2000) in prairie rivers and are a useful tool for assessing population characteristics when different mesh sizes are used concurrently.

We were able to detect a majority of the fish species present in five large prairie rivers in Oklahoma with our sampling approach during a single sampling event. However, our sampling recommendations may not be suitable for all management objectives. Because of the high variability in catch at each sample site, we determined that an extensive amount of effort is needed to obtain a statistically valid estimate of fish species richness within 25% or 10% of the true species richness. Although our sampling protocol enabled us to detect the majority of fish species present at each site, caution must be taken to ensure that rare species are not missed. Rare species are critical to the bioassessment of aquatic systems and not detecting these species can negatively influence the ability of community-based metrics to detect ecological changes (Cao et al. 1998). Additional species will likely be added if sampling is conducted in other seasons. In addition, use of a Bayesian approach to detect unsampled species known to occur at a site (Bayley and Peterson 2001) could be used to improve our sampling protocol. This approach estimates species-specific detection probabilities based on previous knowledge of species occurrence at a sample site and the catchability of each species based on sampling method (e.g., seining). With only slight adjustments, however, we feel that our recommendations can be applied to large prairie rivers throughout the southern Great Plains, as well as similar rivers throughout the northern Great Plains, to aid in the rapid bioassessment, and monitoring of prairie river fish assemblages.

Acknowledgments

We are grateful to those who assisted in the field and laboratory work including Bullit Farris, Brian Collins, and Jill Sporrong. We would like to thank Joseph Bidwell and Anthony Echelle for helpful discussions and comments on the manuscript. Bob Drew, Jim Nolen, Neil Fobes, Redlands Community College, and the Dolese Brothers Sand and Gravel Company for river access. Funding for this project was provided by the Oklahoma Water Resources Board, Oklahoma Department of Wildlife Conservation through a Federal Aid in Sport Fish Restoration Grant (F-57-R), U. S. Geological Survey, and Oklahoma Cooperative Fish and Wildlife Research Unit. The Unit is jointly sponsored by the U. S. Geological Survey, Biological Resources Division; Oklahoma State University; the Oklahoma Department of Wildlife Conservation; and the Wildlife Management Institute.

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Table 1--Physical and chemical characteristics of 15 sites on five large non-wadeable rivers in central Oklahoma; averaged from long term USGS gaging station data. Standard Deviation is in parentheses. Site names were based on city names near the location where fish were collected.

River/Site	Site Abbr	USGS Gage ID	Contributing Drainage Area (km^2)	Discharge (m^3/s)	Specific Conductance (µS/cm)	Turbidity (JTU)
Arkansas R.						
Newkirk	NEW	07146500	113,216.2	69.6 (115.1)	1,652.0 (709.8)	87.0 (96.1)
Ralston	RAL	07152500	141,063.7	207.1 (349.1)	1,680.4 (877.2)	84.1 (132.0)
Coweta	COW	07165570	195,474.2	97.9 (90.8)	1,596.3 (565.6)	30.6 (45.7)
Cimarron R.						
Dover	DOV	07159100	40,696.5	24.6 (52.9)	13,102.7 (7102.6)	186.1 (611.5)
Guthrie	GUT	07160000	43,750.1	35.5 (57.3)	8,916.2 (4379.4)	103.3 (234.0)
Coyle	COY	07161000	46,236.5	46.5 (144.2)	7,695.6 (4818.1)	226.8 (521.0)
N. Canadian R.						
El Reno	ELR	07239500	33,778.6	10.5 (15.2)	1,145.5 (483.8)	15.6 (33.9)
Harrah	HAR	07241550	34,967.4	10.9 (17.0)	1,343.7 (502.6)	25.6 (35.8)
Wetumka	WET	07242000	37,010.9	19.2 (49.9)	3,307.9 (4923.1)	262.5 (718.3)
Washita R.						
Alex	ALE	07328100	12,398.3	12.0 (19.5)	1,220.5 (469.7)	13.7 (5.9)
Pauls Valley	PAU	07328500	13,804.6	30.2 (54.8)	1,320.0 (609.1)	41.2 (54.5)
Durwood	DUR	07331000	18,653.1	50.6 (108.9)	950.4 (391.0)	99.5 (134.7)
Red R.						
Waurika	WAU	07315500	74,392.2	65.3 (114.9)	4,123.9 (2077.1)	134.0 (282.5)
Thackerville	THA	07316000	79,725.0	78.2 (130.9)	3,580.7 (1679.3)	189.6 (392.5)
Arthur City	ART	07335500	115,334.8	163.5 (179.6)	1,229.4 (518.9)	35.6 (31.6)

Table 2--Description of the habitat types used when mapping the sample reach.

Habitat Type	Code	Depth (m)	Velocity (m/s)	Channel Location
Shallow Slow	SS	< 0.75	< 0.20	Typically found along the bank or around mid-channel islands.
Shallow Fast	SF	< 0.75	> 0.20	Typically found mid-channel away from obstructions.
Deep Slow	DS	0.76 – 1.50	< 0.20	Lateral pools typically surrounded by woody debris (or other structure).
Deep Fast	DF	0.76 – 1.50	> 0.20	Lateral or mid-channel pools typically free of obstructions.
Non-wadeable	NW	> 1.50	Any Velocity	Typically found in the thalweg and surrounded by very little structure.
Backwater	BW	Any Depth	< 0.01	Still water either mostly or totally separated from the main channel.

Table 3--Analysis of similarity of fish collections from six habitat types at 15 sites on five large prairie rivers in Oklahoma. Habitats sampled were: shallow fast (SF), shallow slow (SS), deep fast (DF), deep slow (DS), non-wadeable (NW), and backwater (BW). An R-statistic less than 0.5 indicates the two habitat types have a similar species composition and a significance level less than 5% ($P < 0.05$) indicates a significant comparison. Based on fish species composition, habitat groups are either well separated ($R > 0.75$), overlapping but clearly different ($R > 0.50$), or barely separable ($R < 0.25$).

Groups	R Statistic	Significance Level
SS, SF	0.026	0.039
DS, DF	0.080	0.060
DS, NW	0.087	0.095
DF, NW	0.118	0.054
SS, BW	0.174	0.001
SF, BW	0.283	0.001
BW, DS	0.706	0.001
BW, DF	0.709	0.001
SF, DS	0.736	0.001
SF, DF	0.745	0.001
BW, NW	0.757	0.001
SF, NW	0.782	0.001
SS, DS	0.798	0.001
SS, DF	0.801	0.001
SS, NW	0.831	0.001

Table 4--Results from species accumulation curves for shallow/backwater (SBW) and deep/non-wadeable (DNW) habitats from 15 sample sites located on five large prairie rivers in Oklahoma.

River/Site	Habitats Needed To Attain Maximum Species Richness								
	SBW				DNW				Grand Total
	SS	SF	BW	Total	DS	DF	NW	Total	
ARKANSAS R.									
NEW	1	4	2	7	2	0	1	3	10
RAL	3	2	1	6	0	1	0	1	7
COW	3	3	2	8	2	0	0	2	10
CIMARRON R.									
DOV	3	2	3	8	1	3	0	4	12
GUT	3	3	2	8	1	0	1	2	10
COY	2	3	3	8	2	2	2	6	14
N. CANADIAN R.									
ELR	3	1	2	6	2	1	0	3	9
HAR	3	3	2	8	2	3	0	5	13
WET	3	3	3	9	3	1	1	5	14
WASHITA R.									
ALE	2	2	2	6	2	1	1	4	10
PAU	3	2	3	8	2	2	0	4	12
DUR	4	1	4	9	1	1	3	5	14
RED R.									
WAU	4	3	3	10	0	2	0	2	12
THA	4	4	1	9	0	4	0	4	13
ART	3	3	3	9	1	0	1	2	11
Mean (±SD)	3 (0.8)	3 (0.9)	2 (0.8)	8 (1.2)	1 (0.9)	1 (1.2)	1 (0.9)	4 (1.5)	11 (2.1)

Table 5--Species-per-unit-effort (SPUE) for fish species collected in seines, and/or large and small hoop nets from 15 sample sites on five large prairie rivers in Oklahoma. SPUE estimates were used to predict the number of samples required to obtain species richness estimates within 10%, 25%, and 50% of the true population means ($P < 0.05$). N = number of samples collected, and SD = standard deviation.

Gear Type		SPUE		Samples required to detect difference of:		
	N	Mean	SD	10%	25%	50%
Seine	334	3.61	2.03	126	20	5
Small Hoop Net	79	1.16	1.04	322	51	13
Large Hoop Net	51	1.4	1.25	319	51	13

Table 6--Average wetted width and percentages of shallow water (SW), backwater (BW), and deep water (DW) habitat derived from historical digital orthophoto quad maps for 15 sample sites on five large prairie rivers in Oklahoma.

River/Site		Wetted Width (m)	Percentage of Habitat		
			SW	BW	DNW
Arkansas R.					
	NEW	134.7 (53.4)	48.3	10.0	41.7
	RAL	340.9 (91.2)	49.4	11.9	38.8
	COW	466.4 (109.3)	40.1	17.1	42.8
Cimarron R.					
	DOV	131.0 (66.5)	52.2	14.2	33.6
	GUT	131.3 (66.5)	40.1	17.1	42.8
	COY	127.3 (58.9)	47.9	10.1	42.0
N. Canadian R.					
	ELR	21.1 (4.6)	58.4	6.9	34.7
	HAR	29.2 (6.7)	41.8	4.6	53.6
	WET	66.7 (23.9)	28.0	8.7	63.3
Washita R.					
	ALE	44.0 (14.7)	47.0	7.5	45.5
	PAU	68.2 (18.5)	45.3	6.8	47.9
	DUR	74.1 (21.9)	46.4	7.5	46.1
Red R.					
	WAU	245.1 (129.0)	45.4	22.7	31.9
	THA	132.5 (27.0)	32.2	9.7	58.1
	ART	203.8 (46.3)	25.5	13.3	61.2
Mean (±SD)		147.8 (123.0)	43.2 (8.9)	11.2 (4.9)	45.6 (9.7)

Table 7--Minimum sampling distance needed at each site to encounter a minimum of eight shallow water (SW) habitats, or combination of eight SW and backwater (BW) habitats, and four deep water (DW) habitats. Based on data collected from 15 sample sites on five large prairie rivers in Oklahoma.

River/Site		Minimum Distance (m)	Number of Habitats Encountered		
			SW	BW	DW
ARKANSAS R.					
	NEW	700	6	3	9
	RAL	1000	15	5	6
	COW	500	5	4	5
CIMARRON R.					
	DOV	700	7	3	8
	GUT	700	10	0	10
	COY	700	6	3	11
N. CANADIAN R.					
	ELR	1600	14	1	5
	HAR	1500	9	0	17
	WET	1100	7	2	9
WASHITA R.					
	ALE	800	8	1	11
	PAU	600	6	3	7
	DUR	800	6	3	10
RED R.					
	WAU	400	5	6	5
	THA	1100	9	0	22
	ART	1100	7	3	15
Mean (±SD)		886.7 (344.1)	8.0 (3.0)	2.5 (1.8)	10.0 (4.8)

Table 8--Comparison oftotal number of fish caught in two gear types and two hoop net sizes. Based on data collected from 15 sample sites on five large prairie rivers in Oklahoma.

FAMILY/*Species*	Seine	Hoop Net	
		Large	Small
ATHERINOPSIDAE			
Menidia beryllina	1134	0	0
CATOSTOMIDAE			
Carpiodes carpio	335	19	16
Ictiobus bubalus	106	29	7
Ictiobus cyprinellus	8	1	0
Moxostoma erythrurum	1	0	0
Minytrema melanops	1	0	0
CENTRARCHIDAE			
Lepomis cyanellus	28	0	0
Lepomis gulosus	1	0	0
Lepomis humilis	6	0	1
Lepomis macrochirus	366	0	9
Lepomis megalotis	0	0	22
Micropterus punctulatus	20	1	0
Pomoxis annularis	23	0	2
CLUPEIDAE			
Dorosoma cepedianum	85	0	10
Dorosoma petenense	37	0	0
Hiodon alosoides	1	0	0
CYPRINIDAE			
Campostoma anomalum	2	0	0
Cyprinella lutrensis	28442	0	0
Cyprinus carpio	2	28	13
Hybognathus placitus	6002	0	0
Macrhybopsis australis	40	0	0
Macrhybopsis hyostoma	211	0	0
Notropis atherinoides	4126	0	0
Notropis bairdi	589	0	0
Notropis blennius	7	0	0
Notropis buchanani	54	0	0
Notropis stramineus	96	0	0
Phenacobius mirabilis	22	0	0
Pimephales vigilax	1686	0	0
CYPRINODONTIDAE			
Cyprinodon rubrofluviatilis	87	0	0
FUNDULIDAE			
Fundulus zebrinus	109	0	0
ICTALURIDAE			
Ictalurus furcatus	2	2	2
Ictalurus punctatus	23	13	63
Pylodictis olivaris	0	21	34
LEPISOSTEIDAE			
Lepisosteus oculatus	6	0	1
Lepisosteus osseus	11	15	2

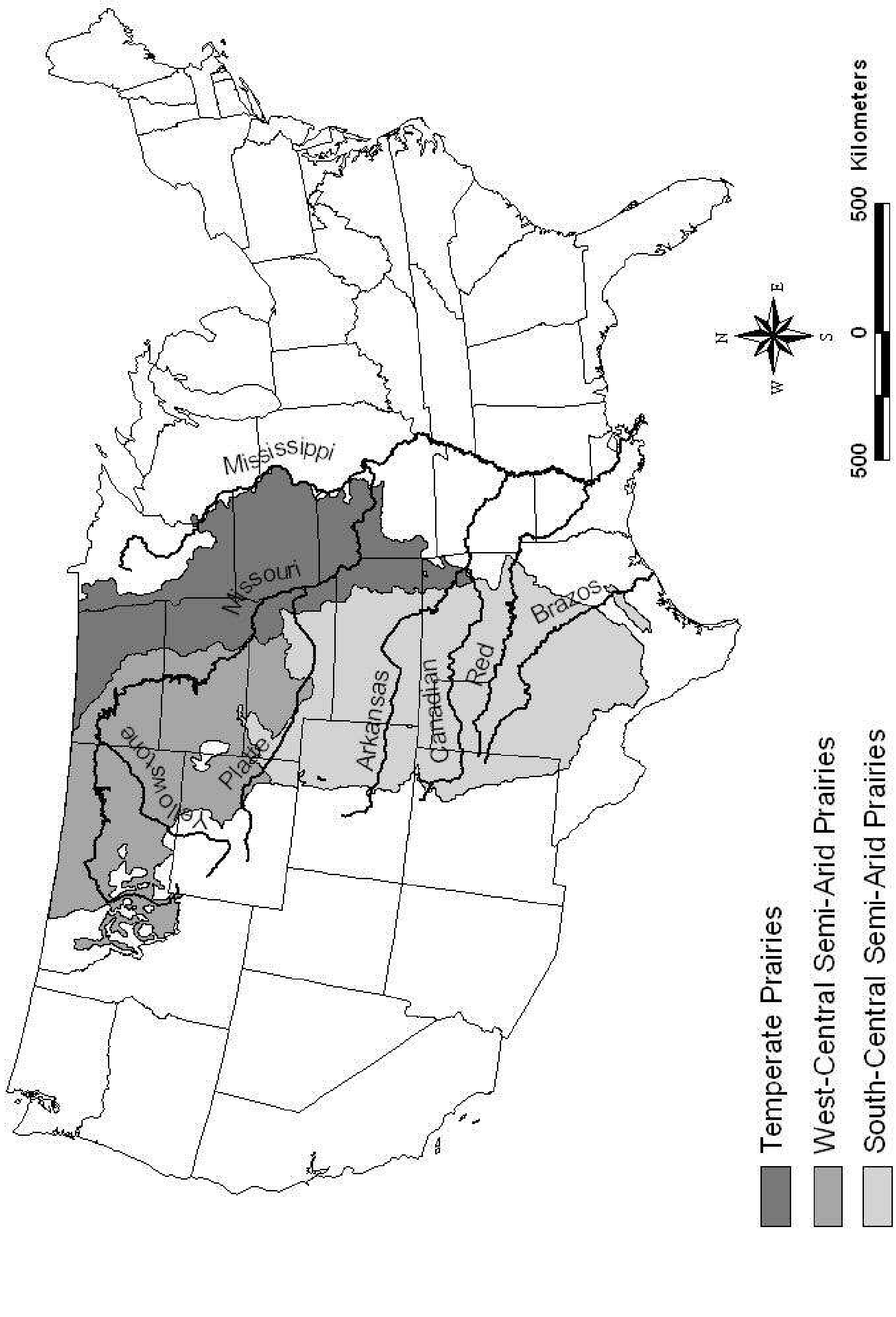
Lepisosteus platostomus	15	0	6
MORONIDAE			
Morone chrysops	4	1	6
Morone saxatilis	8	0	0
PERCIDAE			
Ammocrypta clara	1	0	0
Percina phoxocephala	2	0	0
Percina sciera	5	0	0
Percina shumardi	1	0	0
Sander vitreus	3	0	0
POECILIIDAE			
Gambusia affinis	3575	0	0
SCIAENIDAE			
Aplodinotus grunniens	8	6	12
Mean number of species (±SD)	3.6 (2.04)	1.4 (1.25)	1.2 (1.04)
Mean length (mm) (±SD)	42.4 (37.13)	527.2 (199.15)	357.3 (200.75)
Mean weight (g) (±SD)	3.7 (50.32)	1904.5 (1963.08)	718.9 (917.38)

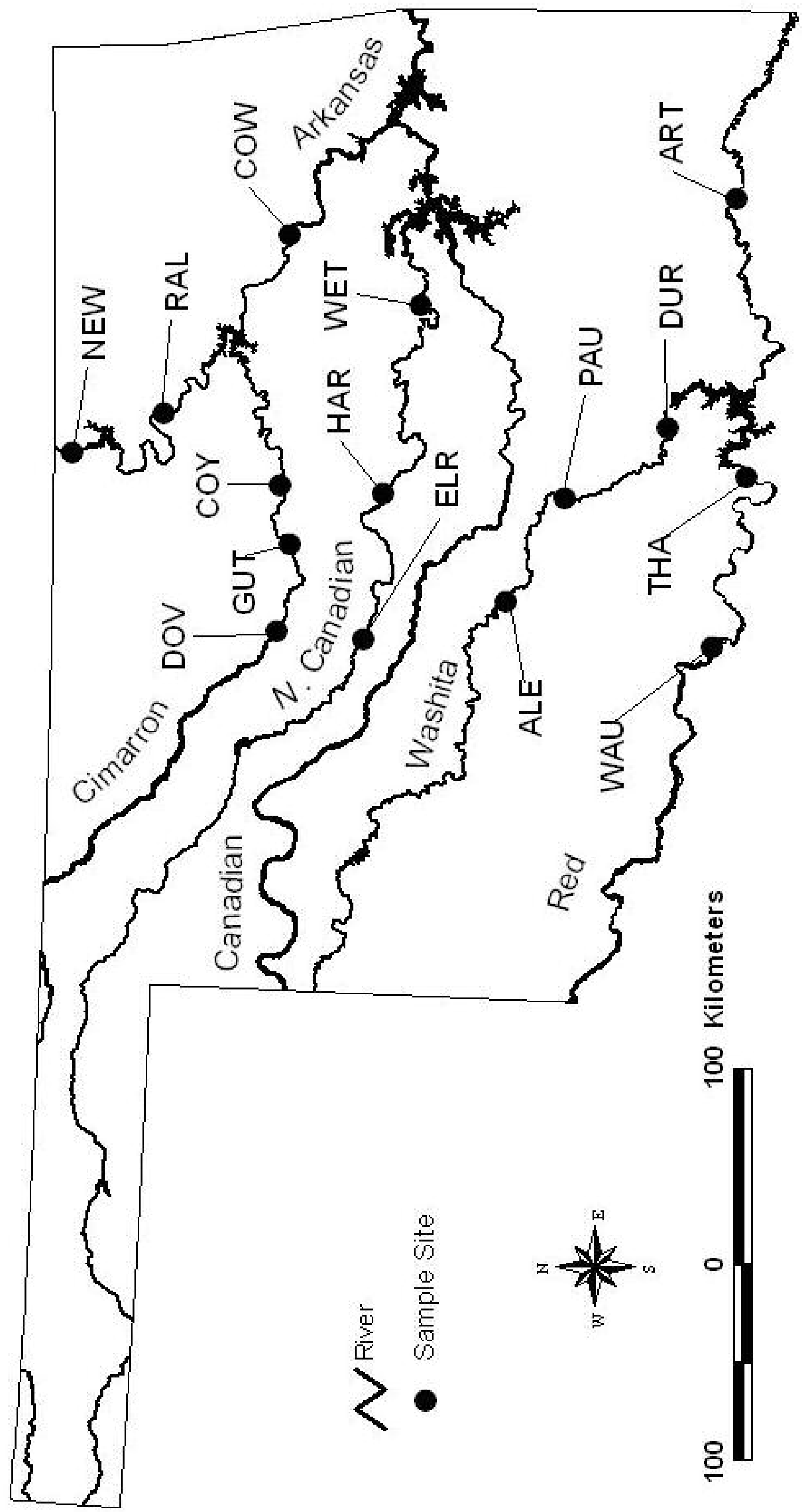
Figure 1: Relationship between large prairie rivers in the interior plains of the U.S. and Omernik's Level II ecoregions (Omernik 1987).

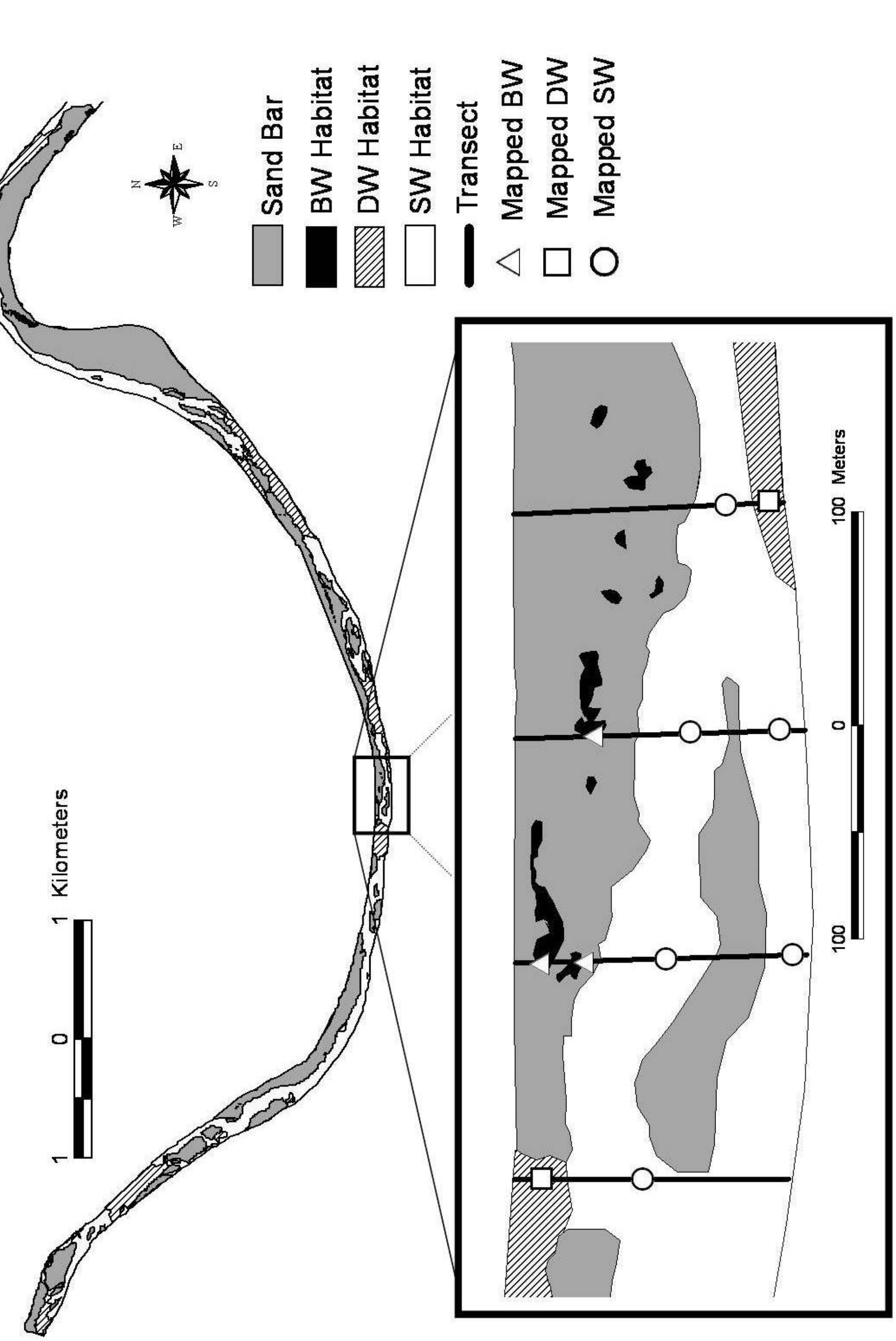
Figure 2: Map of sample sites (see Table 1 for site abbreviations).

Figure 3: A 10 km section of the Cimarron River near Coyle, Oklahoma. Habitat was delineated from digital orthophoto quad maps using ArcView GIS software. The 10 km section was divided into transects placed every 100 m and habitat was mapped and counted along each transect. This process was repeated for each sample site (see Figure 3) so average wetted width and percentages of shallow water (SW), backwater (BW), and deep water (DW) habitat could be calculated.

Figure 4: Flow chart depicting the multistage method for sampling fishes in large prairie river.


Mississippi
Missouri
Yellowstone
Platte
Arkansas
Canadian
Red
Brazos
N
E
S
W
500 0 500 Kilometers
Temperate Prairies
West-Central Semi-Arid Prairies
South-Central Semi-Arid Prairies


NEW
RAL
COW
Arkansas
WET
HAR
COY
GUT
DOV
ELR
PAU
DUR
ART
THA
ALE
WAU
Cimarron
N. Canadian
Canadian
Washita
Red
River
Sample Site
N
E
S
W
100
0
100 Kilometers



Sand Bar
BW Habitat
DW Habitat
SW Habitat
Transect
Mapped BW
Mapped DW
Mapped SW
N
E
S
W
1
0
1
Kilometers
100
0
100
Meters

SITE VERIFICATION

Prior to going into the field, verify site access and assess river and riparian features using Digital Orthophoto Quad (DOQ) maps.

Identify and map habitat types on DOQs to determine length of sample reach needed to encounter eight shallow water (SW) habitats and four deep water (DW) habitats.

Check physical and chemical attributes of the river from USGS gaging station data near the sample site to determine the appropriate protocol for sampling fishes.

⇩

SAMPLE SELECTION & ALLOCATION

Divide sample reach into transects spaced 100m apart.

Identify and number habitats encountered along each transect for the entire sample reach.

Randomly select eight SW habitats and include at least three backwaters when present.

Select four DW habitats from anywhere throughout the sample reach based on the presence of in-stream structure and vegetation.

⇩

FISH SAMPLING

SEINING	HOOP NETTING
Do two seine hauls in each selected SW habitat with each seine haul covering approximately 10 m.	Set one large mesh (50.8 mm) and one small mesh (25.4 mm) hoop net in each selected DW habitat.
Always seine with the current.	Place nets near in-stream structure and vegetation with the opening of the net facing or adjacent to the center point of the structure.
Try to seine near unique microhabitat and in-stream structure	Allow nets to fish for a minimum of 12 hours and a maximum of 24 hours and allow nets to fish overnight.

APPENDIXES

Appendix A--Total abundance of fish species collected in shallow slow (SS), shallow fast (SF), deep slow (DS), deep fast (DF), non-wadeable (NW), and backwater (BW) habitat at 15 sites on five large prairie rivers in Oklahoma.

River/Site	Species	SS	SF	DS	DF	NW	BW	Total
ARKANSAS RIVER								
NEW	*Carpiodes carpio*	0	0	1	0	0	0	1
	Cyprinella lutrensis	215	254	0	0	0	969	1438
	Cyprinus carpio	0	0	4	0	1	0	5
	Fundulus zebrinus	5	0	0	0	0	2	7
	Gambusia affinis	36	3	0	0	0	86	125
	Ictalurus punctatus	0	6	3	1	0	0	10
	Ictiobus bubalus	8	0	4	0	0	24	36
	Lepisosteus oculatus	0	1	0	0	0	0	1
	Lepisosteus osseus	0	0	12	0	0	0	12
	Lepisosteus platostomus	0	0	1	0	1	0	2
	Lepomis macrochirus	0	1	0	0	0	0	1
	Menidia beryllina	469	112	0	0	0	479	1060
	Micropterus puntulatus	0	0	0	0	0	1	1
	Minytrema melanops	0	1	0	0	0	0	1
	Morone chrysops	0	0	1	0	0	0	1
	Morone saxatilis	0	4	0	0	0	0	4
	Notropis atherinoides	34	144	0	0	0	740	918
	Notropis bairdi	2	0	0	0	0	0	2
	Notropis stramineus	0	0	0	0	0	7	7
	Percina phoxocephala	0	2	0	0	0	0	2
	Pimephales vigilax	13	21	0	0	0	33	67
	Polydictis olivaris	0	0	0	2	0	0	2
RAL	*Cyprinella lutrensis*	8	1	0	0	0	149	158
	Dorosoma cepedianum	0	0	0	0	0	6	6
	Gambusia affinis	2	0	0	0	0	1437	1439
	Ictalurus punctatus	0	1	0	0	0	0	1
	Ictiobus bubalus	0	0	0	1	0	0	1
	Lepomis cyanellus	0	0	0	0	0	16	16
	Lepomis macrochirus	0	0	0	0	0	349	349
	Macrhybopsis hyostoma	0	7	0	0	0	0	7
	Menidia beryllina	4	0	0	0	0	8	12
	Micropterus puntulatus	0	0	0	0	0	1	1
	Notropis atherinoides	506	284	0	0	0	59	849
	Phenacobius mirabilis	1	0	0	0	0	0	1
	Pimephales vigilax	0	0	0	0	0	13	13
COW	*Cyprinus carpio*	0	0	4	0	0	0	4
	Ictalurus punctatus	0	0	4	0	0	0	4
	Lepomis macrochirus	0	0	7	0	0	0	7
	Lepomis megalotis	0	0	2	0	0	0	2
	Menidia beryllina	24	1	0	0	0	15	40
	Notropis atherinoides	140	95	0	0	0	106	341
	Pimephales vigilax	8	1	0	0	0	47	56

Appendix--A (continued)

River/Site	Species	SS	SF	DS	DF	NW	BW	Total
	Carpiodes carpio	16	0	0	0	0	0	16
	Cyprinella lutrensis	883	171	0	0	0	551	1605
	Gambusia affinis	0	0	0	0	0	36	36
	Ictiobus bubalus	8	0	2	0	0	0	10
	Macrhybopsis hyostoma	83	97	0	0	0	0	180
	Micropterus puntulatus	0	0	1	0	0	0	1
	Morone saxatilis	1	0	0	0	0	0	1
	Percina shumardi	0	1	0	0	0	0	1
	Phenacobius mirabilis	8	3	0	0	0	0	11
CIMARRON RIVER								
DOV	*Aplodinotus grunniens*	0	0	1	1	0	0	2
	Carpiodes carpio	3	0	0	0	0	1	4
	Cyprinella lutrensis	6	16	0	0	0	129	151
	Cyprinodon rubrofluviatilis	0	0	0	0	0	8	8
	Dorosoma cepedianum	0	0	0	0	0	8	8
	Fundulus zebrinus	5	0	0	0	0	1	6
	Gambusia affinis	4	0	0	0	0	162	166
	Hybognathus placitus	12	15	0	0	0	0	27
	Ictalurus punctatus	0	0	0	1	0	0	1
	Lepomis cyanellus	0	0	0	0	0	2	2
	Micropterus puntulatus	0	0	0	0	0	12	12
	Notropis atherinoides	327	247	0	0	0	270	844
	Phenacobius mirabilis	1	0	0	0	0	0	1
	Polydictis olivaris	0	0	0	1	0	0	1
GUT	*Carpiodes carpio*	11	6	1	0	8	110	136
	Cyprinella lutrensis	45	10	0	0	0	16	71
	Cyprinodon rubrofluviatilis	0	0	0	0	0	8	8
	Cyprinus carpio	1	0	0	0	0	0	1
	Dorosoma cepedianum	2	0	0	0	0	0	2
	Fundulus zebrinus	0	0	0	0	0	3	3
	Gambusia affinis	2	0	0	0	0	40	42
	Hybognathus placitus	322	258	0	0	0	63	643
	Lepisosteus oculatus	0	0	0	0	0	5	5
	Lepomis humilis	1	0	0	0	0	0	1
	Morone chrysops	1	0	0	0	0	0	1
	Notropis atherinoides	77	59	0	0	0	28	164
	Pomoxis annularis	0	0	0	0	0	2	2
COY	*Aplodinotus grunniens*	0	0	3	2	0	0	5
	Cyprinus carpio	0	0	0	0	3	0	3
	Dorosoma cepedianum	0	0	0	0	0	26	26
	Fundulus zebrinus	0	1	0	0	0	80	81
	Hybognathus placitus	140	246	0	0	0	1078	1464
	Ictalurus punctatus	0	0	7	1	0	0	8
	Lepisosteus osseus	0	0	0	1	0	1	2
	Lepomis macrochirus	0	0	1	0	0	4	5
	Notropis atherinoides	284	173	0	0	0	27	484
	Pimephales vigilax	0	0	0	0	0	3	3
	Polydictis olivaris	0	0	1	1	2	0	4

Appendix--A (continued)

River/Site	Species	SS	SF	DS	DF	NW	BW	Total
	Carpiodes carpio	2	1	2	1	0	37	43
	Cyprinella lutrensis	2	36	0	0	0	5	43
	Cyprinodon rubrofluviatilis	0	0	0	0	0	2	2
	Gambusia affinis	0	0	0	0	0	98	98
	Ictiobus bubalus	0	0	0	0	3	0	3
	Macrhybopsis hyostoma	0	1	0	0	0	0	1
	Morone chrysops	0	0	0	4	0	0	4
	Notropis bairdi	60	45	0	0	0	48	153
N. Canadian River								
ELR	*Cyprinella lutrensis*	1691	971	0	0	0	11	2673
	Cyprinus carpio	0	0	1	0	0	0	1
	Fundulus zebrinus	2	5	0	0	0	0	7
	Gambusia affinis	0	0	0	0	0	4	4
	Ictalurus punctatus	0	0	3	16	0	0	19
	Lepomis cyanellus	1	0	0	0	0	1	2
	Lepomis humilis	0	0	0	0	0	2	2
	Lepomis megalotis	0	0	11	8	0	0	19
	Notropis bairdi	1	0	0	0	0	0	1
	Notropis blennius	0	0	0	0	0	1	1
	Notropis stramineus	36	35	0	0	0	0	71
	Phenacobius mirabilis	2	2	0	0	0	1	5
	Pimephales vigilax	9	1	0	0	0	10	20
	Polydictis olivaris	0	0	1	7	0	0	8
	Sander vitreus	0	0	0	0	0	3	3
HAR	*Carpiodes carpio*	0	0	2	6	0	0	8
	Cyprinella lutrensis	439	182	0	0	0	101	722
	Cyprinus carpio	0	0	1	6	0	1	8
	Dorosoma pretense	0	1	0	0	0	23	24
	Gambusia affinis	1	0	0	0	0	94	95
	Hybognathus placitus	0	0	0	0	0	3	3
	Ictalurus furcatus	0	0	0	1	0	0	1
	Ictalurus punctatus	0	0	3	1	0	0	4
	Ictiobus bubalus	0	1	3	9	0	0	13
	Ictiobus cyprinellus	0	0	0	0	0	5	5
	Lepisosteus osseus	0	0	1	0	0	0	1
	Lepisosteus platostomus	0	0	1	0	0	2	3
	Lepomis macrochirus	0	0	0	0	0	2	2
	Lepomis megalotis	0	0	1	0	0	0	1
	Morone chrysops	0	0	0	0	0	1	1
	Notropis buchanani	0	0	0	0	0	14	14
	Notropis stramineus	4	6	0	0	0	0	10
	Pimephales vigilax	2	15	0	0	0	36	53
	Polydictis olivaris	0	0	2	9	0	0	11
	Pomoxis annularis	0	0	0	0	0	4	4
WET	*Cyprinus carpio*	0	0	1	0	0	0	1
	Ictalurus punctatus	0	1	4	0	1	0	6
	Notropis atherinoides	1	3	0	0	0	1	5
	Pimephales vigilax	456	15	0	0	0	211	682

Appendix--A (continued)

River/Site	Species	SS	SF	DS	DF	NW	BW	Total
	Aplodinotus grunniens	4	0	0	0	0	1	5
	Carpiodes carpio	5	0	0	0	0	3	8
	Cyprinella lutrensis	3785	432	0	0	0	8618	12835
	Gambusia affinis	9	0	0	0	0	53	62
	Ictiobus bubalus	0	0	2	0	1	0	3
	Lepisosteus platostomus	0	0	1	0	0	0	1
	Lepomis cyanellus	0	0	0	0	0	1	1
	Lepomis humilis	2	0	0	0	0	1	3
	Polydictis olivaris	0	0	0	3	0	0	3
	Pomoxis annularis	1	0	1	0	0	5	7
WASHITA RIVER								
ALE	*Carpiodes carpio*	6	9	0	0	0	115	130
	Cyprinella lutrensis	1895	1217	0	0	0	720	3832
	Gambusia affinis	2	0	0	0	0	34	36
	Ictalurus furcatus	0	0	1	0	0	0	1
	Ictalurus punctatus	0	0	9	1	1	0	11
	Ictiobus bubalus	1	0	0	0	0	0	1
	Lepisosteus osseus	0	0	0	0	0	7	7
	Lepisosteus platostomus	0	0	0	0	0	1	1
	Lepomis humilis	0	0	0	0	1	0	1
	Macrhybopsis hyostoma	0	2	0	0	0	0	2
	Notropis stramineus	5	1	0	0	0	0	6
	Pimephales vigilax	234	26	0	0	0	27	287
	Polydictis olivaris	0	0	1	0	0	0	1
PAU	*Carpiodes carpio*	4	0	0	2	0	0	6
	Cyprinella lutrensis	1677	530	0	0	0	1197	3404
	Fundulus zebrinus	0	0	0	0	0	1	1
	Gambusia affinis	0	0	0	0	0	116	116
	Ictalurus furcatus	0	0	1	1	0	0	2
	Ictalurus punctatus	2	3	6	5	0	2	18
	Ictiobus bubalus	11	0	1	1	0	25	38
	Lepisosteus osseus	0	0	0	2	0	0	2
	Lepisosteus platostomus	0	0	0	0	0	1	1
	Lepomis cyanellus	1	0	0	0	0	4	5
	Macrhybopsis hyostoma	0	2	0	0	0	0	2
	Notropis stramineus	1	1	0	0	0	0	2
	Percina sciera	2	0	0	0	0	0	2
	Pimephales vigilax	248	7	0	0	0	127	382
	Polydictis olivaris	0	0	1	5	0	0	6
DUR	*Aplodinotus grunniens*	2	0	0	0	0	0	2
	Campostoma anomalum	2	0	0	0	0	0	2
	Cyprinus carpio	0	0	0	1	1	0	2
	Ictalurus punctatus	0	0	1	0	1	5	7
	Ictiobus cyprinellus	1	0	0	0	1	2	4
	Notropis buchanani	1	0	0	0	0	0	1
	Percina sciera	3	0	0	0	0	0	3
	Pimephales vigilax	56	0	0	0	0	22	78
	Polydictis olivaris	0	0	0	0	1	1	2

Appendix--A (continued)

River/Site	Species	SS	SF	DS	DF	NW	BW	Total
	Cyprinella lutrensis	366	25	0	0	0	252	643
	Dorosoma cepedianum	2	0	0	0	0	0	2
	Gambusia affinis	9	0	0	0	0	347	356
	Hiodon alosoides	0	0	0	0	0	1	1
	Ictiobus bubalus	17	0	2	0	1	9	29
	Lepisosteus platostomus	0	0	0	0	0	8	8
	Macrhybopsis hyostoma	1	0	0	0	0	0	1
	Menidia beryllina	7	0	0	0	0	0	7
	Micropterus puntulatus	3	0	0	0	0	2	5
	Morone saxatilis	3	0	0	0	0	0	3
	Moxostoma erythrurum	1	0	0	0	0	0	1
RED RIVER								
WAU	*Aplodinotus grunniens*	0	0	0	1	0	1	2
	Cyprinella lutrensis	88	280	0	0	0	81	449
	Cyprinodon rubrofluviatilis	0	0	0	0	0	17	17
	Cyprinus carpio	0	0	0	1	0	0	1
	Dorosoma cepedianum	0	0	0	0	0	2	2
	Fundulus zebrinus	2	0	0	0	0	0	2
	Gambusia affinis	3	2	0	0	0	150	155
	Hybognathus placitus	48	229	0	0	0	2788	3065
	Ictalurus punctatus	0	0	0	1	0	0	1
	Ictiobus bubalus	1	0	0	1	0	0	2
	Lepisosteus osseus	0	0	0	0	0	1	1
	Lepisosteus platostomus	0	2	0	0	0	0	2
	Lepomis gulosus	0	0	0	0	0	1	1
	Macrhybopsis australis	9	24	0	0	0	3	36
	Macrhybopsis hyostoma	5	5	0	0	0	0	10
	Menidia beryllina	1	1	0	0	0	3	5
	Morone chrysops	0	0	0	0	0	2	2
	Notropis atherinoides	13	43	0	0	0	6	62
	Notropis bairdi	13	27	0	0	0	26	66
	Notropis buchanani	0	3	0	0	0	17	20
	Pimephales vigilax	1	2	0	0	0	30	33
	Polydictis olivaris	0	0	0	3	0	0	3
	Pomoxis annularis	0	0	0	0	0	4	4
THA	*Aplodinotus grunniens*	0	0	0	1	0	0	1
	Cyprinus carpio	0	0	0	1	0	0	1
	Dorosoma cepedianum	2	2	0	0	0	0	4
	Hybognathus placitus	136	11	0	0	0	0	147
	Ictalurus punctatus	0	1	0	1	0	0	2
	Lepomis cyanellus	0	1	0	0	0	0	1
	Macrhybopsis australis	2	2	0	0	0	0	4
	Menidia beryllina	2	0	0	0	0	0	2
	Notropis atherinoides	127	37	0	0	0	0	164
	Pimephales vigilax	1	0	0	0	0	1	2
	Polydictis olivaris	0	0	0	8	0	0	8

Appendix--A (continued)

River/Site	Species	SS	SF	DS	DF	NW	BW	Total
	Cyprinella lutrensis	158	11	0	0	0	0	169
	Dorosoma pretense	13	0	0	0	0	0	13
	Gambusia affinis	112	1	0	0	0	4	117
	Ictiobus bubalus	0	0	0	1	0	0	1
	Lepisosteus platostomus	0	1	0	1	0	0	2
	Macrhybopsis hyostoma	0	6	0	0	0	0	6
	Notropis bairdi	17	1	0	0	0	0	18
	Notropis blennius	3	0	0	0	0	0	3
	Pomoxis annularis	1	0	0	0	0	1	2
ART	*Ammocrypta clara*	0	1	0	0	0	0	1
	Aplodinotus grunniens	0	0	0	0	1	1	2
	Carpiodes carpio	0	1	1	0	2	0	4
	Cyprinella lutrensis	113	65	0	0	0	53	231
	Cyprinodon rubrofluviatilis	0	2	0	0	0	0	2
	Dorosoma cepedianum	17	9	0	0	0	5	31
	Hybognathus placitus	0	6	0	0	0	0	6
	Ictalurus furcatus	0	2	0	0	0	0	2
	Ictalurus punctatus	1	1	0	0	0	0	2
	Ictiobus bubalus	0	1	1	0	0	2	4
	Lepisosteus osseus	0	0	0	0	1	2	3
	Lepisosteus platostomus	1	0	0	0	0	0	1
	Lepomis cyanellus	1	0	0	0	0	0	1
	Macrhybopsis hyostoma	0	2	0	0	0	0	2
	Menidia beryllina	3	4	0	0	0	1	8
	Micropterus puntulatus	1	0	0	0	0	0	1
	Notropis atherinoides	62	48	0	0	0	10	120
	Notropis bairdi	1	0	0	0	0	1	2
	Notropis blennius	0	3	0	0	0	0	3
	Notropis buchanani	11	8	0	0	0	0	19
	Pimephales vigilax	6	4	0	0	0	0	10
	Polydictis olivaris	0	0	0	0	2	0	2
	Pomoxis annularis	5	0	0	0	0	0	5
Total		15776	6667	126	121	33	22863	45586

Appendix B--Abundance and catch-per-unit-effort (CPUE) of fish species collected by seining and hoop netting at 15 sample sites on five large prairie rivers in Oklahoma. ND = no data.

River/Site	Species	Seine		Hoop Net				Total Abundance	Total CPUE
				Large		Small			
		Abundance	CPUE	Abundance	CPUE	Abundance	CPUE		
ARKANSAS RIVER									
NEW	*Carpiodes carpio*	0	0.000	0	0.000	1	0.200	1	0.200
	Cyprinella lutrensis	1438	65.364	0	0.000	0	0.000	1438	65.364
	Cyprinus carpio	0	0.000	3	0.600	2	0.400	5	1.000
	Fundulus zebrinus	7	0.318	0	0.000	0	0.000	7	0.318
	Gambusia affinis	125	5.682	0	0.000	0	0.000	125	5.682
	Ictalurus punctatus	6	0.273	1	0.200	3	0.600	10	1.073
	Ictiobus bubalus	32	1.455	1	0.200	3	0.600	36	2.255
	Lepisosteus oculatus	1	0.045	0	0.000	0	0.000	1	0.045
	Lepisosteus osseus	0	0.000	12	2.400	0	0.000	12	2.400
	Lepisosteus platostomus	0	0.000	0	0.000	2	0.400	2	0.400
	Lepomis macrochirus	1	0.045	0	0.000	0	0.000	1	0.045
	Menidia beryllina	1060	48.182	0	0.000	0	0.000	1060	48.182
	Micropterus puntulatus	1	0.045	0	0.000	0	0.000	1	0.045
	Minytrema melanops	1	0.045	0	0.000	0	0.000	1	0.045
	Morone chrysops	0	0.000	1	0.200	0	0.000	1	0.200
	Morone saxatilis	4	0.182	0	0.000	0	0.000	4	0.182
	Notropis atherinoides	918	41.727	0	0.000	0	0.000	918	41.727
	Notropis bairdi	2	0.091	0	0.000	0	0.000	2	0.091
	Notropis stramineus	7	0.318	0	0.000	0	0.000	7	0.318
	Percina phoxocephala	2	0.091	0	0.000	0	0.000	2	0.091
	Pimephales vigilax	67	3.045	0	0.000	0	0.000	67	3.045
	Polydictis olivaris	0	0.000	1	0.200	1	0.200	2	0.400

Appendix B--(continued)

River/Site	Species	Seine		Hoop Net				Total Abundance	Total CPUE
				Large		Small			
		Abundance	CPUE	Abundance	CPUE	Abundance	CPUE		
RAL	*Cyprinella lutrensis*	158	7.182	0	0.000	0	0.000	158	7.182
	Dorosoma cepedianum	6	0.273	0	0.000	0	0.000	6	0.273
	Gambusia affinis	1439	65.409	0	0.000	0	0.000	1439	65.409
	Ictalurus punctatus	1	0.045	0	0.000	0	0.000	1	0.045
	Ictiobus bubalus	0	0.000	1	0.250	0	0.000	1	0.250
	Lepomis cyanellus	16	0.727	0	0.000	0	0.000	16	0.727
	Lepomis macrochirus	349	15.864	0	0.000	0	0.000	349	15.864
	Macrhybopsis hyostoma	7	0.318	0	0.000	0	0.000	7	0.318
	Menidia beryllina	12	0.545	0	0.000	0	0.000	12	0.545
	Micropterus puntulatus	1	0.045	0	0.000	0	0.000	1	0.045
	Notropis atherinoides	849	38.591	0	0.000	0	0.000	849	38.591
	Phenacobius mirabilis	1	0.045	0	0.000	0	0.000	1	0.045
	Pimephales vigilax	13	0.591	0	0.000	0	0.000	13	0.591
COW	*Carpiodes carpio*	16	0.800	0	0.000	0	0.000	16	0.800
	Cyprinella lutrensis	1605	80.250	0	0.000	0	0.000	1605	80.250
	Cyprinus carpio	0	0.000	1	0.200	3	0.600	4	0.800
	Gambusia affinis	36	1.800	0	0.000	0	0.000	36	1.800
	Ictalurus punctatus	0	0.000	2	0.400	2	0.400	4	0.800
	Ictiobus bubalus	8	0.400	2	0.400	0	0.000	10	0.800
	Lepomis macrochirus	0	0.000	0	0.000	7	1.400	7	1.400
	Lepomis megalotis	0	0.000	0	0.000	2	0.400	2	0.400
	Macrhybopsis hyostoma	180	9.000	0	0.000	0	0.000	180	9.000
	Menidia beryllina	40	2.000	0	0.000	0	0.000	40	2.000
	Micropterus puntulatus	0	0.000	1	0.200	0	0.000	1	0.200
	Morone saxatilis	1	0.050	0	0.000	0	0.000	1	0.050
	Notropis atherinoides	341	17.050	0	0.000	0	0.000	341	17.050

Appendix B--(continued)

River/Site	Species	Seine		Hoop Net				Total Abundance	Total CPUE
				Large		Small			
		Abundance	CPUE	Abundance	CPUE	Abundance	CPUE		
	Percina shumardi	1	0.050	0	0.000	0	0.000	1	0.050
	Phenacobius mirabilis	11	0.550	0	0.000	0	0.000	11	0.550
	Pimephales vigilax	56	2.800	0	0.000	0	0.000	56	2.800
Cimarron R.									
DOV	*Aplodinotus grunniens*	0	0.000	ND	ND	2	0.333	2	0.333
	Carpiodes carpio	4	0.235	ND	ND	0	0.000	4	0.235
	Cyprinella lutrensis	151	8.882	ND	ND	0	0.000	151	8.882
	C. rubrofluviatilis	8	0.471	ND	ND	0	0.000	8	0.471
	Dorosoma cepedianum	8	0.471	ND	ND	0	0.000	8	0.471
	Fundulus zebrinus	6	0.353	ND	ND	0	0.000	6	0.353
	Gambusia affinis	166	9.765	ND	ND	0	0.000	166	9.765
	Hybognathus placitus	27	1.588	ND	ND	0	0.000	27	1.588
	Ictalurus punctatus	0	0.000	ND	ND	1	0.167	1	0.167
	Lepomis cyanellus	2	0.118	ND	ND	0	0.000	2	0.118
	Micropterus puntulatus	12	0.706	ND	ND	0	0.000	12	0.706
	Notropis atherinoides	844	49.647	ND	ND	0	0.000	844	49.647
	Phenacobius mirabilis	1	0.059	ND	ND	0	0.000	1	0.059
	Polydictis olivaris	0	0.000	ND	ND	1	0.167	1	0.167
GUT	*Carpiodes carpio*	127	6.048	ND	ND	9	1.800	136	7.848
	Cyprinella lutrensis	71	3.381	ND	ND	0	0.000	71	3.381
	C. rubrofluviatilis	8	0.381	ND	ND	0	0.000	8	0.381
	Cyprinus carpio	1	0.048	ND	ND	0	0.000	1	0.048
	Dorosoma cepedianum	2	0.095	ND	ND	0	0.000	2	0.095
	Fundulus zebrinus	3	0.143	ND	ND	0	0.000	3	0.143
	Gambusia affinis	42	2.000	ND	ND	0	0.000	42	2.000
	Hybognathus placitus	643	30.619	ND	ND	0	0.000	643	30.619

Appendix B--(continued)

River/Site	Species	Seine		Hoop Net				Total Abundance	Total CPUE
				Large		Small			
		Abundance	CPUE	Abundance	CPUE	Abundance	CPUE		
	Lepisosteus oculatus	5	0.238	ND	ND	0	0.000	5	0.238
	Lepomis humilis	1	0.048	ND	ND	0	0.000	1	0.048
	Morone chrysops	1	0.048	ND	ND	0	0.000	1	0.048
	Notropis atherinoides	164	7.810	ND	ND	0	0.000	164	7.810
	Pomoxis annularis	2	0.095	ND	ND	0	0.000	2	0.095
COY	*Aplodinotus grunniens*	0	0.000	3	0.500	2	0.333	5	0.833
	Carpiodes carpio	40	1.739	2	0.333	1	0.167	43	2.239
	Cyprinella lutrensis	43	1.870	0	0.000	0	0.000	43	1.870
	C. rubrofluviatilis	2	0.087	0	0.000	0	0.000	2	0.087
	Cyprinus carpio	0	0.000	3	0.500	0	0.000	3	0.500
	Dorosoma cepedianum	26	1.130	0	0.000	0	0.000	26	1.130
	Fundulus zebrinus	81	3.522	0	0.000	0	0.000	81	3.522
	Gambusia affinis	98	4.261	0	0.000	0	0.000	98	4.261
	Hybognathus placitus	1464	63.652	0	0.000	0	0.000	1464	63.652
	Macrhybopsis hyostoma	1	0.043	0	0.000	0	0.000	1	0.043
	Ictalurus punctatus	0	0.000	0	0.000	8	1.333	8	1.333
	Ictiobus bubalus	0	0.000	3	0.500	0	0.000	3	0.500
	Lepisosteus osseus	1	0.043	1	0.167	0	0.000	2	0.210
	Lepomis macrochirus	4	0.174	0	0.000	1	0.167	5	0.341
	Morone chrysops	0	0.000	0	0.000	4	0.667	4	0.667
	Notropis atherinoides	484	21.043	0	0.000	0	0.000	484	21.043
	Notropis bairdi	153	6.652	0	0.000	0	0.000	153	6.652
	Pimephales vigilax	3	0.130	0	0.000	0	0.000	3	0.130
	Polydictis olivaris	0	0.000	1	0.167	3	0.500	4	0.667
N. CANADIAN RIVER									
ELR	*Cyprinella lutrensis*	2673	121.500	ND	ND	0	0.000	2673	121.500
	Cyprinus carpio	0	0.000	ND	ND	1	0.167	1	0.167
	Fundulus zebrinus	7	0.318	ND	ND	0	0.000	7	0.318

Appendix B--(continued)

River/Site	Species	Seine		Hoop Net				Total Abundance	Total CPUE
				Large		Small			
		Abundance	CPUE	Abundance	CPUE	Abundance	CPUE		
	Gambusia affinis	4	0.182	ND	ND	0	0.000	4	0.182
	Ictalurus punctatus	0	0.000	ND	ND	19	3.167	19	3.167
	Lepomis cyanellus	2	0.091	ND	ND	0	0.000	2	0.091
	Lepomis humilis	2	0.091	ND	ND	0	0.000	2	0.091
	Lepomis megalotis	0	0.000	ND	ND	19	3.167	19	3.167
	Notropis bairdi	1	0.045	ND	ND	0	0.000	1	0.045
	Notropis blennius	1	0.045	ND	ND	0	0.000	1	0.045
	Notropis stramineus	71	3.227	ND	ND	0	0.000	71	3.227
	Phenacobius mirabilis	5	0.227	ND	ND	0	0.000	5	0.227
	Pimephales vigilax	20	0.909	ND	ND	0	0.000	20	0.909
	Polydictis olivaris	0	0.000	ND	ND	8	1.333	8	1.333
	Sander vitreus	3	0.136	ND	ND	0	0.000	3	0.136
HAR	*Carpiodes carpio*	0	0.000	8	1.600	0	0.000	8	1.600
	Cyprinella lutrensis	722	36.100	0	0.000	0	0.000	722	36.100
	Cyprinus carpio	1	0.050	7	1.400	0	0.000	8	1.450
	Dorosoma pretense	24	1.200	0	0.000	0	0.000	24	1.200
	Gambusia affinis	95	4.750	0	0.000	0	0.000	95	4.750
	Hybognathus placitus	3	0.150	0	0.000	0	0.000	3	0.150
	Ictalurus furcatus	0	0.000	1	0.200	0	0.000	1	0.200
	Ictalurus punctatus	0	0.000	3	0.600	1	0.167	4	0.767
	Ictiobus bubalus	1	0.050	11	2.200	1	0.167	13	2.417
	Ictiobus cyprinellus	5	0.250	0	0.000	0	0.000	5	0.250
	Lepisosteus osseus	0	0.000	0	0.000	1	0.167	1	0.167
	L. platostomus	2	0.100	0	0.000	1	0.167	3	0.267
	Lepomis macrochirus	2	0.100	0	0.000	0	0.000	2	0.100
	Lepomis megalotis	0	0.000	0	0.000	1	0.167	1	0.167
	Morone chrysops	1	0.050	0	0.000	0	0.000	1	0.050
	Notropis buchanani	14	0.700	0	0.000	0	0.000	14	0.700
	Notropis stramineus	10	0.500	0	0.000	0	0.000	10	0.500

Appendix B--(continued)

River/Site	Species	Seine		Hoop Net Large		Hoop Net Small		Total Abundance	Total CPUE
		Abundance	CPUE	Abundance	CPUE	Abundance	CPUE		
	Pimephales vigilax	53	2.650	0	0.000	0	0.000	53	2.650
	Polydictis olivaris	0	0.000	9	1.800	2	0.333	11	2.133
	Pomoxis annularis	4	0.200	0	0.000	0	0.000	4	0.200
WET	*Aplodinotus grunniens*	5	0.238	0	0.000	0	0.000	5	0.238
	Carpiodes carpio	8	0.381	0	0.000	0	0.000	8	0.381
	Cyprinella lutrensis	12835	611.190	0	0.000	0	0.000	12835	611.190
	Cyprinus carpio	0	0.000	0	0.000	1	0.167	1	0.167
	Gambusia affinis	62	2.952	0	0.000	0	0.000	62	2.952
	Ictalurus punctatus	1	0.048	1	0.250	4	0.667	6	0.964
	Ictiobus bubalus	0	0.000	2	0.500	1	0.167	3	0.667
	L. platostomus	0	0.000	0	0.000	1	0.167	1	0.167
	Lepomis cyanellus	1	0.048	0	0.000	0	0.000	1	0.048
	Lepomis humilis	3	0.143	0	0.000	0	0.000	3	0.143
	Notropis atherinoides	5	0.238	0	0.000	0	0.000	5	0.238
	Pimephales vigilax	682	32.476	0	0.000	0	0.000	682	32.476
	Polydictis olivaris	0	0.000	0	0.000	3	0.500	3	0.500
	Pomoxis annularis	6	0.286	0	0.000	1	0.167	7	0.452
WASHITA RIVER									
ALE	*Carpiodes carpio*	130	5.909	ND	ND	0	0.000	130	5.909
	Cyprinella lutrensis	3832	174.182	ND	ND	0	0.000	3832	174.182
	Gambusia affinis	36	1.636	ND	ND	0	0.000	36	1.636
	Ictalurus furcatus	0	0.000	ND	ND	1	0.167	1	0.167
	Ictalurus punctatus	0	0.000	ND	ND	11	1.833	11	1.833
	Ictiobus bubalus	1	0.045	ND	ND	0	0.000	1	0.045
	Lepisosteus osseus	7	0.318	ND	ND	0	0.000	7	0.318
	L. platostomus	1	0.045	ND	ND	0	0.000	1	0.045
	Lepomis humilis	0	0.000	ND	ND	1	0.167	1	0.167
	Macrhybopsis hyostoma	2	0.091	ND	ND	0	0.000	2	0.091
	Notropis stramineus	6	0.273	ND	ND	0	0.000	6	0.273

Appendix B--(continued)

River/Site	Species	Seine		Hoop Net				Total Abundance	Total CPUE
				Large		Small			
		Abundance	CPUE	Abundance	CPUE	Abundance	CPUE		
	Lepomis humilis	0	0.000	ND	ND	1	0.167	1	0.167
	Macrhybopsis hyostoma	2	0.091	ND	ND	0	0.000	2	0.091
	Notropis stramineus	6	0.273	ND	ND	0	0.000	6	0.273
	Pimephales vigilax	287	13.045	ND	ND	0	0.000	287	13.045
	Polydictis olivaris	0	0.000	ND	ND	1	0.167	1	0.167
PAU	*Carpiodes carpio*	4	0.190	2	0.400	0	0.000	6	0.590
	Cyprinella lutrensis	3404	162.095	0	0.000	0	0.000	3404	162.095
	Fundulus zebrinus	1	0.048	0	0.000	0	0.000	1	0.048
	Gambusia affinis	116	5.524	0	0.000	0	0.000	116	5.524
	Ictalurus furcatus	0	0.000	1	0.200	1	0.200	2	0.400
	Ictalurus punctatus	7	0.333	4	0.800	7	1.400	18	2.533
	Ictiobus bubalus	36	1.714	1	0.200	1	0.200	38	2.114
	Lepisosteus osseus	0	0.000	2	0.400	0	0.000	2	0.400
	L. platostomus	1	0.048	0	0.000	0	0.000	1	0.048
	Lepomis cyanellus	5	0.238	0	0.000	0	0.000	5	0.238
	Macrhybopsis hyostoma	2	0.095	0	0.000	0	0.000	2	0.095
	Notropis stramineus	2	0.095	0	0.000	0	0.000	2	0.095
	Percina sciera	2	0.095	0	0.000	0	0.000	2	0.095
	Pimephales vigilax	382	18.190	0	0.000	0	0.000	382	18.190
	Polydictis olivaris	0	0.000	4	0.800	2	0.400	6	1.200
DUR	*Aplodinotus grunniens*	2	0.100	0	0.000	0	0.000	2	0.100
	C. anomalum	2	0.100	0	0.000	0	0.000	2	0.100
	Cyprinella lutrensis	643	32.150	0	0.000	0	0.000	643	32.150
	Cyprinus carpio	0	0.000	2	0.333	0	0.000	2	0.333
	Dorosoma cepedianum	2	0.100	0	0.000	0	0.000	2	0.100
	Gambusia affinis	356	17.800	0	0.000	0	0.000	356	17.800
	Hiodon alosoides	1	0.050	0	0.000	0	0.000	1	0.050
	Ictalurus punctatus	5	0.250	0	0.000	2	0.400	7	0.650
	Ictiobus bubalus	26	1.300	3	0.500	0	0.000	29	1.800

Appendix B--(continued)

River/Site	Species	Seine		Hoop Net				Total Abundance	Total CPUE
				Large		Small			
		Abundance	CPUE	Abundance	CPUE	Abundance	CPUE		
	Ictiobus cyprinellus	3	0.150	1	0.167	0	0.000	4	0.317
	L. platostomus	8	0.400	0	0.000	0	0.000	8	0.400
	Macrhybopsis hyostoma	1	0.050	0	0.000	0	0.000	1	0.050
	Menidia beryllina	7	0.350	0	0.000	0	0.000	7	0.350
	Micropterus puntulatus	5	0.250	0	0.000	0	0.000	5	0.250
	Morone saxatilis	3	0.150	0	0.000	0	0.000	3	0.150
	Moxostoma erythrurum	1	0.050	0	0.000	0	0.000	1	0.050
	Notropis buchanani	1	0.050	0	0.000	0	0.000	1	0.050
	Percina sciera	3	0.150	0	0.000	0	0.000	3	0.150
	Pimephales vigilax	78	3.900	0	0.000	0	0.000	78	3.900
	Polydictis olivaris	0	0.000	0	0.000	2	0.400	2	0.400
RED RIVER									
WAU	*Aplodinotus grunniens*	1	0.040	1	0.333	0	0.000	2	0.373
	Cyprinella lutrensis	449	17.960	0	0.000	0	0.000	449	17.960
	C. rubrofluviatilis	17	0.680	0	0.000	0	0.000	17	0.680
	Cyprinus carpio	0	0.000	0	0.000	1	0.250	1	0.250
	Dorosoma cepedianum	2	0.080	0	0.000	0	0.000	2	0.080
	Fundulus zebrinus	2	0.080	0	0.000	0	0.000	2	0.080
	Gambusia affinis	155	6.200	0	0.000	0	0.000	155	6.200
	Hybognathus placitus	3065	122.600	0	0.000	0	0.000	3065	122.600
	Ictalurus punctatus	0	0.000	0	0.000	1	0.250	1	0.250
	Ictiobus bubalus	1	0.040	1	0.333	0	0.000	2	0.373
	Lepisosteus osseus	1	0.040	0	0.000	0	0.000	1	0.040
	L. platostomus	1	0.040	0	0.000	1	0.250	2	0.290
	Lepomis gulosus	1	0.040	0	0.000	0	0.000	1	0.040
	Macrhybopsis australis	36	1.440	0	0.000	0	0.000	36	1.440
	Macrhybopsis hyostoma	10	0.400	0	0.000	0	0.000	10	0.400
	Menidia beryllina	5	0.200	0	0.000	0	0.000	5	0.200

Appendix B--(continued)

River/Site	Species	Seine		Hoop Net				Total Abundance	Total CPUE
				Large		Small			
		Abundance	CPUE	Abundance	CPUE	Abundance	CPUE		
	Morone chrysops	2	0.080	0	0.000	0	0.000	2	0.080
	Notropis atherinoides	62	2.480	0	0.000	0	0.000	62	2.480
	Notropis bairdi	66	2.640	0	0.000	0	0.000	66	2.640
	Notropis buchanani	20	0.800	0	0.000	0	0.000	20	0.800
	Pimephales vigilax	33	1.320	0	0.000	0	0.000	33	1.320
	Polydictis olivaris	0	0.000	0	0.000	3	0.750	3	0.750
	Pomoxis annularis	4	0.160	0	0.000	0	0.000	4	0.160
THA	*Aplodinotus grunniens*	0	0.000	1	0.200	0	0.000	1	0.200
	Cyprinella lutrensis	169	10.563	0	0.000	0	0.000	169	10.563
	Cyprinus carpio	0	0.000	1	0.200	0	0.000	1	0.200
	Dorosoma cepedianum	4	0.250	0	0.000	0	0.000	4	0.250
	Dorosoma pretense	13	0.813	0	0.000	0	0.000	13	0.813
	Gambusia affinis	117	7.313	0	0.000	0	0.000	117	7.313
	Hybognathus placitus	147	9.188	0	0.000	0	0.000	147	9.188
	Ictalurus punctatus	1	0.063	0	0.000	1	0.250	2	0.313
	Ictiobus bubalus	0	0.000	1	0.200	0	0.000	1	0.200
	L. platostomus	1	0.063	0	0.000	1	0.250	2	0.313
	Lepomis cyanellus	1	0.063	0	0.000	0	0.000	1	0.063
	M. australis	4	0.250	0	0.000	0	0.000	4	0.250
	M. hyostoma	6	0.375	0	0.000	0	0.000	6	0.375
	Menidia beryllina	2	0.125	0	0.000	0	0.000	2	0.125
	Notropis atherinoides	164	10.250	0	0.000	0	0.000	164	10.250
	Notropis bairdi	18	1.125	0	0.000	0	0.000	18	1.125
	Notropis blennius	3	0.188	0	0.000	0	0.000	3	0.188
	Pimephales vigilax	2	0.125	0	0.000	0	0.000	2	0.125
	Polydictis olivaris	0	0.000	5	1.000	3	0.750	8	1.750
	Pomoxis annularis	2	0.125	0	0.000	0	0.000	2	0.125

Appendix B--(continued)

River/Site	Species	Seine		Hoop Net				Total Abundance	Total CPUE
				Large		Small			
		Abundance	CPUE	Abundance	CPUE	Abundance	CPUE		
ART	*Ammocrypta clara*	1	0.050	0	0.000	0	0.000	1	0.050
	Aplodinotus grunniens	0	0.000	0	0.000	2	0.400	2	0.400
	Carpiodes carpio	1	0.050	1	0.333	2	0.400	4	0.783
	Cyprinella lutrensis	231	11.550	0	0.000	0	0.000	231	11.550
	C. rubrofluviatilis	2	0.100	0	0.000	0	0.000	2	0.100
	D. cepedianum	31	1.550	0	0.000	0	0.000	31	1.550
	Hybognathus placitus	6	0.300	0	0.000	0	0.000	6	0.300
	Ictalurus furcatus	2	0.100	0	0.000	0	0.000	2	0.100
	Ictalurus punctatus	2	0.100	0	0.000	0	0.000	2	0.100
	Ictiobus bubalus	1	0.050	2	0.667	1	0.200	4	0.917
	Lepisosteus osseus	2	0.100	0	0.000	1	0.200	3	0.300
	L. platostomus	1	0.050	0	0.000	0	0.000	1	0.050
	Lepomis cyanellus	1	0.050	0	0.000	0	0.000	1	0.050
	M. hyostoma	2	0.100	0	0.000	0	0.000	2	0.100
	Menidia beryllina	8	0.400	0	0.000	0	0.000	8	0.400
	M. puntulatus	1	0.050	0	0.000	0	0.000	1	0.050
	Notropis atherinoides	120	6.000	0	0.000	0	0.000	120	6.000
	Notropis bairdi	2	0.100	0	0.000	0	0.000	2	0.100
	Notropis blennius	3	0.150	0	0.000	0	0.000	3	0.150
	Notropis buchanani	19	0.950	0	0.000	0	0.000	19	0.950
	Pimephales vigilax	10	0.500	0	0.000	0	0.000	10	0.500
	Polydictis olivaris	0	0.000	0	0.000	2	0.400	2	0.400
	Pomoxis annularis	5	0.250	0	0.000	0	0.000	5	0.250
Total		47291	2255.486	136	24.256	206	33.294	47633	2313.036

VITA

Nicholas John Utrup

Candidate for the Degree of

Master of Science

Thesis: DEVELOPMENT OF A RAPID BIOASSESSMENT PROTOCOL FOR SAMPLING FISHES IN LARGE PRAIRIE RIVERS

Major Field: Wildlife and Fisheries Ecology

Biographical:

Personal Data: Born in Lima, Ohio, October 21, 1978, son of Gerald T. Utrup and Nina M. Nuveman.

Education: Graduated from Ottawa-Glandorf High School, Ottawa, Ohio in May 1997; received Bachelor of Science degree in Zoology from The Ohio State University in June 2002; completed the requirements for the Master of Science degree at Oklahoma State University in July 2005.

Experience: Assistant Fish Biologist Intern, Ohio Environmental Protection Agency, Division of Surface Water, Ecological Assessment Unit, June 1999-September 1999; Research Technician, The Ohio State University, Aquatic Ecology Laboratory, September 1999- June 2002; Teaching Assistant and Research Technician, The Ohio State University, Ohio Sea Grant, F.T. Stone Laboratory, June 2001-August 2001; Graduate Research Assistant, Oklahoma Cooperative Fish and Wildlife Research Unit, July 2002-August 2004; Graduate Teaching Assistant, Oklahoma State University, Department of Zoology, August 2004-May 2005; Fishery Biologist, U.S. Fish and Wildlife Service, Columbia Fishery Resources Office, May 2005-present.

Professional Memberships: American Fisheries Society; Oklahoma Chapter of the American Fisheries Society; Oklahoma Academy of Science.

Name: Nicholas John Utrup Date of Degree: July, 2005

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: DEVELOPMENT OF A RAPID BIOASSESSMENT PROTOCOL FOR SAMPLING FISHES IN LARGE PRAIRIE RIVERS

Pages in Study: 63 Candidate for the Degree of Master of Science

Major Field: Wildlife and Fisheries Ecology

Scope and Method of Study: Assessment of the biotic integrity of large rivers depends on efficient and statistically-sound procedures for sampling. Large prairie rivers in the Great Plains ecoregion pose a unique challenge for sampling because their physical and chemical properties limit the types of gear, such as electrofishing, that are traditionally used to sample fish for bioassessments. In this study, I used seining and hoop netting to collect fishes at 15 sites in five large prairie rivers in Oklahoma to (1) determine the minimum amount of effort needed to detect the majority of fish species at a sample site and (2) examine the selectivity of fish species detected by the two gear types. Based on my findings, I present recommendations for sampling fish assemblages in large prairie rivers.

Findings and Conclusions: Analysis of similarities of the fishes collected in six different habitat types identified two distinct habitat types based on fish species composition: shallow/backwater (SBW) habitat (depth ≤ 0.75 m) and deep/non-wadeable (DNW) habitat (depth > 0.75 m). I estimated that eight SBW habitats and four DNW habitats at each sample site were needed to detect a majority of fish species during a sampling event. Minimum sampling distance needed to encounter the required number of habitats ranged from 400 m to 1600 m and averaged 887 m. Gear evaluation showed seining captured more species-per-unit-effort than hoop netting (3.6 and 1.4 respectively); however, hoop netting captured significantly larger fish (527 mm; $P < 0.001$) than seining (42 mm). Based on these results I recommend the following protocol for sampling fish assemblages in large prairie rivers: (1) use aerial photos to determine site accessibility and sampling distance prior to leaving for the field, (2) sample a minimum of eight randomly selected SBW habitats using a seine, and (3) set a minimum of two hoop nets per DNW habitat. With some modifications these recommendations can be applied to similar rivers throughout the Great Plains to aid in the rapid bioassessment and monitoring of fish assemblages in large prairie rivers.

ADVISOR'S APPROVAL: William L. Fisher