Fish Community Monitoring and Sampling Methodology Evaluation

Final Report

Task 2 Report
Assimilate and Compare and Contrast Fish Sampling Gears and Methods from Other River Systems

U.S. Bureau of Reclamation Contract No. 09-SP-40-8309

Prepared for

U.S. BUREAU OF RECLAMATION, ALBUQUERQUE AREA OFFICE
555 Broadway NE, Suite 100
Albuquerque, New Mexico 87102
Telephone: (505) 462-3540

Prepared by

Laura Leslie Burckhardt, Ann M. Widmer, Eric J. Gonzales, and Jon Kehmeier

SWCA ENVIRONMENTAL CONSULTANTS
5647 Jefferson Street NE
Albuquerque, NM 87109
Telephone: (505) 254-1115, Fax: (505) 254-1116
www.swca.com

SWCA Project No. 15968

March 2010

TABLE OF CONTENTS

LIST OF TABLES

PREFACE

This report is being submitted to the U.S. Bureau of Reclamation, Albuquerque Area Office, in partial fulfillment of Contract No. 09-SP-40-8309. The report is the second task of a project to evaluate fish sampling techniques in the Middle Rio Grande (MRG) and develop and implement a study design to monitor fish assemblages. In this report, we identify and assess gears and methods being used in aquatic systems outside the MRG to evaluate various demographic parameters for fish populations and communities. For the assessment, we reviewed a total of 47 manuscripts and reports and compared some of the most commonly used gear types and techniques with the current sampling approaches being used to monitor the fish community of the MRG. We suggest how gear types not currently being used in the MRG could be used to supplement ongoing monitoring data and which gear types are the most applicable for sampling the MRG fish community. Particular emphasis is placed on those gear types best suited for estimating Rio Grande silvery minnow (*Hybognathus amarus*) demographic parameters.

ACKNOWLEDGEMENTS

We thank Mr. Jericho Lewis who serves as Contract Officer and Ms. Jeanne Dye who serves as Contract Officer/Technical Representative for the U.S. Bureau of Reclamation. We appreciate the collaboration and coordination they have provided for this project. We also acknowledge Mr. Joseph Fluder, Office Principal for the Albuquerque Office of SWCA Environmental Consultants, and Dr. Steven W. Carothers for their continued guidance and support on this project.

EXECUTIVE SUMMARY

This Fish Community Monitoring and Sampling Methodology Evaluation Assessment Report evaluates various fish sampling gears and techniques for use in monitoring the Middle Rio Grande (MRG) fish community, with an emphasis on the endangered Rio Grande silvery minnow (*Hybognathus amarus*) (silvery minnow). The project is being conducted for the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) and is coordinated by the U.S. Bureau of Reclamation with technical guidance from the Collaborative Program's Science Workgroup. This assessment reviews active and passive fish capture methods used in other river basins to assess fish abundance, community composition, population structure, and habitat associations.

A detailed review of fisheries literature was conducted to qualitatively assess how various gear types and methods are being used to monitor fisheries communities in river systems outside the MRG. Gear types and methodologies used to sample the array of fish life stages (i.e., egg to adult) were reviewed. Details regarding the deployment and efficacy of the sampling gears were extracted from each paper and summarized in a tabular form to facilitate comparisons. A matrix approach was used to qualitatively assess gear suitability for sampling the MRG fish community and the silvery minnow. This matrix provides a framework for ranking gears according to their applicability in the MRG for the silvery minnow and the entire fish community.

Fish capture methods can be broadly separated into active and passive types. Active capture methods use moving gear types (e.g., seining, trawls, dredges, electrofishing) to collect fish (Hayes et al. 1996) while passive capture methods rely on fish movement into a stationary gear type (e.g., fyke nets, pot gears, larval light traps) that entangles or entraps the fish (Hubert 1996). Active capture methods can be labor intensive, often costing more than passive gear types; however, active gear types often yield reliable quantitative information. Passive gears are relatively easy to deploy and can be less labor intensive and time consuming than active gears, but these gear types are selective for certain sizes, species, or sexes of fish and require a quantitative understanding of gear selectivity to accurately interpret data collected (Hubert 1996).

Our qualitative ranking of gear types resulted in the highest overall score for beach seines, and the second highest overall score for backpack electrofishers and mini-fyke nets. These gear types have been used successfully for sampling the MRG fish community and the silvery minnow. The combined use of these three gear types should provide a more accurate description of the MRG adult fish community than any one of these three gear types will alone.

Gear suitability is dependent on study objectives, methodology used, target species, and logistical and cost constraints. We recommend that clearly defined study objectives be used to determine gear types that are most appropriate for obtaining the desired fish community information and data precision. Our findings indicate that no one gear will be well suited for sampling the entire fish community or the entire range of mesohabitat types and river flows in the MRG. Instead we recommend a multiple-gear approach that includes beach seines, backpack electrofishers, and mini-fyke nets to monitor the MRG fish community and trends in silvery minnow relative abundance.

1.0 INTRODUCTION

This Fish Community Monitoring and Sampling Methodology Evaluation Assessment Report evaluates various fish sampling gears and techniques for use in monitoring the Middle Rio Grande (MRG) fish community, with an emphasis on the endangered Rio Grande silvery minnow (*Hybognathus amarus*) (silvery minnow). The project is being conducted for the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) and is coordinated by the U.S. Bureau of Reclamation (Reclamation) with technical guidance from the Science Workgroup of the Collaborative Program. This assessment reviews active and passive fish capture methods used in other river basins to assess fish abundance, community composition, population structure, and habitat associations. The numbers of papers that utilize various gear types far exceeds what we describe in this report. We selected papers that best represent particular gear types and offer the best case histories to compare and contrast with a river system such as the Rio Grande.

Active capture methods use moving gear types (e.g., seining, trawls, dredges, electrofishing) to collect fish (Hayes et al. 1996). Active capture techniques allow a specified geometric space to be sampled over a set time period, resulting in an accurately defined unit of measure. These sampling gears allow for collection of sample data in a relatively short amount of time (minutes or hours) and are mobile in space and time. Active sampling can be labor intensive and thus typically cost more per sample than passive gears (Hayes et al. 1996).

Passive capture methods rely on fish movement into a stationary gear type (e.g., fyke nets, pot gear, larval light traps) that entangles or entraps the fish (Hubert 1996). Passive gears can yield relative abundance for many species based on the gear deployment time and habitat type in which it was deployed. These gears are relatively easy to deploy and can be less labor intensive and time consuming than active gears. Passive gears are selective for certain sizes, species, or sexes of fish, and a quantitative understanding of gear selectivity is important to accurately interpret data collected with passive gears (Hubert 1996). Measurements of gear selectivity for target species and presampling in target areas can be used to estimate sampling variability and effort required to get an accurate relative abundance estimate.

2.0 METHODS

A review of fisheries literature was conducted to qualitatively assess how various gear types and methods are being used to monitor fisheries communities in river systems outside the MRG. Gear types and methodologies used to sample the array of fish life stages (i.e., egg to adult) were reviewed. The review primarily consisted of published peer-reviewed papers; however, gray literature was consulted when novel gear types and techniques were described. We focused primarily on gear types and methods being used in riverine environments, but we also included papers that describe gear types and methods used in standing bodies of water that may be applicable to the MRG for sampling specific habitats. Abstracts of literature reviewed are provided in Appendix A, and copies of the papers are provided on an attached CD.

Details regarding the deployment and efficacy of the sampling gears were pulled from each paper and summarized in a tabular form to facilitate comparisons. Separate tables were created for seining, electrofishing, trawls, entrapment, eggs and larvae, and other active and passive sampling categories. Many of the papers evaluated two or more gear types and may appear in multiple categories.

A matrix approach was used to qualitatively assess gear suitability for sampling the MRG fish community and the silvery minnow. Each potential gear type was scored from 0 to 4 relative to its suitability (i.e., 0 – not suitable, 1 – suitable for limited application, 2 – marginally suitable, 3 – suitable for most applications, and 4 – highly suitable) for each of the seven following categories: 1) suitability for sampling silvery minnow adults, 2) suitability for sampling silvery minnow juveniles, 3) suitability for sampling silvery minnow larvae and eggs, 4) suitability for sampling the fish community in a medium sandbed river, 5) logistical ease of use, 6) gear purchase cost, and 7) reliability for quantitative information. Scoring was conducted independently by three individuals who were familiar with the literature reviewed. Mean scores were calculated for each gear type and category and summed across categories to produce the total score for each gear type. This matrix provides a framework for ranking gears according to their applicability in the MRG for the silvery minnow and the entire fish community.

3.0 RESULTS

This results section provides 1) a summary of fish sampling gears and methods used in other river systems, 2) a summary of sampling gears and methods currently used in the MRG, and 3) a comparison of the effectiveness of gears used in other systems to those used in the MRG.

3.1 SUMMARY OF FISH SAMPLING GEARS AND METHODS FROM OTHER RIVERS

Summaries of fish sampling gears and methods used from other rivers are provided below for each category of gear type that was commonly used. These gear types include seining, electrofishing, trawls, entrapment gears, and methods for collecting eggs and larvae.

3.1.1 SEINING

Seining is a category of encircling nets that are used to actively capture fish by surrounding them in a wall of netting (Hayes et al. 1996). Commonly used encircling nets for river systems include beach seines, purse seines, and lampara nets. Beach seines are commonly used in shallow water habitats in streams, rivers, lake shorelines, and wetlands. Purse seines and lampara nets are commonly deployed from boats and used to target pelagic fish species in open water habitats. Purse seines typically have lead and float lines that are equal lengths, while lampara nets have a shorter lead line giving it a dustbowl shape.

SUMMARY OF SEINING IN OTHER RIVERS

Eleven studies were reviewed that used seining methods to describe the species composition and fish community structure, determine detection rates of rare species, or estimate abundance of fishes (Table 3.1). Species targeted using seine nets included small- and large-bodied, benthic and mid-water species occupying primarily stream, river, floodplain, and shoreline habitats. Beach seines were the most commonly used seine net in lotic systems.

Beach seines are designed so the net wall extends from the substrate to the water surface. The wings of the net form a vertical wall that funnels fish towards the back, or bunt, of the net (Hayes et al. 1996). The bunt may also be designed with a bag, which is useful for large catches of fish. The bag may be either centered or to one side of the net depending on the method of deployment. The bag may also be designed with additional netting to form a trap and reduce the likelihood of the fish escaping once they are captured. Lead and float lines may also be added to the net of the seine depending on the target species and habitat.

Beach seines in the papers reviewed were constructed of 3.0- to 7.5-mm mesh and were 3 to 15 m long and 1.2 to 3.24 m wide with and without bags, depending on the study area. In shallow-water habitats in lakes and floodplains, seines were also designed with lead and float lines. These seines were constructed of 3.2- to 6.4-mm mesh and were 12.5 to 25.0 m long and 1.8 to 6.0 m wide with and without bags, depending on the target species.

The beach seines were deployed by three methods. The most common method was by two vessels or individuals, pulling the seine either upstream or downstream and encircling fish with the net. The second method involved anchoring one end of the net on shore and then a single vessel or individual pulling the other end of the seine in a 90 to 180 degree arc through the water and back into shore. One study also deployed the beach seine and a lampara net, encircling the fish with the seine and then hauling the wings together, closing the bottom of the net and trapping the fish in the bunt end of the net (Bayley and Herendeen 2000).

Seining was conducted in sample areas that were both open (i.e., fish can immigrate and emigrate) and closed (i.e., immigration or emigration is prevented with the use of block nets). The sample area was surveyed either by single or multiple seine hauls, depending on the study objectives. Multiple seine hauls were used to estimate total abundance, species richness and composition, and fish community structure. Single seine hauls were used to document species distribution and basic population parameters. The area seined or volume of water sampled was recorded to allow for calculation of fish captured per area. Alternatively, catch was documented as fish per seine haul.

The capture efficiency of beach seines are often influenced by the species' position in the water column, their net avoidance behavior, their relative abundance, and their habitat associations (e.g., substrate or channel structure) (Hayes et al. 1996). Studies have found that beach seines can have higher catch efficiencies for species residing in the middle of the water column than for benthic species (Lyons 1986; Lapointe et al. 2006a). However, capture efficiency can be higher for benthic species that swim ahead of the net rather than under or around the net (Hayes et al. 1996). Substrate and underwater structures that may cause the seine to roll or snag can also reduce capture efficiencies. Because this variability can mask differences in species abundance, capture efficiencies should be estimated at least once each season at each study site and for the target species. Capture efficiencies can be estimated by blocking the sample area and using removal methods to deplete the sample area. Capture efficiency is then calculated as a ratio of the number of fish caught in a given seine haul over the total number of fish in the sample area (Hayes et al. 1996).

An alternative method for evaluating gear efficiency or gear selectivity is the "covered codend method" (Pope et al. 1975) where the principle mesh size used is encircled by a finer mesh that captures fish able to pass through the principle gear. This method makes it possible to determine the amount and size of fish that escape through the meshes of the principle gear type.

The majority of the studies (n = 9) used other gears in conjunction with seining to assess the effectiveness of the different methods or to get a better description of the entire fish community (Table 3.1). Overall these studies found seines were most effective for sampling slower water habitats with little structural complexity. A multiple-gear approach was recommended to maximize species detection and produce a better estimate of species compositions in habitats with greater structural complexity (Fago 1998; Clark et al. 2006; Mercado-Silvia and Escandon-Sandoval 2008). Multiple gears also provide a more comprehensive assessment of the different life stages and sizes of fishes that may not be sampled with a single gear type.

Table 3.1. Comparison Table of Seining Methodology Used in Other River Systems

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Bayley and Herendeen 2000	Determine local abundance estimates using correction for capture efficiency.	Amazon River floodplain habitats, Brazil.	Seine was 25 m long (40 m before bags) and 6 m deep in center with 5-mm mesh. The lead line contained 120-g lead cylinders at 35-cm intervals. Floats, 15 cm in diameter, were spaced at 30-cm intervals.	Deployed from canoe(s) in 3 ways: encirclement, beach seining semi-circular set, and lampara seining.	None.	Mid-water, territorial, and demersal species; 41 taxa identified.	Length range was 1.0 to 79.5 cm, with most less than 30 cm.	Encirclement method and beach seining produced more precise data than the lampara net method. Capture efficiency varied by fish size; precision was highest for fishes <50 cm. Gear would need to be calibrated for different net specifications and sampling conditions.
Clark et al. 2006	Determine species composition and fish community structure.	Floodplain lakes with large amounts of woody debris in the White River National Wildlife Refuge, Arkansas.	Seine was 3 m long and 3.24 m wide with 4.7-mm mesh.	One seine haul was taken at evenly spaced shoreline locations, up to 30 hauls per lake. One end of the seine was held stationary and the other end pulled in a semicircular arc.	24-hour fyke net sets.	Twelve families were represented in the catch data, primarily Cyprinidae, Centrarchidae, and Poeciliidae by relative abundance. Species captured included cypress minnow (*Hybognathus hayi*) and Mississippi silvery minnow (*H. nuchalis*).	Specific length ranges not provided. Based on species collected, fyke nets appear to have collected a wider range of fish sizes. Seine catch was dominated by Poeciliidae, Centrarchidae, and Cyprinidae.	Seine hauls were not as efficient as fyke nets for sampling Cyprinidae. The catch rate for cypress minnow was 0.391 per fyke net night and 0.37 per seine haul. The catch rate for Mississippi silvery minnow was 0.57 per fyke net night and 0.12 per seine haul. Fyke nets collected more fish and produced greater species richness and diversity measures than seining. Shoreline seines captured 2 species that fyke nets missed and failed to detect 13 species that were collected with fyke nets. Authors recommended a multiple-gear approach to maximize species detection.
Fago 1998	Determine species composition and fish community structure.	Littoral zone of Wisconsin lakes.	Seine was 9.1 m long and 1.2 m wide with a bag and 4.7-mm mesh.	River site was blocked with 4.7-mesh nets. Two removal passes were made with a towed direct current electroshocker, followed by one seine pass through the enclosure parallel to the shore.	Mini-fyke nets and towed electroshocker.	Sixty-two species were collected, including brassy minnow (*Hybognathus hankinsoni*)	Specific length ranges not provided, but catch was dominated by small-bodied species, Centrarchidae, and common carp (*Cyprinus carpio*).	Brassy minnow was never detected using the electrofishing and seining approach, but was detected at 4 sites using mini-fyke nets. Neither method collected all species. Authors recommended combining the results from both methods to produce a better estimate of species composition.
Koel 2004	Characterize spatial patterns in species richness and examine relationship between species richness and habitat diversity.	Off-channel aquatic habitats on the Mississippi River, including main channel and side channel borders and contiguous backwater shorelines.	Seine was 10.7 m long and 1.8 m wide with 3-mm mesh. It had a square bag measuring 0.9 m on each side.	One end was anchored to the bank while the other end was deployed perpendicular to the bank and swept around in a 90 degree arc to the shoreline in the downstream direction.	Boat electrofishing, mini-fyke nets, fyke nets, and hoop nets.	There were 106 species collected by all gear types. The species collected specifically by seine were not reported.	Specific length ranges not provided. Small-bodied species were primarily collected by mini-fyke nets and seines.	Seines were more effective in side channel borders and backwater shorelines habitats than main channel borders. Electrofishing provided the greatest consistency and overall ability to detect differences in species evenness and diversity among habitats and pools.
Lapointe et al. 2006a	Determine species composition and fish community structure.	Segment of the Detroit River characterized by braided channels, and wide, shallow flats; maximum river width is 4 km and maximum depth is 10 m.	Seine was 15 m long and 2.5 m wide with a 2.5-m bag, and 0.64-cm mesh.	One end was anchored and a boat was used to wrap the seine in a circle (like Bayley and Herendeen 2000).	Boat electrofishing, fyke nets, Windermere traps, trap nets, and minnow traps.	Seine catch was dominated by small-bodied Cyprinidae, Centrarchidae, and yellow perch (*Perca flavescens*). Most common species collected by seine were bluntnose minnow (*Pimephales notatus*) and spottail shiner (*Notropis hudsonius*)	Specific length ranges not provided, but both small-bodied and larger-bodied species were collected by seining.	Seining was the most effective method for sampling shallow offshore sites and for capturing schooling mid-water fishes. Seines detected a greater number of species and collected a greater number of fish per sample than boat electrofishing, fyke nets, or Windermere traps. Trap nets and minnow traps were deemed ineffective. Seine nets missed some of the predatory species, particularly Ameiurus spp., but hoop and seine nets together detected nearly all species.

Table 3.1. Comparison Table of Seining Methodology Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Lyons 1986	Determine local abundance estimates using correction for capture efficiency.	Sparkling Lake, a small, mesotrophic, clear-water lake in northern Wisconsin with a firm, sand-gravel bottom and few obstructions.	Seine was 15.2 m long and 1.8 m wide with a 1.8-m² bag and 6.4-mm stretched mesh. The lead line of the seine had tubular lead weights every 23.5 cm, and the float line had 7.0-cm-diameter × 3.5-cm cylindrical styrofoam floats every 35 cm.	The sample area was blocked with a 6.4-mm mesh net with ends anchored on the shore. The seine was pulled from the outer edge of the block net into shore. Fish were removed in 10 to 18 consecutive hauls.	None.	Mimic shiners (*Notropis volucellus*), juvenile yellow perch, bluntnose minnow, logperch (*Percina caprodes*), Iowa darter (*Etheostoma exile*), juvenile rock bass (*Ambloplites rupestris*), and johnny darter (*Etheostoma nigrum*) were collected.	Fish catch comprised small-bodied species and juvenile medium-bodied species. Length ranged from 35 to 155 mm total length	Seine efficiencies ranged from 24% to 94%. Seine efficiency was higher for mid-water fishes (cyprinids and yellow perch) than for benthic fishes (darters). Seines might be modified (i.e., heavier lead lines) to increase capture efficiency of benthic fishes.
Mercado-Silvia and Escandon-Sandoval 2008	Determine species composition and fish community structure.	San Francisco River, Rio Antigua basin, Mexico. The river has low turbidity, a variety of habitats (riffles, pools, runs), and rocky substrates.	Seine was 3 m long and 2 m wide with 7-mm stretched mesh.	Several passes were made through reaches that were 50 m long covering the entire width of the reach and all habitat types. Seine hauls were pulled into the shore or lifted up in the middle of the river. Brails were used to disturb water around boulders. Kick-seining was used in riffles.	Battery-powered electrofishing, with at least 48 hours between sampling events.	Seine catch was composed of 10 species in the families Poeciliidae, Cichlidae, Synbranchidae, Gobiidae, Characidae, and Pimelodidae.	Specific length ranges were not provided. Seines failed to capture fast-swimming and benthic species.	Electrofishing produced higher estimates of species richness, diversity, and biomass than seining. Species' relative abundance was similar. Seining alone may not be adequate for bioassessment.
Paradis et al. 2008	Determine abundance and size distribution of a target species and age group.	Shallow wetlands in the Lake Saint-Pierre area, Quebec, Canada. Wetlands varied in vegetation density, and sites were divided into 3 depth strata: (0.50–0.75, 0.75–1.00, and 1.00–1.25 m).	Seine was 12.5 m long and 4 m wide with 3.2-mm stretched mesh, floats on the top line, and a lead-core bottom line.	Sites were offshore and approached by boat. The seine was deployed in a circle by wading and then pulled in like a purse seine from the boat. Sample volume ranged between 66.3 and 147.2 m^2.	Pop net and push net for replicate samples at randomly selected locations.	The target species was yellow perch.	Yellow perch collected by seining in July ranged 27 to 66 mm total length.	Seining collected larger fish on average than the pop net when both gears were fished in July. Catch per unit effort and frequency of occurrence were significantly greater with a seine than a pop net in sparsely vegetated habitats. Frequency of occurrence (significant) and catch per unit effort (not significant) were greater with a seine than a pop net in densely vegetated habitats. In July, coefficient of variation (CV) of the seine samples was 0.20 and CV of the pop net samples was 0.24. The high efficiency of the seine in sampling juveniles could be explained by the fact that it sampled a large area.
Poos et al. 2006	Measure species composition / detect rare species.	Sydenham River, Ontario, Canada.	Seine was 8.2 m long and 2 m wide with a 2-m² bag and 7.5-mm mesh.	The seine was pulled by two people with a third lifting the net over obstructions.	Single-pass backpack electrofishing.	Eastern sand darter (*Ammocrypta pellucida*), blackstripe topminnow (*Fundulus notatus*), greenside darter (*Etheostoma blennioides*), and spotted sucker (*Minytrema melanops*) were collected.	Small-bodied species were collected.	Electrofishing was a more effective gear type than seining for sampling fish species at risk, irrespective of the unit (presence/absence or catch per unit effort).
Utrup and Fisher 2006	Determine species composition and species richness.	Fifteen sites on 5 large prairie rivers in Oklahoma, including the Arkansas, Cimarron, North Canadian, Washita, and Red rivers. Discharge ranged 12 to 207 m^3/s.	Seine was 6.1 m long and 1.2 m wide with 4.8-mm mesh.	The seine was only used in shallow-water habitats (<0.75 m), approximately 20 hauls per 1,000-m site. Hauls were made parallel to the shoreline, with the current, for a distance of 10 m. Samples were of discrete mesohabitats. The study measured species per unit effort (i.e., species caught per seine haul).	Small and large hoop nets to sample deeper habitats.	Forty-six species including plains minnow (*Hybognathus placitus*) were collected.	Mean length of fish collected by seining was 42.4 mm (standard deviation [SD] 37.13) and mean weight 3.7 g (SD 50.32). This is considerably smaller than the hoop nets. The mean length of fish collected by small hoop nets was 357.3 mm (SD 200.75) and mean weight of 718.9 g (SD 917.38).	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*], and bullhead minnow [*Pimephales vigilax*]), which made up over 90% of the total catch. In contrast, the majority of fish species captured by hoop nets were catfish (order Siluriformes).

Table 3.1. Comparison Table of Seining Methodology Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Welker and Scarnecchia 2004	Determine species composition, habitat associations, and longitudinal distribution.	Missouri and Yellowstone rivers, North Dakota.	Bag seine was 10.7 m long, 1.8 m tall with a 1.8-m^3 bag and 5-mm ace mesh.	Two bag seine subsamples were taken in each sample unit (250-m length of stream). One end of the seine was held stationary and the other pulled upstream until it was fully extended along the shoreline. The upstream end was then pulled downstream through the water in a 180 degree arc. At the end of the arc, the net was pulled to shore.	A benthic beam trawl in main channel habitats.	Target species were flathead chub (*Platygobio gracilis*), sicklefin chub (*Macrhybopsis meeki*), sturgeon chub (*M. gelida*), and western silvery minnow (*Hybognathus argyritis*).	Fish captured ranged <40 mm to >100 mm, but the length distributions were not separated by gear type.	Most sicklefin and sturgeon chubs were captured in the deep, high-velocity main channel habitat with the trawl, whereas most flathead chubs and western silvery minnows were captured in the shallow, low-velocity channel border habitat with the bag seine.

3.1.2 ELECTROFISHING

Electrofishing is an active sampling methodology that uses electricity, either direct current (DC) or alternating current (AC), to capture, guide, or block the movement of fish. Electrofishing is commonly used to assess species composition and population abundance, structure, and dynamics. A multiple-gear approach is often recommended for assessment of population dynamics or studies where target species are less vulnerable to electrofishing. The effectiveness of electrofishing depends on the transfer of electrical energy from the water into the fish. Vulnerability of fish species and sizes to electrofishing varies, and operational settings should be set so that they result in narcosis among all target species and size classes (Reynolds 1996). Various field parameters and operational settings can be adjusted for use in different drainages and for specific species (Hayes et al. 1996; Reynolds 1996). Standardizing field protocols (spatially, temporally, and operational settings) are important for reducing sampling variance and increasing efficiency, while minimizing deleterious effects to target species (Snyder 2003). The electrofishing system is most commonly boat-, vehicle-, or backpack-mounted. Specialized systems also include shore-based units, electric seines, and electric trawls.

BOAT-MOUNTED UNITS

Boat-mounted electrofishing units are commonly used in water that is too deep or too fast to wade. Electrofishing units can be mounted to boats with hulls constructed of heavy-gauge aluminum, wood, rubber (e.g., hypalon), or fiberglass. Boat-mounted units can be towed, pushed, rowed, or motorized.

This assessment included 15 studies that used boat-mounted electrofishing units to estimate species abundance, composition, fish community structure, species richness and habitat diversity (Table 3.2). Eight studies used electrofishing units mounted in motorized boats, three used units mounted in rafts, three used units on tow barges, and one used a unit mounted in a drift boat that was used as a tow barge. All units used DC current and operational settings were tailored for targeted species. Boat- and raft-mounted units used one to two anode arrays and were used in non-wadeable deeper water habitats. Tow barges utilized two to three anode probes and were used in wadeable habitats.

Electrofishing study designs varied greatly, depending on the study objectives, target species, and environment. The application of electrofishing varied from point samples where the boat was anchored and electricity was applied for a set amount of time (e.g., Lapointe et al. 2006b) to the continuous electrofishing of long reaches (e.g., Meador 2005). Electrofishing was conducted in open or closed study sites, with one or more replicates, and at day or night. Study designs consisting of multiple replicate point samples (e.g., two 1-minute samples per site [Lapointe et al. 2006b]) were more informative than single point samples with a small increase in effort. Point samples permitted a greater length of river to be sampled per day than continuous or removal samples, increasing the chance of encountering rare species (Lapointe et al. 2006b; Janac and Jurajda 2007) and documenting species distributions. Continuous samples were also recommended for documenting species richness, with richness increasing with the length of reach sampled (e.g., Meador 2005). If species abundance estimates were needed, authors generally recommended removal by multiple continuous samples in a closed sample area (e.g., Lyons and Kanehl 1993; Amadio et al. 2006). However, Simonson and Lyons (1995) reported that a single upstream catch per unit effort (CPUE) pass adequately assessed fish species richness, abundance, and assemblage structure in small streams and that the use of block nets was unnecessary. Because electrofishing catches can be highly variable, Peterson and Rabeni (1995) recommended sampling a greater number of sample locations in fewer times per year to increase estimate precision.

The majority of the studies reviewed either multiple types of electrofishing gears (n = 3) or other gears in conjunction with electrofishing (n = 6) to target specific habitat types, to assess the effectiveness of the different methods, or to get a better description of the entire fish community. Overall, studies that used electrofishing methods in conjunction with other gear types advocated the use of a multiple-gear approach to maximize species detection and better characterize community species composition (Fago 1998; Koel 2004; Lapointe et al. 2006a; Ruetz III et al. 2007). While electrofishing provided the greatest consistency and overall ability to detect differences in species evenness and diversity among individual habitats (Koel 2004), abundant small-bodied species and benthic species were often underrepresented in electrofishing samples (e.g., Lapointe et al. 2006a). Species composition and population structure data collected by gears targeting small-bodied and benthic species (e.g., beach seines, hoop nets) were often complimentary to that collected by boat-mounted electrofishing. Studies that used electrofishing methods exclusively generally found these methods to be effective for the primary species they targeted.

BACKPACK UNITS

Nine studies used backpack electrofishing to estimate species abundance, composition, fish community structure, species richness, and habitat diversity in wadeable channel habitats and shallow shoreline areas (see Table 3.2). All units used DC current and operational settings were tailored for targeted species. Studies used one to two anode arrays to sample fish in closed and open sample units, using single to multiple passes.

Backpack electrofishing was effective at sampling targeted fish species, and backpack units in block-netted sections effectively sampled wadeable main channel habitats (Velez 2004; Shea and Peterson 2007). Multiple-pass electrofishing within block-netted sections was also effective for producing precise and accurate population estimates for multiple species of fish (Velez 2004; Kennard et al. 2006). Janac and Jurajda (2007) reported that point abundance samples for age-0 fish were as effective as continuous sampling for monitoring species richness, relative proportion of species, and size structure. Point sampling, a time- and cost-efficient method for monitoring age-0 fish assemblages, was recommended for routine sampling of age-0 fish (Janac and Jurajda 2007).

Many of the studies we reviewed used other gears in conjunction with backpack electrofishing (n = 4) to target specific habitat types, to assess the effectiveness of the different methods, or to get a better description of the entire fish community. These studies reported that habitat complexity had the greatest influence on species composition and community structure (Shea and Peterson 2007). Electrofishing was found to be a more effective gear type than seining for sampling fish species at risk, irrespective of the unit (presence/absence or CPUE) (Poos et al. 2006; Mercado-Silva and Escandon-Sandoval 2008). However, multiple-pass electrofishing plus seining provided more accurate and precise estimates of fish species richness, assemblage composition, and species relative abundances in comparison to single-pass electrofishing alone (Kennard et al. 2006). Intensive sampling of three mesohabitat units (e.g., a riffle–run–pool sequence) was a more efficient sampling strategy to estimate reach-scale assemblage attributes than less intensive sampling over larger spatial scales. This intensive sampling protocol detected changes in assemblage attributes (<20%) with a high statistical power (1-β>0.95), and relatively few stream reaches (<4) need be sampled to accurately estimate assemblage attributes close to the true population means (Kennard et al. 2006).

PRE-POSITIONED FRAME

Pre-positioned electrofishing grids (two-dimensional) or frames (three-dimensional) are structures that are positioned in the streambed, left undisturbed until the fish resume their normal behaviors and position in the stream, and then electrified from a distance. Fish in and next to the frame are immobilized by the electricity and can be netted with dip nets or seines. This gear is generally used in shallow, low-velocity habitats to define species microhabitat associations.

Two studies (see Table 3.2) used electrified pre-positioned frames to estimate relative abundance and characterize species habitat associations in shallow water habitats with high visibility. Dewey (1992) used electrofishing frames (3.1 m long, 1.8 m wide, and 1.2 m high) that were constructed of Polyvinyl chloride (PVC) pipe and electrified by anodes connected to an electrofishing boat. The frame sampled a 5.6-m^2 area. Walsh et al. (2002) used a pre-positioned frame that was 1 × 0.75 m and electrified by a Smith-Root 2.5 generator-powered pulsator (GPP) electrofishing system. Pre-positioned frames were positioned throughout the block-netted sample area and powered one at a time. Study results indicated that pre-positioned frames were effective in waters with high visibility and little vegetation and should not be used in vegetated turbid waters (Dewey 1992). Variation and sampling effort necessary to estimate species richness were higher with the pre-positioned frames than electrified seines (Walsh et al. 2002).

ELECTRIFIED SEINE

An electrified seine usually consists of a solid horizontal brail with anodes dangling at regular intervals. In some designs, the length of the anodes or the length of the brail can be adjusted. The seine can be used to either immobilize fish, so that netters following behind the seine can net them, or herd fish into an entrapment gear. Electrified seines are most effectively applied in shallow, clear-water habitats.

Three studies used electrified seines to estimate species composition, fish community structure, and species habitat associations in wadeable streams and river habitats (see Table 3.2). Electrified seines varied in size and design; however, operational setting could be controlled for targeted species. Electrified seines were used within block-netted sections and multiple passes were conducted to collect fish.

The electrified seine is widely applicable for sampling fish in small to medium-sized streams with low to moderate gradients. Two major constraints on its use involve water depth and clarity. The method is most appropriate for quantitatively estimating species composition and population densities of entire fish assemblages (Angermeier et al. 1991). Two to three passes of the electrified seine was an adequate sampling effort to estimate species richness at each site for one study (Walsh et al. 2002). Peterson and Rabeni (1995) reported that when electric seines were used in combination with boat electrofishing, and benthic trawls, habitat-specific variation among samples ranged from coefficient of variation (CV) of 0.13 to 1.58 (standard deviation

[SD]/mean) and were lower for community attributes (like richness) than biomass estimates. The number of samples needed to ensure CV <0.20 ranged from 2 to 245.

ELECTRIFIED BENTHIC TRAWL

Electrified benthic trawls are trawls (see Section 3.1.3) that have been modified through the addition of anodes (Peterson and Rabeni 1994; Freedman et al. 2009). Benthic trawls are towed behind a boat to sample benthic species. By attaching dangling anodes (i.e., "ticklers") to the trawl's tow ropes, fish are immobilized by electricity and less able to evade the trawl net by swimming under or around it.

Studies we reviewed (see Table 3.2) pulled an electrified benthic trawl through various habitats with multiple passes per sample area. These studies found that the electrified benthic trawl is a useful device for sampling large-river benthic fish communities (Freedman et al. 2009). The electrified trawl captured significantly more fish (mean = 24.7 fish per haul) and species (mean = 3.2 species per haul) than the non-electrified trawl (mean = 11.2 fish per haul and 1.9 species per haul), although the capture of mid-water cyprinid species did not differ substantially. Peterson and Rabeni (1995) reported that when benthic trawls were used in combination with electric seines and boat electrofishing, habitat-specific variation among samples ranged from coefficient of variation (CV) of 0.13 to 1.58 (standard deviation [SD]/mean) and were lower for community attributes (like richness) than biomass estimates. The number of samples needed to ensure CV <0.20 ranged from 2 to 245.

Table 3.2. Comparison Table of Electrofishing Methodology Used in Other River Systems

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Electrofishing Boats (including rafts and barges)								
Amadio et al. 2006	Estimate abundance of target species and identify habitat features.	Perennial rivers in the Wind River watershed, Wyoming.	Raft-mounted, pulsed-DC electrofishing gear.	A three-pass removal method was used in individual pools and runs in each reach (.16 to 3.8 km in length), but individual pools and runs were not isolated with block nets during depletion efforts.	None.	Sauger (*Sander canadensis*) was collected.	Specific length ranges were not provided. Study estimated abundance of adult sauger and reported that 1,258 saugers greater than 300 mm total length were collected.	From 2 to 239 saugers were estimated to occur among the 19 reaches. This was extrapolated to 4,115 (95% confidence interval [CI] 308) over 179 km of lotic habitat.
Fago 1998	Determine species composition and fish community structure.	Littoral zone of Wisconsin lakes.	Towed DC electroshocker with two probes.	River site was blocked with 4.7-mesh nets. Two removal passes were made with the electroshocker, attempting to collect all species and length classes, followed by one seine pass through the enclosure parallel to the shore.	Mini-fyke nets.	Sixty-two species were collected, including brassy minnow (*Hybognathus hankinsoni*).	Specific length ranges were not provided, but catch was dominated by small-bodied species, Centrarchidae, and common carp (*Cyprinus carpio*).	Brassy minnow was never detected using the electrofishing and seining approach, but was detected at 4 sites using mini-fyke nets. Neither method collected all species. Authors recommended combining the results from both methods to produce a better estimate of species composition.
Koel 2004	Characterize spatial patterns in species richness and examine relationship between species richness and habitat diversity.	Off-channel aquatic habitats on the Mississippi River, including main channel borders, side channel borders, and contiguous backwater shorelines.	Boat-mounted, 3,000-W pulsed-DC electrofisher with two netters.	Main channel borders, side channel borders, and contiguous backwater shorelines were fished during daylight hours with standardized electrofishing power.	Fyke nets, seining, and hoop nets.	There were 106 species collected by all gear types. The species collected specifically by electrofishing were not reported.	Specific length ranges were not provided. Small-bodied species were primarily collected by mini-fyke nets and seines.	Electrofishing provided the greatest consistency and overall ability to detect differences in species evenness and diversity among habitats and pools. However, the authors advocated a multiple-gear approach for examining patterns in species richness among habitats.
Lapointe et al. 2006a	Determine species composition and fish community structure.	Segment of the Detroit River characterized by braided channels and wide, shallow flats. Maximum river width is 4 km and maximum depth is 10 m.	Smith-Root boat electrofisher that had a single anode array and pulsed DC (30 Hz; 1,000 volts; 3,600 W).	The boat was held in place over the center of the site while shocking was conducted for 1 minute	Seines, trap nets, fyke nets, Windermere traps, and minnow traps.	Boat electrofishing detected 23 species. Species detected by electrofishing but not seine included bowfin (*Amia calva*), johnny darter (*Etheostoma nigrum*), silver redhorse (*Moxostoma anisurum*), and yellow bullhead (*Ameiurus natalis*).	Specific length ranges were not provided.	Seining was the most effective method for sampling shallow offshore sites and capturing schooling mid-water fishes. Seines detected a greater number of species and collected a greater number of fish per sample than boat electrofishing, fyke nets, or Windermere traps.
Lapointe et al. 2006b	Determine species composition and fish community structure.	Sixty sites in the Canadian Detroit River characterized by braided channels and wide, shallow flats.	Smith-Root 5.0 GPP boat electrofisher with singe anode array and pulsed DC (60 Hz, high voltage, 1–1,000 volts, 8 amps).	Sites were sampled June, August, and fall. The boat was anchored over the site, which was continuously electrofished for 2 minutes (eight 15-second intervals). A second 2-minute replicate was collected after a 5- to 10-minute pause.	None.	Catch was dominated by cyprinids, centrarchids, and yellow perch (*Perca flavescens*), all of which were abundant in the river.	Specific length ranges were not provided.	Benthic species, such as round goby (*Neogobius melanostomus*), were rarely captured despite being abundant in the river. A sampling design of two replicates of 1 minute appeared to balance a large gain of information with a small increase in effort. This design would allow 35 to 50 sites to be sampled per day.
Lyons and Kanehl 1993	Measure target species abundance and size structure.	Third- to fifth-order streams throughout Wisconsin.	Tow barge electrofisher with DC output and three anodes; output ranged from 3 to 7 amps and 100 to 250 volts and boat mounted mini boom shocker (Novotny and Priegel 1974; Reynolds 1983).	Tow barge was used in wadeable waters and the boat mounted mini boom shocker was used in deeper waters. Samples were collected during the day using four techniques: 1) CPUE sampling, 2) recapture sampling, 3) multiple shocker sampling, 4) removal sampling.	None.	Smallmouth bass (*Micropterus dolomieu*) was collected.	Specific sizes were not provided. Authors sampled young-of-year to >354 mm smallmouth bass.	The authors conclude that CPUE sampling provided a reasonably accurate but imprecise index of abundance for smallmouth bass and should not be used for comparisons of abundance among streams that differ in environmental characteristics. Sampling with multiple electrofishing units was recommended for larger and wider streams and removal sampling when abundance estimates are essential.

Table 3.2. Comparison Table of Electrofishing Methodology Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Electrofishing Boats (including rafts and barges), continued								
Meador 2005	Determine species composition and fish community structure.	Basins of the Albemarle-Pamlico, Mississippi embayment, Red River of the North, Rio Grande, Sacramento, San Joaquin-Tulare, Trinity, Upper Colorado , and Upper Mississippi rivers.	Boat electrofisher with pulsed DC. Pulse frequencies ranged from 30 to 60 pulses per second.	Part of the U.S. Geological Survey's National Water-Quality assessment (NAWQA). Boat electrofishing was conducted in the daytime and in a downstream direction. An electrofishing pass the length of the reach was made near the shoreline. A second pass was conducted along the opposite shoreline.	None.	Most common families collected: Catostomidae, Centrarchidae, Cyprinidae, Ictaluridae, and Percidae (targeted).	Specific length ranges were not provided	A single boat electrofishing pass may not be adequate to assess species richness or structure in reaches ranging 500 to 1,000 m. Increasing sampling effort by sampling a longer reach can increase the species richness obtained in a single pass. Sampling distance recommended depends on species richness and patchiness, species with low probabilities of detection, and channel morphology.
Mitro and Zale 2002	Measure abundance of a target species.	Henrys Fork of the Snake River Idaho. River is 25 km in length and varies from 50 to 150 m in width.	Electrofisher mounted in a drift boat that was used as a barge.	Mark-recapture survey. Sites were intensively resampled on 3 to 5 sample occasions. Fish were marked with a unique fin clip on each sample occasion.	None.	Rainbow trout (*Oncorhynchus mykiss*) was collected.	Age-0 fish were recorded.	Small capture probabilities and large confidence intervals made it possible to detect only relatively large changes in abundance, but at a level sufficient to satisfy management needs.
Paukert 2004	Determine CPUE and size structure of target species.	An 8-km reach of the Colorado River near the confluence of the Little Colorado River.	5-m Achilles inflatable boat equipped with pulsed-DC current using a Coffelt Mark XX Complex Pulse System (200–250 volts and 8–10 amps).	Sampling stations (N = 272) consisted of only one general habitat type, so sample time depended on habitat length. CPUE expressed as fish collected per hour of electrofishing.	Trammel nets.	Humpback chub (*Gila cypha*), flannelmouth sucker (*Catostomus latipinnis*), and bluehead sucker (*Catostomus discobolus*) were collected.	Fish >200 mm were targeted, but fish captured by electrofishing ranged in length from approximately 50 mm to 600 mm total length.	Fish collected by electrofishing were substantially smaller than those collected by trammel netting (>200 mm total length). This may be because the gears fished different habitats, which were occupied by different fish life stages. To detect a 25% change in CPUE at a power of 0.9, at least 473 trammel net sets or 1,918 electrofishing samples would be needed in this 8-km reach. Other methods (e.g., mark-recapture) were recommended to supplement.
Peterson and Rabeni 1995	Determine species composition and fish community structure.	Jacks Fork River, Missouri.	Boat-mounted electrofisher and electrified benthic trawl. Boat electrofisher equipped with a Wisconsin ring and operating at 7 amps. Electrified benthic trawl with a 0.5 × 1–m rectangular trawl with a 6-mm mesh bag electrified with 6 amps DC.	Deep water habitats (>1.5m) were sampled with a boat-mounted electrofisher and an electrified benthic trawl. The boat electrofishing sample consisted of six passes alternating upstream/downstream direction across the channel width. Benthic trawl consisted of three passes in a downstream direction moving across the channel width.	Shallow habitats were sampled by electric seine. Riffles were subsampled with a 1-m^2 quadrat sampler with 6-mm mesh.	Bleeding shiner (*Luxilus zonatus*), longear sunfish (*Lepomis megalotis*), and rainbow darter (*Etheostoma caeruleum*) were collected.	Specific length data were not provided. Authors sampled age-0 and age-1 fishes.	Using all three gear types, habitat-specific variation among samples ranged from CV = 0.13 to 1.58 (SD/mean) and were lower for community attributes (like richness) than biomass estimates. The number of samples needed to ensure CV <0.20 ranged from 2 to 245. Studies should allocate more effort to sampling different locations within a stream during relatively few sampling periods.
Pugh and Schramm 1998	Determine species composition, fish community structure, and CPUE.	Lower Mississippi River in sandbar and steep-bank habitats during three river states: falling, low, and rising.	Boat-mounted Smith-Root GPP 7.5 electrofisher powered by a 7,500-W generator. Two power settings used were: 500 volts/60 Hz/12.0–14.0 amps pulsed DC output and 1,000 volts/15 Hz/4.5–5.5 amps pulsed DC.	A minimum of five 5-min samples were collected at voltage setting in both habitats at each of six locations. Steep bank habitat was sampled parallel to the bank in a downstream direction in water 1.2 to 6.0 m deep. Sandbar habitat was sampled by operating the boat in a downstream direction following an S-shaped course in water 1.0 to 3.0 deep.	Hoop nets.	Catch was dominated by large-bodied species (shad and catfish), but also included some shiners.	Specific length data were not provided.	An average electrofishing sample averaged 12 minutes, which included time netting and measuring fish, and required 3 people. An electrofishing sample required 0.6 person-hours of effort per sample. Electrofishing collected wider length ranges of fish and cost less per fish collected than did hoop netting. Authors concluded that low frequency and high frequency pulsed DC electrofishing was effective in lotic habitats.

Table 3.2. Comparison Table of Electrofishing Methodology Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Electrofishing Boats (including rafts and barges), continued								
Ruetz III et al. 2007	Determine species composition and fish community structure.	Littoral zone of Muskegon Lake, Michigan.	Smith-Root electrofishing boat (240 volts, 4 to 6 amps pulsed DC).	The boat was used to sample at night. Transects were 10 min in duration (500-750 m in length) and were conducted parallel to the shoreline. Two people netted fish from the bow while the boat was run at idle speed.	Small-mesh fyke net.	Species strongly associated with electrofishing were Chinook salmon (*Oncorhynchus tshawytscha*), longnose gar (*Lepisosteus osseus*), quillback (*Carpiodes cyprinus*), silver redhorse (*Moxostoma anisurum*), freshwater drum (*Aplodinotus grunniens*), golden redhorse (*Moxostoma erythrurum*), walleye (*Sander vitreus*), gizzard shad (*Dorosoma cepedianum*), channel catfish (*Ictalurus punctatus*), white sucker (*Catostomus commersonii*), emerald shiner (*Notropis atherinoides*), and common carp (*Cyprinus carpio*).	Fish (mean total length = 20.4 cm, standard error [SE] = 1.9 cm) collected by electrofishing were significantly longer than those collected by fyke netting (mean total length = 7.6 cm, SE = 0.5 cm).	Size selectivity of the gears contributed to differences in species composition. Fyke nets and electrofishing provided complimentary information on the fish assemblage. Results supported use of multiple-gear types in monitoring and research surveys.
Shea and Peterson 2007	Determine species composition, fish community structure, and habitat associations.	Flint River in southwestern Georgia, upstream and downstream of the Crisp County Dam.	Boat-mounted, dual electrode Wisconsin ring Smith-Root Type VI-A electrofisher operated at 4 amps pulsed DC.	This gear was used to sample non-wadeable channel units (scour pools, shoals, and transitions) using a standardized six-pass procedure during daylight hours	Backpack electrofisher.	There were 50 species collected, dominated by centrarchids, percids, and cyprinids.	Specific lengths were not provided.	Habitat complexity had the greatest influence on species composition and community structure. Boat electrofishing effectively sampled non-wadeable channel units.
Simonson and Lyons 1995	Determine species composition, fish community structure, and fish CPUE.	Wadeable streams in southern Wisconsin, including cold, cool, and warm water streams.	DC tow-barge.	Each site was divided into two stations: one CPUE and one removal station). Each station was approximately 35 times the mean stream width in length. The CPUE sample consisted of one run downstream. The removal involved three to four removal passes after the station had been blocked with 6-mm mesh nets.	None.	There were 36 species collected, dominated by cyprinids and centrarchids.	Specific lengths were not provided.	Use of block nets had little effect on CPUE during single upstream electrofishing passes; for stations 35 times the mean stream width in length, the overall influence of fish entering and leaving the station was negligible. CPUE and abundance estimates were correlated. A single upstream CPUE pass adequately assessed fish species richness, abundance, and assemblage structure in small streams
Velez 2004	Determine species composition and fish community structure, fish CPUE, and population size.	Verde River in central Arizona. Reaches selected had a range of anthropogenic impact.	Coffelt VVP-15 raft-mounted electrofishing unit.	Used to collect fish in deeper pools and runs. Samples were collected from habitats (one each riffle, run, and pool) blocked with 3.2-cm bar mesh nets. Removal passes (n = 3+) were conducted in each.	Cooperatively with one or more backpack electrofishers.	There were 19 species collected, primarily cyprinids, catostomids, and centrarchids.	Specific lengths were not provided. Fish were divided into age classes 0, 1 and 2+.	The proportion of native fishes was highest in pools and riffles in the headwaters sections and highest in runs and riffles in the downstream sections. Mean density and standing crop for native and nonnative fish varied across season, sections, and habitat classifications.
Backpack Units								
Dauwalter and Pert 2003	Determine species composition and fish community structure.	Wadeable streams in the Ozark Highlands ecoregion of Arkansas characterized by mountainous terrain, steep gradients, and fractured limestone geology.	Smith-Root backpack electrofisher with two anodes and one cathode, pulsed DC.	Stream reaches of 75 mean wetted widths were divided into 15 segments. Each segment was sampled within one pass by the backpack electrofisher wading upstream.	None.	There were 50 species collected, dominated by cyprinids, percids, and centrarchids.	Specific lengths were not provided.	On average, a distance of 101.8 mean stream widths was needed to sample 95% of species richness at a site.

Table 3.2. Comparison Table of Electrofishing Methodology Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Backpack Units, continued								
Dauwalter and Pert 2003	Determine species composition and fish community structure.	Wadeable streams in the Ozark Highlands ecoregion of Arkansas characterized by mountainous terrain, steep gradients, and fractured limestone geology.	Smith-Root backpack electrofisher with two anodes and one cathode, pulsed DC.	Stream reaches of 75 mean wetted widths were divided into 15 segments. Each segment was sampled within one pass by the backpack electrofisher wading upstream.	None.	There were 50 species collected, dominated by cyprinids, percids, and centrarchids.	Specific lengths were not provided.	On average, a distance of 101.8 mean stream widths was needed to sample 95% of species richness at a site.
Janac and Jurajda 2007	Determine species richness, relative abundance, and size structure of the age-0 fish assemblage.	Morava River in a channelized section. Channel widths range from 50 to 60 m, depth is 1 m on average, and the shoreline is strengthened by a boulder bank.	Backpack electrofisher (Lena Bednar, Czech Republic) with a maximum output of 225 to 3,000 volts, a maximum output current of 6 amps., and a pulse frequency of 80 to 95 Hz.	Electrofishing was conducted by wading the bank in an upstream direction. Samples were collected in two ways for comparison 1) point samples consisted of surveying 10 points at each site. Continuous samples consisted of surveying 10 uninterrupted meters of shoreline	None.	Eighteen species and several families were collected.	Age-0 fishes, including small- and large-bodied species, were recorded.	Point sampling allowed the surveying of significantly longer river reaches in the same amount of time than did continuous sampling. No significant differences were detected in the average number of species per site or in species relative abundance between point and continuous samples. Point sampling is recommended because surveying longer river sections enhances the probability of encountering new species.
Kennard et al. 2006	Determine species composition, fish community structure, and fish CPUE.	Wadeable streams of southeastern Queensland, Australia.	Smith-Root backpack DC electrofisher (300–400 volts, 70 Hz frequency, and 4-m pulse width).	Mesohabitats were blocked upstream and downstream with weighted seine nets (1-mm stretched-mesh). The operator and one or two dip-netters electrofished in an upstream direction, using short, intermittent pulses, in a zigzag fashion. Up to five electrofishing passes were conducted in the enclosure.	Seine nets were used in the enclosure after electrofishing effort was complete.	Fish in 13 families were collected.	Maximum size of species was reported. Size ranged from 6 to 100 cm depending on the species.	Multiple-pass electrofishing plus seine netting provided more accurate and precise estimates of fish species richness, assemblage composition and species relative abundances in comparison to single-pass electrofishing alone. Intensive sampling of three mesohabitat units (equivalent to a riffle–run–pool sequence) is a more efficient sampling strategy to estimate reach-scale assemblage attributes than less intensive sampling over larger spatial scales. This intensive sampling protocol detected changes in assemblage attributes (<20%) with a high statistical power ($1-\beta>0.95$) and relatively few stream reaches (<4) need be sampled to accurately estimate assemblage attributes close to the true population means.
Mahon 1980	Measure CPUE.	Several localities in Poland and Ontario.	Battery and generator backpack electrofishers with two anodes wired in parallel.	Each sampling location was isolated with block nets (1-3 mm mesh). Five to seven depletion passes were conducted, working upstream between block nets. After electrofishing was finished, rotenone was applied to collect remaining fish.	Rotenone after completion of electrofishing.	Catch was composed of 37 species, primarily percids (darters) and cyprinids.	Specific length ranges were not provided.	Estimate error was most closely related to the proportion of fish collected and can be best reduced by adding additional passes. Catchability decreased in successive passes. Size-selectivity was not significantly associated with changing catchability.
Mercado-Silva and Escandon-Sandoval 2008	Determine species composition and fish community structure.	San Francisco River, Rio Antigua basin, Mexico. River has low turbidity, a variety of habitats (riffles, pools, runs), and rocky substrates.	Battery-powered Wisconsin ABP-3 electrofisher producing approximately 300 volts of pulsed DC at 20 Hz and pulse width of 2.9 m.	Five sites were sampled in daylight during summer. Sampling reaches were 50 m long (10 times the average width). A single pass was made covering all habitat types and the entire width of the stream. Catch expressed as fish per 50 m.	A seine unit was used in the same sites, with at least 48 hours between sampling events.	Catch was composed of 10 species in the families Poeciliidae, Cichlidae, Synbranchidae, Gobiidae, Characidae, and Pimelodidae.	Specific length ranges were not provided. Electrofishing captured fast-swimming and benthic species that seines missed.	Electrofishing produced higher estimates of species richness, diversity, and biomass than seining. Species' relative abundance was similar. Seining alone may not be adequate for bioassessment.

Table 3.2. Comparison Table of Electrofishing Methodology Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Backpack Units, continued								
Poos et al. 2006	Determine species composition / detect rare species.	Sydenham River, Ontario, Canada.	Backpack electrofisher (pulsed DC current at 200–225 volts, 60 Hz, and pulse length of 3 m).	Single-pass method was used.	Seining.	Target species were eastern sand darter (*Ammocrypta pellucida*), blackstripe topminnow (*Fundulus notatus*), greenside darter (*Etheostoma blennioides*), and spotted sucker (*Minytrema melanops*). Fifty species were collected.	Small-bodied species were recorded.	Electrofishing was a more effective gear type than seining for sampling fish species at risk, irrespective of the unit (presence/absence or CPUE).
Quist et al. 2006	Determine species composition, fish community structure, and fish CPUE.	Muddy Creek, Wyoming. In this headwater stream, wetted widths are generally <2m and channel gradient ranges 2% to 4%. Substrate is dominated by gravel with some boulder, cobble, and sand.	Smith-Root backpack electrofisher.	Compared random and fixed-site sampling designs. Sampling reaches were approximately <200m isolated with block nets. One electrofishing pass was conducted in each reach in an upstream direction.	None.	Bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*C. latipinnis*), white sucker (*C. commersonii*), roundtail chub (*Gila robusta*), speckled dace (*Rhinichthys osculus*), and creek chub (*Semotilus atromaculatus*) were collected.	Specific lengths were not provided.	Detection of 10% or 25% changes in CPUE (fish/100 m²) at 60% statistical power required 50 to 1,000 randomly sampled reaches among species regardless of sampling design. Use of a fixed site sampling design with 25 to 50 reaches greatly enhanced the ability to detect changes in CPUE. Recommend establishment of 25 to 50 fixed reaches.
Shea and Peterson 2007	Determine species composition, fish community structure, and habitat associations.	Flint River in southwestern Georgia, upstream and downstream of the Crisp County Dam.	Smith-Root LR-24 backpack electrofisher operating at 0.25 amps pulsed DC.	Wadeable channel units (edge water, side channel, or backwater) were block netted with 7-mm-mesh nets. Fish were collected using a standardized six-pass procedure. Sample area was consistent among samples.	Boat electrofisher.	There were 50 species collected, dominated by centrarchids, percids, and cyprinids.	Specific lengths were not provided.	Habitat complexity had the greatest influence on species composition and community structure. Backpack electrofishing units in block-netted sections effectively sampled wadeable channel units.
Velez 2004	Determine species composition, fish community structure, and fish CPUE.	Verde River in central Arizona. Reaches selected had a range of anthropogenic impact.	Smith Root Model 12-B (battery powered) and Model 15 (generator powered) backpack electrofishing units.	Used to collect fish in shallow areas and along shorelines. Samples were collected from habitats (one each riffle, run, and pool) blocked with 3.2-cm bar mesh nets. Removal passes (n = 3+) were conducted in each.	Cooperatively with a raft-mounted electrofisher.	There were 19 species collected, primarily cyprinids, catostomids, and centrarchids.	Specific lengths were not provided. Fish were divided into age classes 0, 1 and 2+.	The proportion of native fishes was highest in pools and riffles in the headwaters sections and highest in runs and riffles in the downstream sections. Mean density and standing crop for native and nonnative fish varied across season, sections, and habitat classifications.
Specialized Systems – Pre-positioned Frame								
Dewey 1992	Measure CPUE.	Backwater lake in the upper Mississippi River; water had no discernible current and depths of 0.6 to 1.0 m.	The electrofishing frames (3.1 m long, 1.8 m wide, and 1.2 m high) were constructed of PVC pipe and electrified by anodes connected to an electrofishing boat. The frame sampled 5.6 m^2.	Three frames were set 20 m apart and left undisturbed for 30 min. Each frame was separately electrified. Pulsed DC was applied while two people netted all visible immobilized fish from the interior of the frame. Nets on the outside of the frame were then dropped to enclose the frame and a seine pulled through the enclosure to collect any remaining fish.	Same frame was used with netted sides as a drop net. A pop net was also tested.	Common carp (*Cyprinus carpio*), emerald shiner (*Notropis atherinoides*), tadpole madtom (*Noturus gyrinus*), largemouth bass (*Micropterus salmoides*), warmouth (*Lepomis gulosus*), bluegill (*Lepomis macrochirus*), black crappie (*Pomoxis nigromaculatus*), yellow perch (*Perca flavescens*), and johnny darter (*Etheostoma nigrum*) were collected.	Sizes ranged from 21 to 87 mm total length.	The electrofishing frame, although effective in waters with high visibility and little vegetation, should not be used in vegetated turbid waters.

Table 3.2. Comparison Table of Electrofishing Methodology Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Specialized Systems – Pre-positioned Frame, continued								
Walsh et al. 2002	Characterize species habitat associations.	Shallow-water habitats (<1.0-m deep) in a small, spring-fed stream in northeast Oklahoma.	The pre-positioned area electrofishers (PAEs) were 1 × 0.75 m. Power was supplied to PAEs by a Smith-Root 2.5 GPP electrofishing system (AC, 3 amps).	PAE grids were positioned 2 m apart along transects located 2 m apart through the study site. Eight PAEs were set up at a time and each electrified for 10 s, with about 10 min between samples. The study site was enclosed by two block nets prior to sampling.	Electrified seine.	Banded sculpin (*Cottus carolinae*), cardinal shier (*Luxilus cardinalis*), central stoneroller (*Campostoma anomalum*), creek chub (*Semotilus atromaculatus*), fantail darter (*Etheostoma flabellare*), orangethroat darter (*Etheostoma spectabile*), shadow bass (*Ambloplites ariommus*), slender madtom (*Noturus exilis*), smallmouth bass (*Micropterus dolomieu*), southern redbelly dace (*Phoxinus erythrogaster*), stippled darter (*Etheostoma punctulatum*) were collected.	Small-bodied species were recorded. No differences in length distribution were detected between PAEs and electrified seine, except for smaller fish by PAEs for the orangethroat darter and southern redbelly dace.	The electrified seine sampled each site more efficiently than the PAE samples, but the PAEs allow for a more thorough evaluation of fish microhabitat use. Variation and sampling effort necessary to estimate species richness were higher for the PAEs.
Specialized Systems – Electric Seine								
Angermeier et al. 1991	Determine species composition.	Pool and riffle habitats in two Virginia streams.	Electric seine with a rheostat for regulating circuit amperage, use of fiberglass tubing in the brail, readily engaged or disengaged connections between the brails and drop electrode array, and use of automobile brake cables as drop-electrodes with adjustable lengths.	Mesohabitat to be sampled was enclosed with 0.6-cm mesh nets. The 9.1 m electric seine was then dragged slowly upstream in the enclosure. One person operated each brail and two persons walked behind the seine to retrieve fish. 10 removal passes were made through each mesohabitat to evaluate gear efficiency.	None.	Cyprinids, catostomids, centrarchids, and percids were collected.	Specific length data were not provided.	The electric seine was widely applicable for sampling fish in small to medium-sized streams with low to moderate gradients. Two major constraints on its use involved water depth and clarity. The electric seine was most appropriate for quantitatively estimating species composition and population densities of entire fish assemblages. The first two passes collected 53% to 79% of fish.
Peterson and Rabeni 1995	Determine species composition and fish community structure.	Jacks Fork River, Missouri.	9.14-m electric seine powered by a 120-volt AC generator rated at 2,200 W at 15 amps maximum output and 1,500 W at 12.5 amps continuous output.	Block-netted shallow habitats were sampled by two passes of the electric seine (first upstream and second downstream).	Deep water habitats were sampled with a boat-mounted electrofisher and an electrified benthic trawl. Riffles were subsampled with a 1-m^2 quadrat sampler with 6-mm mesh.	Bleeding shiner (*Luxilus zonatus*), longear sunfish (*Lepomis megalotis*), and rainbow darter (*Etheostoma caeruleum*) were collected.	Specific length data were not provided. Authors sampled age-0 and age-1 fishes.	Using all three gear types, habitat-specific variation among samples ranged from CV = 0.13 to 1.58 (SD/mean) and were lower for community attributes (like richness) than biomass estimates. The number of samples needed to ensure CV<0.20 ranged from 2 to 245. Studies should allocate more effort to sampling different locations within a stream during relatively few sampling periods.
Walsh et al. 2002	Characterize species habitat associations.	Shallow-water habitats (<1.0-m deep) in a small, spring-fed stream in northeast Oklahoma.	The electric seine had two electrode arrays (5 and 10 m) that consisted of 0.5-m lengths of twisted stainless steel cable placed 0.5 m apart across the length of the array. The two arrays could be connected to make a 15-m array.	The 20-m study site was enclosed by two block nets prior to sampling. Five upstream passes were made through the enclosed area, removing and measuring fish after each pass.	PAEs.	Banded sculpin (*Cottus carolinae*), cardinal shier (*Luxilus cardinalis*), central stoneroller (*Campostoma anomalum*), creek chub (*Semotilus atromaculatus*), fantail darter (*Etheostoma flabellare*), orangethroat darter (*Etheostoma spectabile*), shadow bass (*Ambloplites ariommus*), slender madtom (*Noturus exilis*), smallmouth bass (*Micropterus dolomieu*), southern redbelly dace (*Phoxinus erythrogaster*), stippled darter (*Etheostoma punctulatum*) were collected.	Small-bodied species were recorded. No differences in length distribution were detected between PAEs and electrified seine, except for smaller fish by PAEs for the orangethroat darter and southern redbelly dace.	The electrified seine sampled each site more efficiently than the PAE samples. Variation and sampling effort necessary to estimate species richness were lower for the electrified seine than the PAEs. Two to three passes of the electric seine was adequate sampling effort to estimate species richness at each site.

Table 3.2. Comparison Table of Electrofishing Methodology Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Specialized Systems – Electrified Trawl								
Freedman et al. 2009	Determine species composition and fish community structure.	Ohio, Allegheny, and Monongahela rivers in Pennsylvania. The substrate of the Allegheny is gravel and rocks while that of the Monongahela is primarily sand and mud.	Electrified benthic trawl consisted of a Missouri trawl (19.05-mm stretched inner mesh bag and a4.76-mm stretched outer mesh bag. The trawl was modified by adding a 15-cm stretched mesh across the opening of the net as a rock exclusion device. Five 30-cm-long anodes to each of the tow ropes above the otter boards and a wire along the head rope.	Trawl was pulled by a 5.3-m johnboat powered by a 25-hp outboard motor.	Paired sites were sampled with the electrified trawl and the non-electrified trawl.	Twenty-seven species were collected, including cyprinids and small percids.	Specific lengths were not provided. The electrified trawl captured more large fish than the non-electrified trawl.	The electrified trawl captured significantly more fish (mean = 24.7 fish per haul) and species (mean = 3.2 species per haul) than the non-electrified trawl (means = 11.2 fish per haul and 1.9 species per haul). The electrified trawl is a useful device for sampling large-river benthic fish communities
Peterson and Rabeni 1995	Determine species composition and fish community structure.	Jacks Fork River, Missouri.	Rectangular electrified benthic trawl measuring 0.5 × 1 m with a 5-mm mesh bag electrified with a 6-amp DC, with the anode at the top and the cathode at the bottom (Peterson and Rabeni 1994).	Deep water habitats (>1.5m) were sampled with a boat-mounted electrofisher and an electrified benthic trawl. The boat electrofishing sample consisted of six passes alternating upstream/downstream direction across the channel width. Benthic trawl consisted of three passes in a downstream direction moving across the channel width.	Shallow habitats were sampled by electric seine. Riffles were subsampled with a 1-m^2 quadrat sampler with 6-mm mesh.	Bleeding shiner (*Luxilus zonatus*), longear sunfish (*Lepomis megalotis*), and rainbow darter (*Etheostoma caeruleum*) were collected.	Specific length data were not provided. Authors sampled age-0 and age-1 fishes.	Using all three gear types, habitat-specific variation among samples ranged from CV = 0.13 to 1.58 (SD/mean) and were lower for community attributes (like richness) than biomass estimates. The number of samples needed to ensure CV<0.20 ranged from 2 to 245. Studies should allocate more effort to sampling different locations within a stream during relatively few sampling periods.

3.1.3 TRAWLS

Trawls are funnel-shaped nets that are towed through the water, typically behind a motorized boat, capturing fish and funneling them into the cod end of the net (Hayes et al. 1996). Trawls allow managers to sample a specific area or volume of water over a specified time allowing for the calculation of quantitative indices of population abundance. Trawls are typically not effective in habitats where entanglement in vegetation or underwater structures is likely. The trawl design has been adapted for use in particular habitats or species.

Studies we reviewed used otter, Missouri, mini-Missouri, and brail trawls to assess relative abundance, distribution, species composition, and habitat use (Table 3.3). Otter trawls are those that have been modified by adding otter doors to keep the mouth of the net open when towed. The Missouri trawl is an otter trawl with a fine-mesh cover. The mini-Missouri trawl is a miniature version of the regular Missouri trawl. The brail trawl is an adaptation of the mini-Missouri, which has hooks that drag and disturb the substrate in front of the trawl net. The Missouri, mini-Missouri, and brail trawls have been adapted to be more effective at targeting small-bodied fishes.

Haddix et al. (2009) reported that otter trawls were effective for sampling juvenile pallid sturgeon (*Scaphirhynchus albus*) and assessing fish community structure of large-bodied fishes. However, Haddix et al. (2009) found that mini-fyke nets were more effective for sampling small-bodied fish, such as western silvery minnow (*Hybognathus argyritis*), and in shallow habitats (<1.2-m depth) than trawling.

Herzog et al. (2005) reported that the Missouri trawl method was effective for sampling benthic species in moderate to large river systems but cannot be used in water depths less than 0.5 m. Herzog et al. (2005) also reported that the use of smaller mesh cover for the trawl improved the catch of small bodied fishes. The mini-Missouri trawl was found to be effective for sampling small-bodied fishes, including benthic species, when a brail was attached (Herzog et al. 2009; Ridings 2009). The mini-Missouri trawl was successfully used in water depths ranging from 0.5 to 7.3 m (Herzog et al. 2009).

Welker and Scarnecchia (2004) used a benthic beam trawl to sample fish in main channel habitats. The authors reported effectively sampling species such as sicklefin (*Macrhybopsis meeki*) and sturgeon chubs (*M. gelida*) in the deep, high-velocity main channel habitat with the trawl. Species such as flathead chub (*Platygobio gracilis*) and western silvery minnow (*Hybognathus argyritis*) were captured in the shallow, low-velocity channel border habitat with the bag seine.

Table 3.3. Comparison Table of Trawl Sampling Used in Other River Systems

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Haddix et al. 2009	Determine species abundance, distribution, and habitat use in target species.	Missouri River below Fort Peck Dam to its confluence with the Yellowstone River.	Standard otter trawl (7.6 m long, 4.9 m wide, and 0.9 m tall) had an inner (6.35-mm bar) and outer mesh (38-mm bar) and a cod end opening of 406.4 mm. Plywood doors were used to keep the mouth of the trawl open while deployed on the riverbed.	The trawl was deployed from the bow of the boat parallel to the current with two 30.5-m ropes and towed downstream slightly faster than current speed for 75 to 300 m.	Trotlines, trammel nets, and mini-fyke nets.	Pallid sturgeon (*Scaphirhynchus albus*) was the primary target species. Secondary targets were shovelnose sturgeon (*Scaphirhynchus platorynchus*), blue sucker (*Cycleptus elongatus*), sauger (*Sander canadense*), sturgeon chub (*Macrhybopsis gelida*), sicklefin chub (*M. meeki*), speckled chub (*M. aestivalis*), plains minnow (*Hybognathus placitus*), western silvery minnow (*H. argyritis*), and sand shiner (*Notropis stramineus*).	Juvenile and adult large-bodied fishes were collected.	Otter trawls were effective at sampling juvenile sturgeon (mean fork length = 272.2 mm). Mini-fyke nets were the best gear for comparing relative abundance of western silvery minnow between years. Mini-fyke nets collected 371 of the 377 specimens, while otter trawls collected the remaining six. Mini-fyke-nets were also most effective for sampling shallow habitats (<1.2 m depth).
Herzog et al. 2005	Determine species composition and CPUE.	Mississippi River between the Missouri and Ohio river confluences.	Missouri trawl was made of a two-seam slingshot balloon trawl completely covered with 4.76-mm heavy delta mesh. The standard trawl cod end was lined with 3.18-mm ace mesh, so the same size mesh was added to the cover's cod end, which was 2.14 m long and 1.52 m wide.	A standard haul was approximately 350 m and lasted 6 minutes. The trawl was towed by a 7.32-m johnboat equipped with a 90-horsepower outboard motor. The boat was powered in reverse (bow upstream) with continued movement downstream. Effort was recorded in time and distance.	Standard trawl without the fine-mesh cover.	Fish from the families Acipenseridae, Polyodontidae, Lepisosteidae, Clupeidae, Cyprinidae (including Mississippi silvery minnow [*Hybognathus nuchalis*]), Catostomidae, Ictaluridae, Atherinopsidae, Moronidae, Centrarchidae, Percidae, and Sciaenidae were collected	Based on species composition, a large range of sizes were collected.	Trawling location and duration were limited by water depth less than 0.5 m and bottom snags. Catch of small-bodied adult fish was significantly improved by use of the small-mesh cover design. The Missouri trawl is a useful method for sampling the benthic fish community in moderate- to large-sized river systems.
Herzog et al. 2009	Determine species composition and CPUE.	A range of rivers of different sizes, substrates varying from boulders to silt.	Mini-Missouri trawl body was made of 17.46-mm bar mesh netting. The trawl narrowed from 2.44 m wide at the head rope to 0.46 m wide at the midsection and then straight to the cod end of 0.46 m wide. A 3.18-mm heavy delta mesh cover was attached to the trawl that was 4.56 m long and included a cod end of 3.18-mm heavy delta mesh. Otterboards and a buoy were attached to the cod end of the trawl to assist with snag removal.	The mini-Missouri trawl was generally towed by a 4.88-m boat with a 25-horsepower motor and 15- to 60-m towlines. Trawling was conducted in a downstream direction with the boat powered in reverse (bow upstream). The typical haul covered 175 m and lasted 3 minutes. Trawling speed and distance was recorded by global positioning system (GPS) unit.	None.	Primarily cyprinids and percids (darters) were collected.	Small-bodied species were collected.	Successful sampling has been conducted at water depths ranging 0.5 m to 7.3 m, surface water velocities ranging 0 to 1.7 m/s, and Secchi disk transparencies as low as 3 cm. This gear has increased the detection probability of rare small-bodied species over traditional gears (e.g., seine) in diverse river systems.
Ridings 2009	Determine species composition and CPUE.	Missouri River basin.	The mini-Missouri trawl was modified by attaching a mussel brail just in front of the trawl. The brail was 122 cm wide with 61-cm-long brail hook clusters that were attached with carabineers to the towlines about 20 cm boatward of the otter doors, positioning the brail just in front of the lead line of the trawl.	When deployed, the brail was lifted up over the lip of the bow while keeping tension on the ropes even as the trawl was lowered into the water. This was necessary to keep the cod end of the trawl from entangling with the brail hooks. Otherwise, the trawl was used like a mini-Missouri trawl.	None.	Madtoms (*Noturus*), darters (*Etheostomatini*) and sculpins (*Cottus*) were collected.	Small-bodied benthic species were collected.	The brail trawl captured significantly more darters, madtoms, and sculpins than the mini-Missouri trawl without a large increase in snagging.
Welker and Scarnecchia 2004	Determine species composition, habitat associations, and longitudinal distribution.	Missouri and Yellowstone rivers, North Dakota.	A benthic beam trawl was used (2 m wide, 0.5 m tall, 5.5 m long, 0.32-cm inner mesh, 3.81-cm outer chafing mesh, 16.5-cm cod end opening).	Fish in the main channel habitat were sampled with the benthic beam trawl. Three trawl subsamples were in each selected sample unit (250 m of river). For each subsample, the trawl was attached to the bow of the boat and towed downstream (in reverse) beginning at the upstream boundary and proceeding downstream parallel to the shoreline. The subsamples were the thalweg, left of the thalweg, and right of the thalweg.	A bag seine used in main channel border habitats.	Target species were flathead chub (Platygobio gracilis), sicklefin chub (Macrhybopsis meeki), sturgeon chub (Macrhybopsis gelida), and western silvery minnow (Hybognathus argyritis).	Fish captured ranged from <40 mm to >100 mm, but the length distributions are not separated by gear type.	Most sicklefin and sturgeon chubs were captured in the deep, high-velocity main channel habitat with the trawl, whereas most flathead chub and western silvery minnow were captured in the shallow, low-velocity channel border habitat with the bag seine.

3.1.4 ENTRAPMENT GEARS

Entrapment gears are a group of passive fish collection methods that rely on fish entering the gear by their own movement (Hubert 1996). Once captured, the fish have the ability to escape through the entrance; however, design features are incorporated to reduce the likelihood of escape (e.g., funnel necks). Entrapment devices have a variety of design features depending on the target species habitat use, migration patterns, escape reactions, and size. Common entrapment gears include hoop nets, fyke nets, pot gears (e.g. minnow traps, Windermere traps), and weirs.

All entrapment gears are selective for fish attracted to cover, bait, or other fishes. Net construction and deployment and physical, chemical, biological variables can influence the species, size, catch rates, and capture efficiencies of fishes (Hubert 2006; Stone and Gorman 2006). Sampling design should standardize net design, sampling time, habitat types, and other important variables to reduce sampling variability (Holland and Peters 1992; Hubert 2006).

In general, entrapment gears are widely used in fisheries stock assessments due to their low mortality rates and physical harm to fish (Hubert 1996). Entrapment gears can also be modified to allow escapement of small fishes and non-target species such as reptiles and amphibians. Catch rates are typically lower than entanglement gears such as gill or trammel nets.

HOOP NETS

Hoop nets are conical or cylindrical nets, covered with webbing, distended by a series of hoops or frames, with one or more internal funnel-shaped throats that are directed inward from the mouth of the net. Hoop nets do not have any lead or wing walls. The throats are designed to reduce the likelihood of fish escaping and are typically either a square or finger throat design. Hoop nets are often used in main channel habitats because they can be efficiently fished in strong currents (Hubert 2006). These nets can also be used in slower water habitats such as reservoirs and floodplains. They are often used to assess habitat associations, population structure, and life history (Hubert 2006).

We reviewed four studies that used hoop nets to describe species composition, fish community structure, and species richness; estimate relative abundance of fishes; and conduct population estimates (Table 3.4). Hoop nets were used to sample small- and large-bodied fishes in river systems and measured 0.5 to 1.0 m in diameter and 1.0 to 5.0 m long, with 6.0- to 50.8-mm mesh. Hoop nets contained multiple hoops and had one or more funnel-shaped throats. The nets were typically set perpendicular to the shore and set for 12 to 24 hours. The majority of studies (n = 4) tested other sampling techniques in the areas where hoop nets were set to assess the effectiveness of the different methods or to get a better description of the entire fish community.

In studies where multiple gears were used in the same area, authors reported differences in fish assemblages with hoop nets compared to other methods (Pugh and Schramm 1998; Utrup and Fisher 2006). Multiple studies reported hoop nets required more person-hours to deploy, resulted in lower catches rates than other gears, and primarily targeted catfish (family Ictaluridae) (Pugh and Schramm 1998; Coggins et al. 2006; Utrup and Fisher 2006).

FYKE NETS

Fyke nets are similar to hoop nets; however, they are commonly used in lentic habitats and are designed with one to three leads or wing walls attached to the mouth of the net (Hubert 1996). These leads or wings are the same height as the fyke net and intercept swimming fish and guide them into the mouth of the net. For this reason, fyke nets are often more effective than hoop nets at capturing mid-water and schooling fishes. Fyke nets can have circular or rectangular frames and are also referred to as wing nets, frame nets, and trap nets (Hubert 1996). Fyke nets are generally set in shallow or low-velocity areas and can be efficiently used in heavy vegetation. Fyke nets are effective at capturing migratory species that tend to follow shorelines or are seeking cover.

Eight studies we reviewed used fyke nets to describe species composition, fish community structure, and species richness and estimate relative abundance of fishes and habitat use (see Table 3.4). Species targeted by these studies included small- and large-bodied benthic and mid-water species utilizing lower-velocity habitats such as floodplains, backwaters, and shorelines. Nets used in these studies included fyke nets and mini-fyke nets. Fyke nets were constructed of 3- to 25-mm mesh (diamond or bar), 0.9 to 4.6 m high, and 1.2 to 4.6 m wide (square or rectangular frames), and all nets had two wings ranging in length from 1.75 to 7.0 m. Mini-fyke nets were constructed of 3- to 4.7-mm mesh, 0.6 to 0.9 m high, and 0.9 to 4.5 m wide (square or rectangular frames), and each net had a lead but no wings. All nets were typically set perpendicular to the shore and set for 24 hours. One study set the nets for 6, 24, or 28 hours depending on the experimental treatment (Breen and Ruetz III 2006). The majority of fyke net studies (n = 6) tested other sampling techniques in the areas where fyke nets were set to assess the effectiveness of the different methods or to get a better description of the entire fish community and habitat use.

In studies where multiple gears were used in the same area, authors reported differences in fish assemblages with fyke nets compared to other methods due to size selectivity of gears, fish behavior, and location of fish in the water column (Fago 1998; Koel 2004; Breen and Ruetz III 2006; Ruetz et al. 2007; Haddix et al. 2009). In some studies, authors reported that fyke nets collected almost all species detected and the extra person-hours involved in setting the nets were justified by the fisheries information gained (Clark et al. 2006; Lapointe et al. 2006a; Ruetz et al. 2007; Haddix et al. 2009). In studies where species composition and community structure were high priorities, authors recommended a multiple-gear approach consisting of fyke nets, electrofishing, and/or seining (Fago 1998; Koel 2004).

POT GEARS

Pot gears are rigid, portable traps commonly used to capture bottom-dwelling fish and crustaceans that are seeking food or cover (Hubert 1996). In general, pot gears are designed so the fish or crustacean must pass through one or more conical-shaped funnels to enter the trap, reducing the likelihood of escape (Hubert 1996). Trap designs are often modified for species and size selectivity. These traps are relatively inexpensive and easy to use; however, they are not an efficient method for monitoring relative abundance due to the variability among catch rates of trap sets (Hubert 1996; Valdez and Ryel 1995; Valdez and Ryel 1997).

We reviewed two studies that used pot gears, minnow traps, and/or Windermere traps to conduct population estimates or assess species composition and fish community structure (see Table 3.4). Windermere traps are similar to minnow traps, but larger. Species targeted by these studies included juvenile salmonids, ictalurids, centrarchids, and cyprinids. Bryant (2000) deployed baited minnow traps in block-netted sample areas for three to four 90-minute intervals. Lapointe et al. (2006a) deployed baited minnow and Windermere traps in slow-water habitats for 18- to 24-hour periods. Bryant (2000) found that minnow traps could be used to obtain population estimates for juvenile salmon in second- to fifth-order streams. Lapointe et al. (2006a) discovered that minnow traps were ineffective for sampling species composition, but that Windermere traps were as effective as other gears for estimating abundance and richness of benthic species. However, Windermere traps produced significantly lower estimates of abundance and richness for non-benthic species.

Table 3.4. Comparison Table of Entrapment Gears Used in Other River Systems

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Hoop Nets								
Coggins et al. 2006	Determine species abundance and trends by mark-recapture estimators.	Lower Little Colorado River and mainstem Colorado River near its confluence, Arizona.	Hoop nets were 0.5 to 1.0 m in diameter and 1.0 to 5.0 m long with 6-mm mesh and a single or double 10-cm throat.	Hoop nets were set either anchored to shore or in mid-channel pools.	Sites were also sampled by trammel nets and electrofishing.	Target species was humpback chub (*Gila cypha*)n	Length data were not provided, but adult fish were the primary target.	Effort was not standardized among gears and cannot be meaningfully compared. Hoop nets collected a greater number of fish in the Little Colorado River than trammel nets. In the main stem, trammel nets collected a greater number of fish than hoop nets and electrofishing combined.
Holland and Peters 1992	Determine species composition and CPUE.	Lower Platte river in eastern Nebraska. The river is broad, shallow, and braided; more than 90% of the channel is less than 60 cm deep and average velocity of the current is 44 cm/s. The water is turbid.	Hoop nets were 1.5 m long, 0.6 m in diameter, and had four wooden hoops and two throats. Net mesh sizes were 25, 32, and 38 mm. Nylon bait bags were filled with scrap cheese and tied on the top inside the cod end.	Nets were tied off by rope to the bank, set parallel to the flow in 1 to 2 m of water, and weighted down with a concrete block. Nets were set over a two-night period and checked every morning. CPUE was the number of fish captured per net night.	None.	Target species was channel catfish (*Ictalurus punctatus*), which represented 92.7% of the catch. Fourteen other species were also captured.	The 25-mm mesh nets caught catfish that ranged from 114 to 445 mm total length (mean = 266 mm). Fish collected in the 32-mm-mesh nets ranged from 104 to 604 mm (mean = 320 mm) and in the 38-mm-mesh nets ranged 129 to 505 mm (mean = 316 mm). Fish <150 mm fell through the mesh of the nets as they were pulled from the river.	Care should be taken to standardize mesh size of hoop nets because of the differential capture among mesh sizes.
Pugh and Schramm 1998	Determine species composition, fish community structure, and CPUE.	Lower Mississippi River in sandbar and steep bank habitats during three river states: falling, low, and rising.	Hoop nets were two sizes: 1) 61 to cm with 2.5-cm² mesh netting and 2) 122-cm-diameter hoop nets with 3.5-cm² mesh netting. All hoop nets were 4.5 m long and had seven hoop sand two square throats.	Six hoop nets of each size were set at five locations in each habitat. All hoop nets were baited with soybean meal, set with openings facing downstream, and fished overnight. In steep bank habitats, hoop nets were set within 6 m of the shoreline in water 1.2 to 6 m deep. In sandbar habitats, nets were set at depths of 1.0 to 3.0 m.	Boat electrofishing.	Catch in both hoop net sizes was dominated by catfish. A large hoop net also collected river carpsucker (*Carpiodes carpio*), longnose gar (*Lepisosteus osseus*), smallmouth buffalo (*Ictiobus bubalus*), and freshwater drum (*Aplodinotus grunniens*).	Length data were not provided.	Setting a hoop net averaged 4 minutes and retrieving it averaged 5 minutes. Hoop net sampling was done by two people. Therefore, fishing one hoop net overnight required 0.3 person-hours of effort. This is compared to 0.6 person-hours of effort to collect an electrofishing sample. Authors concluded that electrofishing collected wider length ranges of fish and cost less per fish collected than hoop netting.
Utrup and Fisher 2006	Determine species composition and richness.	Fifteen sites on five large prairie rivers in Oklahoma, including the Arkansas, Cimarron, North Canadian, Washita, and Red rivers. Discharge ranged 12 to 207 m^3/s.	Hoop nets were two sizes: 1) large (0.9 × 3.7 m, 50.8-mm mesh) and 2) small (0.6 × 2.4 m, 25.4-mm mesh).	Hoop nets were used in deep water habitats (>0.75 m). Sampling at each site consisted of 6 large hoop and 6 small hoop sets near instream structure and vegetation. All nets were unbaited and fished overnight (approximately 12 hours).	Seines were used to sample shallower habitats.	The majority of fish species captured by hoop nets were catfish. No plains minnow (*Hybognathus placitus*) were collected with hoop nets.	The mean length of fish collected by small hoop net was 357.3 mm (SD 200.75) and mean weight of 718.9 g (SD 917.38). Mean length of fish collected by the large small hoop net was 527.2 (SD 199.15) and mean weight of 1,904.5 g (SD 1963.08). Both hoops collected larger fish than the seine. Mean length of fish collected by seine was 42.4 mm (SD 37.13) and mean weight 3.7 g (SD 50.32).	Seining collected more species per effort than hoop netting. There were distinct differences between the fish assemblage collected by seining and those collected with both sizes of hoop nets, but no difference between the sizes of hoop net.
Fyke Nets (i.e., trap nets)								
Breen and Ruetz III 2006	Determine species composition and catch rate metrics.	Muskegon Lake, Michigan, a 1,697-ha coastal lake with predominately of sand substrate and lacked aquatic vegetation.	Fyke nets were constructed of 4-mm diamond mesh and consisted of a lead (7.2 × 1.1 m) and two wings (1.75 × 1.1 m) attached to the mouth of the net (1.2 × 0.9 m). The body of the fyke net was 4.6 m and contained two internal funnel-shaped throats (outside diameter = 75 cm, inside diameter = 15 cm)	Fyke nets were set perpendicular to the shoreline (average = 16.6 m from lead to shore) and at intervals of 30 m between nets. Nets fished the entire water column depth (<0.8 m) for 6, 24, or 48 hours, depending on experimental treatment.	None.	Banded killifish (*Fundulus diaphanous*), bluntnose minnow (*Pimephales notatus*), round goby (*Neogobius melanostomus*), bowfin (*Amia calva*), and yellow bullhead (*Ameiurus natalis*) were collected.	Specific length ranges were not provided.	Benthic fishes may be overrepresented and water column fishes may be underrepresented in fyke net catches. Escape probabilities of round gobies (benthic species) were always less than bluntnose minnows and banded killifish (water column species) in experiments. The survival probability of the bluntnose minnow increased with soak time, increased with fish density, and decreased with the presence of a predator.

Table 3.4. Comparison Table of Entrapment Gears Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Fyke Nets (i.e., trap nets), continued								
Clark et al. 2006	Determine species composition and fish community structure.	Floodplain lakes in the White River National Wildlife Refuge, Arkansas.	Fyke net frame was constructed of two 0.6 × 1.2–m rectangles and had a 4.5-m-long × 0.6-m-high lead with 3-mm mesh. Net is described by Gutreuter et al. (1995).	Large lakes (>2 ha) were sampled with 3 fyke nets and small lakes (<2 ha) with 2 fyke nets. Nets were set by tying the leads close to shore and dragging the net perpendicular to the shoreline and weighting it with a brick. Sets were 24 hours.	Seines.	Twelve families were represented in the catch data, primarily Cyprinidae, Centrarchidae, and Poeciliidae by relative abundance. Species captured included cypress minnow (*Hybognathus hayi*) and Mississippi silvery minnow (*H. nuchalis*).	Specific length ranges were not provided. Based on species collected, fyke nets appear to have collected a wider range of fish sizes. Fyke catch was dominated by Cyprinidae (41%) and Centrarchidae (47%).	In general, fyke nets appear to have few disadvantages. However, fyke nets are more expensive than seines and the field crew must visit the site twice—once to deploy net and again to retrieve it. The authors concluded that the logistical advantage of single-day sampling using seining did not compensate for the information gained by the 24-hour fyke net set.
Fago 1998	Determine species composition and fish community structure.	Littoral zone of Wisconsin lakes.	Mini-fyke nets had two 0.9 × 0.9–m frames spaced 51 cm apart, four 0.6-m-diameter fiberglass hoops spaced 0.6 m apart, a 0.9-m-diameter throat starting at the first hoop, and a 0.9 × 9.0–m lead. All mesh was 4.7 mm except for the exclusion netting over the opening, which was 2.5 cm.	Mini-fyke nets were set for one night in each lake.	Sites were also sampled by electrofishing and small-mesh seines.	Sixty-two species were collected, including brassy minnow (*Hybognathus hankinsoni*).	Specific length ranges were not provided, but catch was dominated by bluntnose minnow (*Pimephales notatus*), bluegill (*Lepomis macrochirus*), and yellow perch (*Perca flavescens*).	Monte Carlo simulations showed that one fewer mini-fyke net samples was required (N = 14) than seine samples (N = 15) before the average of the number of species missed fell below one. Brassy minnow was never detected using the electrofishing and seining approach, but was detected at four sites using mini-fyke nets. Neither method collected all species. Authors recommended combining the results from both methods to produce a better estimate of species composition.
Haddix et al. 2009	Determine species abundance, distribution, and habitat use in target species.	Missouri River below Fort Peck Dam to its confluence with the Yellowstone River.	Mini-fyke nets had two rectangular frames 1.2 m wide and 0.6 m high and two 0.6 m steel hoops. The lead was 4.5 m long and 0.6 m high, connected to the first frame. Net and lead were 3-mm ace mesh.	The lead was anchored to shore and the net pulled out perpendicular to shore or slightly downstream where higher velocities existed. Mini-fyke nets were set overnight.	Sampling also occurred using trotlines, trammel nets, and otter trawls.	Pallid sturgeon (*Scaphirhynchus albus*), was the primary target species. Secondary targets were shovelnose sturgeon (*Scaphirhynchus platorynchus*), blue sucker (*Cycleptus elongatus*), sauger (*Sander canadense*), sturgeon chub (*Macrhybopsis gelida*), sicklefin chub (*M. meeki*), speckled chub (*M. aestivalis*), plains minnow (*Hybognathus placitus*), western silvery minnow (*H. argyritis*), and sand shiner (*Notropis stramineus*).	Western silvery minnows averaged 70.2 mm total length (range 30–102 mm).	Mini-fyke nets were the best gear for comparing relative abundance of western silvery minnow between years. Mini-fyke nets collected 371 of the 377 specimens, while otter trawls collected the remaining six.
Koel 2004	Characterize spatial patterns in species richness and examine relationship between species richness and habitat diversity.	Off-channel aquatic habitats on the Mississippi River, including main channel borders, side channel borders, and contiguous backwater shorelines.	Mini-fyke nets had a 4.5 × 0.6–m high lead attached to a 0.6 × 1.2–m frame with a 0.6-m-diameter cab. The frame and cab were 3 m long when fully extended. Fyke nets (18-mm mesh) had a 15 × 1.3–m lead, and a 0.9 × 1.8–m frame with a 0.9-m-diameter cab. The frame and cab were 6 m long when fully extended.	Mini-fyke nets (3-mm mesh) were set in main channel borders, side channel borders, and backwater shorelines for 24 hours. Fyke nets were set in backwater shoreline habitats only.	Sites were also sampled by boat electrofishing, seine, and hoop nets.	There were 106 species collected by all gear types. The species collected specifically by fyke net were not reported.	Specific length ranges were not provided. Small-bodied species were primarily collected by mini-fyke nets and seines.	Electrofishing provided the greatest consistency and overall ability to detect differences in species evenness and diversity among habitats and pools. However, the authors advocated a multiple-gear approach for examining patterns in species richness among habitats.

Table 3.4. Comparison Table of Entrapment Gears Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Fyke Nets (i.e., trap nets), continued								
Lapointe et al. 2006a	Determine species composition and fish community structure.	Segment of the Detroit River characterized by braided channels and wide, shallow flats. Maximum river width is 4 km and maximum depth is 10 m.	Fyke nets were 92-cm diameter, 15-cm opening, 8-m lead, and 0.64-cm mesh (authors referred to gear as hoop nets; however, they are technically fyke nets because they use a lead).	Fyke nets were set with the lead perpendicular to and facing shore or with the lead attached to the shore. At each site, hoop nets, Windermere traps, and minnow traps were set on the same day, and passive gears were fished overnight for 18 to 24 hours.	Sites were also sampled using seines, a boat electrofisher, trap nets, Windermere traps, and minnow traps.	The hoop net catch was dominated by spottail shiner (*Notropis hudsonius)* and bluntnose minnow (*Pimephales notatus*). Species collected by hoop net but not seine included black bullhead (*Ameiurus melas*), brook silverside (*Labidesthes sicculus*), freshwater drum (*Aplodinotus grunniens*), longnose gar (*Lepisosteus osseus*), northern pike (*Esox lucius*), and silver redhorse (*Moxostoma anisurum*).	Specific length ranges were not provided, but hoop nets collected more large predatory fishes than seines.	Fyke nets were the gear that took the longest to set and retrieve (15 minutes). They also required two trips to the sample location. Seine nets produced the greatest catch per hours worked and hoop nets the least. However, the authors concluded that with both hoop nets and seines, almost all species were detected.
Lapointe et al. 2006a	Determine species composition and fish community structure.	Segment of the Detroit River characterized by braided channels and wide, shallow flats. Maximum river width is 4 km and maximum depth is 10 m.	Trap nets were 2.5 × 2.5 m with 7-m wings, 35-m lead, and 25-mm mesh.	Trap nets were set in a manner similar to that of hoop nets wherein the lead line was perpendicular to and facing shore.	Sites were also sampled using seines, a boat electrofisher, fyke nets, Windermere traps, and minnow traps.	Trap net catch included channel catfish (*Ictalurus punctatus*).	Specific length ranges were not provided.	Trap nets were ineffective and were not used after sampling at the first seven sites. Although trap nets did capture several fishes (means = 3.1 species, 5.7 fish) including channel catfish, which were not captured by any other method, this gear type was difficult to set and retrieve with a crew of two people.
Ruetz et al. 2007	Determine species composition and fish community structure.	Littoral zone of Muskegon Lake, Michigan.	Small-mesh fyke nets were 4-mm mesh, had a 7.2-m lead that extended from the middle of the net's mouth (1.2 x 0.9 m) and wings (length = 1.75 m) that extended from each side of the mouth at 45 degree angles to the lead.	Three fyke nets were set in shallow areas (depth (<1 m). Two were positioned parallel to the shoreline (leads fished end to end). The third was positioned perpendicular to the shoreline (mouth of net facing shoreline). Sets were approximately 24 hours.	Sites were also sampled by electrofishing boat.	Species strongly associated with fyke netting were brown bullhead (*Ameiurus nebulosus*), common shiner (*Luxilus cornutus*), brook silverside (*Labidesthes sicculus*), banded killifish (*Fundulus diaphanous*), round goby (*Neogobius melanostomus*), yellow bullhead (*Ameiurus natalis*), mimic shiner (*Notropis volucellus*), bluntnose minnow (*Pimephales notatus*), and tadpole madtom (*Noturus gyrinus*).	Fish (mean total length = 7.6 cm, SE 0.5 cm) collected by fyke netting were significantly smaller than those (mean total length = 20.4 cm, SE = 1.9 cm) collected by electrofishing.	Size selectivity of the gears contributed to differences in species composition. Fyke nets and electrofishing provided complementary information on the fish assemblage. Some of the small-bodied fishes associated with fyke netting exhibit schooling behavior (e.g., common shiner, brook silverside, banded killifish, mimic shiner, and bluntnose minnow) and are considered mobile; these traits make them more susceptible to passive gears.
Pot Gears (e.g., minnow traps, Windermere traps)								
Bryant 2000	Determine species abundance by removal estimator.	Small second- to third-order streams and medium-sized fourth- to fifth-order streams; hard substrates.	Minnow traps were 3.2-mm mesh size, 19 cm diameter, and 35.5 cm long.	Traps were set in pools in a blocked reach separated by about 2 m. Forty to fifty traps were used per reach. Traps were baited with salmon eggs and set on the stream bottom next to suspected habitat. Traps were set for 90-minutes periods during three or four sequential capture occasions.	Mark-recapture estimates were compared to removal estimates.	Coho salmon *(Oncorhynchus kisutch)*, Dolly Varden trout (*Salvelinus malma)*, cutthroat trout (*O. clarkia)*, and juvenile steelhead *(O. mykiss)* were collected.	Targeted juvenile salmonids were collected.	Probability of capture was greater than 0.4 for all species. Mean population estimates from mark-recapture were higher than those from the removal estimator. The author concluded that removal population estimates can be obtained with minnow traps if sampling procedures conform to method assumptions.

Table 3.4. Comparison Table of Entrapment Gears Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Pot Gears (e.g., minnow traps, Windermere traps), continued								
Lapointe et al. 2006a	Determine species composition and fish community structure.	Segment of the Detroit River characterized by braided channels and wide, shallow flats. Maximum river width is 4 km and maximum depth is 10 m.	Windermere traps were identical in design to minnow traps, but were larger. Windermere traps were 113-cm long, 67.5-cm diameter, 10-cm opening, and 0.5-cm mesh. Minnow traps were 41-cm long, 18-cm diameter, 2.5-cm opening, and 0.5-cm mesh.	Minnow traps and Windermere traps were baited with cat food. These gears were fished overnight for 18 to 24 hours.	Sites were also sampled using seines, a boat electrofisher, fyke nets, and trap nets.	Minnow traps were deemed ineffective and data not analyzed. Species collected by Windermere traps included ictalurids, centrarchids, and cyprinids. Spottail shiner (*Notropis hudsonius*) comprised most of the catch.	Specific length ranges were not provided.	Minnow traps were ineffective and were not used after sampling at the first seven sites. Windermere traps produced significantly lower abundance and richness than all other gear types but proportionally more benthic species. Seine net catches, which were dominated by mid-water schooling species, were most dissimilar from Windermere trap catches. Windermere traps did not contribute substantially to species richness metrics.

3.1.5 EGG AND LARVAL COLLECTION GEARS

Egg and larval collection techniques used by fisheries professionals vary by the target species reproductive mode and spawning habitats. Pelagic species eggs and larvae are typically targeted by gears that involve filtration of the water through fine-mesh materials (e.g., towed nets) (Kelso and Rutherford 2006). For demersal species that attach their eggs or larvae to vegetation or structures, sampling techniques typically rely on the use of traps or artificial substrates (Kelso and Rutherford 2006). Each gear type has advantages and disadvantages that must be considered.

PASSIVE GEARS

Passive egg and larval collection gears rely on the egg or larva drifting or moving into the gear on its own. Commonly used passive egg collection gears include egg traps, drift samplers, emergence traps, activity traps, and light traps (Kelso and Rutherford 2006). Studies we reviewed used Moore egg collectors (MECs), plankton nets (deployed in a passive method), fixed egg mats, light traps, and drift nets to sample eggs and larvae (Table 3.5).

Altenbach et al. (2000) used an MEC in combination with drift nets to collect drifting eggs in a sandbed river in New Mexico. Altenbach et al. (2000) found that the MEC was more cost effective, efficient, and quantitative than fine-mesh seines or drift nets. More than four times as many eggs were collected in the MEC compared with the drift net, despite the fact that similar volumes of water were sampled.

Braaten et al. (2008) and Floyd et al. (1984) deployed plankton nets from stationary boats to quantify vertical drift location and drift velocity, simulate drift distance, and assess composition, habitat associations, and spawning chronology of fishes. Braaten et al. (2008) found that plankton nets set at various depths in the water column sufficiently sampled drifting larval fish in a large turbid river system. Floyd et al. (1984) reported that in small, low-turbidity streams, larval light traps were more efficient at sampling larval fish.

Gale and Mohr (1978) characterized temporal drift patterns and magnitude of drift. Drift nets were nylon mesh with 0.40 × 0.80–mm openings and 24 × 54–cm rectangular mouths, and were mounted on a small boat. A flow meter was mounted in the mouth of each net. Fixed net samples were collected with the boat pointed upriver for five minutes and push net samples with the boat propelled slowly down river for about 300 m. Gale and Mohr (1978) reported that fixed net samples and the pump method collected the same numbers of larvae per 10 m^3. The authors also reported that streamlined macroinvertebrate nets were easier to clean and injured the fish larvae less frequently than large nets or nets with belly areas.

Firehammer et al. (2006) used fixed egg mats to assess species composition and longitudinal distribution of spawning effort for paddlefish (family Polyodontidae) and sturgeon species (family Acipenseridae) in a turbid sandbed system. Egg mats consisted of a single strip of furnace filter material (0.75 m wide) fitted and secured around an open-ended PVC cylinder 0.75 m long and 0.15 m diameter. A 5.0-kg anchor was secured to one end of the tube and a buoyed hauling line to the other end. The collectors were suspended off the riverbed, but near the bottom of the water column. Three to five egg collectors were deployed as a set across the river channel and two to three sets were deployed per site. Collectors were retrieved and examined for eggs every two to five days. These egg mats were effective at collecting paddlefish and sturgeon eggs, which adhere to rough surfaces (like furnace filters).

ACTIVE GEARS

Active egg and larval collection gears rely on actively capturing or collecting eggs or larvae from the water column. Techniques commonly used in open water habitats include plankton nets, benthic plankton samplers, pelagic trawls, and neuston nets that are towed by a boat (Kelso and Rutherford 2006). In shallow-water habitats, seines, push nets, centrifugal pumps, and electrofishing are commonly used (Kelso and Rutherford 2006). Active methods used to collect demersal species require collecting samples of surfaces with attached eggs. Clipping of vegetation, collection of debris or rocks, or the collection of samples with dredges or corers are commonly used (Kelso and Rutherford 2006). Studies reviewed from other rivers used push seines, sled nets, and a pump to sample for larval fish.

Floyd et al. (1984) used larval seines to assess species composition, habitat associations, and spawning chronology of fishes in small streams. Larval push seines (1.5 m long, 1 m deep, 0.5-mm mesh) were used in combination with larval light traps. The authors reported that the majority of larvae and juveniles were captured by the light traps; less than 1% was taken in drift samples.

Galat et al. (2004) used a sled net to assess species composition, community structure, and CPUE in floodplain habitats. The sled net (25 cm tall, 54 cm wide, 1.4 m long, 500-µm mesh) was designed to float in the upper 0.5 m of the water column in areas deeper than the sled. Runners on the bottom of the sled's frame allowed the sled to ride over the substrate in shallow water. Each sample consisted of a two-minute sled net tow 30 m behind a boat at a speed of approximately 1.0 m/s. Galat et al. (2004) reported success at sampling a variety of species, but this method might have underrepresented benthic larvae (e.g., Acipensiformes).

Gale and Mohr (1978) used a pump to characterize temporal drift patterns and magnitude of drift. The pump intake was even with the bow of the boat and lowered to within 10 cm of the bottom then raised by a hand winch. A larger pipe was placed around the intake to prevent disturbance of the substrate. Replicate pump samples were taken at different depths at three-hour intervals for a 24-hour period. The pumping rate was about 2,500 liters per minute. Pump and fixed net samples collected the same numbers of larvae per 10 m^3. The primary advantage of the pump is that pump output was constant and the volume sampled could be regulated. The disadvantages were serious damage to larvae and the relatively small amount of water that was sampled. Rare fish or fish with clumped distributions might be missed with this method.

Table 3.5. Comparison Table of Egg and Larval Collection Gears Used in Other River Systems

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Passive Gears: Drift Nets, MECs, Collection Tubes, Light Traps								
Altenbach et al. 2000	Collect drifting eggs.	Pecos River, New Mexico.	The MEC is a sluice-box–like device with a rectangular opening at its upstream end (width = 45 cm, height = 33 cm), parallel wooden sides (length = 119 cm), and an open top. The bottom is framed fiberglass window screen (1.6-mm mesh) that is installed at a 23 degree angle relative to the bottom mounting bar. Mounting bars are attached near the posterior end of the mouth and perpendicular to the sides.	During operation, the MEC was held in place by the force of the water that pushed the device against metal fence posts (t posts) that were driven into the stream bottom. Operating the device just below the water's surface prevented collection of floating debris and allowed the aluminum water diverter, positioned on top, to reduce drag under high-velocity conditions. Capture rate of drift by the MEC should be determined based on the volume of water (i.e., CPUE) filtered as opposed to sampling duration. This was accomplished by mounting a flow meter in the mouth of the MEC and by calculating CPUE using the area of the mouth and the appropriate formula for the flow meter employed. MECs and drift nets were paired on nine occasions.	Drift net (0.5-m-diameter mouth, 4-m long, 5-µm-mesh bar) and plankton net fitted on a 36 × 46–cm rectangular frame.	Cyprinids were collected.	Eggs	The MEC is more cost effective, efficient, and quantitative than fine-mesh seines or drift nets. More than four times as many eggs were collected in the MEC compared with the drift net, despite the fact that similar volumes of water were sampled.
Braaten et al. 2008	Quantify vertical drift location, and drift velocity and simulate distance drifted by larval sturgeon.	Side channel of the upper Missouri River near Culbertson, Montana.	One pair of conical plankton nets (750-µm mesh, 1.5 m long, 0.5 m in diameter at the leading end, and 0.09 m in diameter at the cod end) was placed on the port and starboard sides of the boat. Each pair of nets consisted of one net positioned in the upper 0.5 m of the water column and one positioned to sample the lower 0.5 m.	Sturgeon larvae were released into the side channel. Two crew members deployed one pair of nets from the boat. After a 30-second sampling interval, the pair of nets was retrieved and the second pair was deployed. They were alternated for up to 1.5 hours post release.	None.	Shovelnose sturgeon (*Scaphirhynchus platorynchus*) and pallid sturgeon (*S. albus*) were collected.	Larvae	Larvae drifted primarily near the bottom of the water column. This is may be due to their transition to benthic habitats.
Firehammer et al. 2006	Determine species composition and longitudinal distribution of spawning effort.	Lower Yellowstone River in Montana and North Dakota. Substrate is predominantly sand.	This tubular type of collector was built from a single strip of furnace filter material (0.75 m wide), fitted and secured around an open-ended PVC cylinder 0.75 m long and 0.15 m diameter. A 5.0-kg anchor was secured to one end of the tube and a buoyed hauling line to the other end. The collectors were suspended off the riverbed, but near the bottom of the water column.	Three to five egg collectors were deployed as a set across the river channel. Two to three sets were deployed per site. Collectors were retrieved and examined for eggs every two to five days. CPUE was expressed as eggs collected per day.	None.	Paddle fish (*Polyodon spathula*) and sturgeon (*Scaphirhynchus* spp.) were collected.	Eggs	Paddlefish eggs adhere to rough surfaces (like furnace filters). Egg collectors were successfully retrieved 97% of the time. Design prevented collectors from being buried in sand and silt. Mean number of eggs per tube was low (<4) suggesting either collector inefficiency or inability to deploy near spawning sites.
Floyd et al. 1984	Determine species composition, habitat associations, and spawning chronology of fishes.	Small stream in Kentucky.	A conical icthyoplankton net drift net was used (0.5 m diameter, 0.5-mm mesh).	Larvae were sampled twice per week, March through July. Nets were set for three 5-minute intervals 0.5, 1.5, and 3.5 hours after sunset.	Larval fish push seine, light trap.	28 species of cottids, percids, cyprinids, centrarchids, and ictalurids were collected.	Larvae and juveniles	The majority of larvae and juveniles were captured by the light traps; less than 1% was taken in drift samples. Most fish collected in drift samples were ictalurids.
Floyd et al. 1984	Determine species composition, habitat associations, and spawning chronology of fishes.	Small stream in Kentucky.	Light traps were used.	Larvae were sampled twice per week, March through July. Eight light traps were operated for 40 minutes during each sampling effort except when water was turbid.	Drift net, larval push seine.	28 species of cottids, percids, cyprinids, centrarchids, and ictalurids were collected.	Larvae and juveniles	The majority of larvae and juveniles were captured by the light traps; less than 1% was taken in drift samples.

Table 3.5. Comparison Table of Egg and Larval Collection Gears Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Passive Gears: Drift Nets, MECs, Collection Tubes, Light Traps, continued								
Gale and Mohr 1978	Characterize temporal drift patterns and magnitude of drift.	Susquehanna River in northeastern Pennsylvania. Hard bottom.	Drift nets were mounted on a small boat. Drift nets were nylon mesh with 0.40 × 0.80–mm openings and had 24 × 54–cm rectangular mouths. A flow meter was mounted in the mouth of each net.	Two simultaneous replicates were taken near each shore and in the channel between 0800 and 1000 hours. Fixed net samples were collected with the boat pointed upriver for 5 minutes and push net samples with the boat propelled slowly down river for about 300 m. Sampling required two people.	High-capacity gasoline-powered trash pump.	Primarily quillback (*Carpiodes cyprinus*), minnows, common carp (*Cyprinus carpio*), white sucker (*Catostomus commersoniii*), shorthead redhorse (*Moxostoma macrolepidotum*), tessellated darter (*Etheostoma olmstedi*) were collected.	Larvae	Pump and fixed net samples collected the same numbers of larvae per 10 m^3. Streamlined macroinvertebrate nets were easier to clean and injured the fish larvae less frequently than large nets or nest with belly areas.
Active Gears: Larval Seine, Sled Net, Water Pump								
Floyd et al. 1984	Determine species composition, habitat associations, and spawning chronology of fishes.	Small stream in Kentucky.	Larval push seine was used (1.5 m long, 1 m deep, 0.5-mm mesh).	Larvae were sampled twice per week, March through July. A net was pushed through the sampling area of each light trap immediately before the light trap sample was taken.	Drift net, light trap.	28 species of cottids, percids, cyprinids, centrarchids, and ictalurids were collected.	Larvae and juveniles	The majority of larvae and juveniles were captured by the light traps; less than 1% was taken in drift samples.
Galat et al. 2004	Determine species composition, community structure, and CPUE.	Lower Missouri River floodplain.	Larval fishes were collected using a sled net (25 cm tall, 54 cm wide, 1.4 m long, 500-µm mesh). The sled was designed to float in the upper 0.5 m of the water column in areas deeper than the sled. Runners on the bottom of the sled's frame allowed the sled to ride over the substrate in shallow water.	Each study site was sampled on 10 dates at approximately 15-day intervals April through August. Sites were selected in a stratified-random design. Each sample consisted of a two-minute sled net tow 30 m behind a boat at a speed of approximately 1.0 m/s.	None.	A range of species were collected, dominated by cyprinids and centrarchids.	Larvae	This method might have underrepresented fishes whose larvae are primarily benthic (e.g., Acipensiformes).
Gale and Mohr 1978	Characterize temporal drift patterns and magnitude of drift.	Susquehanna River in northeastern Pennsylvania. Hard bottom.	A high-capacity gasoline-powered trash pump was used.	Samples were collected March through August. The pump intake was even with the bow of the boat and lowered to within 10 cm of the bottom then raised by a hand winch. A larger pipe was placed around the intake to prevent disturbance of the substrate. Replicate pump samples were taken at different depths at 3-hour intervals for a 24-hour period. Pumping rate was about 2,500 liters/minute.	Drift net.	Primarily quillback (*Carpiodes cyprinus*), minnows, common carp (*Cyprinus carpio*), white sucker (*Catostomus commersoniii*), shorthead redhorse (*Moxostoma macrolepidotum*), tessellated darter (*Etheostoma olmstedi*) were collected.	Larvae	Pump and fixed net samples collected the same numbers of larvae per 10 m^3. The primary advantage of the pump is that pump output was constant and the volume sampled could be regulated. The disadvantages were serious damage to larvae and the relatively small amount of water that was sampled. Rare fish or fish with clumped distributions might be missed.

3.1.6 OTHER SAMPLING GEARS

ACTIVE GEARS

DROP NETS

Drop nets are an active sampling gear used to sample fish from a known volume of water by tossing the net into the water and enclosing the sample area (Hayes et al. 1996). Because drop nets sample a known volume of water they can be used to estimate relative abundance. Dewey (1992) used drop nets to sample backwater habitats ranging in depths from 0.6 to 1.0 m (Table 3.6). Drop nets were 3.1 m long, 1.8 m wide, 1.2 m high, and sampled 5.6 m^2. Three drop nets were deployed simultaneously within 15 to 20 m of each other. Dewey (1992) found drop nets were effective for sampling in shallow vegetated areas that cannot be sampled with seines and provided consistent quantitative samples.

POP NETS

Pop nets are an active sampling gear used to sample fish within a vertical water column (Hayes et al. 1996). These nets are set on the bottom of the sample area and deployed by a release mechanism. This gear can be used to provide estimates of relative abundance of fishes because they sample a known volume of water. Pop nets can also be used in areas where other gears cannot access due to water volume or vegetation (Hayes et al. 1996). Care must be taken to not scare fish from the sample area prior and during deployment of pop nets.

Two studies used pop nets along with other gear types to estimate relative abundance and size and age distribution of target species in backwater of shallow wetland habitats (depth = 0.6–1.25 m) (see Table 3.6). Pop nets were set in the sample area and then left undisturbed for 30 minutes to 12 hours to allow fish to recolonize the site. Water volumes sampled ranged 7.8 to 18.9 m^3, depending on water depth (Paradis et al. 2008). Dewey (1992) reported that pop nets were well suited for collecting quantitative samples of small fish from vegetation. Paradis et al. (2008) found that for juvenile perch (*Perca* sp.), the seine was more efficient than the pop net in terms of occurrence, abundance, and precision, even in densely vegetated habitats. Paradis et al. (2008) cautioned that enclosure traps, like pop nets, are known to be somewhat biased in that they usually underestimate fish density.

PUSH NETS

Push nets are an active sampling gear that is often used to collect benthic species, such as shrimp, or fish larvae along the surface of the water (Hayes et al. 1996). Push nets can either be pushed through the water by an individual or boat. Paradis et al. (2008) used push nets to estimate abundance and size distribution of yellow perch (*Perca flavescens*) in shallow wetlands (see Table 3.6). The push net consisted of three plankton nets (1.5 m long, 500-µm mesh, opening 0.4 m^2) mounted on an adjustable steel frame placed in front of the boat so that three depths of the water column were sampled simultaneously. The nets were pushed in front of the boat at a rate of approximately 1 m/s along 50-m transects. The occurrence and abundance of larval yellow perch were higher for push nets than pop nets in open-water habitats, but the same in vegetated habitats. The 1.2-mm difference in mean larval total length at non-vegetated sites (pop net length > push net length) suggested that the push net is size-selective in some habitats.

The push net covered a larger area (20 m^2) than the pop net (16 m^2) and sampled a greater number of habitats.

TRAMMEL NETS

Trammel nets are a form of entanglement gear that can be deployed in either actively or passively. Actively deployed trammel nets involve drifting the net through a sample area for a set distance or amount of time. Passively deployed trammel nets involve setting the stationary net in a sample area for a given amount of time. Larger mesh trammel nets are primarily used to sample larger-bodied fishes in river and reservoir habitats. Trammel nets cause less harm to fish compared to other entanglement gears such as gill nets. Small-mesh trammel nets have been used effectively to monitor for juvenile or small-bodied fishes.

Haddix et al. (2009) deployed drifting trammel nets on a large sandbed river system to estimate abundance, distribution, and habitat use of large bodied fishes (see Table 3.6). Trammel nets were 38.1 m long with a 22.4-mm bar inner mesh and a 203.2-mm bar outer wall. Trammel nets were drifted from the bow of the boat and oriented perpendicular to the flow for 75 to 300 m. Trammel nets effectively sampled larger-bodied fishes such as sturgeon, blue sucker (*Cycleptus elongatus*), and river carpsucker (*Carpiodes carpio*); however, other gears (e.g., mini-fyke nets, otter trawls) were used to monitor smaller-bodied fishes.

Two studies used stationary trammel nets to monitor for large bodied fishes (> 200 mm) in river systems (see Table 3.6). Trammel nets used in these studies were 7.6 to 45.7 m long and 1.8 m tall, with 1.3- to 3.8-cm inner mesh and 3- to 30.5-cm outer mesh. Both studies deployed other gears (e.g., hoop nets, electrofishing) to monitor smaller-bodied fishes or smaller-sized classes of target species.

PISCICIDES AND EXPLOSIVES

The use of fish toxicants and explosives was not assessed in this evaluation. The high rates of fish mortality and the potential for water quality problems associated with these methods make them unsuitable for sampling the MRG fish community.

Table 3.6. Comparison Table of Other Active and Passive Gears Used in Other River Systems

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Active Gears – Drop Nets, Pop Nets, Push Nets, Drifting Trammel Nets								
Dewey 1992	Determine CPUE.	Backwater lake in the upper Mississippi River; water had no discernible current and depths of 0.6 to 1.0 m.	The drop nets were PVC frames (3.1 m long, 1.8 m wide, and 1.2 m high) with nets that that dropped on the sides to enclose the sample. The frame sampled 5.6 m^2	Three frames were set 15 to 20 m apart and their nets were simultaneously released after standing undisturbed for 30 minutes; the drop nets were released with a 25-m trip line.	Pop net, electrofishing frame.	Common carp (*Cyprinus carpio*), emerald shiner (*Notropis atherinoides*), tadpole madtom (*Noturus gyrinus*), largemouth bass (*Micropterus salmoides*), warmouth (*Lepomis gulosus*), bluegill (*Lepomis macrochirus*), black crappie (*Pomoxis nigromaculatus*), yellow perch (*Perca flavescens*), and johnny darter (*Etheostoma nigrum*) were collected.	Lengths ranged from 15 to 89 mm.	Authors recommend either the pop net or the drop net for quantitative sampling in shallow vegetated areas that cannot be sampled with seines. Both provide consistent quantitative samples and are less variable than the electrofishing frame.
Dewey 1992	Determine CPUE.	Backwater lake in the upper Mississippi River; water had no discernible current and depths of 0.6 to 1.0 m.	Pop net is a hoop or frame that encloses a column of water with netting as it is raised. The net sampled 5.6 m^2	Three pop nets were set 15 to 20 m apart, left undisturbed for 30 minutes. After a pop net was released, the bottom sections were pursed together to enclose the catch. The top frame and netting were lifted from the water and placed on a stand for removal of the catch.	Drop net, electrofishing frame.	Common carp (*Cyprinus carpio*), emerald shiner (*Notropis atherinoides*), tadpole madtom (*Noturus gyrinus*), largemouth bass (*Micropterus salmoides*), warmouth (*Lepomis gulosus*), bluegill (*Lepomis macrochirus*), black crappie (*Pomoxis nigromaculatus*), yellow perch (*Perca flavescens*), and johnny darter (*Etheostoma nigrum*) were collected.	Lengths ranged from 15 to 87 mm.	Catches with the pop net and the drop net were similar both in number and species composition. Both were well suited for collecting quantitative samples of small fish from vegetation.
Paradis et al. 2008	Determine abundance and size distribution of a target species and age group.	Shallow wetlands in the Lake Saint-Pierre area, Quebec, Canada. Wetlands varied in vegetation density. Sites were divided into 3 depth strata: (0.50–0.75, 0.75–1.00, and 1.00–1.25 m).	Pop net consisted of two frames 4 by 4 m of rigid, 5-cm-diameter PVC pipe. One frame floated with trapped air and one frame was weighted with steel rods and anchored to the bottom. Netting (1.5 m high, 1.2-mm mesh) linked the two frames; the top and bottom were open (no netting).	After the pop net was set, it was left undisturbed for 12 hours to allow fish to recolonize the site. A pin-key attached to a trip cord was used to release the buoyant frame. Fish confined in the pop net were collected using a small stick seine with the same mesh size. Water volumes sampled ranged 7.8 to 18.9 m^3, depending on water depth.	Push nets, seine.	Target species was yellow perch (*Perca flavescens*).	Yellow perch collected by pop net ranged 7 to 20 mm total length in May and 25 to 60 mm in July.	Enclosure traps, like pop nets, are known to be somewhat biased in that they usually underestimate fish density. For juvenile perch, the seine was more efficient than the pop net in terms of occurrence, abundance, and precision, even in densely vegetated habitats.
Paradis et al. 2008	Determine abundance and size distribution of a target species and age group.	Shallow wetlands in the Lake Saint-Pierre area, Quebec, Canada. Wetlands varied in vegetation density. Sites were divided into 3 depth strata: (0.50–0.75, 0.75–1.00, and 1.00–1.25 m).	The push net consisted of three plankton nets (1.5 m long, 500-um mesh, opening $0.4m^2$) mounted on an adjustable steel frame placed in front of the boat so that three depths of the water column were sampled simultaneously.	The nets were pushed in front of the boat at a rate of approximately 1 m/s along 50-m transects.	Pop net, seine.	Target species was yellow perch (*Perca flavescens*).	Yellow perch collected by push net in May ranged 6 to 20 mm total length.	The occurrence and abundance of larval yellow perch were higher for push nets than pop nets in open-water habitats, but the same in vegetated habitats. The 1.2-mm difference in mean larval total length at non-vegetated sites (pop net length > push net length) suggests that the push net is size-selective in some habitats. The push net covered a larger area (20 m^2) than the pop net (16 m^2) and sampled a greater number of habitats.
Active and Passive – Trammel Nets (drifting and stationary)								
Haddix et al. 2009	Determine species abundance, distribution, and habitat use in target species.	Missouri River below Fort Peck Dam to its confluence with the Yellowstone River.	Standard trammel net (38.1 m long) with a 22.4-mm bar inner mesh and a 203.2-mm bar outer wall. The float line is 12.7 mm diameter foam core with a lead line of 22.7 kg.	Trammel nets were drifted from the bow of the boat and oriented perpendicular to the flow for 75 to 300 m.	Trotlines, otter trawl, and fyke nets.	Pallid sturgeon (*Scaphirhynchus albus*), was the primary target species. Secondary targets were shovelnose sturgeon (*Scaphirhynchus platorynchus*), blue sucker (*Cycleptus elongatus*), sauger (*Sander canadense*), sturgeon chub (*Macrhybopsis gelida*), sicklefin chub (*M. meeki*), speckled chub (*M. aestivalis*), plains minnow (*Hybognathus placitus*), western silvery minnow (*H. argyritis*), and sand shiner (*Notropis stramineus*).	Western silvery minnows averaged 70.2 mm total length (range 30–102 mm)	Mini-fyke nets were the best gear for comparing relative abundance of western silvery minnow between years. Mini-fyke nets collected 371 of the 377 specimens, while otter trawls collected the remaining six.

Table 3.6. Comparison Table of Other Active and Passive Gears Used in Other River Systems, continued

Study Citation	Objective	Location	Gear Specifications	Brief Description of Sampling	Other Gears Used in Conjunction	Primary Species	Length Range of Fishes Collected	Major Findings Regarding Sampling Gear
Active and Passive – Trammel Nets (drifting and stationary), continued								
Coggins et al. 2006	Determine species abundance and trends by mark-recapture estimators.	Lower Little Colorado River and mainstem Colorado River near its confluence, Arizona.	trammel nets that were 7.6-45.7 m long, 1.8 m tall, with 1.3-3.8 cm inner mesh and 30-cm outer mesh	In various months, trammel nets were deployed during crepuscular and night periods. Sample locations were chosen at slow-water and current separation points.	Hoop nets and electrofishing.	Target species was humpback chub (*Gila cypha*).	Length data were not provided, but adult fish were the primary target.	Effort was not standardized among gears and cannot be meaningfully compared. Hoop nets collected a greater number of fish in the Little Colorado River than trammel nets. In the mainstem, trammel nets collected a greater number of fish than hoop nets and electrofishing combined.
Paukert 2004	Determine CPUE and size structure of target species.	An 8-km reach of the Colorado River near the confluence of the Little Colorado River.	Trammel nets were 22.9 m long, 1.8 m deep, and consisted of two outer walls of 30.5 cm multifilament netting and an inner wall of 2.5 cm multifilament netting.	Nets were generally tied to the shore and stretched across the river channel, but were occasionally suspended in the mid-water column of the river, usually in deepwater eddies. Nets were checked every 2 hours but remained in the water through several sets.	Boat electrofishing.	Humpback chub (*Gila cypha*), flannelmouth sucker (*Catostomus latipinnis*), and bluehead sucker (*Catostomus discobolus*) were collected.	Fish >200 mm were targeted, but fish captured by electrofishing ranged in length from approximately 50 to 600 mm total length.	Fish collected by trammel netting were larger (> 200 mm) than those collected by electrofishing, in part because the gears fished different habitats. CV for trammel netting ranged from 210 to 566 for electrofishing and 128 to 575 for trammel netting, depending on season, diel period, and species. To detect a 25% change in CPUE at a power of 0.9, at least 473 trammel net sets or 1,918 electrofishing samples would be needed in this 8-km reach.

3.2 GEARS AND METHODS USED IN THE MRG

Four principal gear types are being used to sample the fish community of the MRG, including seines, electrofishing, fyke nets (also referred to as hoop nets), and egg collectors. Minnow traps and dip nets have also been used, but the numbers of samples were too small for evaluation.

3.2.1 SEINES

Fish were collected by rapidly drawing a two-person seine, measuring 3.1 × 1.8 m with small mesh (ca. 5 mm), through up to 20 discrete mesohabitats (usually < 15 m). Each mesohabitat type (e.g., main channel run, backwaters, etc.) was sampled at least once, and the remaining samples were taken in the dominant shoreline run habitats. Mesohabitats with similar conditions (i.e., not exceeding reasonable depths/velocities for efficient seining) were sampled to ensure relatively static capture efficiencies regardless of flows. During spring and summer, a 1.0 × 1.0–m, fine-mesh (ca. 1.5 mm) seine was used to selectively sample shallow low-velocity habitats for larval fish. The average area seined per sample, although expected to be about the same over time, changed from about 250 to 650 m^2. The total area seined increased dramatically after 2001.

CPUE was calculated for each species and each collection as the number of individuals collected per 100 m^2 (surface area) of water sampled. Effort was calculated by multiplying the seine width during sampling (regular = 2.5 m, larval = 0.25 m) by the length of the seine haul. Samples from isolated pools were not included in analyses because densities in these confined habitats were artificially elevated (Dudley and Platania 2008). Mean CPUE was computed for each site from the pool of fish captured by species from all seine hauls (~10) on a single trip divided by the total area seined for all seine hauls at the same site. Data collected in October of each year were used to monitor silvery minnow, and data for the remainder of the year provided insight into the fish community year-round.

This is the longest-running fisheries dataset for the MRG, and it provides an index to species abundance and patterns of abundance. The mean annual estimates are based on pools of about 10 seine hauls at each of about 20 fixed sites per year during October. Statistical analysis and bootstrapping showed that precision of mean CPUE can be improved with increased sample size, possibly by tabulating individual seine hauls rather than pooling all hauls at a given site.

Additional seine samples have been collected approximately monthly since 1993 that can help to assess and monitor fish community richness and diversity. The precision of seine samples taken year-around is lower than that for samples taken in October, but as with October samples, data precision can be improved substantially with increased sample size.

3.2.2 ELECTROFISHING

Fish community surveys have been conducted with raft and all-terrain vehicle (ATV) electrofishing since 2001 and constitute the only ongoing dataset of information for fish assemblages from throughout mesohabitats of the main channel. Three fundamental variations of electrofishing were used to sample fishes in the MRG. These included 1) a 220-volt electrofishing system on a whitewater raft for the main channel, 2) a 220-volt electrofishing system on an ATV during low-flow conditions, and 3) a 110-volt backpack electrofishing system for small, enclosed habitats. Electrofishing was used primarily to survey the fish community of the MRG with a metric of abundance that was numbers of fish captured per hour of electrofishing.

Surveys were conducted by Reclamation biologists within three study reaches of the MRG and portions of the Low Flow Conveyance Channel (LFCC). Within each reach, a varying number of electrofishing passes was conducted at sites selected from previous studies and new sites where monitoring was required. Surveys included a range of habitat types, including natural (defined as not altered), backwater, riprap, and jetty areas. A Smith-Root backpack electrofisher was used for fish surveys in the LFCC. A Smith-Root 1.5-kV pulsed-DC electrofishing system was used to sample designated passes along the study reaches. The electrofishing unit was mounted on a raft with two sphere anodes and adjusted to produce 2.0 to 3.5 amps at 30 pulses per second for sampling in reaches with flows of 400 cubic feet per second (cfs). Water conductance varied from 300 to 600 mS/cm upstream to downstream. Sampling effort was measured as seconds electrofished. The Smith-Root pulsed-DC electrofishing system was also mounted on an Argo ATV replacing the spherical anodes with a pair of wands with anode hoops. The ATV facilitated sampling in 100- to 200-cfs flows where the river channel was wider with shallow water (mean depth < 0.5 m). Two technicians walked beside the ATV, sweeping the water area with the wands. Two additional technicians netted the electro-anesthetized fish.

The numbers of samples with an associated measure of effort increased from about 20 per year to 74 per year in the Albuquerque, Isleta, and San Acacia reaches combined, with the largest numbers of samples collected in the Albuquerque Reach in 2005 and 2007. Additional samples were collected in the Cochiti Reach. Approximately equal amounts of effort were applied in the Albuquerque and San Acacia reaches over time, roughly double that applied in the Isleta Reach. The average time electrofished per sample was relatively consistent over time (5–10 minutes), except for 2003, which had longer sample times (approximately 20 minutes). Accordingly, the total sampling effort per reach tracks closely with the number of samples collected in each reach. This analysis shows that the numbers of electrofishing samples by year were generally not evenly distributed among reaches.

The variability of these data is high, but power analysis indicates that precision can be increased substantially with greater sample size. These data can be used to derive community-based species diversity indices, such as Shannon-Wiener.

3.2.3 ENTRAPMENT GEARS – FYKE NETS

Evaluation of fish populations associated with floodplain restoration and habitat enhancement with large woody debris has been conducted since 2005. Fyke nets (referred to as hoop nets by some researchers) were generally used in floodplains to sample absence or presence of target fish species, as well as densities of fishes. These nets were sometimes used to document movements of fish to and from floodplains. Each fyke net was rectangular, 0.5 m × 0.5 m with 6.4-mm mesh, with two wing walls, and each was secured to the substrate with fence posts. Some fyke nets were baited with a nylon mesh bag of timothy hay placed in the cod end of the hoop net. Water quality data (dissolved oxygen, temperature, conductivity, specific conductance, and salinity), water depth, and current velocity were recorded at each site and/or fyke net.

Silvery minnow CPUE was calculated for fyke net samples by dividing the total number of fish captured by the total number of hours each fyke net was fished on each day. Standardization of fyke net captures (assumes no periodic effect on captures) is expressed as fish per hour and is the index used to assess variation in species abundance among sites throughout the monitoring period.

As with the other datasets, the precision of these data is low, but these samples reveal that larger silvery minnow may be available in floodplain habitats or more efficiently captured with fyke nets.

3.2.4 EGG AND LARVAL COLLECTION

Two techniques were commonly used to collect silvery minnow eggs in the MRG. The most common was the MEC. These egg collectors were generally set at river depths where workers could access them by wading into the river and comfortably monitor the collectors while standing in the river. Egg collectors were set for short time periods to minimize clogging from river debris, and the duration set was generally recorded to compute number of eggs collected per hour. The second technique was a drift net commonly used to sample macroinvertebrates in the water column. These drift nets were set at about the same depths as the MECs, and volume of water filtered was recorded to compute number of eggs collected per cubic meter of water filtered. The MECs were designed and implemented for catching drifting eggs because they allow for the efficient, quantitative, and nondestructive collection of large numbers of semi-buoyant fish eggs without a large accumulation of debris (Altenbach et al. 2000). Silvery minnow eggs were also collected with D-frame kick nets and seines from flooded habitat restoration sites during spring runoff in 2007 to 2009.

3.2.5 EVALUATION OF SAMPLING TECHNIQUES USED IN THE MRG

Widmer et al. (2010) evaluated sampling gears and techniques currently used in the MRG for population monitoring and estimation and recruitment. Summaries of these findings are provided below**.**

SIZE OF RIO GRANDE SILVERY MINNOW COLLECTED

Widmer et al. (2010) found that the mean lengths of silvery minnow caught with seines, electrofishing, and fyke nets were significantly different. Small fish and the greatest size range were caught with seines, and the largest fish with the smallest size range were caught with fyke nets; sizes of fish caught with electrofishing were intermediate.

POPULATION MONITORING

Monitoring of silvery minnow is currently conducted under a fixed block design in which sampling is completed annually in October using seining methodology. Precision of these data is low (CV > 0.25), but our analyses show that increasing sample size to 100 to 150 samples could markedly improve precision.

The electrofishing survey data have also revealed valuable inferences into the possible development of a monitoring program for the fish community with electrofishing. Although the current dataset is imprecise, our analyses show that increased sample size could markedly improve precision. The Shannon-Wiener diversity index was highly sensitive to sample size, and the precision of this community index can also be markedly improved with increased sample size.

3.3 COMPARE AND CONTRAST FISH SAMPLING GEARS AND METHODS FROM OTHER RIVER SYSTEMS TO THE MRG

The matrix scoring structure to evaluate the gears for use in the MRG allowed a maximum of 24 available points for gear types to sample adult and juvenile fish and a maximum of 16 points for gear types to sample larval fish and silvery minnow eggs (Table 3.7). Suitability of gear types and methods depends on the objectives of a monitoring program (e.g., species abundance estimates or species richness indices), the target species or life stages, the environment to be sampled (e.g., different mesohabitats, different river flows), logistical constraints (e.g., river access or navigation, crew safety), and budget constraints (e.g., field crew time and equipment purchase).

The objective of this project is to evaluate gears to sample the entire Rio Grande fish community, with an emphasis on the silvery minnow. Therefore, gears that scored the highest in this exercise are suitable to capture a range of fish species and sizes, including the silvery minnow. However, our findings indicate that no one gear will be well suited for the entire fish community or the entire range of mesohabitat types and river flows in the MRG. We advocate a multiple-gear approach.

Table 3.7. The Matrix Scoring Structure to Evaluate Suitability of Gears for Use in the MRG

Gear Type	Suitability for Silvery Minnow Adults	Suitability for Silvery Minnow Juveniles	Suitability for Silvery Minnow Larvae and Eggs	Suitability For Fish Community	Eas e of Use	Gear Cost	Reliable for Quantitative Estimate	Total
Active Capture Nets								
Beach Seine	4	4	NA	4	4	4	4	**23**
Otter Trawl	1	1	NA	2	2	2	3	**10**
Missouri Trawl	2	1	NA	2	2	2	3	**12**
Mini-Missouri Trawl	3	2	NA	3	2	2	3	**15**
Brail Trawl	2	1	NA	2	2	2	3	**11**
Drifting Trammel Nets	1	0	NA	2	1	2	2	**9**
Active Capture Electrofishing								
Backpack Electrofisher	4	3	NA	4	4	3	4	**21**
Boat Electrofisher	2	2	NA	3	3	2	4	**15**
Electrified Seine	3	3	NA	4	2	3	3	**18**
Barge Electrofisher	4	3	NA	4	3	2	4	**20**
Electric Trawl	1	1	NA	2	2	1	3	**10**
Passive Capture Adults								
Hoop Net	3	2	NA	3	3	3	3	**17**
Fyke Net	3	1	NA	3	3	3	3	**15**
Mini-fyke Net	4	4	NA	3	3	3	3	**21**
Minnow Trap	2	2	NA	2	4	4	2	**16**
Windermere Trap	2	2	NA	3	3	3	2	**16**
Set Trammel Net	1	1	NA	3	3	4	3	**14**
Passive Capture Larval Fish and Eggs								
Drift Net	NA	NA	3	NA	3	3	3	**12**
Moore Egg Collector	NA	NA	4	NA	4	3	4	**14**
Larval Light Trap	NA	NA	3	NA	3	2	3	**11**
Active Capture Larval Fish and Eggs								
Dip Net	NA	NA	4	NA	4	4	1	**13**
Plankton Tow/Push Net	NA	NA	3	NA	3	3	3	**11**
Plankton Tow Sled	NA	NA	3	NA	3	3	3	**12**
Pop Net	NA	NA	3	NA	3	3	3	**12**

Scoring system:
0=Not Suitable, 1= Suitable for Limited Application, 2=Marginally Suitable, 3=Suitable for Most Applications, 4=Highly Suitable, NA=Not Applicable. Scores may not exactly sum due to rounding.

3.3.1 ACTIVE CAPTURE NETS

BEACH SEINE

Our qualitative ranking of gear types resulted in the highest overall score for beach seines (see Table 3.7). This result agrees with the successful use of seines to detect and collect silvery minnow throughout the MRG since 1994 (Dudley and Platania 2008). Beach seines are well-suited for sampling small- to medium-bodied mid-water fishes in a range of habitat types (Lyons 1986). This gear type is portable and inexpensive to purchase. Furthermore, only two to three people are needed for a field crew, and each site only needs to be visited once per sample. The low risk of fish mortality associated with this gear type makes it desirable for monitoring endangered fish populations.

Although beach seines can be deployed from boats, they are most effective in wadeable habitats with little structural complexity (e.g., woody debris). Thus, they are a suitable gear type for a large proportion of the MRG at low flow. Electrofishing may be more effective than seines in deeper, mid-water habitats (Koel 2004; Poos et al. 2006; Mercado-Silva and Escandon-Sandoval 2008), and electrofishing or entrapment gears may be more effective than seines in structurally complex habitats (Clark et al. 2006; Mercado-Silva and Escandon-Sandoval 2008). Assessments of beach seine efficiency relative to other gear types and a range of environmental conditions is recommended for the MRG.

Seine length, mesh size, and method of deployment influenced species capture probability. Large seines (15 m long) deployed by anchoring one end and wrapping the seine in a circle were more efficient than electrofishing, hoop nets, and Windermere traps in the Detroit River (Lapointe et al. 2006a). Similarly, other investigators deployed seines by anchoring one end to shore and sweeping the other end of the seine in a downstream arc through the river with effective results (Koel et al. 2004; Welker and Scarnecchia 2004). Deployment of large seines (approximately 10 m long) may be a viable alternative for sampling large shallow homogenous areas of the MRG. Investigators found that smaller beach seines (<10 m long) produced lower estimates of species richness, abundance, and biomass than backpack electrofishing (Poos et al. 2006; Mercado-Silvia and Escandon-Sandoval 2008) and collected fewer *Hybognathus* species in shoreline zones than fyke netting (Fago 1998; Clark et al. 2006).

While beach seines appear to be suitable for sampling silvery minnow, they may miss or under-represent benthic species and larger-bodied predatory species in species richness assessments (Lapointe et al. 2006a; Mercado-Silva and Escandon-Sandoval 2008). A multiple-gear approach is recommended to fully characterize the fish community of the MRG.

OTTER TRAWL

Otter trawls have been found to be effective for sampling the mid-channel fish community (Haddix et al. 2009). However, this gear was not determined to be very effective for sampling the silvery minnow or the fish community in the MRG because of its limited use in shallow water habitats and low reliability for quantitative estimates (see Table 3.7).

Otter trawls are generally towed behind a boat with a strong motor and can only be safely used in reaches with few snag hazards. In the MRG, use of otter trawls would be limited to low complexity habitats that are deeper than 1 m. This gear type would have little to no utility for sampling during low base flows in the MRG. Additionally, seines have been found to be more effective than otter trawls for sampling species similar to the silvery minnows in channel margins (Welker and Scarnecchia 2004). It may also be more difficult to measure the area sampled and calculate CPUE.

MISSOURI TRAWL

Missouri trawls are an otter trawl modified with a small-mesh cover, so they are more effective for sampling small-bodied species (Herzog et al. 2005). However, this gear was not determined to be very effective for sampling the silvery minnow or the fish community in the MRG because of its limited use in shallow water habitats and low reliability for quantitative estimates (see Table 3.7). The primary advantage of the Missouri trawl for the MRG is that it can sample a wide range of fish sizes and species, and it can sample habitats unavailable to small beach seines. Unlike many entrapment gears, it can be used in high-velocity water, and unlike electrofishing, it is not dependent on water clarity, which is often poor at high flows in the MRG. Furthermore, if the trawl is snagged during a haul, the net can often be disentangled without losing the fish in the cod end of the net, whereas the majority of fish collected in a seine haul is lost when the net is snagged.

The primary drawback of the Missouri trawl is that it is a large gear requiring a boat with a large motor to deploy. As with the otter trawl use of the Missouri trawl in the MRG would be limited to low-complexity habitats that are deeper than 0.5 m. This gear type would have little to no utility for sampling during low base flows in the MRG.

MINI-MISSOURI TRAWL

The mini-Missouri trawl ranked highest (total ranking 15) of trawl gear types reviewed (see Table 3.7). Mini-Missouri trawls are effective for sampling small- and mid-bodied species over a range of environmental conditions (Herzog et al. 2009). It has the same advantages as the Missouri trawl, but is smaller, so it may not need as large a boat to pull it. Robert Hrabik, Missouri Department of Conservation, indicated that it could be towed with a jet boat or hauled in by hand (email communication with Michael Porter, U.S. Army Corps of Engineers, January 29, 2010). However, use in the MRG would still be limited to relatively low-complexity habitats that are deeper than 0.5 m. Used in conjunction with shoreline gears, it may be useful for characterizing species richness and species distribution in the MRG.

The smaller size of the mini-Missouri trawl makes it more applicable for use in the MRG than the larger Missouri trawl. The mini-Missouri trawl can effectively sample fish at depths from 0.5 to 73 m and velocities from 0.0 to 1.7 m/s (Herzog et al. 2009), making it an attractive alternative to beach seines for sampling deeper main channel areas during spring runoff. The primary drawback of the mini-Missouri trawl is that it generally requires a boat to deploy and can only be used in habitats deeper than 0.5 m. As with the otter and Missouri trawls, the mini-Missouri trawl would have little to no utility for sampling during low base flows in the MRG.

BRAIL TRAWL

The brail trawl is a modified mini-Missouri trawl that has a mussel brail attached just in front of the trawl mouth. The intent of the mussel brail is to increase capture efficiency of benthic species by disturbing the substrate before the trawl (Ridings 2009). Brail trawls are effective for sampling benthic species and small-bodied species in hard-bottomed streams. However, this gear was not determined to be very effective for sampling the silvery minnow or the fish community in the MRG because of its limited use in shallow water habitats (see Table 3.7). Additionally, we are unaware of the effectiveness of this gear in sand-bottomed streams. Like the other trawls, use in the MRG would be limited to low-complexity habitats that are deeper than 0.5 m, and it may also be more difficult to measure the area sampled and calculate CPUE.

The brail trawl may be effective for sampling the MRG fish community, especially for benthic species such as dace (*Rhinichthys* spp.) and catfish (ictalurids), but would likely provide no additional benefit over the mini-Missouri trawl for sampling mid-water species like the silvery minnow.

DRIFTING TRAMMEL NET

Drifting trammel nets involve floating the net through a sample area for a set distance or amount of time. They have been found to be effective for collecting juvenile and adult large-bodied migratory fishes during spring runoff (Haddix et al. 2009). However; trammel nets were not as well suited for monitoring yearly trends in relative abundance of small-bodied fishes, such as western silvery minnow, relative to mini-fyke nets (Haddix et al. 2009). The primary drawback of the drifting trammel net is that it requires a boat with motor to deploy and can be hazardous in areas of high-complexity habitats. As with the trawl nets, use of the drifting trammel net in the MRG would be limited to low-complexity habitats that are deeper than 0.5 m. This gear type would have little to no utility for sampling during low base flows in the MRG (see Table 3.7).

3.3.2 ACTIVE CAPTURE ELECTROFISHING

BACKPACK ELECTROFISHER

Our qualitative ranking of gear types resulted in the second highest overall score for backpack electrofishing (see Table 3.7). Backpack electrofishers are a useful sampling tool because they are portable, settings can be standardized, and they are a proven method for sampling complex habitats in the MRG (Fluder et al. 2008).

Backpack electrofishers are well suited for sampling small- to medium-bodied fishes in a range of habitat types (Poos et al. 2006; Janac and Jurajda 2007). Backpack electrofishers produce higher estimates of species richness and abundance when compared to beach seines (Poos et al. 2006), especially in reaches with complex habitats (Mercado-Silva and Escandon-Sandoval 2008). Backpack electrofishers may be better suited than beach seines in the MRG for sampling complex mesohabitat types, such as large woody debris, eddies, backwaters, and shoreline runs.

Despite these benefits, vulnerability to electrofishing varies among species due to innate differences in morphology, physiology, and behavior (Reynolds 1996). Electrofishing tends to select for larger fish of a species (Reynolds 1996) indicating that this gear type will not be as effective as beach seines for sampling young-of-year and juvenile silvery minnow.

While backpack electrofishing is well suited for sampling fish the MRG, its use is relegated to shallow wadeable habitats less than 1.0 m deep. Water clarity can reduce visibility of stunned fish, reducing capture probabilities. Cost of the backpack electrofisher is higher (~$7,500.00) than for beach seines (~$200.00), and the minimum crew size is larger (3 individuals) than the minimum crew size for beach seines (2 individuals). The potential for increased fish mortality associated with this gear type requires that trained staff operate the equipment (Reynolds 1996).

Despite these limitations, backpack electrofishers can be used in conjunction with seine nets to provide more accurate and precise estimates of fish species richness, assemblage composition and species relative abundance in the MRG (Kennard et al. 2006). We recommend a multiple-gear approach that includes backpack electrofishers for sampling in the MRG.

Boat-mounted Electrofisher

Boat-mounted electrofishers include those that are mounted on boats, rafts, or other floating structures. Their main advantages include high portability, settings that can be standardized, a platform for holding buckets and processing fish, and the ability to cover large stretches of river in a short amount of time.

Boat-mounted electrofishers are proven effective for collecting small- to large-bodied fish (Paukert 2004; Amadio et al. 2006). Vulnerability to electrofishing varies among species due to innate differences in morphology, physiology, and behavior (Reynolds 1996). Electrofishing tends to select for larger fish of a species (Reynolds 1996); however, capture probability with this gear type has been shown to be low for salmonids and benthic species (Mitro and Zale 2002; Lapointe et al. 2006b). The potential for increased fish mortality associated with this gear type requires that trained staff operate the equipment (Reynolds 1996).

Primary drawbacks of the motorized boat mounted electrofisher include cost (~$65,000.00) and the need for a trained crew to operate the unit. In contrast to the backpack and barge electrofisher, motorized boat-mounted electrofishers would only be applicable during high discharge, such as those typical of spring runoff, with little to no utility for sampling during low base flows in the MRG. Relative to backpack and barge electrofishers and beach seines, the primary utility of motorized boat-mounted electrofishers may be to sample deep main channel habitats during spring runoff that backpack electrofishers and beach seines cannot.

Electrified Seine

The electrified seine ranked third (total score of 18) of the electrofishing gear types reviewed (see Table 3.7). Electrified seines may be useful for collecting silvery minnow from shallow main channel habitats with little structural complexity. Use of the electrified seine would also be limited to water < 1.0 m deep and would require a larger crew size than beach seines and backpack electrofishers. A generator is necessary for power, and the distance from the power source would be limited by the length of the power cord to the brails, making the electrified seine difficult to transport and operate relative to the beach seine and backpack electrofisher. Despite these limitations the electrified seine may be useful for estimating capture probabilities for species occupying shallow main channel habitat with little structural complexity.

Barge Electrofisher

The barge electrofisher had the second highest ranking (total score of 20) of the electrofishing gear types reviewed (see Table 3.7). The barge electrofisher would be similar in principle to the ATV approach successfully used by Reclamation for collecting silvery minnow in the MRG. Barge electrofishers operate similarly to the backpack electrofisher with the exception that the generator or battery is located on a floating barge instead of a backpack. Barge electrofishers are suitable for collecting small- and medium-bodied fish in wadeable, small to medium-sized rivers (Lyons and Kanehl 1993). This gear is proven effective for estimating CPUE; however, its efficiency is affected by habitat complexity (Lyons and Kanehl 1993).

Barge electrofishers can be used for sampling shallower habitats than boat electrofishers and deeper habitats than beach seines and backpack electrofishers. The primary drawbacks of the barge electrofisher include cost (~$15,000.00), the need for trained staff to operate, and the larger crew size than beach seines.

ELECTRIC TRAWL

The electric trawl was the lowest ranked electrofishing gear type (total ranking 10) and ranked lower than the Missouri and mini-Missouri trawls (see Table 3.7). The addition of electricity to the trawl resulted in higher captures of benthic but not mid-water species (Freedman et al. 2009) indicating that no significant benefit would be realized for sampling silvery minnow relative the Missouri and mini-Missouri trawls. The electric trawl is difficult to transport, requires a significant amount of effort to cover a relatively small area, and requires a source of electricity. These findings resulted in a lower ranking than similar non-electrified Missouri and mini-Missouri trawls.

As with the otter and Missouri trawls, use of the electric trawl in the MRG would be limited to low-complexity habitats that are deeper than 0.5 m. This gear type would have little to no utility for sampling during low base flows in the MRG. The electric trawl would be best suited for a monitoring program intended to accurately estimate CPUE and species diversity for benthic species (Freedman et al. 2009).

3.3.3 PASSIVE CAPTURE ADULTS

HOOP NET

Hoop nets had the ranked second (total score of 17) of the passive capture gear types reviewed (see Table 3.7). Hoop nets are cost effective (~$200.00) and suitable for collecting small- and medium-bodied fish in medium- to large-sized rivers (Holland and Peters 1992; Utrup and Fisher 2006). Hoop nets are a suitable alternative for sampling threatened and endangered species, such as the silvery minnow, because fish are generally collected unharmed and can be released with little or no injury (Hubert 1996). Unlike fyke nets, hoop nets do not have leads or wings and thus are not as effective at capturing schooling or migratory species. Hoop nets are often baited and rely on the fish to enter the net in search of food or cover.

Hoop nets may be useful for sampling deep water areas that are not accessible by backpack electrofishing and beach seines in the MRG. Their applicability would be limited during summer base flow to deeper habitats, and mesh size would influence the species collected.

FYKE NET

Fyke nets ranked third (total score of 15) the passive capture gear types reviewed (see Table 3.7). Fyke nets are typically used in shoreline areas of lakes where the wings are positioned to guide cruising fish into the net (Hubert 1996; Breen and Ruetz III 2006; Clark et al. 2006). These nets are cost effective (~$400.00), can be built for specific species, and are suitable for collecting small- and medium-bodied fish in medium- to large-sized rivers (Breen and Ruetz III 2006). Fyke nets are a suitable alternative for sampling threatened and endangered species because fish are generally collected unharmed and can be released with little or no injury (Hubert 1996).

Fyke nets may be useful for sampling deep water areas that are not accessible by backpack electrofishing and beach seines in the MRG. Their applicability would be limited during summer base flow to deeper habitats; however, the ability to position the wings to "funnel" migratory species that tend to follow shorelines (Hubert 1996) makes them an attractive alternative for sampling silvery minnow during spring runoff.

MINI-FYKE NET

Our qualitative ranking of gear types resulted in the second highest overall score for mini-fyke nets (tied with backpack electrofisher at 21 total points) (see Table 3.7). This result agrees with the successful use of mini-fyke nets to detect and collect silvery minnow from floodplain and backwater habitats during spring runoff in the MRG (Gonzales and Hatch 2009; Hatch and Gonzales 2008, 2010). Mini-fyke nets are proven more effective for detecting *Hybognathus* species than beach seines and electrofishing (Fago 1998) and are a suitable method for comparing annual trends in relative abundance for species in that genus (Haddix et al. 2009). These nets are a suitable alternative for sampling threatened and endangered species because fish are generally collected unharmed and can be released with little or no injury (Hubert 1996).

As with hoop and fyke nets, mini-fyke net construction, size, and deployment method can all influence species composition and catch rates (Hubert 1996). Small-bodied fish can also be susceptible to in-trap predation when collected with mini-fyke nets (Breen and Ruetz III 2006). Mini-fyke nets currently being used in the MRG are designed to reduce in-trap predation by placement of circular 5-cm rings at the throat end of each net section, which precludes larger predatory fish from capture. Mini-fyke nets are not as effective as electrofishing for describing species richness and diversity (Koel 2004); however, their successful use for monitoring daily relative abundance trends of silvery minnow (Gonzales and Hatch 2009) and annual relative abundance trends of western silvery minnow (Haddix et al. 2009) makes them a suitable gear type for monitoring programs intended to monitor trends in relative abundance of *Hybognathus* species.

Mini-fyke nets may be useful for sampling deep water areas that are not accessible by backpack electrofishing and beach seines in the MRG. Their applicability would not be as limited during summer base flow as larger fyke and hoop nets. The ability to position the wings to "funnel" migratory species that tend to follow shorelines (Hubert 1996) makes them an attractive alternative for sampling silvery minnow throughout the year in the MRG. We recommend a multiple-gear approach that includes mini-fyke nets for sampling in the MRG.

MINNOW TRAP

Minnow traps ranked lower than hoop and mini-fyke nets of the passive gear types reviewed (see Table 3.7). Minnow traps have been used successfully in small to medium-sized rivers with hard substrates to sample salmonid species (Bryant 2000). Baited minnow traps in enclosed sections of streams and rivers have proven suitable for estimating abundance via mark-recapture and depletion approaches (Bryant 2000). Conversely, their use in a large river with braided channels and shallow flats was not as effective as beach seines, Windermere traps, or electrofishing (Lapointe et al. 2006a).

Minnow traps are an inexpensive gear that may have some applicability for sampling deep shoreline habitats that beach seines and backpack electrofishers cannot.

WINDERMERE TRAP

Windermere traps ranked lower than hoop and mini-fyke nets but were tied with minnow traps of the passive capture gear types reviewed (see Table 3.7). When used in the Detroit River, Windermere traps produced significantly lower abundance and species richness estimates than beach seines, electrofishing, and hoop nets, while producing highest proportion of benthic species of all gear types used (Lapointe et al. 2006a).

Windermere traps are an inexpensive gear that may have some applicability for sampling deep shoreline habitats that beach seines and backpack electrofishers cannot, especially for studies intending to target benthic species. They may be of little utility for targeting mid-water species such as silvery minnow.

SET TRAMMEL NETS

Set trammel nets were the lowest ranked of the passive capture gear types reviewed (see Table 3.7). Set trammel nets are useful for collecting medium- to large-bodied fish (Coggins et al. 2006). More fish were collected with set trammel nets than electrofishing and hoop nets in the main-stem of the Colorado River; however, fewer fish were collected with set trammel nets than hoop nets in the Little Colorado River (Coggins et al. 2006). These results indicate that trammel nets are most applicable for large river systems.

Set trammel nets may be suitable for sampling main channel habitats during spring runoff in the MRG. They may be of little utility for targeting mid-water species like the silvery minnow.

3.3.4 PASSIVE CAPTURE LARVAL FISH AND EGGS

DRIFT NET

Three passive gear types intended to collect larval fish and eggs were reviewed. Drift nets ranked second of these gear types because they are effective for characterizing temporal drift patterns and the magnitude of drifting larval fish (Gale and Mohr 1978) (see Table 3.7). Although drift nets are suitable for collecting pelagic fish eggs, they are less effective than MECs and require that collected larvae and fish eggs be separated from other organic drift, which is time consuming and usually results in mortality of larval fish and eggs (Altenbach et al. 2000).

Drift nets are easy to use, cost effective, and provide reliable quantitative information regarding drift density and patterns. Although they may be applicable in the MRG for collection of drifting larval fish, we recommend the MEC for collection of pelagic fish eggs.

MOORE EGG COLLECTOR

Our qualitative ranking of gear types intended to capture larval fish and eggs resulted in the highest overall score for the MEC (see Table 3.7). MECs have been used to successfully collect pelagic fish eggs in the Pecos River (Altenbach et al. 2000) and silvery minnow eggs in the MRG (Gonzales and Hatch 2009). When mounted with a flow meter, quantitative estimates of catch rate can be obtained. Although MECs are effective for collecting pelagic fish eggs, their use for collecting drifting larval fish should be tested against the drift net.

MECs are non-destructive (i.e., low mortality of collected eggs), cost effective, efficient, and provide reliable quantitative data of drift densities for pelagic eggs, making them highly suitable for collecting silvery minnow eggs from the MRG. The utility of the MEC for collecting drifting larval fish should be compare to the drift net.

LARVAL LIGHT TRAPS

Larval light traps were the lowest ranked passive gear type for collecting larval fish and eggs (see Table 3.7). These traps are effective at sampling both larval fish and juvenile fish that are not drifting and have proven more effective than drift nets for documenting the larval fish community (Floyd et al. 1984). Larval light traps would be effective for collecting silvery minnow larvae but would be of no utility for collecting silvery minnow eggs.

Larval light traps are easy to use, cost effective, and provide reliable quantitative data. They are a suitable gear type for documenting the larval fish community in the MRG that occupies backwater and floodplain areas, although their effectiveness may be limited by water turbidity. Larval light traps would be of no utility for sampling drifting eggs and higher-velocity main channel habitats in the MRG.

3.3.5 ACTIVE CAPTURE LARVAL FISH AND EGGS

DIP NET

Our qualitative ranking of gear types intended to capture larval fish and eggs resulted in the second highest overall score for dip nets (see Table 3.7). Hatch and Gonzales (2010) successfully used dip nets to collect larval fish and silvery minnow eggs from 10-m transect situated in backwater and floodplain habitats of the MRG.

Dip nets are cost effective, easy to use, and can provide semi-quantitative to quantitative information. Unlike MECs and drift nets, dip nets can be used in areas with little to no flow to collect eggs that are both in and out of suspension in the water column. Dip nets would be of no utility for sampling drifting eggs and larval drift in higher-velocity main channel flows of the MRG.

PLANKTON TOW/PUSH NET

Plankton tow/push nets were the lowest ranked active gear type for collecting larval fish and eggs (see Table 3.7). This gear type has been shown effective for collecting larval fish from wetland areas (Paradis et al. 2008). Plankton tow/push nets require a boat for operation, making their applicability in the MRG limited to high flow spring runoff discharges. Unlike dip nets, they would be unsuitable for sampling shallow low-velocity backwater areas. Plankton tow/push nets may be useful for sampling silvery minnow eggs from deep high-velocity areas such as the thalweg of the MRG during spring runoff.

PLANKTON TOW SLED

The plankton tow sled ranked second of the active gear types for collecting larval fish and eggs (see Table 3.7). The plankton tow sled has been successfully used to collect larval fish from shallow to deep-water habitats; however, these collections tended to under represent fish whose larvae are primarily benthic (Galat et al. 2004). The methodology we reviewed (Galat et al. 2004) required a boat for towing the plankton tow sled, limiting applicability of this gear type to spring runoff discharge in the MRG.

If the methodology used to deploy the plankton tow sled was modified so that it could be manually pulled by field personal, the sled would be suitable for sampling shallow low-velocity backwater areas that plankton tow/push nets are not. Plankton tow sleds may also be useful for sampling silvery minnow eggs from deep high-velocity areas such as the thalweg of the MRG during spring runoff.

POP NET

The pop net ranked second of the active gear types for collecting larval fish and eggs (see Table 3.7). Pop nets have been successfully used to collect larval fish from shallow vegetated wetland areas and tend to underestimate larval fish density relative to seine nets (Paradis et al. 2008). This gear type may be of some utility for sampling heavily vegetated backwater and floodplain areas for silvery minnow larvae and eggs in the MRG and in specific research of microhabitat associations. This gear type costs more and requires significantly more effort to sample floodplain backwater areas than dip nets.

4.0 RECOMMENDATIONS

- Long term monitoring of the MRG fish community has been conducted with beach seines. Our findings indicate that this gear type is a highly suitable gear type for monitoring the MRG fish community and its use should be continued.
- A multiple-gear approach including beach seines, electrofishing (backpack- or barge-mounted), and mini-fyke nets should be used to detect and more accurately categorize the adult fish community in the MRG.
- Mini-fyke nets are a suitable gear type for monitoring daily and yearly trends in relative abundance for *Hybognathus* species in low-velocity backwater and floodplain areas. Mini-fyke net use should be tested in main channel habitats of the MRG during low to base flow to determine the potential to supplement annual long-term silvery minnow monitoring data.
- Capture probabilities should be tested among the three principle gear types (i.e., beach seines, backpack electrofishers, and mini-fyke nets) in various mesohabitats. One approach for determining capture probabilities of the three principle gear types is to use the different gear types to sample fish of a known quantity within an enclosed area. Capture probabilities should be determined for each of the principle gears across sites, years, and seasons if catch rate is used as an index of abundance.
- Little is known regarding main channel occupancy by the MRG fish community during spring runoff. The mini-Missouri trawl may be a suitable gear type for determining which species from the MRG fish community are occupying main channel habitats during spring runoff.
- Our findings indicate that the MEC is a highly suitable gear type for collecting silvery minnow eggs from flowing water habitats. Dip nets are a suitable gear type for collecting larval fish and silvery minnow eggs from slow-water floodplain and backwater areas, but may not be as effective as light traps for collecting larval fish. Effort could be compared between dip nets and light traps to determine which gear type is better suited for collecting larval fish from backwater and floodplain habitats.
- Gear suitability is dependent on study objectives, methodology used, target species, and logistical and cost constraints. We recommend that clearly defined study objectives be used to determine gear types that are most appropriate for obtaining the desired fish community information and data precision.

LITERATURE CITED

Altenbach, C.S., Dudley, R.K., and S.P. Platania. 2000. A new device for collecting drifting semibuoyant fish eggs. Transactions of the American Fisheries Society 129:296–300.

Amadio, C.J., W. Hubert, K. Johnson, D. Oberlie, and D. Dufek. 2006. Abundance of adult saugers across the Wind River watershed, Wyoming. North American Journal of Fisheries Management 26:156–162.

Angermeier, P.L., R.A., Smogar, and Steele, S.D. 1991. An electric seine for collecting fish in streams. North American Journal of Fisheries Management 11:352–357.

Bayley, P.B., and R.A. Herendeen. 2000. The efficiency of a seine net. Transactions of the American Fisheries Society 129:901–923.

Braaten, P.J., D.B. Fuller, L.D. Holte, R.D. Lott, W. Viste, T.F. Brandt, and R.G. Legare. 2008. Drift dynamics of larval pallid sturgeon and shovelnose sturgeon in a natural side channel of the upper Missouri River, Montana. North American Journal of Fisheries Management 28: 808–826.

Breen, M.J., C.R. Ruetz III, and S.E. Lochmann. 2006. Gear bias in fyke netting: evaluating soak time, fish density, and predators. North American Journal of Fisheries Management 26:32–41.

Bryant, M.D. 2000. Estimating fish populations by removal methods with minnow traps in southeast Alaska streams. North American Journal of Fisheries Management 20:923–930.

Clark, S.J., J.R. Jackson, and S.E. Lochmann. 2006. A comparison of shoreline seines with fyke nets for sampling littoral fish communities in floodplain lakes. North American Journal of Fisheries Management 27:676–680.

Coggins, L.G., W.E. Pine III, C.J. Walters, D.R. Van Haverbeke, D. Ward, and H.C. Johnstone. 2006. Abundance trends and status of the Little Colorado River population of humpback chub. North American Journal of Fisheries Management 26:233–245.

Dauwalter, D.C., and E.J. Pert. 2003. Electrofishing effort and fish species richness and relative abundance in Ozark Highland streams of Arkansas. North American Journal of Fisheries Management 23:1152–1166.

Dewey, M.R. 1992. Effectiveness of a drop net, a pop net, and an electrofishing frame for collecting quantitative samples of juvenile fishes in vegetation. North American Journal of Fisheries Management 12:808–813.

Dudley, R.K., and S.P. Platania. 2008. Rio Grande Silvery Minnow Population Monitoring Program Results from 2007. Report to the Middle Rio Grande Endangered Species Collaborative Program and the U.S. Bureau of Reclamation, Albuquerque, New Mexico. 159 pp.

Fago, D. 1998. Comparison of littoral fish assemblages sampled with mini-fyke net or with a combination of electrofishing and small-mesh seine in Wisconsin Lakes. North American Journal of Fisheries Management 18:731–738.

Firehammer, J.A., D.L. Scarnecchia, and S.R. Fain. 2006. Modification of a passive gear to sample paddlefish eggs in sandbed spawning reaches of the Lower Yellowstone River. North American Journal of Fisheries Management 26:63–72.

Floyd, K.B., R.D. Hoyt, and S. Timbrook. 1984. Chronology of appearance and habitat partitioning by stream larval fishes. Transactions of the American Fisheries Society 113:217–223.

Fluder, J.J., S.E. Beck, O. Myers, and E. Gonzales. 2008. Utilization of Large Woody Debris by Rio Grande Silvery Minnow in the Middle Rio Grande. Report to New Mexico Interstate Stream Commission, Albuquerque, New Mexico.

Freedman, J.A., T.D. Stecko, B.D. Lorson, and J.R. Staffer, Jr. 2009. Development and efficacy of an electrified benthic trawl for sampling large-river fish assemblages. North American Journal of Fisheries Management 29:1001–1005.

Gonzales, E.J., and M.D. Hatch. 2009. 2008 Middle Rio Grande Habitat Restoration Monitoring. Santa Fe, New Mexico: New Mexico Interstate Stream Commission.

Hatch, M.D., and Gonzales, E.G. 2008. Los Lunas Habitat Restoration Fisheries Monitoring. Project Summary Report. Albuquerque: U.S. Bureau of Reclamation.

Hatch, M.D., and Gonzales, E.G. 2009. Los Lunas Habitat Restoration Fisheries Monitoring. Project Summary Report. Albuquerque: U.S. Bureau of Reclamation.

Galat, D.L., G.W. Whitledge, L.D. Patton, and J. Hooker. 2004. Larval Fish Use of Missouri River Scour Basins in Relation to Connectivity. Final Report to Missouri Department of Conservation. 88 pp.

Gale, W.F., and H.W. Mohr, Jr. 1978. Larval fish drift in a large river with a comparison of sampling methods. Transactions of the American Fisheries Society 107:46–55.

Haddix, T., L. Holte, and J. Hunziker. 2009. 2008 Annual Report: Pallid Sturgeon Population Assessment and Associated Fish Community Monitoring for the Missouri River: Segment 3. Prepared for the U.S. Army Corp of Engineer - Missouri River Recovery Program. May 2009.

Hayes, D.B., C.P. Ferreri, and W.W. Taylor. 1996. Active Fish Capture Methods. In Fisheries Techniques, second edition, pp. 193–220. American Fisheries Society.

Herzog, D.P., V.A. Barko, J.S. Scheibe, R.A. Hrabik, and D.E. Ostendorf. 2005. Efficacy of a benthic trawl for sampling small-bodied fishes in large river systems. North American Journal of Fisheries Management 25:594–603.

Herzog, D.P., D.E. Ostendorf, R.A. Hrabik, and V.A. Barko. 2009. The mini-Missouri trawl: a useful methodology for sampling small-bodied fishes in small and large river systems. Journal of Freshwater Ecology 24(1):103–108.

Holland, R.S., and E.J. Peters. 1992. Differential catch by hoop nets of three mesh sizes in the Lower Platte River. North American Journal of Fisheries Management 12:237–243.

Hubert, W. 1996. Passive Capture Techniques. In Fisheries Techniques, second edition, pp. 157–192. American Fisheries Society.

Janac, M., and P. Jurajda. 2007. A comparison of point abundance and continuous sampling by electrofishing for age-0 fish in a channelized lowland river. North American Journal of Fisheries Management 27:1119–1125.

Kelso, W.E., and D.A. Rutherford. 2006. Collection, preservation, and identification of fish eggs and larvae. In Fisheries Techniques, second edition, pp. 255–302. American Fisheries Society.

Kennard M.J., B.J. Pusey, B.D., Harch, E. Dore, and A.H. Arthington. 2006. Estimating local stream fish assemblage attributes: sampling effort and efficiency at two spatial scales. Marine and Freshwater Research 57:635–653.

Koel, T.M. 2004. Spatial variation in fish species richness of the Upper Mississippi River system. Transactions of the American Fisheries Society 133:984–1003.

Lapointe, N.W.R., L.D. Corkum, and N.E. Mandrak. 2006a. A comparison of methods for sampling fish diversity in shallow offshore waters of large rivers. North American Journal of Fisheries Management 26:503–513.

———. 2006b. Point sampling by boat electrofishing: a test of the effort required to assess fish communities. North American Journal of Fisheries Management 26:793–799.

Lyons, J. 1986. Capture efficiency of a beach seine for seven freshwater fishes in a north temperate lake. North American Journal of Fisheries Management 6:288–289.

Lyons, J., and P. Kanehl. 1993. A Comparison of Four Electrofishing Procedures for Assessing the Abundance of Smallmouth Bass in Wisconsin Streams. U.S. Forest Service, North Central Forest Experiment Station, General Technical Report NC-159, St. Paul, Minnesota.

Mahon, R. 1980. Accuracy of catch-effort methods for estimating fish density and biomass in streams. Environmental Biology of Fishes 5(4):343–360.

Meador, M.R. 2005. Single-pass versus two-pass boat electrofishing for characterizing river fish assemblages: species richness estimates and sampling distance. Transactions of the American Fisheries Society 134:59–67.

Mercado-Silva, N., and D.S. Escandon-Sandoval. 2008. A comparison of seining and electrofishing for fish community bioassessment in a Mexican Atlantic slope montane river. North American Journal of Fisheries Management 28:1725–1732.

Mitro, M.G., and A.V. Zale. 2002. Estimating abundances of age-0 rainbow trout by mark-recapture in a medium-sized river. North American Journal of Fisheries Management 136:409–415.

Novotny, D.W., and G.R. Priegel. 1974. Electrofishing boats. Improved Designs and Operational Guidelines to Increase the Effectiveness of Boom Shockers. Technical Bulletin 73. Madison, Wisconsin: Wisconsin Department of Natural Resources. 48 p.

Paradis, Y., M. Mingelbier, P. Brodeur, and P. Magnan. 2008. Comparison of catch and precision of pop nets, push nets, and seines for sampling larval and juvenile yellow perch. North American Journal of Fisheries Management 28:1554–1562.

Paukert, C.P. 2004. Comparison of electrofishing and trammel netting variability for sampling native fishes. Journal of Fish Biology 65:1643–1652.

Peterson, J.T., and C.F. Rabeni. 1994. An Integrated Approach to Evaluate Effects of Global Climate Change on Ecological Structure and Function of Ozark Highland Streams. Missouri Cooperative Fish and Wildlife Research Unit, Annual Report, University of Missouri, Columbia.

______. 1995. Optimizing sampling effort for sampling warmwater stream fish communities. North American Journal of Fisheries Management 15:528–541.

Poos, M.S., N.E. Mandrak, and R.L. McLaughlin. 2006. The effectiveness of two common sampling methodologies for assessing imperiled freshwater fishes. Journal of Fish Biology 70:691–708.

Pope, J.A., A.R. Margetts, J.M. Hamley, and E.F. Akyüz. 1975. Manual of methods for fish stock assessment. Part 3, Selectivity of fishing gears. FAO Fisheries Technical Paper 41. Food and Agriculture Organization of the United Nations, Rome, Italy.

Pugh, L.L., and H.L. Schramm. 1998. Comparison of electrofishing and hoopnetting in lotic habitats of the Lower Mississippi River. North American Journal of Fisheries Management 18:649–656.

Quist, M.C., K.G. Gerow, M.R. Bower, and W.A. Hubert. 2006. Random versus fixed-site sampling when monitoring relative abundance of fishes in headwater streams of the Upper Colorado River Basin. North American Journal of Fisheries Management 26: 1011–1019.

Reynolds, J.B. 1983. Electrofishing. In Fisheries Techniques, edited by L.A. Nielsen and D.L. Johnson, pp. 147–164. Bethesda, Maryland: American Fisheries Society.

———. 1996. Electrofishing. In Fisheries Techniques, second edition, pp. 221–253. American Fisheries Society.

Ridings, J. 2009. A brail trawl: An improved gear for sampling darters, madtoms, and sculpins. Missouri Department of Conservation Resource Science 2009, Volume 4, No.11.

Ruetz III, C.R., D.G. Uzarski, D.M. Krueger, and E.S. Rutherford. 2007. Sampling a littoral fish assemblage: comparison of small-mesh fyke netting and boat electrofishing. North American Journal of Fisheries Management 27:825–831.

Shea, C.P., and J.T. Peterson 2007. An evaluation of the relative influence of habitat complexity and habitat stability on fish assemblage structure in unregulated and regulated reaches of a large southeastern warmwater stream. Transaction of the American Fisheries Society 136:943–958.

Simonson, T.D., and J. Lyons. 1995. Comparison of catch per effort and removal procedures for sampling stream fish assemblages. North American Journal of Fisheries Management 15:419–427.

Snyder, D.E. 2003. Electrofishing and its harmful effects on fish: U.S. Geological Survey Information and Technology Report 2003-0002. 149 p.

Stone, D.M., and O.T. Gorman. 2006. Ontogenesis of endangered humpback chub (*Gila cypha*) in the Little Colorado River, Arizona. American Midland Naturalist 155:123–135.

Utrup, N.J., and W.L. Fisher. 2006. Development of a rapid bioassessment protocol for sampling fish in large prairie rivers. North American Journal of Fisheries Management 26:714–726.

Valdez, R.A., and R.J. Ryel. 1995. Life history and ecology of the humpback chub (*Gila cypha*) in the Colorado River, Grand Canyon, Arizona. Final Report of Bio/West, Inc., Logan, Utah, to U.S. Bureau of Reclamation, Salt Lake City, Utah.

Valdez, R.A., and R.J. Ryel. 1997. Life history and ecology of the humpback chub in the Colorado River in Grand Canyon, Arizona. In Proceedings of the Third Biennial Conference of Research on the Colorado Plateau, edited by C. van Riper, III and E.T. Deshler, pp. 3–31. National Park Service Transactions and Proceedings Series 97/12.

Widmer,A.M., L.L. Burckhardt, E.J. Gonzales, and M.D. Hatch. 2010. Fish Community Monitoring and Fish Sampling Methodology Evaluation, Task 1 Report: Assessment of Current Techniques to Sample the Fish assemblages of the Middle Rio Grande. Draft report prepared for the U.S. Department of the Interior, Bureau of Reclamation, New Mexico Projects Office, Albuquerque, Contract No. 09-SP-40-8309. Albuquerque: SWCA Environmental Consultants.

Velez, C.E. 2004. Predation by non-native fish on native fish in the Verde River, Arizona. Master of Science Thesis. University of Arizona.

Walsh, M.G., D.B. Fenner, and D.L. Winkelman. 2002. Comparison of an electric seine and prepositioned area electrofishers for sampling stream fish communities. North American Journal of Fisheries Management 22:77–85.

Welker, T.L., and D.L. Scarnecchia. 2004. Habitat use and population structure of four native minnows (family Cyprinidae) in the upper Missouri and lower Yellowstone rivers, North Dakota (USA). Ecology of Freshwater Fish 13:8–22.

APPENDIX A
BIBLIOGRAPHY OF GEARS AND METHODS FROM OTHER RIVERS

The following are the abstracts or executive summaries extracted from the literature reviewed.

Altenbach, C.S., Dudley, R.K., and S.P. Platania. 2000. A new device for collecting drifting semibuoyant fish eggs. Transactions of the American Fisheries Society 129:296–300.

Several fish species in lotic systems are pelagic broadcast spawners that produce nonadhesive, semibuoyant eggs that drift downstream. This reproductive strategy and egg type appear to be common in Plains stream cyprinids in the west-central United States. Although it is relatively easy to capture semibuoyant eggs, the inability to provide species-specific identification of this life stage has hindered studies on the reproductive ecology and life history of these fishes. While drift nets have been used to collect semibuoyant eggs, the process of separating the reproductive products from other organic drift was time consuming and usually fatal for eggs. We developed a field sampling device, the Moore egg collector, that allowed for the efficient, quantitative, and nondestructive collection of large numbers of semibuoyant fish eggs and that could aid in the study of a variety of organisms that employ drift as a dispersal strategy during a portion of their life history.

Amadio, C.J., W. Hubert, K. Johnson, D. Oberlie, and D. Dufek. 2006. Abundance of adult saugers across the Wind River watershed, Wyoming. North American Journal of Fisheries Management 26:156–162.

The abundance of adult saugers *Sander canadensis* was estimated over 179 km of continuous lotic habitat across a watershed on the western periphery of their natural distribution in Wyoming. Three-pass depletions with raftmounted electrofishing gear were conducted in 283 pools and runs among 19 representative reaches totaling 51 km during the late summer and fall of 2002. From 2 to 239 saugers were estimated to occur among the 19 reaches of 1.6–3.8 km in length. The estimates were extrapolated to a total population estimate (mean 6 95% confidence interval) of 4,115 ± 308 adult saugers over 179 km of lotic habitat. Substantial variation in mean density (range = 1.0–32.5 fish/ha) and mean biomass (range = 0.5–16.8 kg/ha) of adult saugers in pools and runs was observed among the study reaches. Mean density and biomass were highest in river reaches with pools and runs that had maximum depths of more than 1 m, mean daily summer water temperatures exceeding 20ºC, and alkalinity exceeding 130 mg/L. No saugers were captured in the 39 pools or runs with maximum water depths of 0.6 m or less. Multiple-regression analysis and the information-theoretic approach were used to identify watershed-scale and instream habitat features accounting for the variation in biomass among the 244 pools and runs across the watershed with maximum depths greater than 0.6 m. Sauger biomass was greater in pools than in runs and increased as mean daily summer water temperature, maximum depth, and mean summer alkalinity increased and as dominant substrate size decreased. This study provides an estimate of adult sauger abundance and identifies habitat features associated with variation in their density and biomass across a watershed, factors important to the management of both populations and habitat.

Angermeier, P.L., R.A., Smogar, and Steele, S.D. An electric seine for collecting fish in streams. North American Journal of Fisheries Management 11:352–357

We describe the design and use of an electric seine for collecting fish that is reliable, efficient, and broadly applicable in small to medium-size streams. Modifications of previous designs include (1) addition of a rheostat for regulating circuit amperage, (2) use of fiberglass tubing in the brail infrastructure, (3) readily engaged or disengaged connections between the brails and drop electrode array, and (4) use of automobile brake or speedometer cables as drop-electrodes with adjustable lengths. To estimate capture efficiency of the electric seine, we repeatedly electrofished a pool and riffle in each of two Virginia streams. The first two passes with the electric seine captured between 53 and 79% of fish numbers and between 60 and 88% of fish biomass collected by 10 passes. Capture efficiency was relatively high for suckers, low for darters, and variable for minnows and sun fishes. Capture efficiency of the electric seine was similar or superior to that of other electrofishing gear used in wadeable streams. The electric seine is most appropriate for quantitative estimates of species composition or population densities of entire fish assemblages.

Bayley, P.B., and R.A. Herendeen. 2000. The efficiency of a seine net. Transactions of the American Fisheries Society 129:901–923.

We present a method to predict the capture efficiency of a 25-m, 5-mm mesh seine net as a function of fish size and taxon from a diverse fish community. This allows true abundance and size distribution to be estimated from observed catches. Predicted capture efficiency from an empirical model of field calibrations from the Amazon River floodplain was a positively skewed, unimodal function of fish length, whose magnitude depended on method of seine operation and fish taxonomic group. Capture efficiency is the product of efficiency of encirclement as the net is laid (which decreases with increasing fish size) and efficiency of retention as the net is hauled (which increases with increasing fish size). Retention was determined by modeling mark–recapture data. Dividing observed capture efficiency by this retention yielded empirical encirclement efficiency, which was then compared with encirclement efficiency determined from a simulation model of fishes' evasive behavior. The simulation accounts for the fishes' swimming speed relative to the speed of deployment of the seine, threshold distance (how close the disturbance from laying the net must be to initiate evasion), appraisal time (how long a fish continues evasive behavior when it moves outside the threshold distance), and the directionality of evasive movements. Simulated results of encirclement efficiency corresponded to empirically based predictions within plausible ranges of the simulation variables above, although for fish of length exceeding about 50 cm there is a high coefficient of variation in captured biomass due to small numbers and low catchability. We conclude that the method can be used for a wide range of conditions to convert seine capture data to unbiased estimates of abundance and size distribution, but that empirical determinations will still be needed for different net specifications and sampling conditions.

Braaten, P.J., D.B. Fuller, L.D. Holte, R.D. Lott, W. Viste, T.F. Brandt, and R.G. Legare. 2008. Drift dynamics of larval pallid sturgeon and shovelnose sturgeon in a natural side channel of the upper Missouri River, Montana. North American Journal of Fisheries Management 28:808–826.

The drift dynamics of larval shovelnose sturgeon *Scaphirhynchus platorynchus* (1, 2, 6, and 10 d posthatch [dph]) and pallid sturgeon *S. albus* (1, 2, 5, 9, 11, and 17 dph) were examined in a natural side channel of the Missouri River to quantify the vertical drift location of larvae in the water column, determine the drift velocity of larvae relative to water velocity, and simulate the cumulative distance (km) drifted by larvae during ontogenetic development. Larvae were released at the side-channel inlet and sampled at points 100, 500, 900, and 1,300 m downstream. Larvae drifted primarily near the riverbed, as 58–79% of recaptured shovelnose sturgeon and 63–

89% of recaptured pallid sturgeon were sampled in the lower 0.5 m of the water column. The transition from the drifting to the benthic life stage was initiated at 6 dph (mean length, 15.6 mm) for shovelnose sturgeon and at 11–17 dph (mean length, 18.1–20.3 mm) for pallid sturgeon. Across ages, the drift rates of larval shovelnose sturgeon averaged 0.09–0.16 m/s slower than the mean water column velocity. The drift rates of pallid sturgeon were similar to or slightly slower (0.03–0.07 m/s) than the mean water column velocity for 1–11-dph larvae. Conversely, 17-dph larval pallid sturgeon dispersed downstream at a much slower rate (mean, 0.20 m/s slower than the mean water column velocity) owing to their transition to benthic habitats. Drift simulations indicated that the average larval shovelnose sturgeon may drift from 94 to 250 km and the average larval pallid sturgeon may drift from 245 to 530 km, depending on water velocity. Differences in larval drift dynamics between species provide a possible explanation for differences in recruitment between shovelnose sturgeon and pallid sturgeon in the upper Missouri River.

Breen, M.J., C.R. Ruetz III, and S.E. Lochmann. 2006. Gear bias in fyke netting: evaluating soak time, fish density, and predators. North American Journal of Fisheries Management 26:32–41.

Knowledge of gear bias is critical for conducting valid population and community assessments. We studied the biases in fyke netting by investigating the individual effects of soak time (fyke nets were fished for 6, 24, or 48 h), fish density (fyke nets were stocked with 0, 30, or 60 fish/net), and predators (fyke nets were stocked with one or zero bowfin Amia calva) on the escape probability and number of individuals captured (i.e., catch) for three fish species. Overall, escape probabilities were consistently lower for round gobies *Neogobius melanostomus* than for bluntnose minnows *Pimephales notatus* and banded killifish *Fundulus diaphanus*. Both escape probability and catch increased with soak time. Escape probabilities were lower at high fish densities and in the presence of a predator, whereas catch appeared to be unaffected by both factors. We documented predation on fish stocked in fyke nets by free-ranging bowfins and yellow bullheads *Ameiurus natalis*, which is a potential source of bias that will probably vary among systems. Of the factors we investigated, variation in soak time had the strongest effect on catch. Our results were consistent with catch being proportional to soak times of at least 24 to 48 h, although this relationship was highly variable. Thus, standardizing catch by soak time (e.g., net nights) can be appropriate when confronted with low variation in soak time (e.g., 1 d). Finally, our study highlights potential differences in escape probabilities among fish species, a factor that is probably important in determining which species are overrepresented and which are underrepresented in entrapment gear.

Bryant, M.D. 2000. Estimating fish populations by removal methods with minnow traps in southeast Alaska streams. North American Journal of Fisheries Management 20:923–930.

Passive capture methods, such as minnow traps, are commonly used to capture fish for mark–recapture population estimates; however, they have not been used for removal methods. Minnow traps set for 90-min periods during three or four sequential capture occasions during the summer of 1996 were used to capture coho salmon *Oncorhynchus kisutch* fry and parr, Dolly Varden *Salvelinus malma*, cutthroat trout *O. clarki*, and juvenile steelhead *O. mykiss* to estimate population size with the Zippin or generalized removal method. More than 45% of the total catch was obtained during the first capture occasion, and in most cases, the catch during the fourth occasion was less than 15% of the total catch. In most pools, the probability of capture was greater than 0.4 but was lower for coho salmon fry than for coho salmon parr and other species. Mean population estimates for coho salmon parr made with concurrent mark–recapture and removal methods differed significantly in small streams. Estimates from mark–recapture and removal methods were not significantly different for coho salmon fry and Dolly Varden, but mark–recapture estimates were higher than removal estimates in most cases. My results show that removal estimates can be obtained with minnow traps if sampling procedures conform to the assumptions required for the method.

Clark, S.J., J.R. Jackson, and S.E. Lochmann. 2006. A comparison of shoreline seines with fyke nets for sampling littoral fish communities in floodplain lakes. North American Journal of Fisheries Management 27:676–680.

We compared shoreline seines with fyke nets in terms of their ability to sample fish species in the littoral zone of 22 floodplain lakes of the White River, Arkansas. Lakes ranged in size from less than 0.5 to 51.0 ha. Most contained large amounts of coarse woody debris within the littoral zone, thus making seining in shallow areas difficult. We sampled large lakes (>2 ha) using three fyke nets; small lakes (<2 ha) were sampled using two fyke nets. Fyke nets were set for 24 h. Large lakes were sampled with an average of 11 seine hauls/lake and small lakes were sampled with an average of 3 seine hauls/lake, but exact shoreline seining effort varied among lakes depending on the amount of open shoreline. Fyke nets collected more fish and produced greater species richness and diversity measures than did seining. Species evenness was similar for the two gear types. Two species were unique to seine samples, whereas 13 species and 3 families were unique to fyke-net samples. Although fyke nets collected more fish and more species than did shoreline seines, neither gear collected all the species present in the littoral zone of floodplain lakes. These results confirm the need for a multiple-gear approach to fully characterize the littoral fish assemblages in floodplain lakes.

Coggins, L.G., W.E. Pine III, C.J. Walters, D.R. Van Haverbeke, D. Ward, and H.C. Johnstone. 2006. Abundance trends and status of the Little Colorado River population of humpback chub. North American Journal of Fisheries Management 26:233–245.

The abundance of the Little Colorado River population of federally listed humpback chub *Gila cypha* in Grand Canyon has been monitored since the late 1980s by means of catch rate indices and capture–recapture-based abundance estimators. Analyses of data from all sources using various methods are consistent and indicate that the adult population has declined since monitoring began. Intensive tagging led to a high proportion (>80%) of the adult population being marked by the mid-1990s. Analysis of these data using both closed and open abundance estimation models yields results that agree with catch rate indices about the extent of the decline. Survival rates for age-2 and older fish are age dependent but apparently not time dependent. Back-calculation of recruitment using the apparent 1990s population age structure implies periods of higher recruitment in the late 1970s to early 1980s than is now the case. Our analyses indicate that the U.S. Fish and Wildlife Service recovery criterion of stable abundance is not being met for this population. Also, there is a critical need to develop new abundance indexing and tagging methods so that early, reliable, and rapid estimates of humpback chub recruitment can be obtained to evaluate population responses to management actions designed to facilitate the restoration of Colorado River native fish communities.

Dauwalter, D.C., and E.J. Pert. 2003. Electrofishing effort and fish species richness and relative abundance in Ozark Highland streams of Arkansas. North American Journal of Fisheries Management 23:1152–1166

We sampled 15 stream sites in the Ozark Highlands ecoregion of Arkansas and examined the effect of increased backpack electrofishing effort on the richness and relative abundance estimates of fish species. Each site was 75 mean stream widths (MSWs) long and was divided into 15 consecutive segments that were each 5 MSWs long. For each site the percent of empirical and theoretical species richness and the percent of relative abundance similarity to the entire fish assemblage were calculated by adding consecutive segments using an approach that resulted in 15 accumulation curves per assemblage character for each stream site. On average, a distance of 53.8 MSWs (SD = 7.4) was needed to sample 95% of empirical species richness at a stream site, which was equal to an area of 2,722.0 m^2 (SD = 1,967.0). For sampling 95% of theoretical species richness, an average of 101.8 MSWs (SD = 34.5), or 5,055.7 m^2 (SD = 3,667.4) was needed. Obtaining 95% relative abundance similarity required an average sampling effort equivalent to 24.0 MSWs (SD = 8.9), or 1,269.7 m^2 (SD = 932.1). Mean stream width explained more variance in the reach lengths and areas needed for estimates of species richness and relative abundance than did riffle2pool sequence length or watershed size. Our results should offer insight into species richness and relative abundance accumulation rates when using a one-pass backpack electrofishing sample in Ozark highland streams of Arkansas.

Dewey, M.R. 1992. Effectiveness of a drop net, a pop net, and an electrofishing frame for collecting quantitative samples of juvenile fishes in vegetation. North American Journal of Fisheries Management 12:808–813.

I compared quantitative samples collected by a drop net, a pop net, and an electrofishing frame from vegetated habitats of a backwater lake in the upper Mississippi River. All gears sampled an area of 5.6 m2. Catches with all three gears were dominated by juvenile centrarchids, mainly bluegills Lepomis macrochirus. In vegetated, turbid water, catches were significantly less with the electrofishing frame than with the two nets because observing and netting stunned fish was difficult. Capture efficiencies with the electrofishing frame were much higher in nonvegetated, relatively clear water (mean efficiency, 80%) than in vegetated, turbid water (mean efficiency, 5%). Catches with the drop net and pop net were similar in both number and species composition. Both the pop net and drop net were well suited for collecting quantitative samples of small fish from vegetation.

Fago, D. 1998. Comparison of littoral fish assemblages sampled with a mini-fyke net or with a combination of electrofishing and small-mesh seine in Wisconsin lakes. North American Journal of Fisheries Management 18:731–738.

Mini-fyke nets (MFN) were compared with a combination of electrofishing and a small-mesh seine (ESMS) to assess their relative abilities to describe littoral fish assemblages in 19 Wisconsin lakes (110–2,454 ha). Eighteen locations in each lake were sampled by both sampling methods. Each method missed an average of four species per lake that were collected by the other method. Two-thirds of the species missed were species that were caught at 5% or more of the total stations. Two-thirds of the 55 species that were collected by only one method in a lake were only collected in other lakes by that same method. Monte Carlo simulations of sampling intensity for each sampling method showed that the number of stations needed to miss on average fewer than one species of the total caught by that method was 15 stations for the ESMS and 14 stations for the MFN. A better estimate of species composition was obtained by combining the results from both methods than from the individual estimates of either method.

Firehammer, J.A., D.L. Scarnecchia, and S.R. Fain. 2006. Modification of a passive gear to sample paddlefish eggs in sandbed spawning reaches of the Lower Yellowstone River. North American Journal of Fisheries Management 26:63–72.

A passive sampling technique was developed to collect eggs and confirm potential spawning sites for paddlefish *Polyodon spathula* in sandbed reaches of the lower Yellowstone River, Montana and North Dakota. In 2000, egg collectors modeled after the mats used in sturgeon research proved difficult to retrieve from the riverbed and did not collect eggs. In 2001 and 2002, tubular egg collectors designed to remain suspended off the bottom were successfully retrieved 97% of the time and collected 130 acipenseriform eggs along suspected spawning sites (99% of differentiable eggs were genetically confirmed as paddlefish). In both years, eggs were typically collected in mid-June after peak periods of Yellowstone River discharge and at river temperatures of 15–22°C. During collection periods in 2001 and 2002, 20% and 45% of retrieved tubes, respectively, had at least one egg, and 84% of all eggs were found on tubes retrieved from the channel thalweg. Although eggs were spatially distributed in a clumped manner at sample sites, the mean number of eggs per tube was low (<4), suggesting either collector inefficiency, the inability to deploy collectors in close proximity to concentrations of spawning paddlefish, or the widespread distribution of spawning effort over the lower Yellowstone River.

Floyd, K.B., R.D. Hoyt, AND S. Timbrook. 1984. Chronology of appearance and habitat partitioning by stream larval fishes. Transactions of the American Fisheries Society 113:217–223

Larval and juvenile representatives of 28 species were collected from a small stream in Kentucky in 1982 with light traps, push seine, and drift net. The majority of both larvae and juveniles were captured in the light trap; fewer than 1% were taken in drift samples. All but three species were taken at least once in the light traps. Most larvae and juveniles congregated along shoreline areas and used most of the eight habitat areas sampled to some extent. Sunfish species tended to stay in the same general shoreline areas where spawned, whereas riffle-current species left their nest sites as larvae and moved to shoreline nursery areas. Species captured as drift specimens were mostly channel catfish *Ictalurus punctatus* and flathead catfish *Pylodictis olivaris* with exceptions the order of species appearance was cottids, percids, cyprinids, centrarchids and ictalurids. There was considerable overlap of species and resource sharing was extensive. The duration of larval occurrences ranged from 16 weeks for logperch *Percina caprodes* to 3 weeks for catfish. Spawning duration was influenced by species' behavior and water influxes.

Freedman, J.A., T.D. Stecko, B.D. Lorson, and J.R. Stauffer, Jr. 2009. Development and efficacy of an electrified benthic trawl for sampling large-river fish assemblages. North American Journal of Fisheries Management 29:1001–1005.

Sampling small benthic and lithophilic fish species in large rivers and lakes presents challenges not adequately addressed by conventional survey methods such as boat electrofishing and gill netting. The development of the Missouri trawl has helped to address these issues; however, our observations by scuba diving when using the Missouri trawl have revealed avoidance of the trawl by benthic fishes, especially in rocky substrates. Therefore, we equipped a Missouri trawl with a cathode–anode electrical array to facilitate capture by attracting and immobilizing fish. In 40 paired comparisons with a standard Missouri trawl in the upper Ohio River drainage of Pennsylvania, this electrified PSU trawl captured significantly more fish and species as well as more large fish. The PSU trawl also captured more species and more fish across habitats and rivers within the drainage. The PSU trawl is therefore a useful new device for sampling large-river benthic fish communities.

Galat, D.L., G.W. Whitledge, L.D. Patton, and J. Hooker. 2004. Larval Fish Use of Missouri River Scour Basins in Relation to Connectivity. Final Report to Missouri Department of Conservation. 88 pp.

Knowledge of how larval fishes use floodplain habitats is essential to guide efforts to restore ecological integrity of altered large river ecosystems. Assemblage structure, temporal patterns of abundance, density, and taxa richness for larval fishes were examined in twelve lower Missouri River floodplain scour basins created by the "Great Flood of 1993". Study sites were chosen to encompass the full range of lateral connectivity and included three continuously connected, four periodically connected, and five isolated scour basins. Connectivity was quantified for each scour basin by three components: distance between river and scour (m), duration of connection (d), and an index of water exchange between river and scour. Each study site was sampled on 10 dates at approximately 15-day intervals from April through August 1996. Five random sample locations were chosen within each site on each sampling date. Larval fishes were collected using a boat-towed sled net. Connectivity strongly influenced taxa richness and assemblage structure of larval fishes in lower Missouri River scour basins, but mean catch-per-unit-effort for all larval taxa combined was not related to connectivity. Differences in larval fish assemblage structure among sites were associated with distance between river and scour, duration of connection, and the exchange index but were not related to morphological differences among scours. Taxa richness increased with increasing connectivity due to addition of larvae of rheophilic taxa that were rare or absent in isolated scours. Increasing connectivity resulted in larval fish assemblages changing from a fauna dominated by gizzard shad and centrarchids in isolated scours to an increasingly more diverse assemblage that included greater abundances of riverine taxa. Higher variability in connectivity was observed among periodically connected scours compared to isolated or continuously connected scours. This resulted in greater variation in larval fish assemblages among periodically connected waterbodies. Increasing connectivity via greater duration or exchange or lower distance from the river will enhance accessibility of scours for rheophilic taxa.

Duration and timing of connection strongly influenced larval fish assemblages among scour basins. Connection with the Missouri River during late summer and early fall enhanced access to all continuously connected scour basins and one periodically connected scour basin for *Hypopthalmichthys* spp., *Hybognathus* spp., *Macrhybopsis* spp., freshwater drum, grass carp, and emerald shiner. Relative importance of floodplain and in-channel, shallow-water habitats for recruitment of larval fishes is not currently known for the lower Missouri River.

Gale, W.F., and H.W. Mohr. 1978. Larval fish drift in a large river with a comparison of sampling methods. Transactions of the American Fisheries Society 107:46–55.

Larval fish drift in the rocky-bottomed Susquehanna River (northeastern Pennsylvania) was investigated during 1974-1975. Near SSES (Susquehanna Steam Electric Station) at least 18 species of drifting larvae were collected by nets mounted on a stationary boat or by pumping. Maximum densities of 15.4 and 27.1 larvae/10 m s were found in June 1974 and 1975, respectively. Quillback, *Carpiodes cyprinus* (56%), minnows (25%), and carp, *Cyprinus carpio* (14% of the total) were the most abundant larvae caught in 1974 by pumping. The few larvae that drifted during the day were mostly near the bottom. Large numbers of quillback, white sucker (*Catostomus commersoni*), shorthead redhorse (*Moxostoma macrolepidotum*) and tessellated darter (*Etheostoma olmstedi*) larvae drifted near the river surface at night. Drift was maximum at about 2400 h. Overall, the day/night drift ratio was 1/3.8. In 1974 at Falls, the control station upstream of SSES and several intervening coal mine effluents, maximum density of drifting larvae was 1.4 fish/10 m s, less than 10% of that at SSES. Density of spawning-sized fish was about three fold higher at Falls than at SSES. Boat-mounted nets and the pump sampler had equal sampling efficiencies. Condition of larvae in pump samples was related to net material, mesh size, net shape, and pumping duration. Larvae in best condition were in 5-min samples pumped into slender nets (mouth/length ratio 1/10) made of fine-meshed monofilament nylon.

Haddix, T., L. Holte, and J. Hunziker. 2009. 2008 Annual Report: Pallid Sturgeon Population Assessment and Associated Fish Community Monitoring for the Missouri River: Segment 3. Prepared for the U.S. Army Corp of Engineer - Missouri River Recovery Program. May 2009.

Montana Fish, Wildlife and Parks has been conducting pallid sturgeon *Scaphirhynchus albus* population assessment sampling in segment 3 for the past three years (2006-2008). We have captured more pallid sturgeon in every year of sampling, both due to increased level of effort and more pallid sturgeon in the river. During 2008 only 20% of all pallid sturgeon captured were from the 2007-year class, which was a significant decrease from 2007 where the 2006-year class made up 43% of the total catch and 2006 when 82% of the catch was from the 2005-year class. Although we have not observed large increased in pallid sturgeon CPUE of our standard gears, the fact that a larger proportion of the fish we are catching have been residing in the river longer is evidence that the stocking program is producing viable fish that are recruiting to older age classes. A total of 130 hatchery reared pallid sturgeon were sampled in segment 3 during 2008, an increase from 92 and 49 pallid sturgeon sampled in 2007 and 2006, respectively. Additionally, nine different year classes of pallid sturgeon were sampled in segment 3 during 2008 and increase from six-year classes in 2007 and four in 2006. While it is evident that the propagation efforts are increasing the total number and year classes of pallid sturgeon in the Missouri River, it is important to note that no wild pallid sturgeon have been sampled in all three years of sampling, which further supports the hypothesis that no natural recruitment is occurring in the Missouri River downstream of Fort Peck Dam.

While trammel nets and otter trawls have been effective gears for collecting juvenile pallid sturgeon, trotlines were employed with more effort in 2008 and were a very successful complimentary gear. During 2008 we deployed trotlines once in 23 river bends, which is less effort than we expend with trammel nets and otter trawls (both gears are used to sample each river bend twice a year). In this effort we collected 30 pallid sturgeon, however trotlines captured the four largest pallid sturgeon sampled in 2008 and all four were from older age classes that have not shown up in the catch of our standard gears in all three years of sampling. Until the trotline effort of 2008 we were not sure any of the 1997, 1998, or 1999-year classes of stocked pallid sturgeon had survived in segment 3.

Pallid sturgeon distributed throughout the length of segment 3, with slightly higher densities in the downstream most areas. Pallid sturgeon stocked into segment 3 on average move less than fish stocked in the more altered waters of segment 2 upstream. This may suggest this is higher quality habitat than the more altered sections directly downstream of Fort Peck Dam.

Pallid sturgeon stocked into RPMA 2 of the Missouri River and recaptured in segment 3 have shown a general trend of decreasing growth rates as they age. Similarly, we see a decrease in the relative condition of hatchery reared pallid sturgeon as they grow into larger size classes. However, our sample size of older age classes of pallid sturgeon is small and we would expect that once they reach larger sizes and they become more piscivores both their growth rates and relative condition might increase. Furthermore, although the Missouri River downstream of Fort Peck Dam is highly altered, hatchery reared juvenile pallid sturgeon stocked in this section of the Missouri River have shown to have higher survival rates than their counterparts stocked into the more pristine Yellowstone River (Hadley and Rotella 2009). Lending further evidence that this reach of river is an important component in the recovery of pallid sturgeon in the Upper Basin.

The shovelnose sturgeon *Scaphirhynchus platorynchus* population in segment 3 seems to be healthy. In the past three years we've collected a large variety of size classes of shovelnose sturgeon and have seen evidence of YOY and age-1 rearing. Although shovelnose sturgeon are recruiting into the population, we have only found YOY and age-1 fish in the downstream most portions of segment 3 where the river is somewhat more naturalized when compared to the highly altered upstream portions closer to Fort Peck Dam. In all we observed a shovelnose to pallid sturgeon ration of 2.9:1 in segment 3 during 2008, a decrease from 3.2:1 in 2007 and 3.1:1 in 2006. These data should not be taken as less shovelnose sturgeon are occupying segment 3, but rather that due to the propagation efforts more pallid sturgeon are now residing in the river.

Similar to the distribution of juvenile shovelnose sturgeon, YOY and age-1 sauger *Sander canadensis* are only found in the downstream portions of segment 3. Additionally, the abundance of sicklefin chubs *Macrhybopsis meeki* and sturgeon chubs *M. gelida* seems to be directly tied to how altered the river is and are more abundant in the downstream less altered areas. Other native fishes such as river carpsuckers *Carpiodes carpio* and flathead chubs *Platygobio gracilis* seem to show a positive response to higher Missouri and Milk River flows.

During 2007 the Missouri River had discharge peaks that far surpassed both 2006 and 2008 and the Milk River contributed large amounts of suspended sediment in 2007 and very little in 2006 or 2008. The relative abundance of YOY river carpsuckers and flathead chubs were much greater in the higher water year of 2007, when compared to 2006 and 2008. We have also seen the spatial distribution of some native minnows respond to increases in suspended sediment, where fish tend to be move further upstream than during low suspended sediment times when the Milk River is not flowing. Other fishes such as fathead minnows *Pimephales promelas*, white suckers *Catostomus commersonii* and longnose suckers *C. catostomus* seem to have the opposite response to higher flows, where their juvenile abundance was highest in the lowest flow year of

2006. More years of fish abundance data and differing operations of Fort Peck Dam and varying water years from the Milk River will help us better understand the relationship between flow, suspended sediment and fish production in the Missouri River.

Herzog, D.P., V.A. Barko, J.S. Scheibe, R.A. Hrabik, and D.E. Ostendorf. 2005. Efficacy of a benthic trawl for sampling small-bodied fishes in large river systems. North American Journal of Fisheries Management 25:594–603.

We conducted a study from 1998 to 2001 to determine the efficacy of a benthic trawl designed to increase species detection and reduce the incidence of zero catches of small-bodied fishes. We modified a standard two-seam slingshot balloon trawl by covering the entire trawl with a small-mesh cover. After completing 281 hauls with the modified (Missouri) trawl, we discovered that most fish passed through the body of the standard trawl and were captured in the cover. Logistic regression indicated no noticeable effect of the cover on the catch entering the standard portion of the modified trawl. However, some fishes (e.g., larval sturgeons *Scaphirhynchus* spp. and pallid sturgeon *S. albus*) were exclusively captured in the small-mesh cover, while the catch of small-bodied adult fish (e.g., chubs *Macrhybopsis* spp.) was significantly improved by use of the small-mesh cover design. The Missouri trawl significantly increased the number and species of small-bodied fishes captured over previously used designs and is a useful method for sampling the benthic fish community in moderate- to large-size river systems.

Herzog, D.P., D.E. Ostendorf, R.A. Hrabik, and V.A. Barko. 2009. The mini-Missouri trawl: A useful methodology for sampling small-bodied fishes in small and large river systems. Journal of Freshwater Ecology 24(1):103–108.

Sampling has been conducted in small to large rivers of the Midwest and northeastern United States to determine the usefulness of a modified Missouri trawl designed to increase species detection of small-bodied fish species. We modified the Missouri trawl, which is a 4.8 m standard two-seam slingshot balloon trawl with a small mesh cover, by reducing the size (to a 2.44 m) and cover. The modified Missouri trawl (a.k.a the mini-Missouri trawl) increased the number of small bodied aquatic species of concern captured over that of previously used gears. For instance, shoal chub (*Macrhybopis hyostoma*) had only been captured in the St. Croix River of Minnesota at three locations since 1960, yet we sampled it at 14 new locations in September, 2004 employing this methodology. Because of our success in these diverse and numerous systems, we believe this is a useful methodology for sampling the benthic fish community in many aquatic systems when other sampling methods are difficult to use because of water depths and/or velocities.

Holland, R.S., and E.J. Peters. 1992. Differential catch by hoop nets of three mesh sizes in the Lower Platte River. North American Journal of Fisheries Management 12:237–243.

We sampled fish from six sites along the lower Platte River with cheese-baited hoop nets with mesh sizes of 25, 32, and 38 mm during 1989. Bank habitats sampled were categorized as naturally stabilized banks, eroding banks, revetments, and hard points. Nets were set approximately in proportion to availability of bank habitats at each site. We collected 1,023 fish in 976 net-nights. The 25-mm-mesh nets caught 82% of the fish in 45.5% of the total net-nights. Significantly fewer fish (18.0% of total) were caught in 32- and 38-mm-mesh nets from 54.5% of the net-nights. Hoop nets were species-selective—92.7% of the fish collected were channel catfish *Ictalurus punctatus*. Mean length of channel catfish significantly increased with mesh size: 266 mm (SD = 45.1 mm) with 25-mm-mesh nets, 320 mm (SD, 65.0 mm) with 32-mm-mesh nets, and 316 mm (SD = 130.4 mm) with 38-mm-mesh nets. The pattern of decreased capture with increasing mesh size was consistent within individual habitat types. General linear models based on rank transformed channel catfish lengths indicated that all three mesh sizes were significantly different in terms of the mean locations of the ranked lengths. Care should be taken to standardize mesh size of hoop nets because of the differential capture among mesh sizes.

Janac, M., and P. Jurajda. 2007. A comparison of point abundance and continuous sampling by electrofishing for age-0 fish in a channelized lowland river. North American Journal of Fisheries Management 27:1119–1125.

Because of its efficiency as a sampling method, electrofishing of age-0 fish is often used to assess natural reproduction in rivers. However, little is known about the relative tradeoffs of accuracy and efficiency of different electrofishing methods. For monitoring purposes, it is important to find a method that accurately estimates age-0 fish assemblages and that is relatively quick and inexpensive. Though some studies have compared the suitability of different methods for addressing particular research or management questions, to our knowledge this is the first study comparing two different electrofishing sampling strategies: point abundance and continuous. We compared time effectiveness and accuracy of estimating age-0 fish assemblages obtained by point abundance and continuous electrofishing on the lowland Morava River (Danube River basin, Czech Republic). Forty sites were surveyed by each strategy along two types of shoreline: submerged vegetation and boulder bank. Both strategies yielded similar qualitative data (species richness, relative proportion of species, and size structure) along each shoreline type. Point abundance sampling required a shorter amount of survey time than did continuous sampling. We conclude that point abundance sampling is the more suitable method for routine sampling of age-0 fish assemblages in lowland rivers.

Kennard M.J., B.J. Pusey, B.D., Harch, E. Dore, and A.H. Arthington. 2006. Estimating local stream fish assemblage attributes: sampling effort and efficiency at two spatial scales. Marine and Freshwater Research 57:635–653

As part of a wider study to develop an ecosystem-health monitoring program for wadeable streams of south-eastern Queensland, Australia, comparisons were made regarding the accuracy, precision and relative efficiency of single-pass backpack electrofishing and multiple-pass electrofishing plus supplementary seine netting to quantify fish assemblage attributes at two spatial scales (within discrete mesohabitat units and within stream reaches consisting of multiple mesohabitat units).The results demonstrate that multiple-pass electrofishing plus seine netting provide more accurate and precise estimates of fish species richness, assemblage composition and species relative abundances in comparison to single-pass electrofishing alone, and that intensive sampling of three mesohabitat units (equivalent to a riffle–run–pool sequence) is a more efficient sampling strategy to estimate reach-scale assemblage attributes than less intensive sampling over larger spatial scales. This intensive sampling protocol was sufficiently sensitive that relatively small differences in assemblage attributes (<20%) could be detected with a high statistical power ($1-\beta>0.95$) and that relatively few stream reaches (<4) need be sampled to accurately estimate assemblage attributes close to the true population means. The merits and potential drawbacks of the intensive sampling strategy are discussed, and it is deemed to be suitable for a range of monitoring and bioassessment objectives.

Koel, T.M. 2004. Spatial variation in fish species richness of the upper Mississippi River system. Transactions of the American Fisheries Society 133:984–1003.

Important natural environmental gradients, including the connectivity of off-channel aquatic habitats to the main-stem river, have been lost in many reaches of the upper Mississippi River system, and an understanding of the consequences of this isolation is lacking in regard to native fish communities. The objectives of this study were to describe patterns of fish species richness, evenness, and diversity among representative habitats and river reaches and to examine the relationship between fish species richness and habitat diversity. Each year (1994–1999) fish communities of main-channel borders (MCB), side channel borders (SCB), and contiguous backwater shorelines (BWS) were sampled using boat-mounted electrofishing, mini-fyke-nets, fyke nets, hoop nets, and seines at a standardized number of sites. A total of 0.65 million fish were collected, representing 106 species from upper Mississippi River Pools 4, 8, 13, and 26; the open (unimpounded) river reach; and the La Grange Reach of the Illinois River. Within pools, species richness based on rarefaction differed significantly among habitats and was highest in BWS and lowest in MCB ($P<0.0001$). At the reach scale, Pools 4, 8, and 13 consistently had the highest species richness and Pool 26, the open-river reach, and the La Grange Reach were significantly lower ($P<0.0001$). Species evenness and diversity indices showed similar trends. The relationship between native fish species richness and habitat diversity was highly significant ($r^2 = 0.85$; $P = 0.0091$). These results support efforts aimed at the conservation and enhancement of connected side channels and backwaters. Although constrained by dams, pools with high native species richness could serve as a relative reference. The remnants of natural riverine dynamics that remain in these reaches should be preserved and enhanced; conditions could be used to guide restoration activities in more degraded reaches.

Lapointe, N.W., L.D. Corkum, and N.E. Mandrak. 2006a. A comparison of methods for sampling fish diversity in shallow offshore waters of large rivers. North American Journal of Fisheries Management 26:503–513.

Few studies of fish assemblages have been conducted in large rivers owing to the difficulties of sampling such complex systems. We evaluated the effectiveness of six different gear types (seine nets, boat electrofishers, hoop nets, Windermere traps, trap nets, and minnow traps) in sampling the fish assemblage at 30 sites in the shallow offshore waters of the middle Detroit River in July and August 2003. A total of 2,449 fish representing 38 species in 15 families were captured by seining (1,293 fish, 29 species), boat electrofishing (398 fish, 23 species), hoop nets (524 fish, 26 species), and Windermere traps (234 fish, 14 species). Trap nets and minnow traps were not effective in sampling offshore littoral sites. Significantly higher fish species richness and abundance were obtained and more unique species were captured by seine nets than by any other gear type. When effort is constant, the highest richness and abundance are obtained by seine nets. Windermere traps produced significantly lower abundance and richness than all other gear types, but proportionally more benthic species. Total species accumulation rates were not markedly reduced when Windermere trap data were excluded. Use of additional Windermere traps at each site could increase abundance, but samples taken by Windermere traps had the lowest rarefied richness among gear types at any level of abundance. Nonmetric multidimensional scaling showed that seine-net catches, which were dominated by midwater schooling species (brook silverside *Labidesthes sicculus*, emerald shiner *Notropis atherinoides*, and mimic shiner *N. volucellus*), were most dissimilar from Windermere trap catches, which were dominated by centrarchids. Seine nets were the most effective gear for sampling offshore waters.

Lapointe, N.W.R., L.D. Corkum, and N.E. Mandrak. 2006b. Point sampling by boat electrofishing: a test of the effort required to assess fish communities. North American Journal of Fisheries Management 26:793–799.

Point sampling by electrofishing is often used to study fishes in large rivers and lakes whereby a specific location is electrofished without moving the anode. Short (1–5-s) samples are taken under the belief that many small samples are preferred over a few large ones for statistical analyses. However, this typically results in relatively little time spent sampling fishes compared with time spent measuring abiotic factors and traveling among sites. We evaluated the optimal sampling duration and number of replicates per site to balance sample size and number for community-level studies. In 2004, 165 point samples were taken from shallow Canadian waters of the Detroit River. Sites were continuously electrofished for 2 min (eight 15-s intervals), and a second replicate of 2 min was taken after a pause. Subsets of the data were used to compare various designs of sampling duration and number of replicates. A sampling design of two replicates of 1 min appeared to be ideal because it balanced a large gain of information with a small increase in effort. This design would allow 35–50 sites to be sampled per day, depending on the detail of abiotic measurements. Compared with data from the first 15-s interval only, sampling for two replicates of 1 min resulted in fewer null (no fishes captured) samples (19% instead of 53%). The number of common (found at .5% of samples) species also increased from 12 to 19. By increasing the effort for point sampling by electrofishing at each site, a better understanding of the fish assemblage was obtained. This allows for more complete analyses of community composition and habitat preference.

Lyons, J. 1986. Capture efficiency of a beach seine for seven freshwater fishes in a north temperate lake. North American Journal of Fisheries Management 6:288–289.

Daytime seining efficiencies were estimated for shoreline fish populations in Sparkling Lake, a small mesotrophic clear-water lake in northern Wisconsin. Except for rock bass (Ambloplites rupestris), efficiency was related to the typical position of each species in the water column; efficiencies were higher for midwater fishes (cyprinids and yellow perch, *Perca flavescens*) than for benthic fishes (darters, Etheostoma spp.). Efficiencies for many species might be improved by modifications of seining technique or use of heavier lead lines that would keep the seine closer to the bottom.

Lyons, J., and P. Kanehl. 1993. A Comparison of Four Electrofishing Procedures for Assessing the Abundance of Smallmouth Bass in Wisconsin Streams. U.S. Forest Service, North Central Forest Experiment Station, General Technical Report NC-159, St. Paul, Minnesota.

The Upper Midwest region of the United States contains many streams with smallmouth bass (*Micropterus dolomleu*) populations. Many of these streams provide ex*c*ellent fishing opportunities (WDNR 1978, Holschlag 1990), but fisheries management of them is hampered by inadequate data on smallmouth bass population characteristics (Forbes 1985). Efforts to collect smallmouth bass population data have been impeded by an absence of standardized sampling procedures, *c*oupled with the inherent difficulty of effe*c*tively sampling the types of streams where smallmouth bass live (Cleary and Greenbank 1954, Hendri*c*ks *et al*. 1980). Sin*c*e 1987, we have been sampling small-mouth bass streams throughout Wisconsin. One of our goals has been to develop effective procedures for colle**c**ting and interpreting smallmouth bass p**o**pulation data. In this paper, we compare results from four popular sampling approaches that involved sampling smallmouth bass with a "stream shocker" (also known as a "tow barge shocker"), a type of electroshocker widely used in Wisconsin and other States (Lazauski and Malvestuto 1990; Paul Seelbach, Michigan Department of Natural Resources, unpublished data). We provide guidelines based on our comparison for estimating the abundance of smallmouth bass in streams shallow enough to sample by wading. In the process of examining sampling procedures, we have generated a substantial database on smallmouth bass abundance and size structure in Wisconsin streams. We present and briefly discuss the data base in this paper. We hope that the sampling guidelines presented here will be used by biologists in Wisconsin and surrounding States to expand and improve the data base. A larger data base will lead to a better understanding of smallmouth bass population dynamics, and better management of smallmouth bass fisheries in streams of the Upper Midwest.

Mahon, R. 1980. Accuracy of catch-effort methods for estimating fish density and biomass in streams. Environmental Biology of Fishes 5(4):343–360.

At each of 11 localities a section of stream was closed off with nets and an electrofisher used to estimate the abundance of fishes in the section. Each section was fished from 5-7 times with each fishing equaling one unit of effort. Using the catch-effort methods of Leslie, DeLury and Ricker, separate estimates were made for each species. In several cases species were split into size groups and estimates made for each group. The fish remaining in each section after the fishings were collected using rotenone. Thus the estimates could be compared to the actual number of fish present. Estimates were considered to be either ‘good’, if the regressions used in the above methods were statistically significant or ‘bad’ if they were not significant. Lower limits for the number of fish and mean weight of a fish for ‘good’ estimates were identified. The Leslie and Ricker estimates, which did not differ significantly, were least in error. They tended to underestimate (- 21.6% on the average for the Leslie method). Direct estimates of biomass did not differ significantly from those made using the estimates for numbers and the mean weight of fish caught. The interrelationships among variables such as mean weight, numbers, catchability, density, biomass, number of catches used, proportion of fish taken during the estimate, number of fish in the last catch and their relationships with the error of the estimates were examined using correlation and principal components analysis. Error was most closely related to the proportion of fish collected. The effects of other variables such as mean weight affected error through catchability and subsequently the proportion of fishes caught. It was not possible to predict a significant proportion of the error using variables which could be measured without a complete collection. The effects of locality, electrofisher, and species on error were examined. Each accounted for a significant proportion of the variability in error but primarily by affecting the proportion of fish caught. These results suggest that the most appropriate way of decreasing error would be to increase the total effort and consequently the proportion of fish collected. This would be best done by increasing the number of fishings used in the estimate. Catchability tended to decrease in successive fishings. The observed trends in changing catchability accounted for most of the error. Size-selectivity, which was evident as a change in mean weight in successive catches, was not significantly associated with changing catchability.

Meador, M.R. 2005. Single-pass versus two-pass boat electrofishing for characterizing river fish assemblages: species richness estimates and sampling distance. Transactions of the American Fisheries Society 134:59–67

Determining adequate sampling effort for characterizing fish assemblage structure in non-wadeable rivers remains a critical issue in river biomonitoring. Two-pass boat electrofishing data collected from 500–1,000-m-long river reaches as part of the U.S. Geological Survey's National Water- Quality Assessment (NAWQA) Program were analyzed to assess the efficacy of single pass boat electrofishing. True fish species richness was estimated by use of a two-pass removal model and nonparametric jackknife estimation for 157 sampled reaches across the United States. Compared with estimates made with a relatively unbiased nonparametric estimator, estimates of true species richness based on the removal model may be biased, particularly when true species richness is greater than 10. Based on jackknife estimation, the mean percent of estimated true species richness collected in the first electrofishing pass ($\text{p-hat}_{j,s1}$) for all 157 reaches was 65.5%. The effectiveness of single-pass boat electrofishing may be greatest when the expected species richness is relatively low (.10 species). The second pass produced additional species (1–13) in 89.2% of sampled reaches. Of these additional species, centrarchids were collected in 50.3% of reaches and cyprinids were collected in 45.9% of reaches. Examination of relations between channel width ratio (reach length divided by wetted channel width) and $\text{p-hat}_{j,s1}$ values provided no clear recommendation for sampling distances based on channel width ratios. Increasing sampling effort through an extension of the sampled reach distance can increase the percent species richness obtained from single-pass boat electrofishing. When single-pass boat electrofishing is used to characterize fish assemblage structure, determination of the sampling distance should take into account such factors as species richness and patchiness, the presence of species with relatively low probabilities of detection, and human alterations to the channel.

Mercado-Silva, N., and D. S. Escandon-Sandoval. 2008. A comparison of seining and electrofishing for fish community bioassessment in a Mexican Atlantic slope montane river. North American Journal of Fisheries Management 28:1725–1732.

Tropical freshwater fish monitoring and conservation strategies depend on data from surveys made with a variety of sampling methodologies. These methodologies have inherent biases that can lead to different data interpretations. We compared two commonly used sampling techniques—seining and electrofishing—in the calculation of community parameters and ecosystem bioassessment in a montane river in the Gulf of Mexico drainage in the state of Veracruz, Mexico. We specifically evaluated whether seining was sufficient for fish community assessment. Electrofishing produced higher estimates of species richness (45%), diversity (~30%), and biomass (~80%) than seining. It also produced higher biotic integrity scores. Species' relative abundance was generally similar for species captured with both techniques, but seines failed at capturing fast-swimming and benthic species. Thus, seining alone offered an incomplete perspective on the fish community and may not be adequate for bioassessment. Our results and methodology can help in the design of future survey efforts and the creation of correction factors that can aid managers to better sample biological communities and apply adequate conservation strategies.

Mitro, M.G., and A.V. Zale. 2002. Estimating abundances of age-0 rainbow trout by mark-recapture in a medium-sized river. North American Journal of Fisheries Management 136:409–415.

We developed and evaluated a sampling methodology to obtain mark–recapture data to estimate abundances of age-0 rainbow trout *Oncorhynchus mykiss* in 70–125-m-wide reaches of the Henrys Fork of the Snake River, Idaho. Sampling by electrofishing was concentrated in sample areas that were 100 m long and extended from bank to bank; these areas were electrofished 3–5 times within periods of 3–17 d. Adjacent 50-m-long areas upstream and downstream were sampled to quantify movements out of the 100-m sample areas. We evaluated assumptions—closed population and equal catchability—using the field data, and we used simulation to identify the most appropriate abundance estimator for sparse data. Both closed and open population abundance estimators were evaluated. Most trout (84%) were recaptured in the area where they were marked, but about 10% had moved downstream and about 6% were recaptured upstream. Multistrata model analyses confirmed that apparent mortality rates, and hence movement rates, were low. The Chao *Mt* estimator, which assumes that capture probabilities vary with capture occasion, performed best for simulated closed populations; bias was minimal and interval coverage was near or at the nominal level. This estimator was also robust to minor violations of the closure assumption; performance was better for larger closure violations when capture probabilities were smaller. Application of the Chao *Mt* estimator to our field data resulted in a median capture probability of 0.036, a median capture efficiency of 16.7%, and a median recapture rate of 5.4%. Average abundance estimates in the sample areas provided indices of abundance and extrapolated estimates provided total abundance estimates for river sections 1–4 km long. Small capture probabilities and large confidence intervals made it possible to detect only relatively large changes in abundance, but this level of discrimination was sufficient to satisfy management needs.

Paradis, Y., M. Mingelbier, P. Brodeur, and P. Magnan. 2008. Comparison of catch and precision of pop nets, push nets, and seines for sampling larval and juvenile yellow perch. North American Journal of Fisheries Management 28:1554–1562.

Abundance estimates of larval and juvenile fish require unbiased and precise sampling techniques. Even if an appropriate sampling technique is chosen, fish abundance estimates can be inaccurate if there is no assessment of the gear precision. Our first objective was to compare catch characteristics of pop nets, push nets, and seines for sampling occurrence, abundance, and size of age-0 yellow perch *Perca flavescens* in shallow habitats with different vegetation densities. The second objective was to estimate the precision (coefficient of variation [CV]) with which each sampling gear measured larval and juvenile yellow perch abundance. Larval fish were collected in May 2003 via pop nets and push nets, and juveniles were collected in July 2003 via pop nets and seines. Significant differences in yellow perch occurrence and abundance were observed between sampling gears and sampling periods. May occurrence and abundance of larval yellow perch were higher for push nets than for pop nets in open-water habitats but were the same in vegetated sites. The seine was the most effective gear for sampling juvenile yellow perch in both sparsely and densely vegetated habitats during July. The average total length of larval yellow perch sampled with pop nets in May was significantly higher than that of fish sampled with push nets. Average total length of juvenile yellow perch in July was significantly higher for seine samples than for pop-net samples. Our results showed that (1) high precision levels can be reached with pop nets and push nets during May sampling of yellow perch larval stages but (2) the precision level is lower in July when pop nets and seines are used to sample juvenile stages. The CV suggests that aggregations of age-0 yellow perch increased between May and July, which has important implications for sampling design.

Paukert, C.P. 2004. Comparison of electrofishing and trammel netting variability for sampling native fishes. Journal of Fish Biology 65:1643–1652.

The variability in size structure and relative abundance (CPUE; number of fish ≥200mm total length, LT, collected per hour of electrofishing or trammel netting) of three native Colorado River fishes, the endangered humpback chub *Gila cypha*, flannelmouth sucker *Catostomus latipinnis* and bluehead sucker *Catostomus discobolus*, collected from electrofishing and trammel nets was assessed to determine which gear was most appropriate to detect trends in relative abundance of adult fishes. Coefficient of variation (CV) of CPUE ranged from 210to 566 for electrofishing and 128 to 575 for trammel netting, depending on season, diel period and species. Mean CV was lowest for trammel nets for humpback chub ($P = 0.004$) and tended to be lower for flannelmouth sucker ($P = 0.12$), regardless of season or diel period. Only one bluehead sucker >200mm was collected with electrofishing. Electrofishing and trammel netting CPUE were not related for humpback chub ($r = -0.32$, $P = 0.43$) or flannelmouth sucker ($r = -0.27$, $P = 0.46$) in samples from the same date, location and hour set. Electrofishing collected a higher proportion of smaller (<200 mm LT) humpback chub ($P<0.001$), flannelmouth suckers ($P<0.001$) and bluehead suckers ($P<0.001$) than trammel netting, suggesting that conclusions derived from one gear may not be the same as from the other gear. This is probably because these gears fished different habitats, which are occupied by different fish life stages. To detect a 25% change in CPUE at a power of 0.9, at least 473 trammel net sets or 1918 electrofishing samples would be needed in this 8-km reach. This unattainable amount of samples for both trammel netting and electrofishing indicates that detecting annual changes in CPUE may not be practical and analysis of long-term data or stock assessment models using mark-recapture methods may be needed to assess trends in abundance of Colorado River native fishes, and probably other rare fishes as well.

Peterson, J.T., and C.F. Rabeni. 1995. Optimizing Sampling Effort for Sampling Warmwater Stream Fish Communities. North American Journal of Fisheries Management 15:528–541.

We measured the variation of some commonly used fish community attributes for two warmwater stream reaches during June-October 1992 and 1993. Habitat-specific variation among samples, expressed as coefficients of variation (SD/mean) collected throughout the study ranged from 0.13 to 1.58 and were lower for community-level attributes such as species richness (total number of species) and total fish biomass than for biomass estimates of bleeding shiner *Luxilus zonatus,* longear sunfish *Lepomis megalotis,* and rainbow darter *Etheostoma caeruleum.* Corresponding estimates of the number of samples needed to ensure 20% precision at the 95% confidence level ranged from 2 to 245 and indicated that fewer samples are needed to precisely estimate community level attributes than to estimate individual species biomass. A significant negative relationship ($P < 0.05$) between coefficients of variation and predicted sampling efficiency suggested that low sampling efficiencies may increase sample variance. Significant heterogeneity of variance ($P < 0.05$) among habitat types suggested that physical habitat characteristics also influenced sample variance. Mixed-model analysis of variance was used to examine spatial variance (between sampling locations, across time) and temporal variance (among sampling periods, across locations) for species richness and fish biomass. Eighteen variance components were significant, ($P < 0.01$) and in 12 of these, spatial variation exceeded temporal variation. When age-0 fish were excluded from analysis, spatial variation exceeded temporal variation in 13 of the 14 significant components. Our results indicate that the optimum sampling strategy for warmwater streams during June-October includes the collection of many samples from all habitat types during one sampling period in September-October.

Poos, M.S., N.E. Mandrak and R.L. McLaughlin. 2007. The effectiveness of two common sampling methodologies for assessing imperiled freshwater fishes. Journal of Fish Biology 70:691–708.

This study tested the hypothesis that the most common gear type used to sample fishes in wadeable systems, electrofishing, was more effective than another commonly used gear type, seining, for sampling fish species at risk. Five predictions were tested. At sites where species at risk were detected, (1) the probability of detecting the species at risk, (2) the probability of only one gear type detecting the species at risk and (3) the estimated catch per unit effort of the species at risk, was as high as, or higher, when using electrofishing than when using a seine. (4) The number of sample sites required to detect a species at risk within a watershed and (5) the number of subsections required to detect a species at risk within a site, were as low as, or lower, using electrofishing than the number required using a seine. Based on analyses of these measurements, electrofishing was a more effective gear type than seining for sampling fish species at risk, irrespective of the unit (presence or absence or catch per unit effort) or scale of measurement (watershed or site level). Dissolved oxygen, turbidity, specific conductivity and nitrate concentrations were measured at each site and did not account for the between gear differences. Selection of sampling gear can be a fundamental consideration for the assessment of fish species at risk, where, unlike common species, they may be particularly influenced by small population sizes, restricted geographic ranges and narrow habitat preferences. Resource managers must weigh differences in the risks of injury of fish species at risk against differences in the effectiveness of each gear type when deciding between gear types and the utility of the assessments they represent.

Pugh, L.L., and H.L. Schramm, Jr. 1998. Comparison of electrofishing and hoopnetting in lotic habitats of the lower Mississippi River. North American Journal of Fisheries Management 18:649–656.

We compared catch rates and sampling costs of two types of hoop nets (61 cm and 122 cm diameter) and two types of pulsed DC electrofishing (500 V/60 Hz and 1,000 V/15 Hz) in lotic habitats in main and secondary channels of the lower Mississippi River. Forty fish species were collected in 474 hoop-net-nights and 320 electrofishing samples (5 min each). Two species were collected only by hoop nets, whereas 19 species were collected only by electrofishing. Using field personnel time as the unit of effort, electrofishing catch per unit of effort for most species was higher and less variable than for hoop nets. Electrofishing collected wider length ranges of fish and cost less per fish collected than did hoopnetting. Compared to hoopnetting, we found low frequency (15 Hz) and high frequency (60 Hz) pulsed DC electrofishing was an effective method for assessment of fishes in lotic habitats in the lower Mississippi River.

Ridings, J. 2009. A brail trawl: An improved gear for sampling darters, madtoms, and sculpins. Missouri Department of Conservation Resource Science 2009, Volume 4, No. 11.

Stream fishes such as madtoms (*Noturus*), darters (*Etheostomatini*), and sculpins (*Cottus*) elude seines and standard trawls. When a trawl is pulled over rocky substrates, species that are beneath or between rocks are forced to evacuate if the lead line of the trawl topples the rock. The direction the fish evacuates depends on several factors affecting whether or not the fish is captured or is 'run over' by the trawl.

If the substrate is disturbed just ahead of the trawl, fishes beneath the rocks are flushed into the water column and enter the front of the trawl regardless of the direction from which the fishes evacuate the cover. A mussel brail is designed to disturb substrate by dragging several dull treblehook-like pieces of steel through the substrate. A mussel brail attached to the tow lines of a trawl just far enough ahead to force fish into the water column, yet not far enough ahead to allow time to evade the trawl, may increase the probability of capture of these species.

Quist, M.C., K.G. Gerow, M.R. Bower, and W.A. Hubert. 2006. Random versus fixed-site sampling when monitoring relative abundance of fishes in headwater streams of the Upper Colorado River Basin. North American Journal of Fisheries Management 26:1011–1019.

Native fishes of the upper Colorado River basin (UCRB) have declined in distribution and abundance due to habitat degradation and interactions with nonnative fishes. Consequently, monitoring populations of both native and nonnative fishes is important for conservation of native species. We used data collected from Muddy Creek, Wyoming (2003–2004), to compare sample size estimates using a random and a fixed-site sampling design to monitor changes in catch per unit effort (CPUE) of native bluehead suckers *Catostomus discobolus*, flannelmouth suckers *C. latipinnis*, roundtail chub *Gila robusta*, and speckled dace *Rhinichthys osculus*, as well as nonnative creek chub *Semotilus atromaculatus* and white suckers *C. commersonii*. When one-pass backpack electrofishing was used, detection of 10% or 25% changes in CPUE (fish/100 m) at 60% statistical power required 50–1,000 randomly sampled reaches among species regardless of sampling design. However, use of a fixed-site sampling design with 25–50 reaches greatly enhanced the ability to detect changes in CPUE. The addition of seining did not appreciably reduce required effort. When detection of 25–50% changes in CPUE of native and nonnative fishes is acceptable, we recommend establishment of 25–50 fixed reaches sampled by one-pass electrofishing in Muddy Creek. Because Muddy Creek has habitat and fish assemblages characteristic of other headwater streams in the UCRB, our results are likely to apply to many other streams in the basin.

Ruetz III, C.R., D.G. Uzarski, D.M. Krueger, and E.S. Rutherford. 2007. Sampling a littoral fish assemblage: comparison of small-mesh fyke netting and boat electrofishing. North American Journal of Fisheries Management 27:825–831.

We compared small-mesh (4-mm) fyke netting and boat electrofishing for sampling a littoral fish assemblage in Muskegon Lake, Michigan. We hypothesized that fyke netting selects for small-bodied fishes and electrofishing selects for large-bodied fishes. Three sites were sampled during May (2004 and 2005), July (2005 only), and September (2004 and 2005). We found that the species composition of captured fish differed considerably between fyke netting and electrofishing based on nonmetric multidimensional scaling (NMDS). Species strongly associated with fyke netting (based on NMDS and relative abundance) included the brook silverside *Labidesthes sicculus*, banded killifish *Fundulus diaphanus*, round goby *Neogobius melanostomus*, mimic shiner *Notropis volucellus*, and bluntnose minnow *Pimephales notatus*, whereas species associated with electrofishing included the Chinook salmon *Oncorhynchus tshawytscha*, catostomids (*Moxostoma* spp. and *Catostomus* spp.), freshwater drum Aplodinotus grunniens, walleye *Sander vitreus*, gizzard shad *Dorosoma cepedianum*, and common carp *Cyprinus carpio*. The total length of fish captured by electrofishing was 12.8 cm (95% confidence interval = 5.5– 17.2 cm) greater than that of fish captured by fyke netting. Size selectivity of the gears contributed to differences in species composition of the fish captured, supporting our initial hypothesis. Thus, small-mesh fyke nets and boat electrofishers provided complementary information on a littoral fish assemblage. Our results support use of multiple gear types in monitoring and research surveys of fish assemblages.

Shea, C.P., and J.T. Peterson 2007. An evaluation of the relative influence of habitat complexity and habitat stability on fish assemblage structure in unregulated and regulated reaches of a large southeastern warmwater stream. Transaction of the American Fisheries Society 136:943–958.

River regulation and development are the foremost problems threatening lotic fishes and other aquatic biota in the United States. The operation of hydroelectric facilities can influence both habitat availability and environmental stability in downstream reaches. We evaluated the relative influence of habitat complexity and environmental stability on fish assemblage structure at unregulated and hydropower-regulated reaches of the Flint River in southwestern Georgia. The availability of different habitat types was highly variable at the regulated reach owing to large, daily fluctuations in discharge. Habitat-specific fish assemblages also differed between reaches, as a greater number of species occupied identical habitat types at the unregulated reach, most notably in shallow, slow-flowing habitats. Differences in fish assemblage structure between study reaches in comparable habitat types were explained equally well by patterns of habitat structure and variability. Within-reach patterns of fish assemblage structure were best explained by patterns of habitat structure at both study reaches. However, the relative influence of habitat complexity and habitat stability differed within each study reach, habitat variability influencing fish assemblage structure to a greater extent at the regulated reach than at the unregulated reach. These differences suggest that both habitat structure and variability influence Flint River fish assemblages and that flow regulation associated with hydropower operation primarily affects riverine fish communities by increasing environmental variability. Thus, flow management plans for regulated rivers based on minimum flows may be most effective when implemented in conjunction with plans that reduce the spatial and temporal variability of habitat availability, particularly in shallow, slow-flowing habitats.

Simonson, T.D., and J. Lyons. 1995. Comparison of catch per effort and removal procedures for sampling stream fish assemblages. North American Journal of Fisheries Management 15:419–427.

Methods used to estimate fish abundance in streams should be chosen based on the precision required by the study, the available time, and the number and kinds of species targeted. When entire assemblages of predominantly small, nongame fishes are to be sampled, most existing procedures have limitations. We compared estimates of species richness, abundance, and assemblage structure based on catch per effort (CPE) during a single low-barge electrofishing sample versus intensive tow-barge electrofishing removal sampling procedures with block nets in paired, contiguous stations on nine streams in southern Wisconsin. Use of block nets had little effect on CPE during single upstream electrofishing passes; for stations approximately 35 times the mean stream width in length, the overall influence of fish entering and leaving the station appeared to be negligible. Estimates of abundance, based on total catch and based on the removal model, were higher in removal stations than in CPE stations. However, estimates of abundance between stations were correlated, and estimates of species richness and assemblage structure were similar. Relative to removal sampling, a single upstream CPE pass adequately assessed fish species richness, abundance, and assemblage structure in small streams.

Utrup, N.J., and W.L. Fisher. 2006. Development of a rapid bioassessment protocol for sampling fish in large prairie rivers. North American Journal of Fisheries Management 26:714–726.

We used seining and hoop netting to collect fish at 15 sites in five large prairie rivers in Oklahoma to (1) determine the amount of effort needed to detect the maximum number of species at a sample site and (2) examine the selectivity of fish species detected by the two gear types. Analysis of the similarities of the fish collected in six different habitat types identified two distinct habitat types based on fish species composition: shallow–backwater (SBW) habitat (depth $\leq$ 0.75 m) and deep–nonwadeable (DNW) habitat (depth $\geq$0.75 m). We estimated that between 6 and 10 (mean = 8) SBW habitats and between 1 and 6 (mean = 4) DNW habitats at each sample site were needed to obtain maximum species richness during a sampling event. The sampling distance needed to encounter the minimum number of habitats ranged from 400 to 1,600 m and averaged 887 m. Gear evaluation showed that 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.

Velez, C.E. 2004. Predation by non-native fish on native fish in the Verde River, Arizona. Unpublished M.S. thesis, Department of Agriculture, University of Arizona, Tucson.

The density, standing crop and relative abundance of fish populations have been documented in various environments; however, these measures have not been well studied in desert rivers, especially those of the American Southwest. We estimated the distribution, relative abundance, density, and standing crop of fishes in the Verde River, Arizona from March 2002 through January 2003. We examined density and standing crop of fishes by geographic area (headwaters to confluence with a larger river), habitat classification (pool, riffle, run), and season. Over 30,700 fishes were collected, comprising six native species and 13 non-native species. Only three native species and seven non-native species were found throughout the river. Mean density of fish native to the river was highest in the headwaters. Highest standing crop and/or density varied by fish species. Bluegill *Lepomis macrochirus*, common carp *Cyprinus carpio*, rainbow trout *Oncorhynchus mykiss*, and green sunfish *Lepomis cyanellus* were primarily in pools; largemouth bass *Micropterus salmoides* and Sonora sucker *Catostomus insignis* in both pools and runs; roundtail chub *Gila robusta* in runs; and flathead catfish *Pylodictis olivaris*, longfin dace *Agosia chrysogaster*, red shiner *Cyprinella lutrensis*, and yellow bullhead *Ameiurus natalis* in riffles.

Greatest standing crop and density of all fishes was in the spring and summer. Smallmouth bass, green sunfish, common carp and yellow bullhead were most common in the higher elevation headwaters, while largemouth bass, bluegill, longfin dace, channel catfish and desert sucker, and tilapia were more common at lower elevation, higher discharge areas of the river. The mean total standing crop of fish in this desert river ranged from 60.9 kg/ha to 255.3 kg/ha in different sections, which was similar to mean standing crops of temperate and tropical rivers around the world in less arid regions.

Walsh, M.G., D.B. Fenner, and D.L. Winkelman. 2002. Comparison of an electric seine and prepositioned area electrofishers for sampling stream fish communities. North American Journal of Fisheries Management 22:77–85.

We sampled shallow-water habitats (<1.0 m deep) in a small, spring-fed stream in northeast Oklahoma with an electric seine (ES) and prepositioned area electrofishers (PAEs) to compare the efficacy of the two gear types for characterizing stream fish communities. The ES is commonly used for this purpose, while PAEs are most often employed to relate fish distribution to specific microhabitats. We collected 11 fish species, 8 of which were captured by both gear types. Nonparametric extrapolation methods indicated that the ES and the PAEs estimated species richness similarly, although variation and sampling effort necessary to estimate species richness were higher for the PAEs. We used canonical correspondence analyses to determine if the ES and the PAEs sampled fish communities similarly and to evaluate patterns of species distribution relative to environmental variables. The analyses indicated that the ES and the PAEs sampled fish communities similarly. However, species relationships to environmental variables differed between the two methods, probably due to differences in scale of microhabitat measurements. Our results suggest that both methods can be used to characterize fish communities in small streams. Each method has its advantages: the ES appears to sample more efficiently, but PAEs allow for more thorough evaluation of fish microhabitat use.

Welker, T.L., and D.L. Scarnecchia. 2004. Habitat use and population structure of four native minnows (family Cyprinidae) in the upper Missouri and lower Yellowstone rivers, North Dakota (USA). Ecology of Freshwater Fish 13:8–22.

In 1997 and 1998, sampling was conducted on the Missouri and Yellowstone rivers, North Dakota, to obtain information on the distribution, abundance, and habitat use of the flathead chub (*Platygobio gracilis*), sicklefin chub (*Macrhybopsis meeki*), sturgeon chub (*Macrhybopsis gelida*), and western silvery minnow (*Hybognathus argyritis*). The study area consisted of four distinct river segments near the confluence of the Missouri and Yellowstone rivers – three moderately altered segments that were influenced by a main-stem dam and one quasi-natural segment. One moderately altered segment was located at the confluence of the two rivers (mixing-zone segment (MZS)). The other two moderately altered segments were in the Missouri River adjacent to the MZS and extended up-river (above-confluence segment (ACS)) and down-river (below-confluence segment (BCS)) from this segment. The quasi-natural segment (Yellowstone River segment (YRS)) extended up-river from the MZS in the Yellowstone River. Catch rates with the trawl for sickelfin chub and sturgeon chub and catch rates with the bag seine for flathead chub and western silvery minnow were highest in the BCS and YRS. Most sicklefin and sturgeon chubs were captured in the deep, high-velocity main channel habitat with the trawl (sicklefin chub, 97%; sturgeon chub, 85%), whereas most flathead chub and western silvery minnow were captured in the shallow, low-velocity channel border habitat with the bag seine (flathead chub, 99%; western silvery minnow 98%). Best-fit regression models correctly predicted the presence or absence of sicklefin chub, flathead chub, and western silvery minnow more than 80% of the time. Sturgeon chub presence and absence were predicted correctly 55% of the time. Best-fit regression models fit to fish number data for flathead chub, sicklefin chub, and sturgeon chub and fish catch-per-unit-effort (CPUE) data for flathead chub also provided good fits, with R^2 values ranging from 0.32 to 0.55 ($P<0.001$). The higher density and catch of the four native minnows in the YRS and BCS suggest that these two segments are better habitat than the ACS and MZS.