# Fish Distribution and Abundance

**Volume 3**

**of**

**Population Structure and Habitat Use of Benthic Fishes Along the Missouri and Lower Yellowstone Rivers**

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## PREFACE

### Population Structure and Habitat Use of Benthic Fishes Along the Missouri and Lower Yellowstone Rivers

This research is reported in the 12 volumes listed below. Reports are available through the U. S. Army Corps of Engineers, the primary contracting agency for the overall project. Contact: Becky Latka, U. S. Army Corps of Engineers, CENWO-PM-AE, 106 South 15th Street, Omaha, NE 68102 (rebecca.j.latka@usace.army.mil, 402/221-4602), for paper copies or access online in PDF format at: http://www.nwo.usace.army.mil/html/pd-e/benthic_fish/benthic_fish.htm. Anticipated date of publication is in (parentheses) for volumes not yet available. Please use the citation format suggested here without the email address when referencing Final Report volumes.

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## EXECUTIVE SUMMARY

This volume (Volume 3) is part of the final report for the Benthic Fishes Study, which was a research project conducted on the warm-water Missouri River from Montana to Missouri by a consortium of Cooperative Research Units (ID, MT, SD, KS, IA, MO), the Columbia Environmental Research Center (U. S. Geological Survey), and the Montana Department of Fish, Wildlife, and Parks. The goal was to evaluate the status of bottom dwelling or benthic fishes and riverine habitat to assist the U. S. Army Corps of Engineers and other federal and state agencies in managing the Missouri River system. The history, design, objectives, and working hypotheses of the study and review of key literature on the Missouri River fishes are in Volume 1. An analysis of physical habitat features is in Volume 2. An analysis of the growth, mortality, and recruitment of selected benthic species is in Volume 4.

The purposes of this volume are to describe the distribution and abundance of benthic fishes and show associations with major macrohabitats and physical habitat features. The study was done in the main channel of the Missouri River from Montana to St. Louis, Missouri, between July and October 1996, 1997, and 1998.

The study design divided the Missouri River main channel into three zones and 15 segments progressing from Segment 3 in Montana to Segment *27* just upstream from the confluence of the Missouri River with the Mississippi River. The least-altered zone was the upper Missouri and lower Yellowstone Rivers. The inter-reservoir zone included segments downstream from dams in Montana, North Dakota, and South Dakota. The channelized zone was downstream from Sioux City, Iowa, to the Mississippi River. In the least-altered zone were two segments of the Missouri River upstream from Fort Peck Dam and one segment of the lower Yellowstone River (Segments 3, 5, 9; numbers always underlined). In the inter-reservoir zone were five riverine segments (Segments **7**, **8**, **10**, **12**, **14**; numbers always **bold**) isolated between dams and one segment (Segment **15**) downstream from Gavins Point Dam that was open downstream to the channelized zone. In the channelized zone were six segments (Segments *17*, *19*, *22*, *23*, *25*, *27*; numbers always in *italics*) distributed relatively uniformly throughout the 1,176 km length of the channelized zone.

Fish were sampled in six macrohabitats (secondary channel-connected, secondary channel-nonconnected, tributary mouth, mainstem outside bend, mainstem inside bend, and mainstem channel crossover). Outside bends, inside bends, and channel crossovers were combined into the variable termed "BEND" for some analyses. Five fishing gears were used - gill net, bag seine, bottom trawl, drifting trammel net, and electrofishing. The most productive were the bag seine (45% of total catch) and electrofishing (43% of total catch), but all gears were useful. For example, our study was the first extensive use of a bottom trawl, which caught most sturgeon chubs and sicklefin chubs.

The benthic fishes assemblage included commercial (e.g., catfish), recreational (e.g., sauger), and imperiled species (e.g., pallid sturgeon) that are directly important to economic considerations of river management; and also included a group of prey species (e.g., emerald shiner, sand shiner) that are important to river ecology and to the food webs of fish predators. Benthic fishes are species that use the river bottom for much of their life requirements, rather than use mid-depths or off channel habitats. Benthic species are sometimes the first to signal deleterious environmental changes because stressors in river systems converge on and have cumulative impacts on benthic habitat and biota.

We collected 77,196 specimens of all 26 benthic species. Total catch ranged from four pallid sturgeons to about 20,000 emerald shiners. Relative abundance among the benthic fishes assemblage for the most common species was 25% for emerald shiner, 13% for flathead chub, 9% for river carpsucker, 9% for channel catfish, and 6% for white sucker. Five species of benthic fishes did not inhabit the entire mainstem because their distribution was limited to the upper basin (burbot, white sucker) or lower basin (flathead catfish, blue catfish, sand shiner). More sturgeon chubs (1,933) and sicklefin chubs (709) were caught than expected due to their previously documented rarity; most were captured in the bottom trawl. Two of the four large pallid sturgeons captured were caught in the Yellowstone River, one in a Missouri River segment near the Yellowstone confluence, and one in a channelized zone segment. Pallid sturgeons were collected in deep (1.7 – 4.8 m) swift (0.5 – 1.0 m/sec) water; three in the inside bend macrohabitat and one in a tributary mouth.

Catch per unit effort (C/E) was compared among year of study, zone, segment, and macrohabitat. Significant year effects in C/E were found for 9 of 42 possible contrasts; however, because our interest was in zone and segment effects years were not examined further. Data were not useful because of low catches for eight species (3 *Hybognathus* species, pallid sturgeon, burbot, bigmouth buffalo, sand shiner, white sucker), thus leaving the combination of five gears for 18 species with which to address the 22 planned contrasts among zones and selected segments. Data for some gears were inadequate because of low catches, thus leaving 42 species/gear combinations to test each of the 22 contrasts (42 x 22 = 924 possible tests). In this

group of possible tests, catches were sometimes too low for making certain contrasts (e.g., when only two segments were compared), thus resulting in a total of 446 statistical tests of which 85 were significant and 361 were not significant. The complex mix of responses was often difficult to interpret. Significant results for one species/gear combination were sometimes contradicted by data from another gear. However, some general trends were apparent.

Twenty of 86 zone contrasts were significant. Significant contrasts indicated that catches of seven species [channel catfish (gillnet), flathead chub, freshwater drum, sauger, shorthead redhorse, sicklefin chub, sturgeon chub] were higher in the least-altered zone than in the inter-reservoir or channelized zones, whereas channel catfish seine catches showed the opposite trend. Several lines of evidence (relative abundance, species richness, total catch, segment similarity analysis, analysis of C/E) indicated that these benthic fishes population metrics were lower in the inter-reservoir zone. Segment **12** between Garrison Dam and the upper end of Lake Oahe often had the lowest ranking of any segment for population metrics.

Other contrasts were planned to test segment effects within zones. No trends in C/E were discovered in contrasts between three segments upstream and three segments downstream from Kansas City. Contrasts were not possible for 11 species and 19 of 24 possible contrasts of C/E were not significant. No trends in C/E were found in contrasts between Missouri River Segments (3 and 5), and Yellowstone River Segment 9 in the least-altered zone. The C/E for emerald shiner (seine data), flathead chub (electrofishing data), shorthead redhorse (trammel net data), and sicklefin chub (trawl data) was higher in Segments 3 and 5 than in Segment 9, whereas four other species/gear combinations indicated higher catches in Segment 9 than in Segments 3 and 5.

Thirteen species increased in total catch from Ft Peck Dam to the upper end of Lake Sakakawea, but the influence of the Yellowstone River on this trend was not supported by statistical comparisons of C/E among segments up- and downstream from its confluence. Only the sicklefin chub had higher C/E downstream from the Yellowstone confluence than above.

A group of segment contrasts was planned to examine the difference between C/E upstream and downstream from reservoirs (i.e., Fort Peck Lake, Lake Sakakawea, Lewis and Clark Lake). For Fort Peck Lake and Lake Sakakawea the C/E was higher upstream from the reservoirs for four species/gear combinations (flathead chub, shorthead redhorse, sicklefin chub, sturgeon chub) and lower upstream for one species/gear combination (common carp). However, presence data for eight species showed a pattern of higher catches upstream from reservoirs than downstream (emerald shiner, burbot, flathead chub, sauger, sicklefin chub, smallmouth buffalo, stonecat, sturgeon chub).

In Segment **15**, which was not isolated between reservoirs, C/E was similar to those in other segments as judged by the 103 insignificant contrasts of 122 possible contrasts. The segments upstream (Segment **14**) and downstream (Segment **15**) from Lewis and Clark Lake are listed as National Recreational River reaches. The species assemblage was similar in these two segments, but we collected about 5,000 fish in Segment **14** and about 17,000 (about one-third emerald shiners) in Segment **15**. The trend in higher total catch in Segment **15** than in Segment **14** was supported by the C/E and presence data for nine species.

Fish abundance in Segments **15** and *17* (first channelized segment) are often compared because of the different channel forms in each segment. For contrasts involving Segments **15** and channelized zone segments, four species (common carp, emerald shiner, flathead catfish, river carpsucker) had higher C/E in Segment **15** and three species had lower (channel catfish, freshwater drum, river carpsucker). The C/E values were usually higher in Segment **15** when compared to Segment *17* alone, but there was no trend when other channelized segments were included with Segment *17*.

A second goal of the study was to investigate the relationship between habitat characteristics and presence of benthic fishes. Total catch and fish presence were analyzed for associations with macrohabitats and physical habitat variables (e.g., velocity, depth, turbidity, substrate size) at each site of fishing gear deployment. No species could be termed a "macrohabitat specialist". Total catch was high for every species in at least three macrohabitats; catches were high for all species in inside bends and secondary channel-connected macrohabitats; but only six species had high total catches in channel crossovers (channel catfish, flathead chub, sicklefin chub, shovelnose sturgeon, stonecat, sturgeon chub). Conclusions about macrohabitat use are for the summer-early autumn sampling period only; we assume that fish use more than one habitat depending on season and life stage.

Analysis of variance of species presence with habitat measures resulted in habitat associations for all benthic fishes except the fathead minnow. Stepwise logistic regression analysis was also used to identify habitat conditions that might be useful in predicting fish presence. The $R^2$ values ranged from 0.01 to 0.06 for nine species, and from 0.06 to 0.36 for 13 species. These data help fill in gaps in our knowledge about habitat needs of individual species. For example, the likelihood of presence of shovelnose sturgeon increased with

increased water depth and velocity ($R^2 = 0.27$). Mean depth at shovelnose sturgeon presence locations was 2.4 m; mean velocity at presence locations was 0.6 m/sec.

Ordination plots were used to summarize general trends in associations of benthic species with segments, macrohabitats, and environmental variables. Three species assemblages and segments grouped roughly by zones. Sauger, sturgeon chub, flathead chub, burbot, sicklefin chub and stonecat were grouped with least-altered Segments 3, 5, 9, (and Segment **10**). Fathead minnow, shorthead redhorse, bigmouth buffalo, white sucker, and walleye were grouped with inter-reservoir Segments **7**, **8**, and **12**. Fishes associated with silt substrates and slow water velocity conditions (e.g., bigmouth buffalo, smallmouth buffalo, sauger, walleye, freshwater drum) were grouped with non-connected secondary channels and tributary mouths. Grouped in the BEND habitat were fishes such as shovelnose sturgeon, sicklefin chub, blue sucker, sturgeon chub, and flathead catfish. The benthic fishes assemblage used a wide range of substrate types, water velocities and water depths so habitat diversity is important in conserving these species.

About 37,000 specimens of 80 other species brought the ichthyofaunal list developed during this study to106 species. We caught 52 other species in 1996, 67 other species in 1997, and 54 other species in 1998. Of the non-benthic species, more than 1,000 specimens were collected of gizzard shad, goldeye, longnose sucker, quillback, red shiner, spotfin shiner, and white crappie. Other commonly captured native species were longnose dace, river shiner, shortnose gar, and silver chub. The general longitudinal pattern for all 106 benthic and non-benthic species was an increase in species richness from the Montana to Missouri sections of the river. Total catch over all years of all species averaged about 8,000 fish per segment in the least-altered zone, 4,000 fish per segment in the inter-reservoir zone, and 6,000 fish per segment in the channelized zone.

We found 12 species had not been reported in the open literature, and did not find 30 species reported after other surveys. As noted for certain benthic species, distribution of some of the 80 non-benthic species was not basin wide because of native range limitations. For example, gizzard shad was the most commonly caught species (about 25,000 captured), but it was not found upstream from Segment **14** (South Dakota). On the other hand, longnose sucker was also common (4,973 collected), but was not found downstream from Segment **12** (North Dakota). The goldeye was common (3,836 collected) and found in every segment, but lowest catches were in inter-reservoir Segments **12** and **14**. Native species composed 85% of the 106 species collected. We found five exotic species, including two Asian carps (grass carp, bighead carp), and 11 introduced species that had been stocked as game fish or prey species into reservoirs (e.g., bluegill, green sunfish, largemouth bass, smallmouth bass, rainbow smelt, rainbow trout). We also found three hybrids: 1) striped bass x white bass, 2) walleye x sauger, and 3) green sunfish x *Lepomis* sp. (i.e., bluegill, orangespotted sunfish).

Combining distribution and abundance results for the benthic fish assemblage presented here with results from other volumes on fishes and their habitats provides a comprehensive, river-wide perspective of how these species have responded to natural and anthropogenic factors in the riverscape. Lessons learned at the large spatial and temporal scales examined can serve as a guide for planning other great river studies or for monitoring Missouri River fishes. We hope these results will assist the U. S. Army Corps of Engineers and other federal and state agencies in managing and restoring the Missouri River and its native fishes while it continues to contribute to the economic health of the basin.

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## INTRODUCTION

Much is known about the fish community of the Missouri River basin. The Missouri River has had a rich fisheries history since the first notes on fishes were made by Lewis and Clark (Moring 1996). Of the 171 species found in the basin, about 138 are native (Cross et al. 1986 report 173 species in the basin) and about 100 occur in the mainstem (Galat et al. 2005). The lower basin was a refuge for fishes during glaciation, so archaic families - Acipenseridae (sturgeons), Polyodontidae (paddlefish), Lepisosteidae (gar), and Hiodontidae (goldeye) - exist (Cross et al. 1986). In the late 1800s the river supported a large commercial fishery that was still substantial ($725,000 per year) in the 1970s, but is much less today. A recent ban on commercial fishing for channel catfish has probably benefited the recreational fishery (Stanovick 1999, Mestl 1999a). The river has always supported sport fishing, which expanded greatly when reservoirs and tailrace fisheries were created by six mainstem dams. The most important sport fishes are channel catfish, paddlefish, and walleye. See Tables 1 and 2 for list of scientific names of fishes. Contemporary fisheries issues are 1) the decline of native fishes and 2) the invasion of exotic species.

Native fishes have been identified as the group most jeopardized by past and present management practices on the Missouri River. About one-fifth are currently listed as rare, threatened, or of special concern by states or the federal government (Galat et al. 2005). However, states on the periphery of a species range may list a species as being rare within their boundaries, while the fish is abundant elsewhere in the basin. While only one mainstem fish (pallid sturgeon) is currently listed as endangered by the federal government, as many as 35 native species may be declining because of competition from new species, river fragmentation, and loss or change of habitat (Hesse 1996, Galat et al. 2005). Most conclusions about the status of Missouri River fishes are based on studies limited to certain segments of the river, but some of these studies have been intensive in those segments (reviewed by Hesse 1996).

Because of the great length (3,768 km) and interjurisdictional nature of the Missouri River, there have been no coordinated, riverwide assessments of fish populations. However, species lists have been made for the mainstem in the lower basin (e.g., Galat et al. 1996), middle basin (e.g., Hesse 1996, Berry and Young 2004), upper basin (Hendrickson et al. 1995), and for the Yellowstone River (White and Bramblett 1993). A basinwide fishery review was done by Hesse et al. (1989), who listed 171 fish species in the basin, and a more recent main channel and reservoir fishery review by Galat et al. (2005), who listed 136 species in 25 families. Native fishes compose 79% of the mainstem ichthyofauna, 54% are classified as “big river” species. Populations of 17 species are increasing, of which about half are introduced. Populations of 24 species are declining in distribution and abundance, and 11 species are listed by two or more states as imperiled.

Management of the Missouri River is controversial because of stakeholder conflicts (e.g., recreation, flood control, transportation, power production, irrigation), which are well known, much studied, and recently litigated (NRC 2002). The Corps of Engineers (CE) has synthesized information on basinwide economic uses and environmental resources including fishes (e.g., CE 1998). Galat et al. (2005) listed river conservation efforts that were underway, but noted that many are site specific and few are being evaluated for benefits to fish. Hesse et al. (1989) suggested the need for a holistic approach to future fisheries research because fish conservation necessitates a river-wide understanding of biotic and abiotic factors that affect fishes. The study reported here, known as the Benthic Fishes Study, attempted the holistic research approach.

### Scope of the Benthic Fishes Study

The study was conducted by six Cooperative Research Units (Montana, Idaho, South Dakota, Iowa, Kansas, Missouri) and the Columbia Environmental Research Center, Columbia, Missouri, which are in the Biological Resources Discipline of the U. S. Geological Survey, and by the Montana Department of Fish, Wildlife and Parks (Montana FWP), Fort Peck, Montana. Researchers with the Montana FWP worked on the Missouri River downstream from Fort Peck Dam to the confluence of the Yellowstone River and on the Yellowstone River. Researchers at the Columbia Environmental Research Center (Columbia ERC) provided statistical and fish biology expertise, and participated in developing the study design, managing the data, and writing final reports.

A pilot study was done in 1995 (Braaten and Guy 1995), after which fieldwork was carried out for 3 years on 15 riverine segments (18 segments in 1996) of the warm-water Missouri River, from Montana to the confluence with the Mississippi River in Missouri (Figure 1). Coordinated fieldwork using standardized methods was done during the summers of 1996, 1997, and 1998 at mainstem segments in each state. Volume I gives detailed information on the background and scope of the study, generally characterizes the Missouri River system, describes fishes and habitat, and gives the history and conduct of the study (Berry and Young 2001).

Table 1. Common and scientific names of species in the benthic fishes assemblage. The T and E category refers to federally threatened (T) and endangered (E) species and species listed by states as "Species of Concern" (Galat et al. 2005).

| T and E | Recreational | Commercial | Prey |
|---|---|---|---|
| pallid sturgeon *Scaphirhynchus albus* | channel catfish *Ictalurus punctatus* | bigmouth buffalo *Ictiobus cyprinellus* | white sucker *Catostomus commersonii* |
| flathead chub *Platygobio gracilis* | blue catfish *Ictalurus furcatus* | common carp *Cyprinus carpio* | stonecat *Noturus flavus* |
| sturgeon chub *Macrhybopsis gelida* | flathead catfish *Plyodictis olivaris* | smallmouth buffalo *Ictiobus bubalus* | shorthead redhorse *Moxostoma macrolepidotum* |
| sicklefin chub *Macrhybopsis meeki* | walleye *Sander vitreum* | | fathead minnow *Pimephales promelas* |
| W. silvery minnow *Hybognathus argyritis* | sauger *Sander canadense* | | brassy minnow *Hybognathus hankinsoni* |
| plains minnow *Hybognathus placitus* | freshwater drum *Aplodinotus grunniens* | | sand shiner *Notropis stramineus* |
| blue sucker *Cycleptus elongatus* | | | emerald shiner *Notropis atherinoides* |
| burbot *Lota lota* | | | river carpsucker *Carpiodes carpio* |
| shovelnose sturgeon *Scaphirhynchus platorynchus* | | | |
| Total = 9 | 6 | 3 | 8 |

The research **goal** of the Benthic Fishes Study was to evaluate changes in the Missouri River fish community on a large spatial scale to assist the U. S. Army Corps of Engineers and other federal agencies, state agencies, and tribes in managing the river. The overall objectives of the Benthic Fishes Study were:

1) describe and evaluate recruitment, growth, size structure, body condition, and relative abundance of selected benthic fishes;
2) characterize physical features (e.g., velocity, turbidity) in dominant habitats where fishes were collected; and
3) describe use of dominant habitats used by benthic fishes.

**Purpose of Volume 3**

This volume on the distribution and abundance of fishes in the warm-water portion of the mainstem Missouri and Yellowstone Rivers is Volume 3 of a 12-volume final report to the U. S. Army Corps of Engineers. The purpose of this volume is to report on the distribution, abundance, and habitat associations of 26 species of benthic fishes and on the distribution of 80 other species that were also caught during the study.

**Large River Fish Studies in the Mississippi Basin**

The Missouri River is a tributary to the Mississippi River, as are many other small and large rivers in the Mississippi River's 29-state basin. The physical and biological attributes of 20 rivers in the Mississippi River basin have been summarized (Berry and Galat 1993). Major uses and changes influencing aquatic biota include impoundment, channel modifications, irrigation withdrawal, commercial navigation, loss of riparian floodplain and instream flow, introduced fishes, and a host of water quality problems. Despite these factors, 12 rivers of the Mississippi River basin had unchanged or improved fish communities (Berry and Galat 1993). The largest rivers in the Mississippi River basin (i.e., upper Mississippi, Ohio, Tennessee, Arkansas) have also been greatly modified, but overall

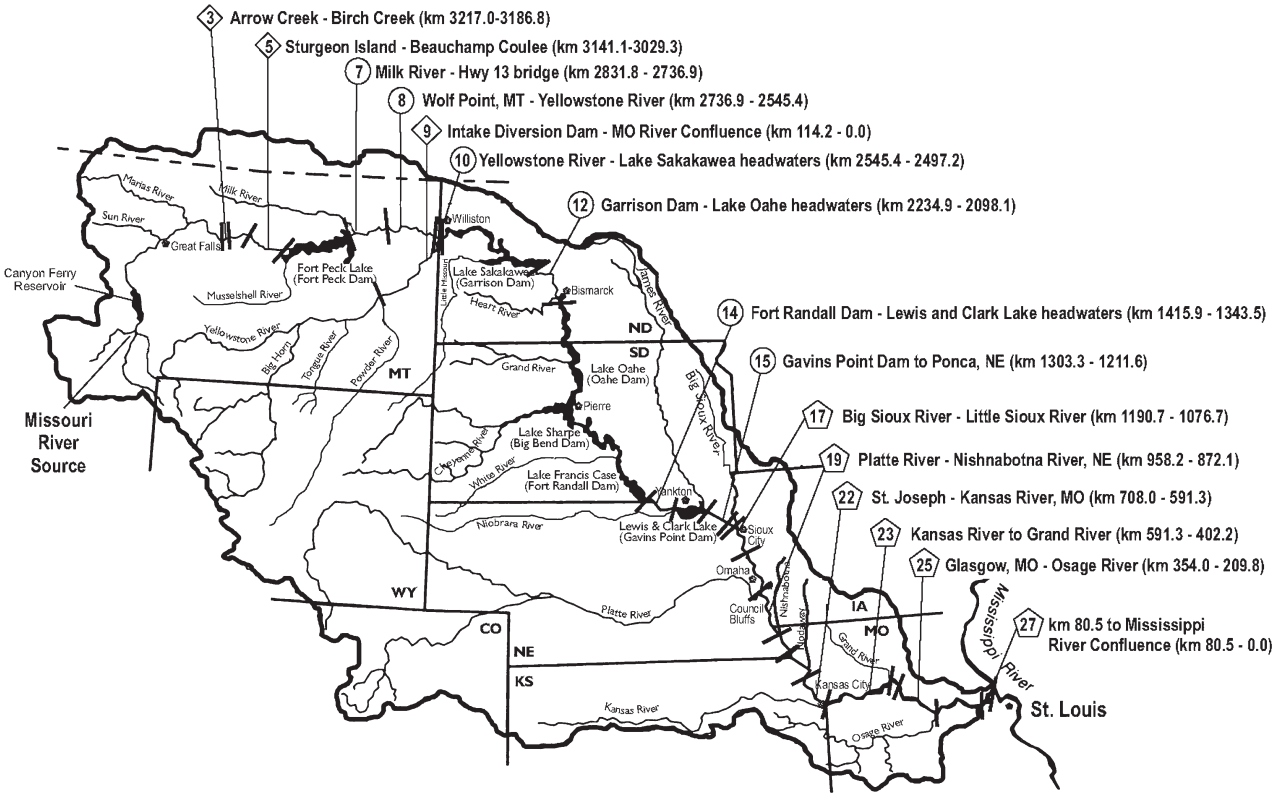



Figure 1. Missouri River Benthic Fishes Study area from Montana to its confluence with the Mississippi River in Missouri.

comparisons to the Missouri River are difficult because the type of modification is fundamentally different among rivers.

In the 2,333-km long Arkansas River, the lower 726 km have been made navigable by 17 locks and dams. About 137 fish species inhabit the mainstem Arkansas River, including navigation pools in the lower river (Limbird 1993). Species richness in the mainstem increases from 42 in the upper Colorado section to 108 in lower Arkansas section.

The 1,045-km-long Tennessee River, the fifth largest in the nation with regard to discharge, lost 12 riverine fish species after impoundment by nine mainstem dams (Voightlander and Poppe 1989). About 225 species inhabit the basin, but there are few flowing-water reaches between dams. Major stresses in the basin are: low dissolved oxygen, point source pollution, non-point source pollution, and cultural eutrophication.

Permanent restrictions have been placed on the 2,096-km-long Ohio River by a lock and dam system. The fish community of about 60 species in the middle and upper mainstem has changed compared to pre-1900 records (Van Hassel et al. 1988, Reash and Van Hassel 1988). Lithophilic spawners and species intolerant of pollution have declined or been eliminated (e.g., paddlefish, mooneye, highfin carpsucker); but the fish community has improved in recent years, as 22 species increased in abundance and only 7 (mostly omnivores) species declined. Tributaries were a habitat feature associated with high species richness.

On the 3,731-km-long Mississippi River, the upper river is controlled by 19 navigation dams that make broad shallow impoundments to create a slack-water navigation channel 2.7-m deep from St. Louis to St. Paul (Weiner et al. 1998). The lower Mississippi River has been channelized and shortened by 229 km; but remains un-impounded, although the natural floodplain has been decreased by about 90% by levee construction. About 241 fish species are reported in the mainstem and species diversity changes from about 60 in headwaters, 132 in the upper Missouri River basin and 150 species in the lower Missouri River basin. About 32 species found in the mainstem usually inhabit tributaries (Fremling et al. 1989). Catch of swift-water species (e.g., shovelnose sturgeon, blue sucker, blue catfish, and sicklefin chub) has declined in the upper river, but not in the lower part. Commercial harvest quantities have remained fairly constant (Fremling et al. 1989), but have changed in species composition from native fishes (e.g., buffalo) to exotic fishes (e.g., Asian carp). Harvest of American eel and channel catfish have recently declined.

Public uses of the Missouri River are similar to uses of other rivers in the Mississippi River basin. A mix of federal and nonfederal programs deal with river management and natural resource conservation, as discussed in Volume 1 (Berry and Young 2001). However, the 3,768-km-long Missouri River is unlike other large rivers because much of the main channel is riverine, but highly regulated. The Missouri River is divided into three approximately equal length zones as discussed in Volume 2 (Galat et al. 2001). The upper zone represents a "least-altered" zone, which includes the lower Yellowstone River. The middle zone is characterized by six large mainstem reservoirs and short riverine segments between the reservoirs. The lower zone is channelized for navigation and flows are controlled by discharges from upstream dams and by inputs from tributaries. Habitat data collected during the Benthic Fishes Study, and reported in Volume 2, was comprehensive. The synthesis of the habitat data showed that environmental and anthropogenic factors interacted to produce patterns in physical habitat that differed at the zone, segment, and macrohabitat scale. The diversity of habitats within river segments was addressed by characterizing six macrohabitats: channel crossover, inside bend, outside bend (these were grouped into a BEND category), secondary channel connected, secondary channel not-connected, and tributary mouth. These macrohabitats were also sampled for fish, so Volumes 2 and 3 are somewhat complimentary. Pegg and Pierce (2002a) simplify and interpret the complex changes in flow occurring along the Missouri and lower Yellowstone Rivers. They (Pegg and Pierce 2002b) concluded that human alteration may have the strongest influence in distinguishing fish community differences along the Missouri and lower Yellowstone Rivers.

In summary, habitat conditions in most rivers in the Mississippi River basin are not comparable to data from the Missouri, because most rivers have much smaller basins and different modifications that influence the fishery. For example, navigation pools dominate the lower segments of major rivers except the Mississippi and Missouri Rivers. Navigation pools include both lentic (lake) and lotic (river) segments, thus increasing fish diversity compared to the lower section of the Missouri, which is lotic. Compared to other rivers in the basin, diversity in the Missouri River is limited by variable flow, high turbidity, extreme temperatures, and low habitat diversity (Cross et al. 1986). However, rivers in the Mississippi River basin have common uses such as recreation, commercial fisheries, industrial and municipal water supply, irrigation, transportation, hydropower, waste assimilation, and flood control.

## STUDY AREA

The 3,768-km-long Missouri River basin encompasses 137 million ha, including 2.5 million ha in Canada. The river flows from its confluence with the Gallatin, Madison, and Jefferson Rivers in southwestern Montana, near Three Forks, generally east and south through the Northern Great Plains to its confluence with the Mississippi River near St. Louis, Missouri (Figure 1). The upper one third of the river is relatively natural (termed the least-altered zone or LA zone in this report), the middle one-third is mostly impounded by six dams (termed the inter-reservoir zone or IR zone), and the lower one-third has been channelized (termed the channelized zone or CH zone). We also included the lower 114 kms of the Yellowstone River from its confluence with the Missouri River as part of the LA zone.

Glaciation greatly influenced the basin and its fishes. Streams in the upper Missouri basin once had Arctic outlets, but now flow to the Gulf of Mexico (Cross et al. 1986). Because of glaciation, most tributaries and the largest tributaries to the Missouri River are right bank tributaries, flowing into the Missouri River from the west. No fishes are endemic to the Missouri and Yellowstone Rivers; pallid sturgeon, shovelnose sturgeon, sicklefin chub, and sturgeon chub are examples of characteristic native species.

Fisheries issues are usually related to changes in physical habitat or to water quality downstream from dams. There is little water quality degradation upstream from Sioux City, Iowa. Downstream from Sioux City, domestic and industrial pollution is limited to the areas directly downstream from municipalities (Schmulbach et al. 1992). Consequently, fish habitat has been the focus of many investigations. Summarized below are important fish habitat issues presented in detail in Volumes 1 and 2.

### Morphometry and Hydrology

The series of dams have fragmented habitat, blocked fish migration, and created water quality conditions that harm native riverine fishes. For example, it is hypothesized that suppression of the spring flood pulse has caused loss of spawning cues (i.e., warm-water coupled with river stage increases) that triggered spawning activity in native river fishes.

Floodplain inundation in the spring is thought to be important to the fish community. The Missouri River has two general periods of flooding, which are now highly modified by storage reservoirs. The "March rise" is caused by snowmelt in the plains and the break-up of ice in the main channel and tributaries. Waters in the March rise usually inundate the flood plain in the

upper portion of the basin. The "June rise" is produced by runoff from melting mountain snow and rainfall throughout the basin. Discharges from large tributaries in the lower basin (e.g., Platte River) still cause occasional flood plain inundation in the lower basin, sometimes later in the summer than is natural (Hesse 1996, Latka et al. 1993). The present hydrograph allows less flood plain inundation and is more predictable than the natural hydrograph (Galat and Lipkin 2000). These conditions were less of a factor in the LA zone (Montana) than in the IR zone and upper-CH zone. Discharges from large tributaries in the CH zone (e.g., Platte River, Kansas River, Osage River) cause a flood pulse in the lower CH zone.

Water turbidity is a fundamental habitat feature affecting fishes. The mainstem and tributary reservoirs collect much of the alluvium previously transported downstream. Navigation in the lower 1,200 km of the river is facilitated by dikes, revetments, and sills, which make the channel nearly self-scouring. Unnatural degradation and aggredation processes have deteriorated fish and wildlife habitat.

**Energy for Fish Production**

Organic matter inputs (termed allochthonous material) from the floodplain are important to river ecology (Allan et al. 1997). The amount of allochthonous and autochthonous organic matter in the Missouri River is unknown, but trends in organic matter inputs in the IR and CH zones have been studied. Allochthonous organic material (e.g., vegetation, humic material) comes from the floodplain; autochthonous material (e.g., phytoplankton, aquatic macrophytes) is produced within the river. Researchers have hypothesized that changes in the floodplain and river in the IR and CH zones have reduced organic matter sources and inputs and fish population matrices such as production, growth, and recruitment (Hesse et al. 1988, Schmulbach et al. 1992). Fish population matrices for selected benthic fishes are presented in Volume 4 of the Benthic Fishes Study final report (Pearce et al. 2004). The authors reported that patterns in fish growth and condition differed among zones and related the findings to river productivity, growing season, local conditions, and other factors.

An early comprehensive study of river productivity and commercially important fishes concluded that fish diet and growth emphasized the bottom feeding habits of the Missouri River fishes. It also emphasized the importance of allochthonous organic matter in the Missouri River ecosystem (Berner 1951). Since Berner's study, changes in the floodplain have occurred (Hesse et al. 1988, Johnson 1992, Becker and Gorton 1995) and are generally characterized as follows: the natural riparian vegetation in bottomland hardwoods, grasslands, and wetlands has been reduced, while cultivated land has increased from 18% to 83% since settlement. The river now has few backwaters with emergent and submergent aquatic plants because of channelization and channel degradation. Organic material from these plant communities has been reduced (about 65%, Hesse et al. 1989), so less organic material can enter the river in floodwaters or from tributaries.

Autochthonous organic matter (e.g., aquatic plants, phytoplankton) is produced within the river from sunlight. Although reservoirs have reduced turbidity in the mainstem, sunlight remains a limiting factor to plankton and periphyton production. However, when turbidity decreases in rivers, some riverine fish species are replaced by sight-feeding planktivores and piscivores adapted to lentic habitats and clear water (Pflieger and Grace 1987). Such changes were apparent by 1974 in the lower Missouri River (Funk and Robinson 1974).

On the other hand, man-made channel structures provide habitat for aufwuchs (periphyton) colonization and reservoirs release tons of plankton that partly offset the loss of production from natural habitat. Algae, detritus, phytoplankton, and periphyton are consumed by many fish species in the riverine portions of the Missouri River (Walburg and Nelson 1966, McComish 1967, Nelson et al. 1968, Troelstrup 1985). Invertebrate response to habitat change is complex. For example, river current velocity of 1-3 m/s and shifting substrates probably reduce benthic macroinvertebrate production, whereas flow constancy probably helps benthic invertebrate and aufwuchs communities (Waters 1995).

**Fish Macrohabitats**

In general, fish macrohabitats associated with islands, sand bars, and backwaters have declined; whereas deep and swift main channel habitats have increased (FWS 1980, Becker and Gorton 1995). About 396,000 ha (990,000 acres) of bottomland and 1,216 km (760 miles) of channel are inundated by reservoirs in the upper river and stable flows and channelization has harmed about 66,400 ha (166,000 acres) of natural aquatic habitat in the lower river (CE 1981, Becker and Gorton 1995). Mitigating negative impacts has been an ongoing Corps program (Becker and Gorton 1995), especially recent efforts to create fish habitat with environmental engineering techniques (Galat et al. 2005). For example, about 1200 ha (30,000 acres) of bottomland and chutes have been restored, erodible stream banks protected while improving bank habitat, and dikes notched for improved fish habitat. Remnant unchannelized reaches on the South Dakota/Nebraska border are still somewhat similar to historic conditions, except for altered hydrographs (Schmulbach et al.

1975, 1981; Kallemeyn and Novotny 1977, Modde and Schmulbach 1977).

Macrohabitats are characterized by features such as velocity, depth, and substrate that are important to fish. Just as the number and area of macrohabitats have changed, physical conditions have also changed. For example, historical river velocities were usually 0.3-0.8 m/s, but downstream from Gavins Point Dam (for example, Latka et al. 1993) velocities between 0.8 m/s and 1.3 m/s occur more frequently than they did historically.

In summary, curtailed river functions include floodplain inundation, natural hydrograph and water temperature, sediment and organic matter input and transport, and instream cover for fishes. These alterations have caused an estimated loss of 216 million kg of fish production annually (Hesse and Sheets 1993). Commercial fish harvest was reduced 80% (IFMRC 1994), and about one-fifth of the native species are listed as imperiled (Galat et al. 2005).

**Missouri River Fishes**

Until the most recent list of main channel fishes was compiled (Galat et al. 2005), only regional lists were available: 91 species in Missouri reaches (Galat et al. 1996), 77 species in Nebraska-South Dakota reaches (Hesse 1996), 72 in North Dakota reaches (Mizzi 1994), and 42 in Montana reaches (Berg 1981). The 1,091-km long Yellowstone, a tributary to the Missouri River and included in our study in part, is the longest free-flowing river in the contiguous United States (White and Bramblett 1993). Although introduced species, water withdrawals, agriculture and energy developments, and logging continue to threaten the Yellowstone, it is said to have retained much of the character it had at the time of the Lewis and Clark expedition in 1806 (White and Bramblett 1993).

Today there are about 150 fish species known to occur in the Missouri River basin (Hesse 1996, Galat et al. 2005). Fifty-four percent are classified as "big river" species, residing primarily in the main channel, and 93% of these are fluvial dependent or fluvial specialists. Populations of 17 species are increasing and 53% of these are introduced. Twenty-three of 24 species, whose populations are decreasing, are native (Galat et al. 2005). Table 2 shows the species captured during the conduct of the Benthic Fishes Study, other than the 26 selected benthic fishes, which were listed in Table 1. The most important warm-water sport fishes in the Missouri River are walleye, sauger, yellow perch, channel catfish, paddlefish, shovelnose sturgeon, and northern pike. We review here the most comprehensive studies of mainstem fishes, grouped by zone.

***Channelized (CH) Zone***

Commercial fishery reports provide the oldest information (Funk and Robinson 1974). Over harvesting caused the decline of some species (e.g., centrarchids) by the early 1900s and of others (e.g., catfishes, freshwater drum) later. Fishes associated with clear water (e.g., skipjack herring, white bass) increased after upstream impoundment. Sixty-seven species had been documented in the Missouri portion of the river by 1983 (Pflieger and Grace 1987). In the Nebraska-Iowa section, 40-57 species were documented during the 1960s and 1970s (Schmulbach et al. 1975, Hesse et al. 1982). Eleven species (e.g., sauger, blue catfish, flathead chub) had downward population trends and sturgeon chub and sicklefin chub were rarely seen (Hesse et al. 1993, Hesse 1994).

***Inter-Reservoir (IR) Zone***

In the South Dakota portion, 45 species were found by seining (Bailey and Allum 1962). Eleven "big river" species were abundant in the free-flowing river downstream from Fort Randall Dam (Kallemeyn and Novotny 1977). Fish catches decreased from the relatively natural section in South Dakota to the upper channelized section in Iowa (Schmulbach et al. 1975). Annual monitoring has produced 54 species from the South Dakota-Nebraska border waters in the 1990s (Mestl 1999, Wickstrom 1999).

Fish surveys of riverine reaches in North Dakota were limited prior to 1991. Mizzi (1994) listed 70 species that had been recorded in the mainstem and collected 42 species by using seines and minnow traps in major macrohabitats (except main channel) near Bismarck and Williston, North Dakota. Standardized annual surveys with multiple gears produced 52 species downstream from Lake Sakakawea and 36 upstream (Hendrickson et al. 1995).

***Least-Altered (LA) Zone***

In Montana, Berg (1981) found 53 species representing 14 families in the Missouri River, including tributaries and Fort Peck Lake, and 42 species in the main channel habitats. There are three fishery zones in the Yellowstone River, progressing from cold water in the mountains to warm-water at the confluence with the Missouri River (White and Bramblett 1993). Forty-nine species are listed in the warm-water zone, which was included in our study.

## METHODS

Standard operating procedures for macrohabitat identification, fish collection, physical measurements, data management, and statistical analyses were used (Sappington et al. 1998).

### Fish Sampling

We targeted 26 benthic species for evaluation (Table 1) and counted and identified other fish species (Table 2). Criteria for inclusion in the benthic fishes assemblage were 1) primarily benthic habitat use; 2) important as native, commercial, recreational, or prey; and 3) presence in most of the mainstem. The benthic assemblage comprised representatives of six families: Acipenseridae (shovelnose and pallid sturgeon), Cyprinidae or minnows (10 species), Catostomidae or suckers (six species), Ictaluridae or catfishes (four species), Gadidae (burbot), Percidae (walleye and sauger), and Sciaenidae (freshwater drum). The assemblage is not meant to be a guild, which is made up of ecologically similar species. In our benthic fishes assemblage are species with different body shapes, mouth placements, swimming abilities, spawning requirements, and functional designations (e.g., omnivore, detritivore, predator, reviewed by Bergstedt et al. 2004). The assemblage includes all benthic fishes listed "at risk" by basin states.

A brief summary of the appearance, size, and ecology of each fish in the benthic fishes assemblage is included in Volume 1. The summaries were compiled from Pfleiger (1997), Harlan and Speaker (1987), Bailey and Allum (1962), Morris et al. (1974), Brown (1971), and Baxter and Stone (1995).

#### *Fish Identification and Treatment*

Fish identification and treatment protocols were spelled out in SOP 4.1 (Sappington et al. 1998). The identification key used by research teams in the lower basin was Pfleiger (1997), in the middle basin were Page and Burr (1991), and in the upper basin was Brown (1971). We were able to identify 97% of the fish to species. We encountered 1,193 fish that could not be identified in the field - mostly larval fish, age-O fish, or fish that were damaged during capture (e.g., crushed among debris in the trawl). Another 3,770 fish could be identified only to genus or family (Table A1-1), excluding specimens of the abundant *Hybognathus* genus.

The *Hybognathus* group (western silvery minnow, plains minnow, brassy minnow) was an exception. Field identification to species is difficult using external characteristics (Schmidt 1994), so field workers have either combined samples as *Hybognathus* spp. (Holton 1990) or retained all specimens for identification by necropsy. The species can usually be determined by examination of the basoccipital bone (Bailey and Allum 1962, Loomis 1997). About 90% accuracy can be attained on larger specimens in the field by using eye diameter, pupil diameter, and number and size of scale rows across the belly (Loomis 1997). We used these characteristics to identify fish to species when possible; otherwise, we identified them only to genus. We caught 12,523 *Hybognathus* sp. and identified 374 western silvery minnows, 57 plains minnows, and 142 brassy minnows.

Voucher specimens of species in our benthic fishes assemblage (excluding pallid sturgeon) were sent to Dr. William Pflieger for verification. Of the 461 specimens submitted, 10 were incorrectly identified (Pflieger et al. 1999). These were juvenile forms of walleye, white sucker, stonecat, and sicklefin chub. Forty-nine specimens of other fishes were also sent for verification. All field identities were correct except for two specimens presumptively identified as ghost shiner (*Notropis buchanani*), which were probably spotfin shiner (*N. spiloptera*) and bigmouth shiner *(N. dorsalis*).

Fish were treated following Guidelines for Use of Fishes in Field Research (AFS 1988) and our SOP 4.2 (Sappington et al. 1998). In general, fish were held in aerated live wells, weighed and measured (total length) as soon as possible, and returned alive if not used as a voucher specimen or for age and growth analysis. We followed SOP 4.3 when handling the four pallid sturgeons that were captured (Sappington et al. 1998).

#### *Sampling Gears*

To account for the physical diversity of the river, we sampled three continuous and three discrete macrohabitats (Figure 2, Table 3). Continuous macrohabitats were repeatable habitat units made up of channel crossovers (CHXO), inside bends (ISB), and outside bends (OSB), which we later combined to form the macrohabitat class termed "BEND". Discrete macrohabitats were tributary mouths (TRM), secondary channels connected (SCC), and secondary channels non-connected (SCN). The SCNs had little or no flow and were open to the river at the downstream end. Others have also recognized and studied these and other instream macrohabitat types in the Missouri River (Schmulbach et al. 1981, Cobb et al. 1989, Wilcox 1993, Hesse 1996). Bends, tributaries, and secondary channels are complex, so we further divided these macrohabitats into smaller units termed "mesohabitats".

Mesohabitats of ISBs were sand bars, channel borders, deep pools, and steep shorelines; there were large and small TRMs and deep and shallow SCCs. We also allowed a "wild card" macrohabitat for unusual macrohabitats (e.g., dam tailraces) that were unique to some segments.

Table 2. Mainstem fishes of the Missouri River from Missouri to Montana, including the lower Yellowstone River. Hybrids are excluded. MT = warm water Montana reaches; YR = warm water lower Yellowstone River; ND = North Dakota; SD-IA-NE = South Dakota, Iowa, and Nebraska to Fort Randall Dam; MO-KS = Missouri to Kansas reach; BFS = Benthic Fishes Study, 1996-1998 (total catch in all segments). Bold shows the benthic fishes in our study.

| Family | Common name | Scientific name | MT [5] | YR [4] | ND [3] | SD-IA-NE [2] | MO-KS [1] | BFS |
|---|---|---|---|---|---|---|---|---|
| Petromyzontidae | Chestnut lamprey | *Ichthyomyzon* castaneus | | | | | X | 2 |
| | Silver lamprey | *I. unicuspis* | | | | X | | |
| Acipenseridae | Lake sturgeon | *Acipenser* fulvescens | | | | | X | 5 |
| | **Shovelnose sturgeon** | ***Scaphirhynchus platorynchus*** | **X** | **X** | **X** | **X** | **X** | **1560** |
| | **Pallid sturgeon** | ***S. albus*** | **X** | **X** | **X** | **X** | **X** | **4** |
| Polyodontidae | Paddlefish | *Polyodon* spathula | X | X | X | X | X | 9 |
| Lepisosteidae | Shortnose gar | *Lepisosteus* platostomus | | | X | X | X | 614 |
| | Longnose gar | *L. osseus* | | | | X | X | 185 |
| | Spotted gar | *L. oculatus* | | | | | | 2 |
| Amidae | Bowfin | *Amia calva* | | | | X | | 1 |
| Hiodontidae | Goldeye | *Hiodon* alosoides | X | X | X | X | X | 4014 |
| | Mooneye | *H. tergisus* | | | | | X | |
| Anguillidae | American eel | *Anguilla* rostrata | | | | X | X | |
| Clupeidae | Skipjack herring | *Alosa chrysochloris* | | | | X | X | 10 |
| | Alabama shad | *A. alabamae* | | | | | X | |
| | Gizzard shad | *Dorosoma* cepedianum | | | | X | X | 25930 |
| | Threadfin shad | *D. petenense* | | | | | | 1 |
| Osmeridae | Rainbow smelt | *Osmerus* mordax | | X | X | X | X | 23 |
| Esocidae | Northern pike | *Esox lucius* | X | X | X | X | X | 368 |
| | Grass pickerel | *E. americanus* vermiculatus | | | | | | 1 |
| | Muskellunge | *E. masquinongy* | | | | | | 1 |
| Cyprinidae | **Common carp** | ***Cyprinus carpio*** | **X** | **X** | **X** | **X** | **X** | **3037** |
| | Goldfish | *Carassius* auratus | X | X | X | X | | 5 |
| | Lake chub | *Couesius* plumbeus | X | X | X | | | 1 |
| | Utah chub | *Gila atraria* | | | X | | | |
| | Common shiner | *Luxilus cornutus* | | | X | | X | 2 |
| | N. redbelly dace | *Phoxinus* eos | X | X | X | | | 1 |
| | Finescale dace | *P. neogaeus* | X | | X | | | |
| | Grass carp | *Ctenopharyngodon* idella | | | | X | X | 16 |
| | Bighead carp | *Hypophthalmichthys* nobilis | | | | | X | 22 |
| | Silver carp | *H. molitrix* | | | | | X | |
| | Golden shiner | *Notemigonus* crysoleucas | X | X | X | X | X | 66 |
| | Creek chub | *Semotilus* atromaculatus | | X | X | X | X | 67 |
| | Pearl dace | *Margariscus* margarita* | | X | X | | | 1 |
| | Silver chub | *Macrhybopsis* storeriana | | | | X | X | 423 |
| | Gravel chub | *Erimystax* x-punctatus | | | | | X | |
| | Speckled chub | *Macrhybopsis* aestivalis | | | | X | X | 326 |
| | **Sturgeon chub** | ***M. gelida*** | **X** | **X** | **X** | **X** | **X** | **2051** |
| | **Sicklefin chub** | ***M. meeki*** | **X** | **X** | **X** | **X** | **X** | **709** |
| | **Flathead chub** | ***Platygobio gracilis*** | **X** | **X** | **X** | **X** | **X** | **12838** |
| | Suckermouth minnow | *Phenacobius* mirabilis | | | | X | X | 10 |
| | **Emerald shiner** | ***Notropis atherinoides*** | **X** | **X** | **X** | **X** | | **20362** |
| | Rosyface shiner | *N. rubellus* | | | | | X | |
| | Redfin shiner | *Lythrurus* umbratilis | | | | | X | |
| | Silverband shiner | *Notropis* shumardi | | | | X | X | 2 |
| | Striped shiner | *Luxilus chrysocephalus* | | | | | X | |

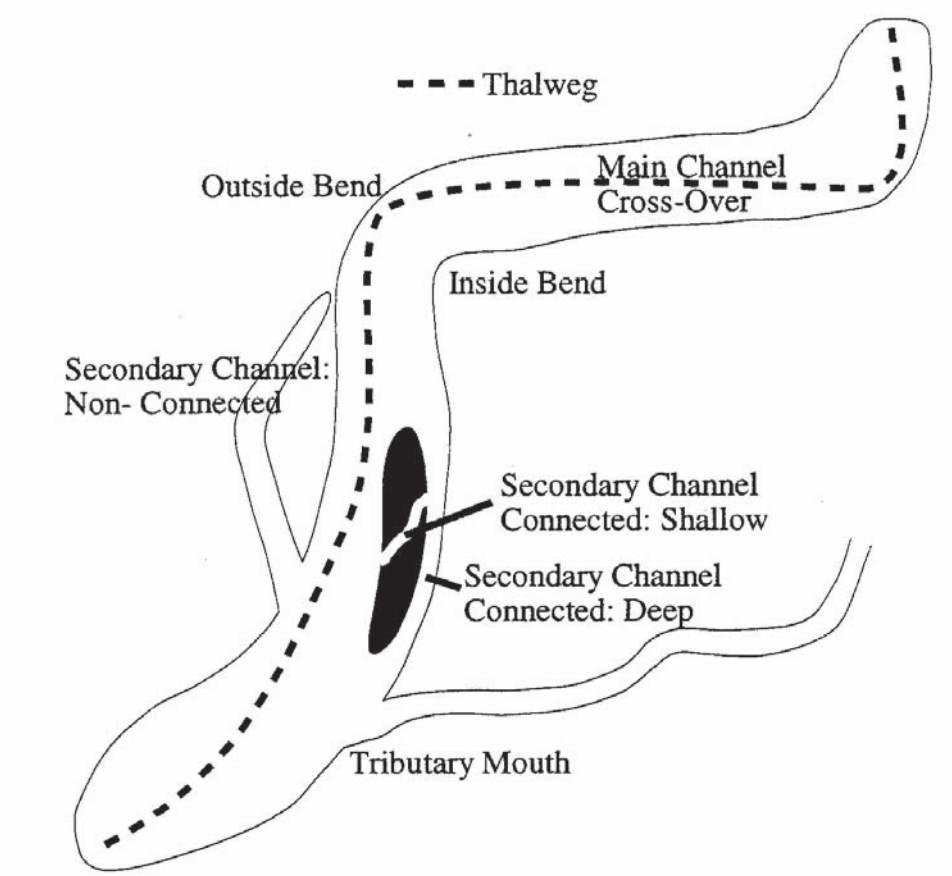
| Family | Common name | Scientific name | MT[5] | YR[4] | ND[3] | SD-IA-NE[2] | MO-KS[1] | BFS |
|---|---|---|---|---|---|---|---|---|
| | River shiner | *Notropis blennius* | | | | X | X | 876 |
| | Bigeye shiner | *N. boops* | | | | | X | 5 |
| | Bigmouth shiner | *N. doralis* | | | | X | X | 109 |
| | Spottail shiner | *N. hudsonius* | | | X | X | | 493 |
| | Spotfin shiner | *Cyprinella spiloptera* | | | | X | X | 1751 |
| | Red shiner | *Cyprinella lutrensis* | | | | X | X | 2382 |
| | **Sand shiner** | ***Notropis stramineus*** | | **X** | **X** | **X** | **X** | **693** |
| | Channel shiner | *N. wickliffi* | | | | | X | |
| | Mimic shiner | *N. volucellus* | | | | X | | 100 |
| | Ghost shiner | *N. buchanani* | | | | | X | 2 |
| | **Brassy minnow** | ***Hybognathus hankinsoni*** | **X** | **X** | | **X** | **X** | **142** |
| | **Western silvery minnow** | ***H. argyritis*** | **X** | **X** | **X** | **X** | **X** | **374** |
| | **Plains minnow** | ***H. placitus*** | **X** | **X** | **X** | **X** | **X** | **57** |
| | Bluntnose minnow | *Pimephales notatus* | | | X | X | X | 42 |
| | **Fathead minnow** | ***P. promelas*** | **X** | **X** | **X** | **X** | **X** | **739** |
| | Bullhead minnow | *P. vigilax* | | | | | | 11 |
| | Central stoneroller | *Campostoma anomalum* | | | | X | X | |
| | Largescale stoneroller | *C. oligolepis* | | | | | X | 2 |
| | Blacknose dace | *Rhinichthys atratulus* | | | | X | | |
| | Longnose dace | *Rhinichthys cataractae* | X | | X | | | 453 |
| Catostomidae | **Blue sucker** | ***Cycleptus elongatus*** | **X** | **X** | **X** | **X** | **X** | **200** |
| | **Bigmouth buffalo** | ***Ichthiobus cyprinellus*** | **X** | **X** | **X** | **X** | **X** | **517** |
| | Black buffalo | *I. niger* | | | | | X | |
| | **Smallmouth buffalo** | ***I. bubalus*** | **X** | **X** | **X** | **X** | **X** | **485** |
| | **River carpsucker** | ***Carpiodes carpio*** | **X** | **X** | **X** | **X** | **X** | **6688** |
| | Highfin carpsucker | *C. velifer* | | | | | X | 6 |
| | Quillback | *C. cyprinus* | | | | X | X | 1962 |
| | **White sucker** | ***Catostomus commersonii*** | **X** | **X** | **X** | **X** | **X** | **2204** |
| | Longnose sucker | *C. catostomus* | X | X | X | | | 4980 |
| | Northern hog sucker | *Hypentelium nigricans* | | | | | X | X1 |
| | Golden redhorse | *Moxostoma erythrurum* | | | | | X | 17 |
| | **Shorthead redhorse** | ***M. macrolepidotum*** | **X** | **X** | **X** | **X** | **X** | **1200** |
| | River redhorse | *M. carinatum* | | | | | | 3 |
| | Mountain sucker | *Catostomus platyrhynchus* | X | X | X | | | |
| Ictaluridae | Black bullhead | *Ameiurus melas* | X | X | X | X | X | 16 |
| | Yellow bullhead | *A. natalis* | | X | | X | X | 6 |
| | **Channel catfish** | ***Ictalurus punctatus*** | **X** | **X** | **X** | **X** | **X** | **5656** |
| | **Blue catfish** | ***I. furcatus*** | | | | **X** | **X** | **382** |
| | Tadpole madtom | *Noturus gyrinus* | | | | | X | 1 |
| | Freckled madtom | *N. nocturnus* | | | | | X | 8 |
| | **Stonecat** | ***N. flavus*** | **X** | **X** | **X** | **X** | **X** | **342** |
| | Slender madtom | *N. exilis* | | | | | | 1 |
| | **Flathead catfish** | ***Pylodictis olivaris*** | | | | **X** | **X** | **1456** |
| Salmonidae | Lake herring | *Coregonus artedi* | | | | | | 24 |
| | Lake whitefish | *C. clupeaformis* | | | | | | 2 |
| | Mountain whitefish | *Prosopium williamsoni* | X | | | | | |
| | Brown trout | *Salmo trutta* | X | X | | | | 1 |
| | Cutthroat trout | *Oncorhynchus clarki* | X | | | | | |
| | Brook trout | *Salvelinus fontinalis* | X | | | | | |
| | Rainbow trout | *Oncorhynchus mykiss* | X | X | | | | 21 |
| | Chinook salmon | *O. tshawytscha* | | | | | | 1 |

| Family | Common name | Scientific name | MT [5] | YR [4] | ND [3] | SD-IA-NE [2] | MO-KS [1] | BFS |
|---|---|---|---|---|---|---|---|---|
| | Coho salmon | *O. kisutch* | X | | | | | |
| Gadidae | **Burbot** | ***Lota lota*** | **X** | **X** | **X** | **X** | **X** | **220** |
| Cyprinodontidae | Blackstripe topminnow | *Fundulus notatus* | | | | | X | |
| | Banded killifish | *F. diaphanus* | | | X | | | 4 |
| | Plains topminnow | *F. sciadicus* | | | | X | | |
| | Plains killifish | *F. zebrinus** | | X | | X | | |
| Poeciliidae | Western mosquitofish | *Gambusia affinis* | | | | | X | 227 |
| | Variable platyfish | *Xiphophorus variatus* | | | X | | | |
| Gasterosteidae | Brook stickleback | *Culaea inconstans* | X | | X | | | 2 |
| Cottidae | Mottled sculpin | *Cottus bairdi* | X | X | X | | | 15 |
| Atherinidae | Brook silverside | *Labidesthes sicculus* | | | | | X | 16 |
| Percichthyidae | White perch | *Morone americana* | | | | X | | 2 |
| | White bass | *M. chrysops* | X | X | X | X | X | 542 |
| | Yellow bass | *M. mississippiensis* | | | | | | 6 |
| | Striped bass | *M. saxatilis* | | | | | | 21 |
| Centrarchidae | Spotted bass | *Micropterus punctulatus* | | | | | X | 58 |
| | Smallmouth bass | *M. dolomieu* | X | X | X | X | X | 407 |
| | Largemouth bass | *M. salmoides* | X | X | X | X | X | 314 |
| | Warmouth | *Lepomis gulosus* | | | | | X | |
| | Pumpkinseed | *L. gibossus* | X | X | X | X | | |
| | Green sunfish | *L. cyanellus* | X | X | X | X | X | 210 |
| | Orangespotted sunfish | *L. humilis* | | | X | X | X | 127 |
| | Longear sunfish | *L. megalotis* | | | | | X | 1 |
| | Redear sunfish | *L. microlophus* | | | | X | X | |
| | Bluegill | *L. macrochirus* | X | | X | X | X | 671 |
| | Rock bass | *Ambloplites rupestris* | | X | | X | X | 22 |
| | White crappie | *Pomoxis annularis* | X | X | X | X | X | 1480 |
| | Black crappie | *P. nigromaculatus* | X | X | X | X | X | 199 |
| Percidae | **Walleye** | ***Sander vitreum*** | **X** | **X** | **X** | **X** | **X** | **561** |
| | **Sauger** | ***S. canadense*** | **X** | **X** | **X** | **X** | **X** | **614** |
| | Slenderhead darter | *Percina phoxocephala* | | | | | X | |
| | Ozark logperch | *P. caprodes fulvitaenia* | | | | | X | |
| | Logperch | *P. caprodes* | | | | | | 5 |
| | Johnny dar | *Etheostoma nigrum* | | | X | X | X | 130 |
| | Iowa darter | *E. exile* | X | | X | | | |
| | Yellow perch | *Perca flavescens* | X | X | X | X | | 768 |
| Sciaenidae | **Freshwater drum** | ***Aplodinotus grunniens*** | **X** | **X** | **X** | **X** | **X** | **2770** |

* Margariscus = Semotilus; F. kansae = F. zebrinus
[1] Galat et al. 1996
[2] Bailey and Allum 1962, Morris et al. 1974, Berry unpublished
[3] Mizzi 1993
[4] White and Bramblett 1993
[5] Berg 1981

Five gears were used to collect fishes. Experimental gill nets were 30.5 m long x 1.8 m deep with four 7.6-m panels of 19, 38, 51, and 76-mm mesh. Trammel nets were 22.9 m long and 1.8 m deep, with a 25-mm inner mesh and 203-mm outer mesh (bar measure). Bag seines were 10.7 m long and 1.8 m deep with 5-mm mesh. The benthic trawl was hung on a rigid frame with skis. The trawl net was 2-m wide, 0.5-m deep, and 5.5-m long with 3.2-mm inner mesh. Electrofishing was done with a 5,000-watt generator using pulsed DC current and 2 netters with 5-mm mesh dip nets. A minimum of two fish collection gears was used in each

Figure 2. Schematic showing macrohabitats sampled during the Benthic Fishes Study.




mesohabitat (Table 3). The exceptions were shallow habitats (i.e., shallow SCCs and ISB sand bars) where only a seine was used. Data were reported as total catch and catch per unit effort (C/E), which for trammel net and trawl was fish/100m, for seine was fish/haul, for electrofishing was fish/minute, and for gill net was fish/hour.

**Habitat Physical Measurements**

Water temperature, velocity, depth, conductivity, turbidity, and substrate composition were measured at sites where fishes were sampled using standard methods (Sappington et al. 1998). One or more measurements of each physical habitat variable was made each time a gear was deployed to collect fish (trends summarized in Volume 2, Galat at al. 2001). We tried to limit temperature influences by sampling only in mid- to late-summer on the upper ascending limb and upper descending limb of the water temperature curve. Most samples were collected at water temperatures between 14 and 26°C, but the range of temperatures where fish were collected was from 8-32°C. Benefits of sampling in mid- to late-summer were: 1) sampling was more effective after high spring flows decline, and 2) young fishes were usually large enough to capture, identify, and age.

The physical habitat measurements have several applications, which is why they are traditional stream habitat measurements (McMahon et al. 1996, Bain and Stevenson 1999). They show trends in conditions among segments and among macrohabitats that explain differences in fish community or population attributes. Physical measurements can be used to predict fish habitat suitability and allow future scientists to conduct fisheries studies under similar conditions.

**Study Design**

Sampling fishes with both active and passive gears in six dominant macrohabitats during the summers allowed us to characterize the fish community in terms of kinds and number of species in any gear, macrohabitat, river segment or zone. We could determine the C/E of certain species because we recorded effort when using each gear. The goal was to compare the C/E of

Table 3. Collection gears and Missouri River habitats. Secondary channels are non-connected (non-con) or connected (con).

| Habitats | | Fish Collection Gears | | | | |
|---|---|---|---|---|---|---|
| **Macro-** | **Meso-** | **Seine[1]** | **Gill net[2]** | **Electrofish.[3]** | **Trawl[4]** | **Trammel[5]** |
| Secondary channel non-con | | X | X | X | | |
| Secondary channel con | shallow | X | | | | |
| | deep | X | | X | X | X |
| Channel crossover | | | | | X | X |
| Channel outside bend | | | | X | X | X |
| Channel inside bends | channel border | | | | X | X |
| | bars | X | | | | |
| | pools | | X | | | |
| | steep shoreline | | | X | | |
| Tributary mouth | small | | X | X | | |
| | large | | | X | X | X |

[1]Bag seine was 10.7-m-long and 1.8-m-high with 5-mm mesh
[2]Gill net 30.5-m-long and 1.8-m-high; four 7.6-m-long panels of 19-, 38-, 51-, and 76-mm mesh
[3]Boat electrofishing with 5,000-watt generator and pulsed DC, two netters with 5-mm mesh dip nets
[4]Bottom trawl mouth 2-m-wide and 0.5-m-high; net was 5.5-m-long with inner net of 3.2-mm mesh
[5]Drifted trammel net 22.9-m-long and 1.8-m-deep with 25-mm mesh inner and 203-mm mesh outer wall

the benthic assemblage among zones and segments throughout the Missouri and lower Yellowstone Rivers. To meet this goal, we partitioned the river into 15 segments and grouped the segments into 3 zones.

***Zones***

Progressing from headwaters to the confluence, we partitioned the mainstem into three zones: 1) the least-altered (LA) zone, which was the Yellowstone and Missouri upstream from Fort Peck Lake; 2) the inter-reservoir (IR) zone, which is the free-flowing reaches downstream from Fort Peck, Garrison, Fort Randall, and Gavins Point dams; and 3) the channelized (CH) zone, which is from Sioux City, Iowa, to the confluence with the Mississippi River (Table 4). We also included the lower 114 kms of the Yellowstone River from its confluence with the Missouri River as part of the LA zone. The lower reaches of the Yellowstone are similar to those in the Missouri River in that both are warmwater rivers with about the same drainage area (200,000 $km^2$) and mean annual discharge (300 $m^3/s$) at their confluence. Cross et al. (1986) showed a close relationship between Yellowstone and upper Missouri River fish communities. The possibility of differences in river segments within zones leads to a second level of the study - the segment scale.

***Segments***

We partitioned the river into segments (10-100 km long) based on geomorphic (e.g., tributaries, geology) and constructed features (e.g., impoundments, channelization, urban areas). A preliminary study design included 27 river segments, but we sampled 19 in 1996 and then 15 in 1997 and 1998 (Table 4). To aid the reader in recalling segment location, we use a specific font code which is - LA segments are underlined (because the LA zone is "special"), **IR** segments are bold (because reservoirs are "full"), and *CH* segments are italicized (because flow in the CH zone is "swift"). Groups of segments were considered representative of each zone (i.e., Segments 3, 5, and 9 represented the LA zone).

However, because of the broad spatial scale of zones, there was the possibility that physical conditions in each segment might differ within a zone (Galat et al. 2001). Segments in the LA zone were in the Missouri River (Segments 3, 5) and Yellowstone River (Segment 9), so we tested the assumption that fish catches in Segments 3 and 5 were similar to catches in Segment 9. The IR zone Segments **7**, **8**, and **10** could be influenced by the considerable discharge from the Yellowstone River; Segment **15** in the IR zone on the South Dakota-Nebraska border is downstream from Gavins Point Dam and thus open to the CH zone. Other segments in the IR zone (i.e., Segments **12** and **14)** are limited upstream by a dam and downstream by a reservoir. In the CH zone, segments might be influenced by tributary inputs or by the presence of large municipalities (e.g., Kansas City).

Table 4. List of sections, zones, and segments of the Missouri and Yellowstone Rivers included in the Benthic Fishes Study, 1995-2000. rm = river mile; rkm = kilometer; * = not sampled in 1997 and 1998. LA = least-altered zone, IR = inter-reservoir zone, and CH = channelized zone. Segments numbers are written in a standard format used in all reports from this study: underlined = LA segments, bold = **IR segments** , and italics = *CH segments*

| Section and zone | Seg. No. | Segment description and length (mi) | Segment boundaries rm | rkm |
|---|---|---|---|---|
| Missouri headwaters LA | 3 | Arrow Creek - Birch Creek, 19 | 1999-1980 | 3217-3187 |
| | 4* | Birch Creek - Sturgeon Island, 28 | 1980-1952 | 3186-3141 |
| | 5 | Sturgeon Island - Beauchamp Coulee, 70 | 1952-1882 | 3141-3029 |
| Yellowstone LA | 9 | Intake diversion - confluence, 71 | 71-0 | 114-0 |
| IR | **6*** | Ft Peck Dam - Milk R., 10 | 1770-1760 | 2847-2831 |
| | **7** | Milk R.- Wolf Pt, 59 | 1760-1701 | 2831-2737 |
| | **8** | Wolf Pt - Yellowstone R., 99 | 1701-1582 | 2737-2545 |
| | **10** | Yellowstone R. - L. Sakakawea, 30 | 1582-1552 | 2545-2497 |
| | **12** | Garrison Dam - Lake Oahe, 85 | 1398-1304 | 2235-2098 |
| | **14** | Ft Randall - Niobrara R., 45 | 880-835 | 1416-1343 |
| | **15** | Gavins Pt Dam - Ponca, NE, 57 | 810-753 | 1303-1212 |
| CH | *17* | Big Sioux R. - Little Sioux R., 71 | 740-669 | 1191-1077 |
| | *18** | L. Sioux R. - Platte R., 74 | 669-595 | 1076-958 |
| | *19* | Platte R. - Nishnabotna R., 54 | 595-542 | 958-872 |
| | *21** | Rulo, NE - St. Joseph, 58 | 498-440 | 801-708 |
| | *22* | St. Joseph - Kansas R., 72 | 440-367 | 708-591 |
| | *23* | Kansas R. - Grand R., 117 | 367-250 | 591-402 |
| | *25* | Glasgow - Osage R., 90 | 220-130 | 354-210 |
| | *27* | Missouri R. rm50 - Mississippi R., 50 | 50-0 | 80-0 |

***Macrohabitats***

We used stratified random sampling to sample benthic fishes and associated habitat variables. Our strata were the six macrohabitats mentioned above (i.e., ISB, TRM, CHXO, OSB, SCC, SCN). Three macrohabitats (TRM, SCC, and SCN) and river bends (which included ISB, CHXO, and OSB macrohabitats) were randomly selected within segments that were the experimental blocking. We planned to randomly select five of each macrohabitat within a segment each year. For example, we always had five CHXOs in each segment, so over the course of the study, 225 CHXOs were sampled (Table 5). However, annual differences in water conditions determined the number of mesohabitats (i.e., when

water was low, there were less ISB pools and more SCNs than during high-water years). For example, there were not always five SCNs, so only 109 were sampled.

Attempting to sample an equal number of macrohabitats per segment resulted in a disproportionally large number of the more rare macrohabitats (e.g., TRMs, SCNs) relative to their availability. Galat et al. (2001) provide greater detail about habitat definition and differences based on physical and hydrological features.

***Hypotheses***

Our working hypotheses were formed from literature that suggested that population status of fishes at risk within the Missouri River varies geographically. Healthiest populations of more species are thought to persist in the LA zone. The section of the Missouri River where population declines seem to be the greatest is in the middle Missouri River, especially in reaches between reservoirs with degraded channels downstream from reservoirs. In the lower CH zone in Missouri, populations might be more stable (Pflieger and Grace 1987) than those in the Nebraska section (Hesse et al. 1993). Factors responsible for these longitudinal differences are not immediately apparent, but may relate to habitat availability and viability of fish populations.

The SOP manual (Sappington et al. 1998) lists several null and alternate statistical hypotheses. For example, the following hypothesis is about zonal differences:

*Null hypothesis:* There is no difference among zones in the catch of benthic fishes.
*Alternate hypothesis:* The catch of benthic fishes is lower in IR and CH zones.

The following hypotheses relate to segment differences:

*Null hypothesis*: There is no difference in fish catch in segments immediately upstream and downstream from reservoirs.
*Alternate hypothesis*: The catch of benthic fishes is different upstream and downstream from reservoirs.
*Null hypothesis*: The catch of benthic fishes is the same among LA zone segments.
*Alternate hypothesis*: The catch of benthic fishes differs among LA segments.
*Null hypothesis*: The catch of benthic fishes is the same upstream and downstream from Kansas City.
*Alternate hypothesis*: The catch of benthic fishes in higher upstream from Kansas City.

Table 5. Number of segments and macrohabitats where fish were collected and physical habitat measured during the Benthic Fishes Study of the Missouri River, 1996-1998. Fifteen segments are listed because these are the segments that were sampled each year.

| Segment | Macrohabitat | | | |
|---|---|---|---|---|
| | River bend | Secondary channel-connected | Secondary channel-non-connected | Tributary mouth |
| 3 | 15 | 16 | 1 | 0 |
| 5 | 15 | 24 | 6 | 0 |
| **7** | 15 | 20 | 12 | 11 |
| **8** | 15 | 25 | 16 | 12 |
| 9 | 15 | 24 | 16 | 3 |
| **10** | 15 | 15 | 10 | 2 |
| **12** | 15 | 16 | 12 | 8 |
| **14** | 15 | 20 | 7 | 12 |
| **15** | 15 | 25 | 8 | 13 |
| *17* | 15 | 1 | 0 | 17 |
| *19* | 15 | 6 | 0 | 16 |
| *22* | 15 | 2 | 4 | 19 |
| *23* | 15 | 15 | 1 | 17 |
| *25* | 15 | 25 | 1 | 19 |
| *27* | 15 | 25 | 15 | 11 |
| Total | 225 | 259 | 109 | 160 |

Comparing relative fish abundance among segments was one of the key analytical approaches of this study. We planned 22 segment contrasts that seemed to relate to management of the river system (Table 6). The 22 contrasts address four basic questions and relate to working hypotheses. The first is "Do fish catches differ among zones?" Because some segments within zones were possibly unique, contrasts were planned to partition the LA zone into its Missouri River and Yellowstone River segments, and the IR zone into Segment **15** and other segments. Three other contrasts concerning basic questions relating to working hypotheses in differences in fish catch were:

above and below the confluence of the Yellowstone River?
upstream and downstream of reservoirs?
upstream and downstream of Kansas City?

Table 6. Summary of planned segment contrasts for catch of benthic fishes. For each contrast the question asked was: is there a statistically significant difference between mean catch-per-unit-effort between or among the segments groupings? Least-altered (LA) segments are underlined, **inter-reservoir (IR) segments** are in bold, and *channelized segments (CH)* are in italics. MOR = Missouri River, YSR = Yellowstone River; segments are in the Missouri River unless indicated otherwise.

| Contrast ID | Segments contrasted | Description of segments grouped and contrast |
|---|---|---|
| Upper Missouri River - lower Yellowstone River comparisons | | |
| A | 3, 5 vs. 9 | Least-altered MOR vs. least-altered lower YSR (MOR LA zone vs. YSR LA zone) |
| B | 3, 5 vs. **7**, **8** | Least-altered MOR vs. **inter-reservoir** MOR below Fort Peck Dam to YSR (MOR LA zone vs. FTP IR zone) |
| C | 9 vs. **7**, **8** | Least-altered lower YSR vs. **inter-reservoir** MOR below Fort Peck Dam to YSR (YSR LA zone vs. FTP IR zone) |
| 3 zones comparisons | | |
| D | 3, 5,9 , vs. **7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27* | Least-altered zone segments vs. **inter-reservoir** zone segments vs. *channelized* zone segments (LA zone vs. IR zone vs. CH zone) |
| Inter-reservoir comparisons | | |
| E | 5 vs. **7** | Least-altered above Fort Peck Lake (Sturgeon Island to Beauchamp Coulee) vs. **inter-reservoir** below Fort Peck Dam to Milk River (AFTP LA zone vs. BFTP IR zone) |
| F | **8** vs. **10** | **Inter-reservoir** MOR below Wolf Point to YSR vs. **inter-reservoir** MOR from YSR to Lake Sakakawea headwaters, (BWFP IR zone vs. ASAK IR zone) |
| G | **10** vs. **12** | **Inter-reservoir** MOR from YSR to Lake Sakakawea headwaters vs. **inter-reservoir**, Garrison Dam to Lake Oahe headwaters (ASAK IR zone vs. BSAK IR zone) |
| H | **14** vs. **15** | **Inter-reservoir,** Fort Randall Dam - Lewis and Clark Lake headwaters vs. **inter-reservoir,** Gavins Point Dam-Ponca (AL&C IR zone vs. BL&C IR zone) |
| I | **15** vs. *17* | **Inter-reservoir,** Gavins Point Dam-Ponca vs. first *channelized* river segment, Big Sioux River-Little Sioux River (BL&C IR zone vs. 1ST CHAN) |
| Intra-zone comparisons | | |
| J | 3, 5, vs. 9, vs. **7**, **8**, **10**, **12**, **14**, vs. **15** vs. *17*, *19*, *22*, *23*, *25*, *27* | Least-altered MOR segments vs. least-altered lower YSR segments vs. **inter-reservoir** segments above Gavins Point Dam vs. **inter-reservoir** segment below Gavins Point Dam vs. *channelized* zone segments (MOR LA zone vs. YSR LA zone vs. IR zone vs. BL&C IR zone vs. CH zone) |
| Channelized river comparisons | | |
| K | *17*, *19*, *22* vs. *23*, *25*, *27* | *Channelized*, Big Sioux River to Kansas City vs. *channelized* , Kansas City to mouth (AKC CH vs. BKC CH) |

***Data Management***

Data were recorded on three data sheets - habitat data, fish field data, and laboratory fish data - as described in detail in Volume 1. Barcodes on each data sheet linked the three sheets and facilitated data entry and management. A collection was defined as a sampling venture consisting of a unique combination of location, time, and sampling gear. Data sheets were sent to the quality control officer and statistician, who managed data entry into an electronic database and developed a usable data set based on the reasonableness of each value (Sappington et al. 2005).

***Statistical Analyses***

Fish distribution was reported as total catch in each segment. Relative abundance for each benthic species was calculated as the proportion of that species in the total catch of benthic species (x 100). Relative abundance data were used to test for similarities of the benthic fishes assemblage among segments by using Morisita's index as follows:

$$C_H = \frac{2 \sum X_{ij} X_{ik}}{[\sum X^2_{ij}/N^2_j) + \sum X^2_{ik}/N^2_k)]N_j N_k}$$

Where: $C_H$ = Simplified Morisita Index of Simplicity (Horn 1966).

$X_{ij}$, $X_{ik}$ = Number of individuals of species $i$ in sample $j$ and sample $k$

$N_j = \sum X_{ij}$ = Total number of individuals in sample $j$

$N_k = \sum X_{ik}$ = Total number of individuals in sample $k$

The Morisita Index ranges from zero (no similarity) to slightly greater than one (high similarity).

The C/E data were used for analyses of segment contrasts, but data were filtered to acquire the most meaningful biological information from the data. We used filters to determine which data would be analyzed. As a coarse filter, we eliminated four species from the analysis. No analyses were done for pallid sturgeon since only four fish were collected. Likewise, no analyses were done on Hybognathus spp. (i.e., brassy minnow, plains minnow, and western silvery minnow) due to difficulties in identifying these fishes. Also, some patterns in the data were obvious and did not require statistics in order to justify their discussion. For example, the fact that burbot catches were zero in Segments *17-27* does not require any statistics to conclude that catches in the LA zone were higher than those in the CH zone.

For the remaining species, a series of criteria were applied to the data to provide a consistent decision process on how to proceed with the statistical analysis of the data for each species. These criteria were designed to apply parametric statistics by providing a set of data that adequately met (or met through transformation) the assumptions of normality and homogeneity of variance associated with parametric statistics.

Other filters related to the amount of the catch by gear, segment, or year. This second set of criteria were:

1. Data for a year, segment, or macrohabitat were used if one fish of a species was collected in a year, segment, or macrohabitat. This allowed inclusion of all years, but excluded SCNs for blue sucker. When a species was absent, the segment was excluded from the analysis for that species.
2. Data from a <u>gear</u> were not used if the catch was <5% of the total catch for that species. For example, burbot catches were 3, 9, 4, and 0 respectively for seine, trawl, trammel net, and gillnet; values were <5% of the total catch of 220 burbot, so these gears were excluded from analyses of burbot catches.
3. Data were included if the catch by <u>species</u> in a year by one gear was >10% of the total number of fish collected for that species over all years by that gear.
4. Data were included if catch in a <u>segment</u> by a gear was >2% of the total number of fish collected for that species and gear over all segments.
5. Data were included if the catch in a <u>macrohabitat</u> by a gear was >5% of the total number of fish collected for that species and gear over all macrohabitats.

It is important to reiterate that a low catch eliminated some data from statistical analysis. Low (no) catch could have been an indication that the species was limited by natural factors (i.e., native range) or manmade changes in habitat in each zone or segment. Less likely explanations for low catch are 1) because gears were not deployed correctly (e.g., time, location, depth) or 2) fish were not present because of seasonal migratory patterns.

The data that resulted from the application of the above criteria were used to analyze C/E data for year, zone, segment, and macrohabitat effects. Our primary interest was in zone and segment effects. Our study was limited to summer months and at most the macrohabitat data are relevant only for that time period. We assumed that all macrohabitats would be used during the life of the fish and during all seasons.

Before any statistical analysis could be conducted, the raw data had to be collapsed to the within year, within segment, and within macrohabitat levels by

averaging. The structure of data collection in any macrohabitat was one of multiple gear subsamples within each of a set of multiple gears that were deployed within each of a set of multiple mesohabitats in that macrohabitat.

The varying numbers of subsamples collected at the gear, mesohabitat, and macrohabitat level necessitated the use of a hierarchical approach for calculating means. Averaging was conducted in a hierarchical order, so that each subsample had the appropriate level of influence on the resulting means. In this hierarchical process we first calculated the mean for each gear deployed within a mesohabitat subsample. The gear means were then averaged within each mesohabitat subsample. We then averaged mesohabitat means within each macrohabitat sample to produce a macrohabitat mean.

After producing the macrohabitat means, ISB, OSB, and CHXO means were averaged per replicate to produce a macrohabitat mean for BEND to replace the three separate means. The averaging of the three BEND macrohabitats into one mean was necessary because they were not selected independently of each other (i.e., all three were sampled at each bend). It is this final set of macrohabitat means (i.e., one of each BEND, TRM, SCC, and SCN) that was used in statistical analyses.

The macrohabitat means for each habitat variable were then analyzed for constancy and normality of errors variance using SAS/LAB software as part of SAS (SAS 1992). The SAS/LAB software tested constancy of variance of residuals from the three-way analysis of variance (ANOVA) model (i.e., year, segment, macrohabitat) with two-way and three-way interactions using chi-square goodness of fit test between predicted and residual values. The SAS/LAB software suggested transformations as necessary to obtain constant variance.

Analysis of variance was used to test for differences in the response variable (i.e., C/E) among independent variables (e.g., zone, segment) at alpha = 0.05 (Bonferroni-adjusted alphas were used for multiple comparisons). A usual result was that catches from only one or two gears were sufficient for analysis. For each gear, as many as three ANOVAs were performed that combined different levels of year, segment, and macrohabitat data based on which factor was the primary focus. A macrohabitat was excluded if it was not sampled in a segment of interest in order to preserve that segment data for analyses.

Various levels of analyses were done based on the number of zero catch values and whether or not normality and homogeneity of variance assumptions could be met. One analysis level was termed "replicate" when there were limited zeros for macrohabitat replicates (this level provided the highest N). The second analysis level was termed "macrohabitats" when zeros forced us to average macrohabitat replicates, thus loosing power (N). We used results from the ANOVA that provided the most information based on the number of segments, macrohabitats, and years included in the analysis.

Segments were combined to make a series of planned contrasts (Table 6). The segment contrasts were planned to address questions that were determined to be most important. Examples are: differences among the LA zone segments (Contrasts A, B, C in Table 6), differences among zones (contrasts D, J), differences among the IR zone segments (contrasts E, F, G, H, I), and differences among the CH zone segments up and downstream from Kansas City.

Other analyses were used to investigate the association between catch and physical habitat category (e.g., depth, velocity, substrate). The relation between total catch over all years to categories of each physical habitat variable was presented as a bar chart, as was done for each individual year in annual reports (Dieterman et al. 1997, Young et al. 1998). Following Wildhaber et al. (2000) data were also analyzed using one-way ANOVA of presence/absence as the independent variable. We then used stepwise multiple logistic regression without year, segment, and macrohabitat main effects to determine which habitat variables were related to fish presence. We relied on $R^2$ values to show the value of the model, but also report AIC values for the intercept only and full models. Finally, we calculated correlations between habitat covariates (e.g., velocity and percent silt). To summarize the fish-habitat association information, we used ordination methods in CANOCO (ter Braak 1998). We used partial canonical correspondence analysis (PCCA) of species with segments and macrohabitats, and canonical correspondence analysis (CCA) of species with transformed environmental variables. We also show correlation plots of transformed environmental variables with macrohabitat and segment PCCA ordination results.

## RESULTS

We caught 134,163 fish over the three years of the study (Table A1-2). This total includes all specimens of 1) benthic fishes species, 2) other fishes collected, 3) hybrids, 4) specimens identified only to family or genus, 5) unidentified larvae and young-of-the-year, and 6) all fish captured in Segments 4, **6**, *18*, and *21* that were only sampled in 1996. Total catch by year was as follows:

| Year of study (Appendix Table) | Total catch |
|---|---|
| 1996 (Table A1-3) | 27,443 |
| 1997 (Table A1-4) | 56,186 |
| 1998 (Table A1-5) | 50,534 |

The increased catch after 1996 was due to a change in SOPs that produced more effort with seines, electrofishing, and gill netting.

### Mainstem Missouri River Fish Community

We identified 113,997 fishes of 106 species (Table 7). Twelve species that had not been reported for the mainstem Missouri River were:

| | | |
|---|---|---|
| spotted gar | threadfin shad | grass pickerel |
| bullhead minnow | river redhorse | slender madtom |
| Chinook salmon | yellow bass | logperch |
| lake whitefish | muskellunge | striped bass |

These species may have been found by others, but were not included in the overview publications that we reviewed (Table 2). On the other hand, 30 species have been reported by others that were not captured during our survey (Table 2):

| Family | Species not collected in 1996-1998 |
|---|---|
| Petromyzontidae: | silver lamprey |
| Hiodontidae: | mooneye |
| Anguillidae: | American eel |
| Clupeidae: | Alabama shad |
| Cyprinidae: | Utah chub, finescale dace, silver chub, gravel chub, rosyface shiner, redfin shiner, striped shiner, silver carp, channel shiner, central stoneroller, blacknose dace |
| Catostomidae: | black buffalo, mountain sucker |
| Salmonidae: | cutthroat trout, brook trout, coho salmon, Mt. whitefish |
| Cyprinodontidae: | blackstripe topminnow, plains killifish, plains topminnow |
| Centrarchidae: | warmouth, pumpkinseed sunfish, redear sunfish |
| Percidae: | slenderhead darter, Iowa darter, Ozark logperch |

### Species Presence and Distribution

We sampled fish in the same 15 study segments each year of the study (Table 7). Number of species generally increased in the downstream direction (Figure 3A). Total catch was lowest in IR segments **7**, **8**, and **10**, and highest in LA segment 9 and CH segments *15* and *27* (Figure 3B). Trends apparent in this figure are supported by other data, but it is inappropriate to use total catch numbers to compare segments and zones because there were differences among segments in the number of macrohabitats sampled, except BENDS (Table 5). In Segments **15** and *27*, catches of gizzard shad and emerald shiner accounted for about half of the total catch.

Here we present results in three categories: 1) 26 species in the benthic assemblage, 2) 16 non-indigenous species (includes common carp), and 3) 65 other species.

#### *Benthic Fishes Assemblage*

We caught 77,196 identifiable benthic fishes representing all species of the assemblage that was the focus of our investigation (Table 8). Total catch of benthic fishes (Figure 4) was highest in LA Segments 5 and 9 and generally lower in most IR segments (except Segment **15**) than in other segments. Total catch declined between Segments **15** and *17* and then gradually increased downriver. Sampling effort was the same in each segment for BENDS but not for other macrohabitats, so total catch data show only general trends. Thirteen species had wide distributions that were important to our experimental design for river-wide comparisons. Certain zone and segment contrasts were possible with other species that had lower total catch or were not as widely distributed.

Relative abundance (Table 9) was highest for emerald shiner (24.6% of benthic fishes assemblage), followed by flathead chub (13.3%), river carp sucker (9.4%) and channel catfish (9%). The proportion of each species was dissimilar among zones (Figure 5A). The assemblages in the LA and CH zones were similar among segments (Morisita's Index about 0.75) whereas the assemblages in the IR zone segments were dissimilar (Morisita's Index = 0.3). The range of Morisita's Indices was much wider in the IR zone, with Segment **12** indicating that the assemblage there was unlike that in other segments (Figure 5B).

We caught the three species that are considered rare (Galat et al. 2005): four endangered pallid sturgeon, 2,044 sturgeon chubs, and 704 sicklefin chubs. Each was found in all three zones. Of the eight benthic species categorized as prey species, the highest total catch was for the emerald shiner, which made up 24.6 % of benthic assemblage and 15% of all fishes sampled (Table A1-6), followed by river carpsucker (9.4%

Table 7. Total number of identifiable fish from 15 segments. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10 -15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Common name | *Scientific name* | Missouri River Segment | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | |
| Banded killifish | *Fundulus diaphanus* | | | | | | | 4 | | | | | | | | | 4 |
| Bigeye shiner | *Notropis boops* | | | | | | | | | | | | 1 | | | 4 | 5 |
| Bighead carp | *Hypopthalmichthys nobilis* | | | | | | | | | | | 1 | 3 | 1 | 2 | 12 | 19 |
| Bigmouth buffalo | *Ictiobus cyprinellus* | | 3 | 7 | 102 | 4 | 299 | 34 | 6 | 23 | 19 | 9 | 3 | 1 | 6 | 1 | 517 |
| Bigmouth shiner | *Notropis dorsalis* | | | | | | | | | 68 | 17 | | 2 | | 15 | 6 | 108 |
| Black buffalo | *Ictiobus niger* | | | | | | | | | | | | | 2 | | | 2 |
| Black bullhead | *Ameiurus melas* | | | | | 2 | 5 | 1 | 5 | | 2 | | | | | | 15 |
| Black crappie | *Pomoxis nigromaculatus* | 9 | 137 | | | | 3 | 2 | 17 | 10 | 2 | 4 | 7 | 1 | 6 | | 198 |
| Blue catfish | *Ictalurus furcatus* | | | | | | | | | | | 1 | 79 | 92 | 109 | 101 | 382 |
| Blue sucker | *Cycleptus elongatus* | 8 | 7 | 8 | 6 | 11 | 1 | 4 | | 36 | 53 | 9 | 19 | 24 | 1 | 6 | 193 |
| Bluegill | *Lepomis macrochirus* | | | | | | | 1 | 103 | 39 | 32 | 14 | 87 | 89 | 187 | 115 | 667 |
| Bluntnose minnow | *Pimephales notatus* | | | | | | | | 3 | 1 | | | | | 15 | 23 | 42 |
| Bowfin | *Amia calva* | | | | | | | | | | | | | | | 1 | 1 |
| Brassy minnow | *Hybognathus hankinsoni* | | | | | | | | 2 | 82 | 3 | 55 | | | | | 142 |
| Brook silverside | *Labidesthes sicculus* | | | | | | | | | | | 7 | | | 8 | 1 | 16 |
| Brook stickleback | *Culaea inconstans* | | | | 1 | | | 1 | | | | | | | | | 2 |
| Brown trout | *Salmo trutta* | | 1 | | | | | | | | | | | | | | 1 |
| Bullhead minnow | *Pimephales vigilax* | | | | | | | | | | | | 3 | 4 | 1 | 3 | 11 |
| Burbot | *Lota lota* | 11 | 113 | 4 | 5 | 18 | 63 | 4 | 1 | 1 | | | | | | | 220 |
| Channel catfish | *Ictalurus punctatus* | 60 | 196 | 62 | 78 | 526 | 148 | 29 | 403 | 257 | 551 | 334 | 733 | 846 | 569 | 709 | 5501 |
| Chestnut lamprey | *Ichthyomyzon castaneus* | | | | | | | | | | | | | | 2 | | 2 |
| Chinook salmon | *Oncorhynchus tshawytscha* | | | 1 | | | | | | | | | | | | | 1 |
| Cisco | *Coregonus artedi* | 1 | | 7 | | | | 5 | | | | | | | | | 13 |
| Common carp | *Cyprinus carpio* | 132 | 157 | 102 | 282 | 164 | 352 | 97 | 234 | 413 | 108 | 152 | 162 | 160 | 208 | 241 | 2964 |
| Common shiner | *Luxilus cornutus* | | | | | | | | | | | | | | | 2 | 2 |
| Creek chub | *Semotilus atromaculatus* | | | 5 | 30 | 29 | | 1 | | | | | 2 | | | | 67 |
| Emerald shiner | *Notropis atherinoides* | 1277 | 2502 | 84 | 41 | 623 | 104 | 7 | 1137 | 4965 | 544 | 2322 | 1201 | 1113 | 2594 | 1470 | 19984 |
| Fathead minnow | *Pimephales promelas* | 1 | | 201 | 66 | 94 | 6 | 317 | 8 | 8 | 12 | 13 | 4 | 2 | 1 | 1 | 734 |
| Flathead catfish | *Pylodictus olivaris* | | | | | | | | 3 | 133 | 130 | 298 | 163 | 210 | 145 | 188 | 1270 |

| Common name | *Scientific name* | Missouri River Segment | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | |
| Flathead chub | *Platygobio gracilis* | 3015 | 2322 | 170 | 868 | 5487 | 804 | | 10 | 7 | 1 | 1 | 4 | 5 | 2 | 2 | 12698 |
| Freckled madtom | *Noturus nocturnus* | | | | | | | | | | | | | | | 8 | 8 |
| Freshwater drum | *Aplodinotus grunniens* | 129 | 121 | 10 | 16 | 23 | 23 | | 47 | 374 | 130 | 321 | 528 | 303 | 360 | 347 | 2732 |
| Ghost shiner * | *Notropis buchanani* | | | | | | | | | | | | 1 | | | 1 | 2 |
| Gizzard shad | *Dorosoma cepedianum* | | | | | | | | 174 | 4360 | 2469 | 2330 | 5026 | 1887 | 2048 | 6886 | 25180 |
| Golden redhorse | *Moxostoma erythrurum* | | | | | | | | | | 1 | | 2 | 14 | | | 17 |
| Golden shiner | *Notemigonus crysoleucas* | | | | | | 4 | 1 | 1 | 55 | | 1 | | | | | 66 |
| Goldeye | *Hiodon alosoides* | 136 | 327 | 445 | 774 | 606 | 452 | 61 | 56 | 188 | 319 | 112 | 68 | 77 | 132 | 83 | 3836 |
| Goldfish | *Carassius auratus* | | | | | | | | | | | | 3 | 2 | | | 5 |
| Grass carp | *Ctenopharyngodon idella* | | | | | | | | | 6 | 1 | 3 | 1 | 1 | 2 | 2 | 16 |
| Grass pickerel | *Esox amer. vermiculatus* | | | | | | | | | 1 | | | | | | | 1 |
| Green sunfish | *Lepomis cyanellus* | | | | | 7 | 1 | | 11 | 16 | 2 | 4 | 65 | 64 | 13 | 21 | 204 |
| Highfin carpsucker | *Carpiodes velifer* | | | | | | | | | 1 | | | 1 | | 1 | 2 | 5 |
| Johnny darter | *Etheostoma nigrum* | | | | | | | 20 | 80 | 22 | 4 | 3 | | | | 1 | 130 |
| Lake chub | *Couesius plumbeus* | 1 | | | | | | | | | | | | | | | 1 |
| Lake sturgeon | *Acipenser fulvescens* | | | | | | | | | | | | | | 4 | 1 | 5 |
| Lake whitefish | *Coregonus clupeaformis* | | | | 2 | | | | | | | | | | | | 2 |
| Largemouth bass | *Micropterus salmoides* | | | | | | | | 164 | 46 | 22 | 8 | 30 | 13 | 28 | 3 | 314 |
| Largescale stoneroller | *Campostoma oligolepis* | | | | | | | | | | | | | | 2 | 2 | 4 |
| Logperch | *Percina caprodes* | | | | | | | | | | | | | 1 | 4 | | 5 |
| Longear sunfish | *Lepomis megalotis* | | | | | | | | | | | | | | 1 | | 1 |
| Longnose dace | *Rhinichthys cataractae* | 113 | 89 | 10 | 13 | 217 | 5 | | | | | | | | | | 447 |
| Longnose gar | *Lepisosteus osseus* | | | | | | | | | 38 | 7 | 5 | 28 | 23 | 43 | 36 | 180 |
| Longnose sucker | *Catostomus catostomus* | 150 | 21 | 39 | 14 | 8 | 7 | 4734 | | | | | | | | | 4973 |
| Mottled sculpin | *Cottus bairdi* | 7 | 6 | | | | | | | | | | | | | | 13 |
| Mimic shiner | *Notropis volucellus* | | | | | | | | 1 | 4 | 2 | | 3 | | | 90 | 100 |
| Muskellunge | *Esox masquinongy* | | | | | | | 1 | | | | | | | | | 1 |
| Northern hog sucker | *Hypentelium nigricans* | | | | | | | | | | 1 | | | | | | 1 |
| Northern pike | *Esox lucius* | 13 | 38 | 58 | 60 | 44 | 86 | 12 | 17 | 17 | 4 | 3 | | | 1 | | 353 |
| Northern redbelly dace | *Phoxinus eos* | | | 1 | | | | | | | | | | | | | 1 |
| Orangespotted sunfish | *Lepomis humilis* | | | | | | | | | 4 | | 2 | 79 | 12 | 5 | 18 | 120 |

| Common name | *Scientific name* | Missouri River Segment | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | |
| Paddlefish | *Polyodon spathula* | | | | 1 | | 1 | | 1 | 2 | 2 | 2 | | 1 | 2 | 3 | 15 |
| Pallid sturgeon | *Scaphirhynchus albus* | | | | | 2 | 1 | | | | | | 1 | | | | 4 |
| Pearl dace | *Margariscus margarita* | | | | | 1 | | | | | | | | | | | 1 |
| Plains minnow | *Hybognathus placitus* | | | 2 | | | 23 | | | | | 12 | | | 14 | 6 | 57 |
| Quillback | *Carpiodes cyprinus* | | | | | | | | 42 | 1875 | 11 | 4 | 9 | 11 | 3 | 6 | 1961 |
| Rainbow smelt | *Osmerus mordax* | | | | | | | 19 | 1 | 1 | | | | | 1 | | 22 |
| Rainbow trout | *Oncorhynchus mykiss* | 1 | | 14 | | | | | | | | | | | | | 15 |
| Red shiner | *Cyprinella lutrensis* | | | | | | | 4 | 55 | 254 | 81 | 19 | 95 | 144 | 272 | 1436 | 2360 |
| Rock bass | *Ambloplites rupestris* | | | | | | | | 13 | 9 | | | | | | | 22 |
| River carpsucker | *Carpiodes carpio* | 58 | 129 | 387 | 232 | 1164 | 58 | 60 | 212 | 516 | 256 | 716 | 234 | 142 | 1397 | 1069 | 6630 |
| River redhorse | *Moxostoma carinatum* | | | | | | | | | | 1 | | 1 | | | | 2 |
| River shiner | *Notropis blennius* | | | | | | | | 23 | 200 | 180 | 144 | 89 | 77 | 105 | 30 | 848 |
| Sand shiner | *Notropis stramineus* | | | | | | | 1 | 12 | 383 | 56 | 4 | 19 | 11 | 38 | 166 | 690 |
| Sauger | *Sander canadense* | 53 | 106 | 24 | 47 | 68 | 55 | 5 | 21 | 79 | 31 | 26 | 37 | 17 | 21 | 6 | 596 |
| Shorthead redhorse | *Moxostoma macrolepidotum* | 357 | 226 | 30 | 125 | 69 | 18 | 22 | 22 | 237 | 44 | | | 8 | 5 | 6 | 1169 |
| Shortnose gar | *Lepisosteus platostomus* | | | | 1 | 1 | | | 9 | 44 | 30 | 58 | 105 | 125 | 93 | 138 | 604 |
| Shovelnose sturgeon | *Scaphirhynchus platorynchus* | 31 | 123 | 100 | 51 | 253 | 63 | 50 | 17 | 62 | 103 | 70 | 190 | 218 | 126 | 58 | 1515 |
| Sicklefin chub | *Macrhybopsis meeki* | | 267 | | 81 | 124 | 70 | | | 1 | | 1 | 9 | 6 | 70 | 75 | 704 |
| Silver chub | *Macrhybopsis storeriana* | | | | | | | | 8 | 1 | 13 | 49 | 158 | 55 | 37 | 66 | 387 |
| Silverband shiner | *Notropis shumardi* | | | | | | | | | | | | 1 | | | 1 | 2 |
| Skipjack herring | *Alosa chrysochloris* | | | | | | | | | | | | | 1 | 4 | 5 | 10 |
| Slender madtom | *Noturus exilis* | | | | | | | | | | | | 1 | | | | 1 |
| Smallmouth bass | *Micropterus dolomieu* | 2 | | | 2 | 1 | | 19 | 147 | 230 | 5 | | | | | | 406 |
| Smallmouth buffalo | *Ictiobus bubalus* | 27 | 9 | 34 | 43 | 21 | 110 | 1 | 17 | 97 | 14 | 10 | 12 | 16 | 25 | 47 | 483 |
| Speckled chub | *Macrhybopsis aestivalis* | | | | | | | | | | | 43 | | 24 | 61 | 191 | 319 |
| Spotfin shiner | *Cyprinella spiloptera* | | | | | | | | 718 | 768 | 144 | 114 | 1 | 2 | | | 1747 |
| Spottail shiner | *Notropis hudsonius* | 46 | 170 | 17 | 62 | 35 | 20 | 4 | 3 | 13 | 2 | | | | | | 372 |
| Spotted bass | *Micropterus punctulatus* | | | | | | | | | | | | | 3 | 36 | 19 | 58 |
| Spotted gar | *Lepisosteus oculatus* | | | | | | | | | | | | | | 1 | | |
| Stonecat | *Noturus flavus* | 9 | 92 | 5 | 28 | 140 | 34 | | 4 | 4 | 1 | 1 | 6 | 6 | 2 | 9 | 341 |
| Striped bass | *Morone saxatilis* | | | | | | | | | | | | | 1 | 6 | 14 | 21 |

| Common name | *Scientific name* | Missouri River Segment | | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | |
| Striped shiner | *Luxilus chrysocephalus* | | | | | | | | | | | | | | | 1 | 1 |
| Sturgeon chub | *Macrhybopsis gelida* | 1 | 577 | 28 | 125 | 1228 | 32 | | | | 4 | 7 | 12 | 16 | 10 | 4 | 2044 |
| Suckermouth minnow | *Phenacobius mirabilis* | | | | | | | | | | | | | 4 | 2 | 4 | 10 |
| Tadpole madtom | *Noturus gyrinus* | | | | | | | | | | | | 1 | | | | 1 |
| Threadfin shad | *Dorosoma petenense* | | | | | | | | | | 1 | | | | | | 1 |
| Walleye | *Sander vitreum* | 28 | 41 | 8 | 79 | 57 | 21 | 48 | 76 | 161 | 21 | 9 | 1 | 4 | 1 | 2 | 557 |
| Western mosquitofish | *Gambusia affinis* | | | | | | | | | | | | 3 | 16 | 29 | 179 | 227 |
| W. silvery minnow | *Hybognathus argyritis* | | | 8 | 2 | 5 | 356 | | | 1 | | 2 | | | | | 374 |
| White bass | *Morone chrysops* | | | | 3 | 8 | | 1 | 40 | 197 | 19 | 20 | 46 | 75 | 43 | 65 | 517 |
| White crappie | *Pomoxis annularis* | 23 | 69 | 3 | 66 | 52 | 229 | | 925 | 38 | 4 | 15 | 21 | 5 | 18 | 6 | 1474 |
| White perch | *Morone americana* | | | | | | | | | | | 1 | | | | | 1 |
| White sucker | *Catostomus commersoni* | 80 | 3 | 376 | 270 | 40 | 6 | 1362 | 6 | 2 | | | | | | | 2145 |
| Yellow bass | *Morone mississippiensis* | | | | | | | | | | | | | | 1 | 5 | 6 |
| Yellow bullhead | *Ameiurus natalis* | | | | | | 1 | | | | 1 | 3 | 1 | | | | 6 |
| | *Perca flavescens* | 2 | 58 | 13 | 26 | | 7 | 23 | 492 | 140 | 7 | | | | | | 768 |

*Shiner probably misidentified

Figure 3. Catch of identifiable fishes collected at 15 warm-water, riverine segments of the Missouri River from Montana (Segment 3) to Missouri (Segment *27*) in three zones. A. Number of species. B. Total number of fishes caught.

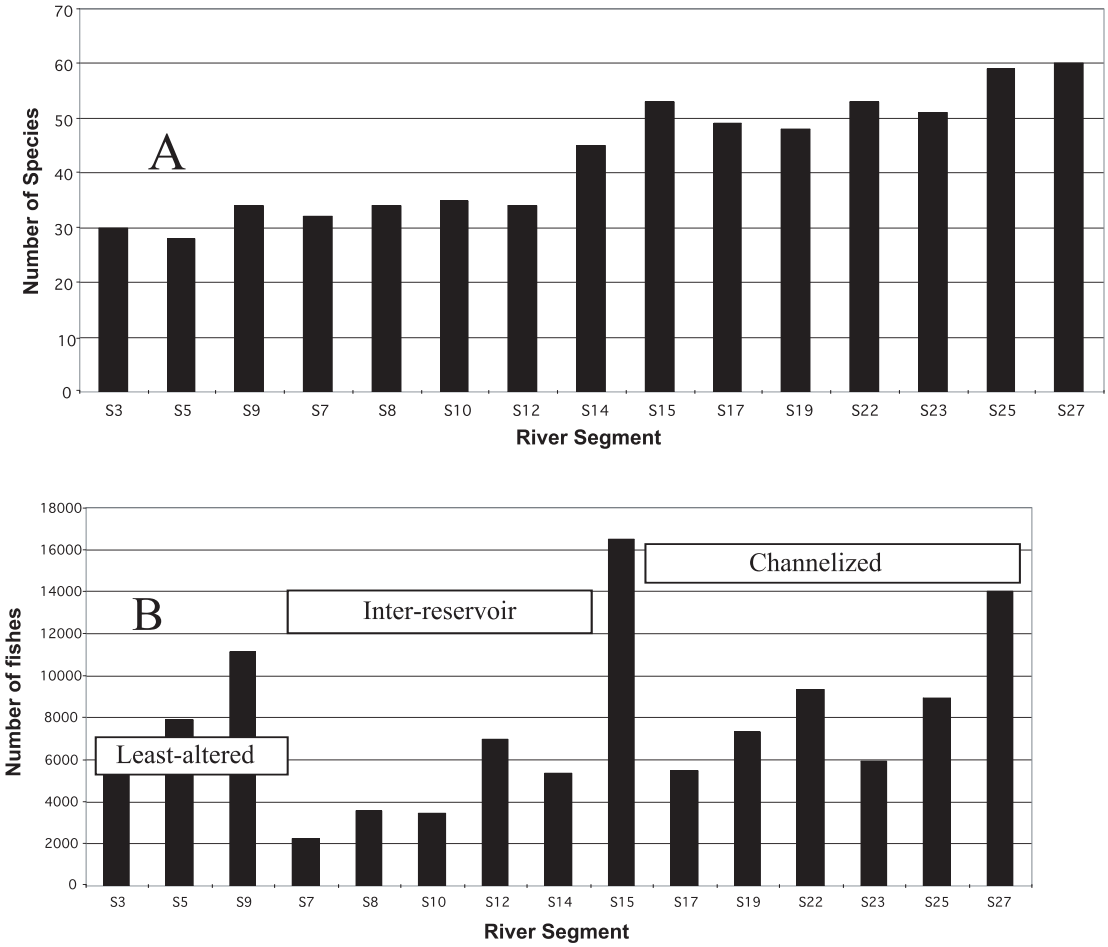



Figure 4. Total catch of 26 species of benthic fishes by segment. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8**, **10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

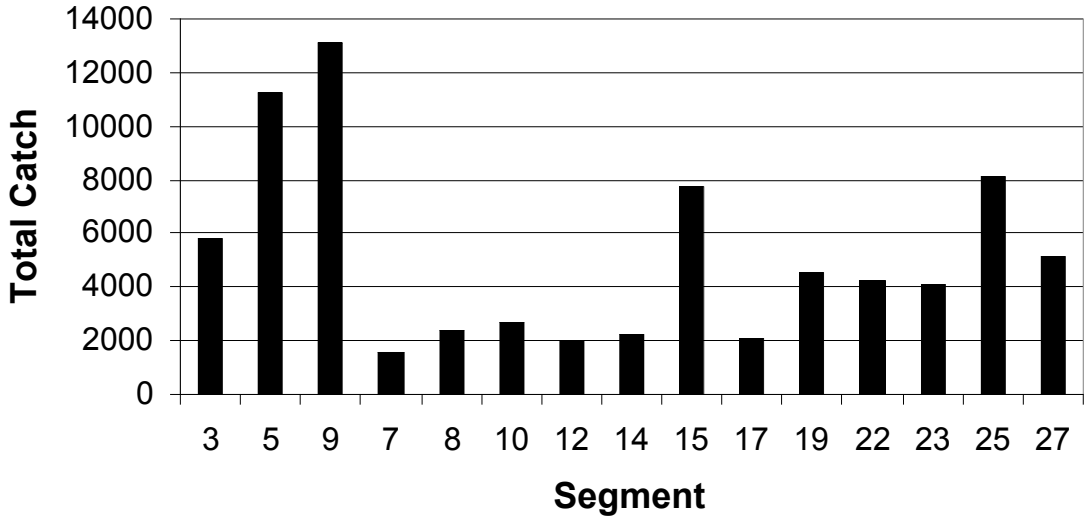


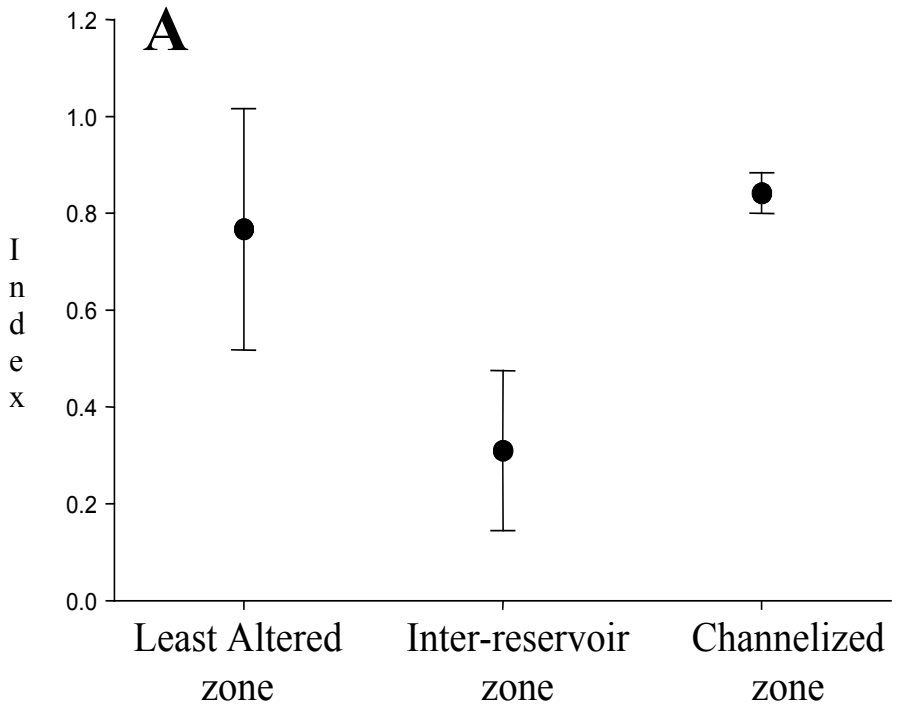
Table 8. Total number by species of the 77,169 fish in the benthic fishes assemblage collected in 15 segments of the Missouri River, 1996-1998. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

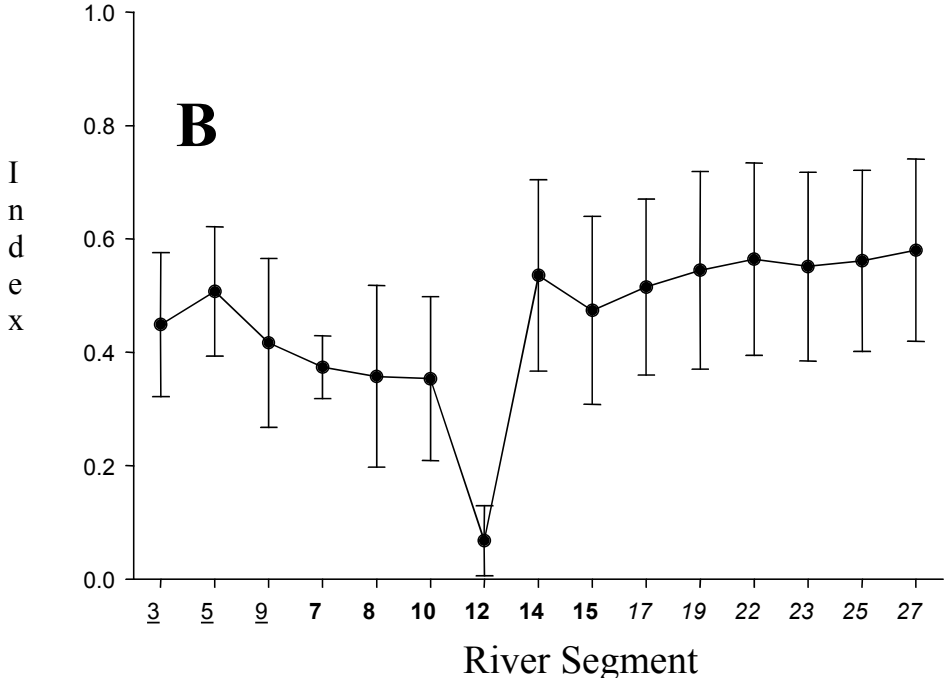
| Common and scientific name | | MT | MT | MT-Y | MT | MT | ND | ND | SD | SD | IA | IA-KA | MO | MO | MO | MO | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | 9 | **7** | **8** | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | |
| Bigmouth buffalo | *Ictiobus cyprinellus* | | 3 | 4 | 7 | 102 | 299 | 34 | 6 | 23 | 19 | 9 | 3 | 1 | 6 | 1 | 517 |
| Blue catfish | *Ictalurus furcatus* | | | | | | | | | | | 1 | 79 | 92 | 109 | 101 | 382 |
| Blue sucker | *Cycleptus elongatus* | 8 | 7 | 11 | 8 | 6 | 1 | 4 | | 36 | 53 | 9 | 19 | 24 | 1 | 6 | 193 |
| Burbot | *Lota lota* | 11 | 113 | 18 | 4 | 5 | 63 | 4 | 1 | 1 | | | | | | | 220 |
| Channel catfish | *Ictalurus punctatus* | 60 | 196 | 526 | 62 | 78 | 148 | 29 | 403 | 257 | 551 | 334 | 733 | 846 | 569 | 709 | 5501 |
| Common carp | *Cyprinus carpio* | 132 | 157 | 164 | 102 | 282 | 352 | 97 | 234 | 413 | 108 | 152 | 162 | 160 | 208 | 241 | 2964 |
| Emerald shiner | *Notropis atherinoides* | 1277 | 2502 | 623 | 84 | 41 | 104 | 7 | 1137 | 4965 | 544 | 2322 | 1201 | 1113 | 2594 | 1470 | 19984 |
| Flathead chub | *Platygobio gracilis* | 3015 | 2322 | 5487 | 170 | 868 | 804 | | 10 | 7 | 1 | 1 | 4 | 5 | 2 | 2 | 12698 |
| Flathead catfish | *Pylodictus olivaris* | | | | | | | | 3 | 133 | 130 | 298 | 163 | 210 | 145 | 188 | 1270 |
| Fathead minnow | *Pimephales promelas* | 1 | | 94 | 201 | 66 | 6 | 317 | 8 | 8 | 12 | 13 | 4 | 2 | 1 | 1 | 734 |
| Freshwater drum | *Aplodinotus grunniens* | 129 | 121 | 23 | 10 | 16 | 23 | | 47 | 374 | 130 | 321 | 528 | 303 | 360 | 347 | 2732 |
| Pallid sturgeon | *Scaphirhynchus albus* | | | 2 | | | 1 | | | | | | 1 | | | | 4 |
| River carpsucker | *Carpiodes carpio* | 58 | 129 | 1164 | 387 | 232 | 58 | 60 | 212 | 516 | 256 | 716 | 234 | 142 | 1397 | 1069 | 6630 |
| Sand shiner | *Notropis stramineus* | | | | | | | 1 | 12 | 383 | 56 | 4 | 19 | 11 | 38 | 166 | 690 |
| Sauger | *Sander canadense* | 53 | 106 | 68 | 24 | 47 | 55 | 5 | 21 | 79 | 31 | 26 | 37 | 17 | 21 | 6 | 596 |
| Shorth. redhorse | *Moxost. macrolepidotum* | 357 | 226 | 69 | 30 | 125 | 18 | 22 | 22 | 237 | 44 | | | 8 | 5 | 6 | 1169 |
| Shoveln. sturgeon | *Scaphirhyn. platorynchus* | 31 | 123 | 253 | 100 | 51 | 63 | 50 | 17 | 62 | 103 | 70 | 190 | 218 | 126 | 58 | 1515 |
| Sicklefin chub | *Macrhybopsis meeki* | | 267 | 124 | | 81 | 70 | | | 1 | | 1 | 9 | 6 | 70 | 75 | 704 |
| Sturgeon chub | *Macrhybopsis gelida* | 1 | 577 | 1228 | 28 | 125 | 32 | | | | 4 | 7 | 12 | 16 | 10 | 4 | 2044 |
| Smallmouth buffalo | *Ictiobus bubalus* | 27 | 9 | 21 | 34 | 43 | 110 | 1 | 17 | 97 | 14 | 10 | 12 | 16 | 25 | 47 | 483 |
| Stonecat | *Noturus flavus* | 9 | 92 | 140 | 5 | 28 | 34 | | 4 | 4 | 1 | 1 | 6 | 6 | 2 | 9 | 341 |
| Walleye | *Sander vitreum* | 28 | 41 | 57 | 8 | 79 | 21 | 48 | 76 | 161 | 21 | 9 | 1 | 4 | 1 | 2 | 557 |
| White sucker | *Catostomus commersoni* | 80 | 3 | 376 | 270 | 40 | 6 | 1362 | 6 | 2 | | | | | | | 2145 |
| Hybo. minnows | *Hybognathus spp.* | 518 | 4259 | 2648 | 38 | 34 | 3 | 0 | 5 | 1 | 23 | 227 | 828 | 931 | 2398 | 610 | 12523 |
| W. silvery min. | *H. argyritis* | | | 5 | 8 | 2 | 356 | | | 1 | | 2 | | | | | 374 |
| Plains min. | *H. placitus* | | | | 2 | | 23 | | | | | 12 | | | 14 | 6 | 57 |
| Brassy min. | *H. hankinsoni* | | | | | | | | 2 | 82 | 3 | 55 | | | | | 142 |

Table 9. Relative abundance of benthic fishes in 15 segments of the Missouri River, 1996-1998. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Species | 3 | 5 | 9 | **7** | **8** | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | Mean % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bigmouth buffalo | 0.00 | 0.03 | 0.05 | 6.12 | 0.18 | 13.17 | 1.67 | 0.27 | 0.30 | 0.90 | 0.20 | 0.07 | 0.02 | 0.07 | 0.02 | 1.54 |
| Blue catfish | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 1.86 | 2.23 | 1.35 | 1.97 | 0.50 |
| Blue sucker | 0.14 | 0.06 | 0.08 | 0.48 | 0.27 | 0.04 | 0.20 | 0.00 | 0.46 | 2.52 | 0.20 | 0.45 | 0.58 | 0.01 | 0.12 | 0.37 |
| Burbot | 0.19 | 1.00 | 0.14 | 0.24 | 0.22 | 2.77 | 0.20 | 0.04 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.32 |
| Channel catfish | 1.04 | 1.74 | 4.01 | 3.72 | 3.47 | 6.52 | 1.42 | 17.98 | 3.31 | 26.23 | 7.37 | 17.27 | 20.48 | 7.04 | 13.85 | 9.03 |
| Common carp | 2.28 | 1.40 | 1.25 | 6.12 | 12.53 | 15.50 | 4.75 | 10.44 | 5.32 | 5.14 | 3.35 | 3.82 | 3.87 | 2.57 | 4.71 | 5.54 |
| Emerald shiner | 22.04 | 22.23 | 4.75 | 5.04 | 1.82 | 4.58 | 0.34 | 50.74 | 63.98 | 25.89 | 51.25 | 28.29 | 26.94 | 32.07 | 28.72 | 24.58 |
| Flathead chub | 52.03 | 20.63 | 41.88 | 10.20 | 38.56 | 35.40 | 0.00 | 0.45 | 0.09 | 0.05 | 0.02 | 0.09 | 0.12 | 0.02 | 0.04 | 13.31 |
| Flathead catfish | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 1.71 | 6.19 | 6.58 | 3.84 | 5.08 | 1.79 | 3.67 | 1.93 |
| Fathead minnow | 0.02 | 0.00 | 0.72 | 12.06 | 2.93 | 0.26 | 15.53 | 0.36 | 0.10 | 0.57 | 0.29 | 0.09 | 0.05 | 0.01 | 0.02 | 2.20 |
| Freshwater drum | 2.23 | 1.08 | 0.18 | 0.60 | 0.71 | 1.01 | 0.00 | 2.10 | 4.82 | 6.19 | 7.08 | 12.44 | 7.33 | 4.45 | 6.78 | 3.80 |
| Pallid sturgeon | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.01 |
| River carpsucker | 1.00 | 1.15 | 8.88 | 23.22 | 10.31 | 2.55 | 2.94 | 9.46 | 6.65 | 12.18 | 15.80 | 5.51 | 3.44 | 17.27 | 20.89 | 9.42 |
| Sand shiner | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.54 | 4.94 | 2.67 | 0.09 | 0.45 | 0.27 | 0.47 | 3.24 | 0.85 |
| Sauger | 0.91 | 0.94 | 0.52 | 1.44 | 2.09 | 2.42 | 0.24 | 0.94 | 1.02 | 1.48 | 0.57 | 0.87 | 0.41 | 0.26 | 0.12 | 0.95 |
| Shorth. redhorse | 6.16 | 2.01 | 0.53 | 1.80 | 5.55 | 0.79 | 1.08 | 0.98 | 3.05 | 2.09 | 0.00 | 0.00 | 0.19 | 0.06 | 0.12 | 1.63 |
| Shoveln. sturgeon | 0.53 | 1.09 | 1.93 | 6.00 | 2.27 | 2.77 | 2.45 | 0.76 | 0.80 | 4.90 | 1.54 | 4.48 | 5.28 | 1.56 | 1.13 | 2.50 |
| Sicklefin chub | 0.00 | 2.37 | 0.95 | 0.00 | 3.60 | 3.08 | 0.00 | 0.00 | 0.01 | 0.00 | 0.02 | 0.21 | 0.15 | 0.87 | 1.47 | 0.85 |
| Sturgeon chub | 0.02 | 5.13 | 9.37 | 1.68 | 5.55 | 1.41 | 0.00 | 0.00 | 0.00 | 0.19 | 0.15 | 0.28 | 0.39 | 0.12 | 0.08 | 1.63 |
| Smallmouth buffalo | 0.47 | 0.08 | 0.16 | 2.04 | 1.91 | 4.84 | 0.05 | 0.76 | 1.25 | 0.67 | 0.22 | 0.28 | 0.39 | 0.31 | 0.92 | 0.96 |
| Stonecat | 0.16 | 0.82 | 1.07 | 0.30 | 1.24 | 1.50 | 0.00 | 0.18 | 0.05 | 0.05 | 0.02 | 0.14 | 0.15 | 0.02 | 0.18 | 0.39 |
| Walleye | 0.48 | 0.36 | 0.44 | 0.48 | 3.51 | 0.92 | 2.35 | 3.39 | 2.07 | 1.00 | 0.20 | 0.02 | 0.10 | 0.01 | 0.04 | 1.03 |
| White sucker | 1.38 | 0.03 | 2.87 | 16.20 | 1.78 | 0.26 | 66.73 | 0.27 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.97 |
| Hybo minnows | 8.94 | 37.85 | 20.21 | 2.28 | 1.51 | 0.13 | 0.00 | 0.22 | 0.01 | 1.09 | 5.01 | 19.51 | 22.54 | 29.65 | 11.92 | 10.72 |

Figure 5. Mean and 95% confidence interval for Morisita's index values for comparisons of the fish assemblage across zones (A) and segments (B) of the Missouri River. Higher mean indicates a more similar assemblage. The matrix table of Morisita values is appendix Table A1-9.



of benthic assemblage, 5% of fish community), and white sucker (6% of benthic assemblage). The group of *Hybognathus* minnow was also abundant (10.7% of benthic fishes).Other prey species (shorthead redhorse, fathead minnow, sand shiner, and stonecat) made up less than 1% of the catch each.

The seven recreational species in the benthic fishes assemblage group were common and widely distributed, except for the blue catfish, which was found only in five segments of the CH zone, and the burbot, which was not collected in the CH zone. Total catch of channel catfish was 5501 fish, compared to the total catch of 1270 flathead catfish. The catch of walleye (n = 557) and sauger (n = 596) was about the same. Freshwater drum (n = 2732) were found in all segments, except Segment **12**, and made up about 2% of the total catch of 106 species.

***Gear Selectivity***

Gear selectivity, defined as > 50% of the total catch by species, was obvious for certain species (Tables 10, 11). The bag seine accounted for about 50% of collected benthic fishes, whereas electrofishing accounted for about 37% (Table 10). The bag seine caught >71% of five species (e.g., flathead chub), whereas electrofishing caught >55% of six species (e.g., bigmouth buffalo). Together, these two gears produced >56% of the catch of nine species. Other gears were important in adequately sampling certain species. For example, the benthic trawl captured most of the blue catfish, stonecats, sicklefin chubs, and sturgeon chubs (Table 11). The drifting trammel net captured more shovelnose sturgeon than did all other gears combined. Also, about 47% of the blue suckers were caught in drifting trammel nets and 79% were caught in two gears (trammel nets, electrofishing).

Data on the catch of all species combined by gear type has little biological meaning, but are presented in Table 11 to illustrate some problems of statistical comparison of C/E among segments. Most fish were caught in the seine and by electrofishing, so data from these gears met analysis criteria often. When ISBs, OSBs, and CHXOs were combined to the variable "BEND" the segment catch criterion (>2%) was often met so BEND was usually included in an ANOVA for segment contrasts. In other cases, only the catch from one macrohabitat met the >5% total catch criterion for a particular gear type. For segments, many zero catches or catches that did not meet the >2% criterion eliminated some segments from the analysis. We always stipulate the gear, segment, and macrohabitat included in the ANOVA.

Following for each species are results of distribution, total catch, C/E by gear and macrohabitat, zone and segment contrasts of mean C/E, and physical habitat associations with total catch and fish presence and absence. The results for the blue catfish include a lengthy presentation about how the data were filtered for statistical analysis and a lengthy table of all results. For other species, we present only a summary table of significant results and include the lengthy ANOVA table in the Appendix.

***Blue Catfish***

Blue catfish ranged into the 850-900-mm size class (Figure 6). Total length of most fish in the sample was <150 mm. All fish were found in CH Segments *19-27* where C/E was highest in ISB and SCC macrohabitats with minor catches in all other macrohabitats (Table 12, Figure 7). For each benthic species, we provide the mean C/E data (Table 12) and show C/E as a bar chart for each macrohabitat (e.g., SCC), gear type (e.g., BT, benthic trawl), and segment (Figure 7). There were many zeros in the data, which are shown by open squares on each Figure (i.e., Figure 7 and other similar figures). We include <u>either the tabled data or the bar chart</u> in the results section depending on which enhances readability and understanding of the results; but for each species, the companion table or chart is in Appendix 2.

In the bar charts, we were usually able to report C/E on a scale of C/E < 1.0 on the y-axis. However, some species were caught at C/E > 1.0 in some gears, and we have adjusted the scale of the y-axis to accommodate, so some figures have mixed scales among the macrohabitat charts. For example, Figure 7 shows that all blue catfish were captured in the CH zone. The C/E data for blue catfish shows C/E values <1 (unit depends on gear) for TRM and other macrohabitats except SCCs where the C/E was >1.0 fish/haul for the seine. Seines and the benthic trawl were effective gears. More sampling gears contributed to the total catch in ISB and SCC macrohabitats than in other macrohabitats (Figure 7).

Using criteria applied to the capture data for each species (see Methods), we conducted statistical analyses (ANOVA) of segment effects and analyzed contrasts among groups of segments that were standard throughout the study. For the blue catfish, there was one instance of significant year effects (Table 13), but we do not discuss influences of year on the catch of any species. However, the results for year are in Appendix 3 for each species.

There was one significant macrohabitat effect (ANOVA 3, P = 0.005) among the three ANOVAs for the trawl data (Table 13). We were not primarily interested in macrohabitat effects since we assumed that most fish use one habitat or another depending on size

Table 10. Total catch of benthic fishes in each of five gear types used over three years, 1996-1998, in 15 segments of the Missouri River.

| Common name | Scientific name | Sampling gear | | | | |
|---|---|---|---|---|---|---|
| | | Seine[1] | Trawl[2] | Trammel[3] | Gill net[4] | Electro.[5] |
| Bigmouth buffalo | *Ictiobus cyprinellus* | 167 | 1 | 0 | 13 | 331 |
| Blue catfish | *Ictalurus furcatus* | 43 | 229 | 13 | 30 | 67 |
| Blue sucker | *Cycleptus elongatus* | 1 | 10 | 90 | 30 | 62 |
| Burbot | *Lota lota* | 3 | 9 | 4 | 0 | 204 |
| Channel catfish | *Ictalurus punctatus* | 1690 | 1387 | 296 | 761 | 1338 |
| Common carp | *Cyprinus carpio* | 326 | 13 | 51 | 253 | 2322 |
| Emerald shiner | *Notropis atherinoides* | 5835 | 16 | 0 | 0 | 14126 |
| Flathead chub | *Platygobio gracilis* | 10632 | 112 | 78 | 0 | 1876 |
| Flathead catfish | *Pylodictus olivaris* | 0 | 11 | 2 | 25 | 1236 |
| Fathead minnow | *Pimephales promelas* | 532 | 0 | 0 | 0 | 202 |
| Freshwater drum | *Aplodinotus grunniens* | 820 | 553 | 1 | 92 | 1266 |
| Pallid sturgeon | *Scaphirhynchus albus* | 0 | 2 | 2 | 0 | 0 |
| River carpsucker | *Carpiodes carpio* | 4761 | 12 | 54 | 508 | 1281 |
| Sand shiner | *Notropis stramineus* | 639 | 2 | 0 | 0 | 49 |
| Sauger | *Sander canadense* | 47 | 15 | 55 | 100 | 365 |
| Sicklefin chub | *Macrhybopsis meeki* | 20 | 684 | 0 | 0 | 0 |
| Shorthead redhorse | *Mox. macrolepidotum* | 264 | 7 | 114 | 80 | 689 |
| Shovel. sturgeon | *Scaph. platorynchus* | 4 | 152 | 973 | 355 | 8 |
| Smallmouth buffalo | *Ictiobus bubalus* | 131 | 1 | 23 | 98 | 216 |
| Stonecat | *Noturus flavus* | 9 | 261 | 5 | 3 | 63 |
| Sturgeon chub | *Macrhybopsis gelida* | 98 | 1939 | 0 | 0 | 7 |
| Walleye | *Sander vitreum* | 78 | 3 | 11 | 153 | 308 |
| White sucker | *Catostomus commersonii* | 2001 | 9 | 14 | 13 | 106 |
| Hybo. minnows | *Hybognathus spp.* | 10456 | 18 | 0 | 0 | 2050 |
| W. silvery minnow | *H. argyritis* | 339 | 5 | 0 | 0 | 30 |
| Plains minnow | *H. placitus* | 52 | 1 | 0 | 0 | 4 |
| Brassy minnow | *H. hankinsoni* | 84 | 1 | 0 | 0 | 57 |
| | Total | 39032 | 5453 | 1786 | 2514 | 28263 |
| | Percent | 50.7 | 7.1 | 2.3 | 3.3 | 36.7 |

[1]Bag seine used in ISB-bars, SCC, and SCN

[2]Benthic trawl used in ISB-border, CHXO, OSB, TRB-deep, SCC-deep

[3]Drifting trammel net used in ISB-border, CHXO, TRB-deep, SCC-deep

[4]Gill net used in ISB-pools, TRB-small, SCN

5 Electrofishing used in ISB-border, CHXO, TRB, SCN, SCC-deep

Table 11. List of gears showing selectivity (>50% of catch) for species in the benthic fishes assemblage. Percent of total for that species is in parenthesis.

| Seine | Trawl | Trammel | Electrofishing | Electrofishing & Seining |
|---|---|---|---|---|
| Flathead chub (84%) | Blue catfish (60%) | Shovelnose sturgeon (64%) | Smallmouth buffalo (64%) | Bigmouth buffalo (96%) |
| Sand shiner (92%) | Sicklefin chub (97%) | Blue sucker[1] (47%) | Burbot (93%) | Channel catfish[2] (56%) |
| Hybo. minnows (83%) | Stonecat (76%) | | Sauger[3] (62%) | Emerald shiner (99%) |
| River carpsucker (71%) | Sturgeon chub (95%) | | Walleye[3] (55%) | Fathead minnow (100%) |
| White sucker (93%) | | | Common carp (79%) | Freshwater drum (76%) |
| Fathead minnow (73%) | | | Flathead catfish (97%) | River carpsucker (91%) |
| | | | Shorthead redhorse (60%) | Shorthead redhorse (82%) |
| | | | | Smallmouth buffalo (72%) |
| | | | | Hybo. minnows (99%) |

[1] For the blue sucker, the trammel net and electrofishing gears accounted for 79% of the catch.
[2] The channel catfish were caught in substantial numbers in all gears; the least productive was the drifting trammel net that produced only 5% of the catch.
[3] Sauger and walleye were caught in all gears, but the combination of electrofishing and gill netting produced 79% of the sauger and 83% of the walleye.

of fish, collection time of day or month, river discharge or other conditions. We do not discuss ANOVA results relating to macrohabitat effects, but results are in Appendix 3 for each species.

Segment comparisons were a main focus of our research, so the results of segment contrasts are presented in detail. For some species (i.e., bigmouth buffalo, burbot, sand shiner, white sucker, pallid sturgeon) total catches were inadequate for statistical analysis of catch among segments. For the 18 species with total catches that allowed ANOVA, there were no significant segment effects for five species (blue catfish, fathead minnow, stonecat, smallmouth buffalo, walleye). We include the full ANOVA results for these species in the Appendix 3 as shown in Table 13 for the blue catfish.

Below we list reasons for excluding certain analyses of the blue catfish data. No statistical analyses were done:

In Segments 3-*17* because no fish were caught.

For drifting trammel net catch because <5% of the total catch was caught in drifting trammel nets.

For electrofishing; although 17% of the total catch was by electrofishing, there was inadequate catch in certain segments and macrohabitats.

For beach seine catch; although 11% of the total catch was in beach seines, there was inadequate catch in certain segments (e.g., 19) and macrohabitats (e.g., SCN in all segments).

For stationary gill nets; although 8% of the total catch was in gill nets, there was inadequate catch in certain segments and macrohabitats.

For benthic trawl in Segment *19* because no fish were caught, and Segment *22* because no SCCs or TRMs were sampled.

For replicate benthic trawl data at the macrohabitat level in Segments *23*, *25*, and *27* because the number of zeros, normality, and consistency of variance test showed significant assumption violations at the replicate level.

For the blue catfish, analyses of C/E data were possible for the benthic trawl data for all years (Table 13). One ANOVA was done at the macrohabitat level (N = 18) using data for three Segments (*23*, *25*, and *27*), and BEND and SCC data. The second ANOVA was done at the replicate level (N = 59) using three Segments (*22*, *23*, *25*) and BEND and TRM data. A third analysis was

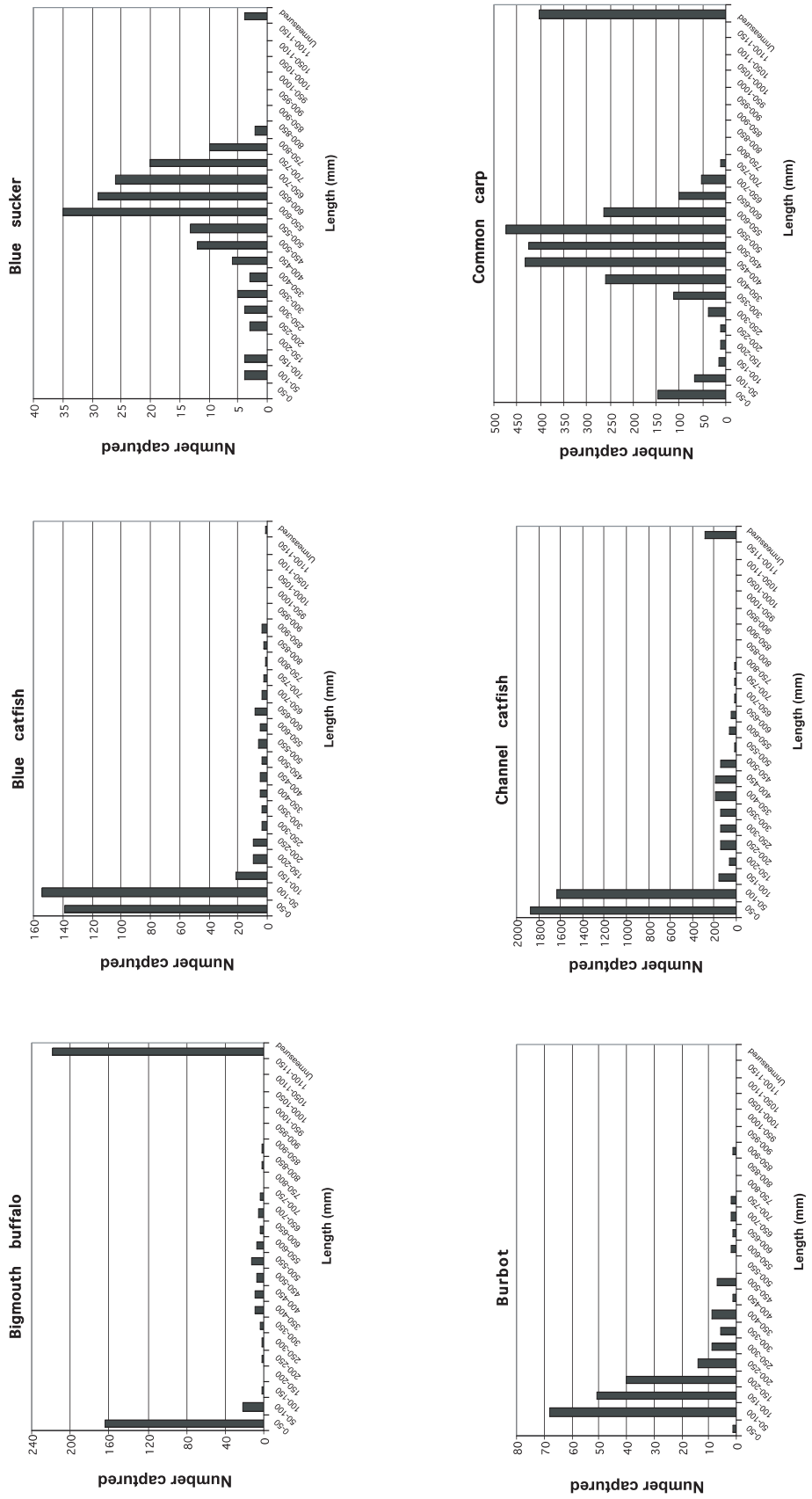



Figure 6. Length, frequency, distribution for six species of benthic fishes collected from 15 segments of the main channel of the Missouri River, 1996-1998. Bar in far right of figure indicates number of fish not measured.

Table 12. Blue catfish catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100 m), BT = benthic trawl (fish/100 m), BS = benthic seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and macrohabitat | | Missouri River segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| BT | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.013 | 0.022 | 0.071 | 0.022 |
| BT | ISB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.597 | 0.507 | 0.711 | 0.202 |
| BT | OSB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.023 | 0 | 0.089 |
| BT | SCC | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0.420 | 1.085 | 0.898 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0.628 | 0.317 | 0.204 | |
| DTN | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.046 | 0.044 | 0.030 | 0.059 |
| DTN | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 | 0 |
| DTN | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.194 | 0 | 0.567 | 0.078 |
| BS | OSB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | |
| BS | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 1.250 | 0.162 | 0.056 | 0.033 |
| BS | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| BS | TRM | | | | 0 | | 0 | | | | | | | | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0.036 | 0.023 | 0.038 |
| EF | OSB | 0 | | | | | | | | | | | | 0.018 | 0.013 | 0.030 |
| EF | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0.015 | 0.015 | 0.044 |
| EF | SCN | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | | | 0 |
| EF | TRM | | | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0.005 | 0 | 0.008 | 0 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0 | 0 | 0.002 | 0.025 | 0.007 | 0.027 | 0.018 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0.048 |
| SGND | TRM | | | 0 | | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0.002 | 0 | 0.005 |

done for replicate benthic trawl C/E in two Segments (*23, 25*) and three macrohabitats (BEND, SCC, TRM). We discuss the most robust analysis emphasizing the most segments, but also considering the most years and macrohabitats. For the blue catfish, the focus is on ANOVAs 1 and 2 (Table 13). Segment effects were insignificant for both ANOVAs; no segment contrasts were possible for ANOVA 1 but one was possible for ANOVA 2. For ANOVA 2, there were significant year effects (P = 0.003), but segment effects (P = 0.38) and macrohabitat effects (P = 0.2) were insignificant.

None of the planned segment contrasts were possible in ANOVA 2, except for the result contrasting the benthic trawl C/E of blue catfish up- and downstream from Kansas City. There was no difference (P = 0.179) in the trawl C/E up- and downstream from Kansas City. However, upstream Segments *17* and *19* were not included in the analysis because they did not meet the criteria for analysis (only one fish was caught).

Five contrasts between macrohabitats were possible in ANOVAs 1, 2, and 3 (see last rows in Table 13). Only one (ANOVA 3) indicated a significant difference (P = 0.002) in trawl C/E of blue catfish between BEND and TRM in Segments *23* and *25*. However, there was

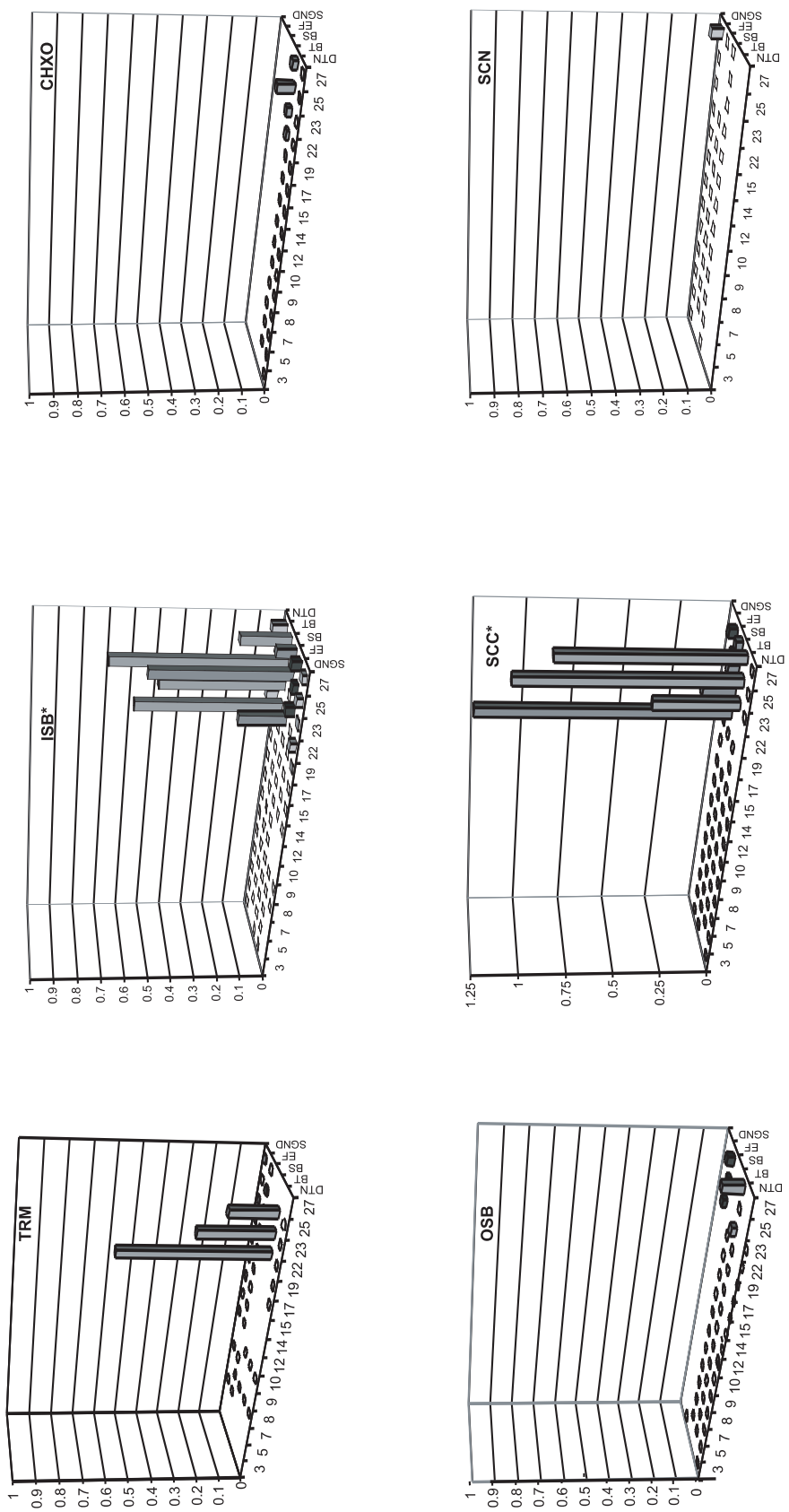



Figure 7. Catch per effort of blue catfish from 15 segments (3 = Montana, 27 = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability.

Table 13. Analysis of variance (ANOVA) probabilities with F-values in parentheses for blue catfish collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers' mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Benthic Trawl | | |
|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 3 |
| Analysis level | Macrohabitat | Replicate | Replicate |
| N1 | 8 | 59 | 66 |
| Years | 1996-1998 | 1996-1998 | 1996-1998 |
| Segments | *23-27* | *22-25* | *23 and 25* |
| Macrohabitats | BEND, SCC | BEND, TRM | BEND, SCC, TRM |
| | | | |
| Year | 0.232 (2.15) | 0.003 (6.76) | 0.659 (0.42) |
| Segment | 0.688 (0.41) | 0.382 (0.98) | 0.678 (0.17) |
| Macrohabitat | 0.138 (3.42) | 0.268 (1.26) | 0.005 (5.82) |
| Year/segment interaction | 0.349 (1.51) | 0.546 (0.78) | 0.910 (0.09) |
| Year/macrohabitat interaction | 0.215 (2.32) | 0.009 (5.21) | 0.377 (1.08) |
| Segment/macrohabitat interaction | 0.738 (0.33) | 0.203 (1.65) | 0.556 (0.59) |
| **Year** | | | |
| Bonferroni-adjusted alpha<br>(experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* |
| 1996 vs. 1997 | 0.127 | 0.215 | 0.844 |
| 1996 vs. 1998 | 0.177 | 0.0008* | 0.541 |
| 1997 vs. 1998 | 0.789 | 0.019$^{m}$ | 0.379 |
| **Segment** | | | |
| Bonferroni-adjusted alpha<br>(experiment-wise alpha) | | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* | |
| *Missouri –Yellowstone Rivers* | | | |
| Least-altered MOR vs. least-altered YSR<br>(3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Ft Peck Dam to YSR<br>**(9 vs.7, 8) FTP_IR_VS_YSR_LA** | | | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Ft Peck Dam to YSR<br>(3, 5 vs. **7**, **8)** **MOR_LA_VS_FTP_IR** | | | |
| *3-Zones* | | | |
| Least-altered vs. inter-reservoir<br>(3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | | | |
| Least-altered vs. channelized<br>(3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | | |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | | | |
| *5-zones* | | | |

| Statistic | Benthic Trawl | | |
|---|---|---|---|
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | | | |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | | | |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | | | |
| *Reservoir related* | | | |
| Least-altered segment above Ft. Peck Lake vs. inter-reservoir segment below Ft. Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | |
| Inter-reservoir MOR from YSR to L. Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | |
| Inter-reservoir between Ft. Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | | | |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1$^{ST}$_CHAN** | | | |
| *Channelized river* | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | | 0.179 *22* vs. *23*, *25* | |
| **Macrohabitat** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)$^{m}$ 0.05 (0.05)* | 0.033 (0.1)$^{m}$ 0.017 (0.05)* | 0.033 (0.1)$^{m}$ 0.017 (0.05)* |

| Statistic | Benthic Trawl | | |
|---|---|---|---|
| BEND vs. SCC | 0.138 | | 0.045 |
| BEND vs. SCN | | | |
| BEND vs. TRM | | 0.268 | 0.002* |
| SCC vs. SCN | | | |
| SCC vs. TRM | | | 0.064 |
| SCN vs. TRM | | | |

Table 14. Means of trawl catch (fish/100m) of blue catfish and list of possible segment contrasts from the 22 planned contrasts shown in Table 13 for C/E for the blue catfish. LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone, AKC = above Kansas City, BKC = below Kansas City.

| General Contrast | Segment contrast | | Trawl<br>P value<br>Means |
|---|---|---|---|
| Among LA | | | |
| LA vs. IR and CH | | | |
| Among IR | | | |
| IR vs. CH | | | |
| Among CH | AKC vs. BKC | *22* vs. *23, 25* | P = 0.179<br>0.26, 0.20 |

no difference (P = 0.268) in C/E between BEND and TRM when the C/E from Segment *22* was added (ANOVA 2).

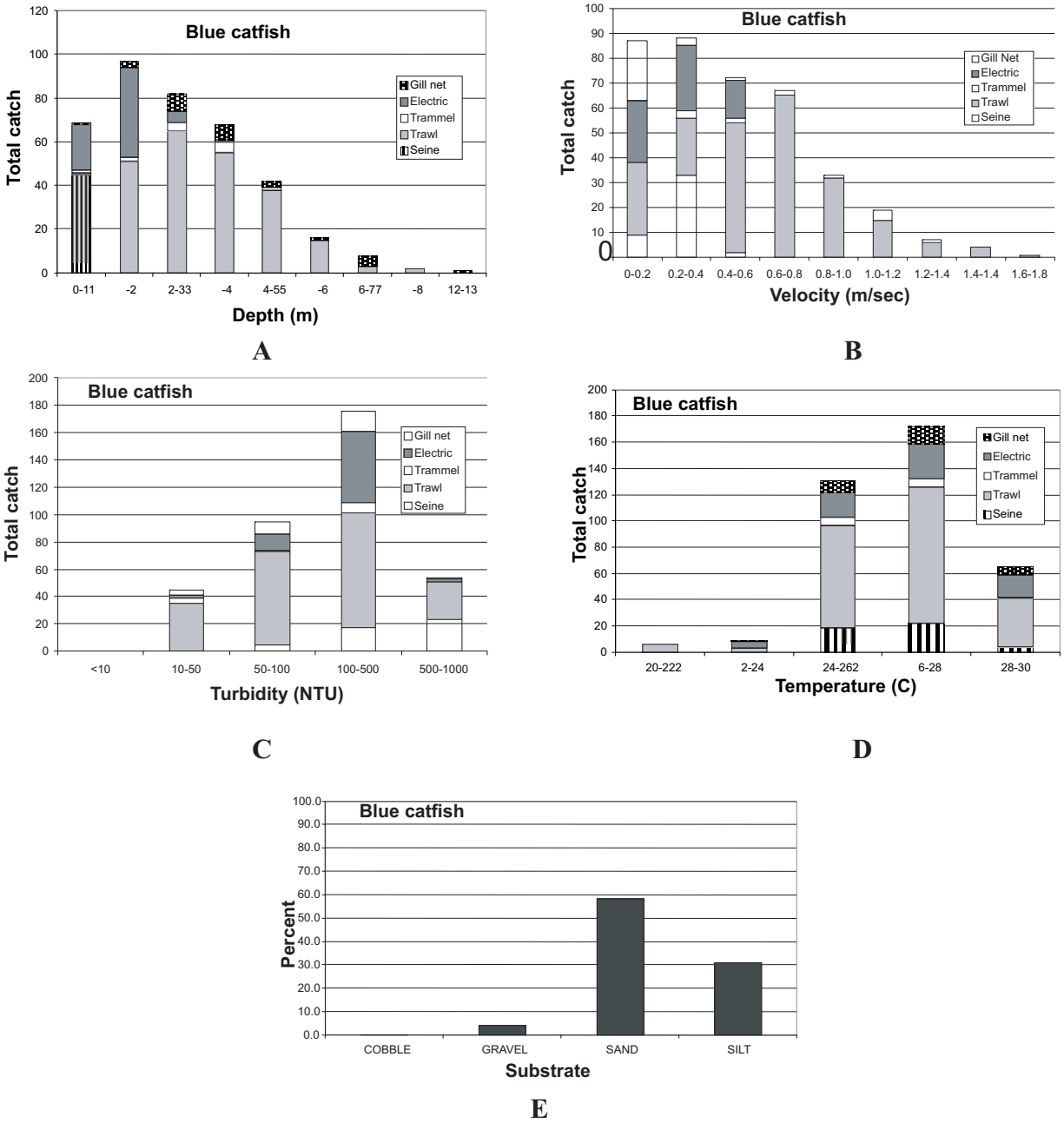
We shortened the presentation of results for other species in a summary table of the significant segment contrast results from the large ANOVA table of all possible contrasts (e.g., Table 13) for the most robust ANOVA. Results from all ANOVAs for all species and all gears are shown in Appendix 3. The summary table for blue catfish (Table 14) lists five general contrasts that were planned for river segments, and then shows specific segment contrasts by gear and mean catch. If no segment contrasts are listed, then none were significant for that general contrast category. We list results from the fishing method(s) that produced C/E data that was sufficient for statistical contrasts. For the blue catfish (Table 14), the only possible contrast was among three CH segments (*22* vs. *23*, *25*) with adequate catch in the benthic trawl. However, there was no statistical difference in C/E among segments above (AKC, 0.26 fish/100 m) and below Kansas City (BKC, 0.2 fish/100 m) (P = 0.179). As pointed out above, the low catch in Segments *17* and 19 caused these segments to be excluded from the analysis, so there is probably a trend of lower blue catfish density above Kansas City compared to below Kansas City. This is a situation where the trend is obvious without the need for statistical analysis.

To report habitat analysis results, the association of each species with physical habitat conditions across all years is presented as bar charts of the cumulative total catch for all gears in various categories of physical and water quality conditions (Figure 8). Similar figures have been presented by year for the first two years of the study (Dieterman et al. 1997, Young et al. 1998). General information on habitat associations of the blue catfish become apparent when the catch by depth data are combined with other figures for total catch in various classes of velocity, turbidity, temperature, and substrate type (Figure 8).

Blue catfish were caught by seining and electrofishing at depths <1 m, but the highest total catch was by trawling at depths from 1 to 5 meters (Figure 8A). Total catch of blue catfish was highest between 24 and 30°C (Figure 8D), and at turbidity measurements between 100-500 NTU (Figure 8C). Most blue catfish were caught in four velocity categories (0.0-0.2, 0.2-0.4, 0.4-0.6, and 0.6-0.8 m/sec, Figure 8B) over sandy substrate with some silt (Figure 8E). These macrohabitat and physical habitat associations represent seasonal (summer–early fall) habitat associations and not year-round life requisites, because blue catfish migrate upstream in the spring to spawn in tributaries where they build a nest cavity, and move downstream in the fall to winter in deep pools with warmer water than in other macrohabitats (Graham 1999).

To analyze fish associations with habitat in further detail, we used one-way ANOVA to compare mean habitat conditions at sites where blue catfish were present with habitat conditions where blue catfish were

Figure 8. Total catch of blue catfish over three years (1996-1998) in association with depth (A), velocity (B), turbidity (C), temperature (D), and percent of catch over four substrates (E).



absent (Table 15). One-way ANOVA indicated that where blue catfish were present, eight of the nine physical habitat variables were significantly different than at locations where blue catfish were absent. For example, velocity was higher (0.473 m/sec) at sites where fish were present than at sites there they were absent (0.190 m/sec). Depth was greater (2.6 m) at presence sites than at absence sites (1.3 m) and so forth. The proportion of gravel, sand, and silt was different ($P < 0.0001$) between blue catfish presence and absence sites. Blue catfish were present where there was more sand (46% vs. 23% at absence sites), and gravel (3% vs. <1% at absence sites), and less silt (40% vs. 72% at absence sites) than at absence sites. These data are summarized for all species in Table 16 and the details of the one-way ANOVA for each species is included in Appendices A4-1 through A4-6.

Stepwise logistic regression results (Table 15) indicated that the likelihood of presence of blue catfish increased with increased water velocity ($P = 0.002$), depth ($P < 0.0009$), and temperature ($P < 0.0001$) and decreased with conductivity ($P = 0.016$), thus affirming results from the ANOVA. The logistic regression $R^2$ (0.34) was the second highest in this study (Table 16) and indicated that 34% of the variance in presence was explained by the model including velocity, depth, temperature and conductivity. The "intercept only" model had an AIC = 278 whereas the full model had an AIC = 204, a 27% decline in AIC value that roughly approximates the $R^2$ value (i.e., 34%). Because our models usually have few (<5) parameters, we will comment only on the $R^2$ values, but AIC and concordance values can be found in the tables in Appendix A4. A summary of the regression $R^2$ for each species are included in Table 16, and mean habitat values for habitat factors significant to the regression model are underlined in Table 16.

Conductivity was often correlated with turbidity and varied little among macrohabits within segments (Galat et al. 2001). We limited our discussion of conductivity associations with species presence, but present mean conductivity values for presence and absence sites for each species in Appendix 4 for reference, and note instances when conductivity is important in regression analysis.

Some significant habitat variables predicting fish presence were correlated with other habitat variables. The correlations are useful because they help explain why environmental factors were significant when considered alone in the ANOVA, but insignificant to the logistic regression analyses. For blue catfish example, substrate geometric mean was significantly different between presence and absence sites when considered alone, but fell out of the regression model, probably because it was highly correlated with water velocity. Velocity accounted for 51% of the variation that geometric mean accounted for alone, so there was a non-significant geometric mean effect in the logistic regression analysis. Significant correlations that help with the interpretation of the results are mentioned only in the text (i.e., not tabled).

For each species we conclude with a summary of the analyses as follows for the blue catfish. In summary, blue catfish were found only in the channelized zone. Most of the fish that we collected were small (<150 mm long) and most (60%) were caught in the benthic trawl. Catch was insufficient to make most statistical contrasts. Mean C/E in the trawl was similar above and below Kansas City, but the low catch in segments above Kansas City that were not included in the analysis, suggested that abundance was lower above Kansas City than downstream from the City. Sites where the blue catfish was present had water that was swifter, deeper, warmer, and more turbid that sites where the fish was absent. Substrates at presence sites were coarser (more gravel and sand and less silt) than at absence sites.

***Bigmouth Buffalo***

The bigmouth buffalo is a large (400-900 mm long), long-lived (10-20 years) species that is found throughout the Mississippi River drainage in rivers and reservoirs, and has wide habitat associations (Edwards 1983). Many fish were <100 mm long, but specimens from 300 to 700 mm were collected (Figure 6). We collected 517 bigmouth buffalo (Table 7) but after filtering the total catch, data were inadequate for ANOVA for any gear type.

Bigmouth buffalo were present in all segments except Segment 3, but most were caught in the IR zone (Figure 9). Only 10 fish were caught in the trawl, trammel and gillnet combined. Of the remainder, 152 fish were collected in seines and 307 were captured by electrofishing. For ANOVA segment contrasts, Segments **8**, **10**, **12** produced adequate (>2%) seine catches and Segment **10** produced adequate electrofishing sample sizes, but the overall catch was inadequate for making planned segment contrasts. However, statistics were not needed to show the obvious trend among zones - bigmouth buffalo were more abundant in the IR than in other zones (Figure 9, Table A2-1). The trend data also relate to segment contrasts concerning the influence of the Yellowstone River, because the highest catches in the Missouri River were in Segments **8** and **10** near the Yellowstone River confluence. It was also obvious that the catch upstream from Lake Sakakawea in Segments **8** and **10** were much higher than the catch below Lake Sakakawea in Segment **12**.

Table 15. One-way ANOVA and logistic regression for presence/absence of the blue catfish in various physical habitat conditions. One-way ANOVA tested means differences between sites with and without a species for each of the habitat variables measured based on transformed data (see text for transformations used); means are back transformed values. Stepwise logistic regression tested the ability of each of the groups of physical variables to predict the presence of a species based on untransformed data. NU stands for "not used in logistic regression". NS stands for "not significant in logistic regression".

| Physical Habitat Variable | **Means with/without fish**<br>(N, % var., P-value)<br>[Parameter Est., P-value] |
|---|---|
| Water velocity (m/sec) | 0.473/0.190<br>(213, 22.7, <0.0001)<br>[2.5530, 0.0022] |
| Water depth (m) | 2.608/1.307<br>(214, 21.5, <0.0001)<br>[0.5718, 0.0009] |
| Water temperature (C) | 26.13/24.58<br>(207, 9.4, <0.0001)<br>[0.3754, <0.0001] |
| Water turbidity (NTU) | 120.96/68.67<br>(213, 9.7, <0.0001)<br>[NS] |
| Water conductivity (μ S/cm) | 663.5/669.16<br>(204, 0.0,0.7609)<br>[-0.00319, 0.0158] |
| Substrate geometric mean* | 2.751/0.203<br>(214, 28.7, <0.0001)<br>[NS] |
| Proportion gravel % [NU] | 0.029/0.005<br>(214, 8.8, <0.0001) |
| Proportion sand % [NU] | 0.466/0.231<br>(214, 7.0, <0.0001) |
| Proportion silt % [NU] | 0.399/0.719<br>(214, 10.1, <0.0001) |
| Logistic regression R-squared | 0.34 |
| Logistic regression % concordance | 84.8 |
| Intercept only AIC value | 278.7 |
| Full model AIC value | 204.1 |

*Unitless index

Table 16. Mean habitat conditions at presence (p) and absence (a) sites for benthic fishes. Significantly different (one-way ANOVA, alpha = 0.05) means are in bold. Species are listed in decreasing magnitude of the logistic regression R-squared ($R^2$). Underlined means are those habitat features significant in the stepwise logistic regression model. Proportion (%) of gravel, sand, and silt were not used in the stepwise logistic regression, and proportion of gravel, sand, and silt may not add to 100% because of rounding errors and minor proportions of other substrate types (i.e., cobble, clay). Supporting statistical details are in Appendices A4-1 to A4-6.

| Species | $R^2$ | Velocity m/sec | | Depth m | | Temp. C | | Turbidity NTU | | Geomean | | Gravel % | | Sand % | | Silt % | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | p | a | p | a | p | a | p | a | p | a | p | a | p | a | p | a |
| Flathead catfish | 0.36 | **0.5** | **0.2** | **2.7** | **1.3** | **25** | **24** | **75** | **60** | **2.1** | **0.2** | **2** | **1** | 41 | 36 | **44** | **57** |
| Blue catfish | 0.34 | **0.5** | **0.2** | **2.6** | **1.3** | **26** | **24** | **120** | **68** | **2.7** | **0.2** | **3** | **1** | **46** | **23** | **40** | **72** |
| Sicklefin chub | 0.34 | **0.6** | **0.4** | **2.1** | **1.1** | **21** | **23** | 80 | 69 | **2.1** | **1.2** | 8 | 5 | 60 | 60 | 18 | 23 |
| Shovelnose sturg. | 0.27 | **0.6** | **0.3** | **2.4** | **1.2** | 22 | 22 | **57** | **44** | **3.1** | **0.4** | **7** | **3** | **60** | **30** | **18** | **52** |
| Channel catfish | 0.25 | 0.3 | 0.3 | **1.9** | **1.2** | **24** | **20** | **53** | **29** | 0.7 | 0.6 | 3 | 4 | **33** | **51** | **50** | **34** |
| Sturgeon chub | 0.25 | **0.6** | **0.4** | **1.6** | **0.8** | 20 | 20 | 49 | 37 | **1.9** | **1.1** | 12 | 10 | 63 | 50 | **16** | **27** |
| Flathead chub | 0.17 | **0.4** | **0.2** | 1.0 | 1.4 | 21 | 20 | 51 | 42 | **1.4** | **0.1** | **12** | **1** | **46** | **20** | **27** | **75** |
| Stonecat | 0.15 | **0.6** | **0.4** | **2.0** | **1.5** | 23 | 23 | 65 | 49 | **3.6** | **1.9** | **16** | **6** | 56 | 64 | 16 | 19 |
| Burbot | 0.14 | **0.6** | **0.4** | **1.8** | **0.8** | 21 | 22 | 59 | 42 | 3.0 | 2.6 | 19 | 23 | 50 | 40 | 18 | 20 |
| Common carp | 0.14 | 0.3 | 0.3 | **1.9** | **1.3** | **23** | **21** | **48** | **36** | 0.6 | 0.6 | 2 | 3 | **31** | **57** | **57** | **30** |
| River carpsucker | 0.11 | **0.3** | **0.4** | **1.5** | **1.7** | **23** | **22** | **43** | **35** | **0.4** | **1.0** | **1** | **4** | **30** | **50** | **58** | **30** |
| Blue sucker | 0.10 | **0.6** | **0.4** | **2.4** | **1.6** | **23** | **22** | 51 | 45 | **4.7** | **0.7** | **7** | **4** | **60** | **41** | **18** | **43** |
| Freshwater drum | 0.06 | 0.4 | 0.3 | **1.9** | **1.5** | 24 | 24 | **61** | **31** | 1.0 | 0.7 | 3 | 4 | **30** | **43** | **54** | **40** |
| Smallmouth buff. | 0.05 | **0.2** | **0.4** | 1.6 | 1.6 | **23** | **22** | 46 | 46 | **0.5** | **0.8** | **2** | **4** | **24** | **44** | **63** | **40** |
| Bigmouth buffalo | 0.05 | **0.1** | **0.2** | 1.3 | 1.1 | **22** | **20** | 38 | 34 | **0.1** | **0.3** | 1 | 1 | **16** | **47** | **82** | **50** |
| Walleye | 0.05 | **0.3** | **0.4** | 1.5 | 1.5 | **22** | **21** | **34** | **26** | **0.4** | **0.9** | 2 | 5 | **33** | **47** | **54** | **33** |
| White sucker | 0.05 | 0.3 | 0.4 | 1.2 | 1.4 | 16 | 17 | 23 | 26 | 0.6 | 0.7 | 3 | 6 | 48 | 43 | 37 | 37 |
| Sand shiner | 0.04 | 0.4 | 0.3 | 1.7 | 1.7 | **25** | **24** | **56** | **34** | **1.5** | **0.5** | 2 | 2 | **55** | **38** | **31** | **52** |
| Shorthead redhorse | 0.04 | **0.4** | **0.3** | 1.5 | 1.5 | 21 | 22 | **33** | **42** | **1.0** | **0.6** | **7** | **2** | 40 | 40 | 37 | 43 |
| Emerald shiner | 0.01* | 0.3 | 0.3 | 1.6 | 1.6 | 23 | 23 | 48 | 41 | 0.9 | 0.6 | 5 | 3 | **33** | **43** | 47 | 42 |
| Sauger | 0.01 | 0.3 | 0.3 | 1.7 | 1.5 | **22** | **23** | 45 | 47 | 0.6 | 0.8 | 4 | 3 | **30** | **40** | **54** | **41** |
| Fathead minnow | 0 | 0.3 | 0.3 | 1.5 | 1.5 | 20 | 20 | 30 | 28 | 0.6 | 0.5 | 1 | 2 | 40 | 43 | 48 | 45 |

*Increased with decreased conductivity, 660 µS/cm at presence sites, 704 µS/cm at absence sites.

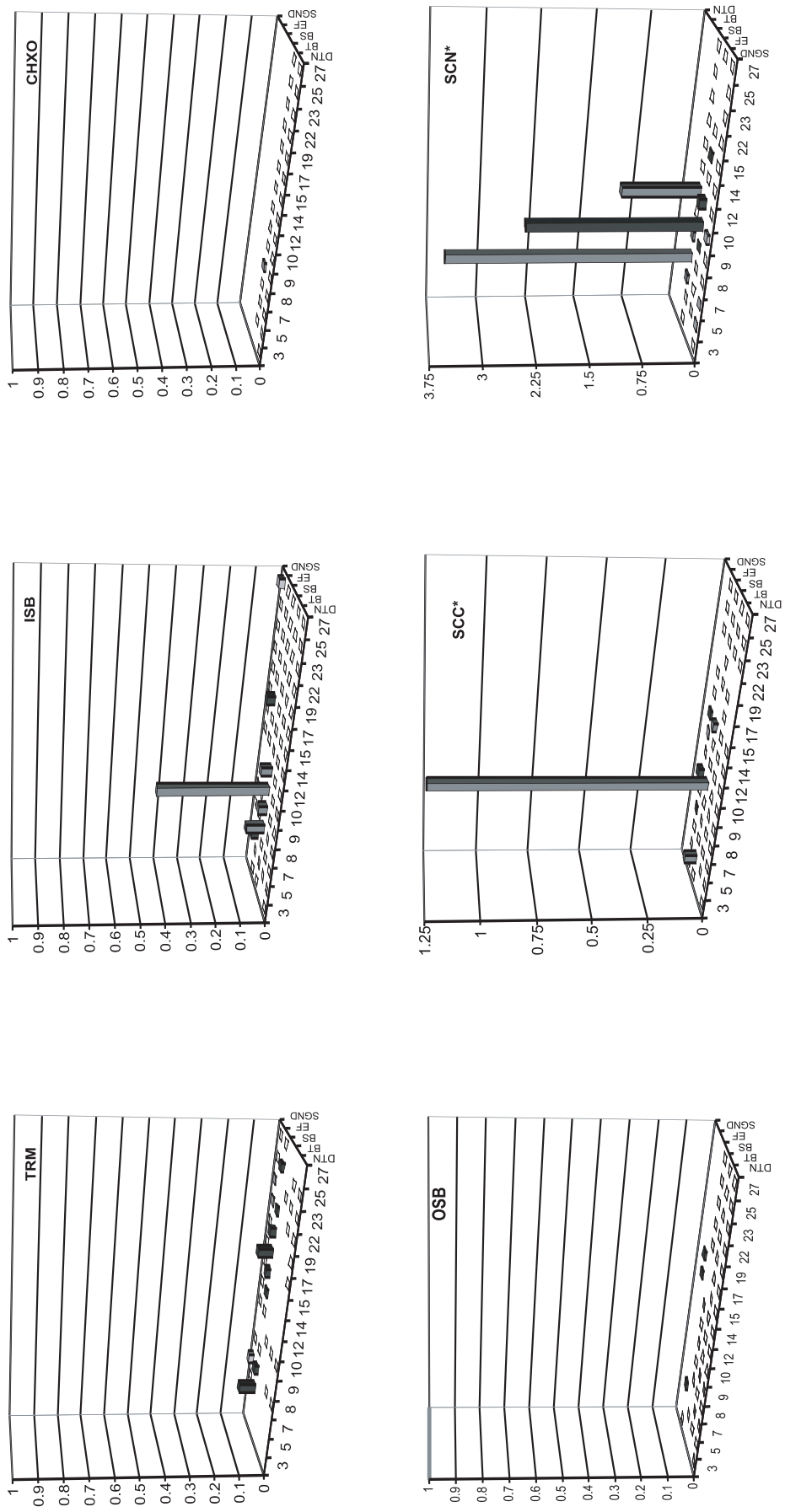
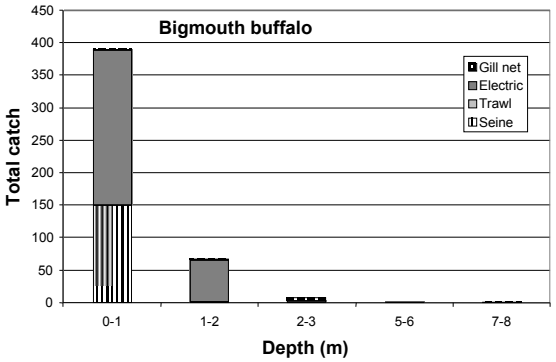
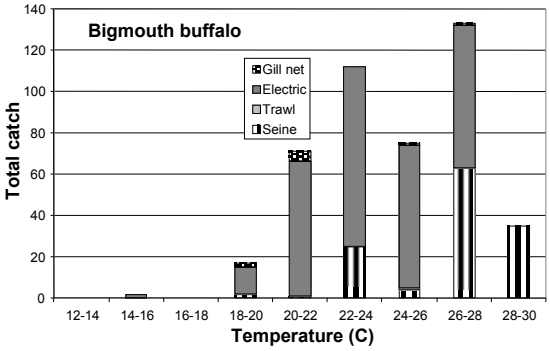



Figure 9. Catch per effort of bigmouth buffalo from 15 segments (3 = Montana, 27 = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), BT = benthic trawl (fish/100m). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-1.

Figure 10. Total catch of bigmouth buffalo over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).




A

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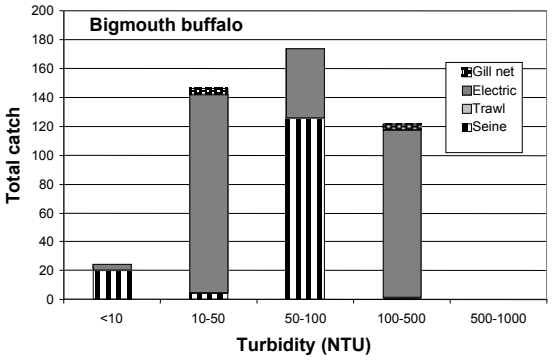
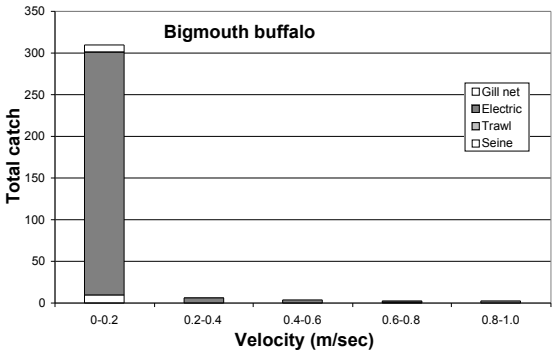
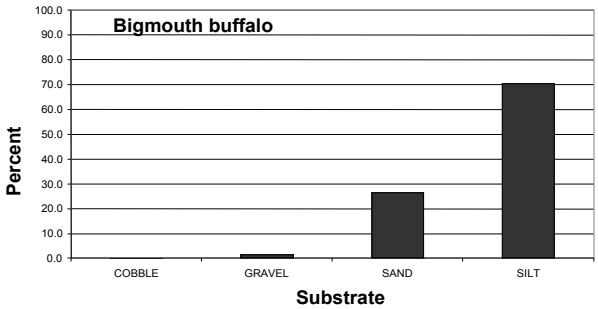



C




D




E

Most bigmouth buffalo were caught at depths of <1 m and velocities <0.2 m/sec over predominantly silt substrates (Figure 10), and this species had a broad turbidity and temperature association. Comparison of mean habitat conditions at presence and absence sites indicated that that velocity was lower (0.1 m/s) where fish were present compared to where they were absent (0.2 m/s), water temperature higher, and the geometric mean particle size smaller where fish were present (Table 16, Table A4-1). The proportion of sand was lower (16 % compared to 47%) and the proportion of silt was higher (82% compared to 50%) where fish were present compared to where they were absent. Hence the one-way ANOVA results agree with the generalization made by inspecting Figure 10. Turbidity ranged from 10-500 NTUs where most fish were caught, but there was no significant difference in turbidity levels between presence and absence sites. Stepwise multiple regression analysis showed that the likelihood of presence of bigmouth buffalo increased with increasing water temperature, but the amount of variation explained was only about 5% ($R^2 = 0.05$). No habitat covariates were significant so velocity and substrate geometric mean, which were significant when considered alone, fell out of the regression model because of their marginal influence on fish presence (Table 16).

In summary, the bigmouth buffalo was widespread with highest total catch in the IR zone. Bigmouth buffalo were most susceptible to capture in seines or by electrofishing, however, catch was too low for statistical analysis. Visual inspection of the C/E figures suggested that higher densities occurred in the IR segments and near the confluence of the Yellowstone River. Presence sites had water that was slower and warmer, and finer substrates than did absence sites.

***Blue Sucker***

The blue sucker is listed as a species of concern by several states (Galat et al. 2005). It is widely distributed in the Missouri, Ohio, and upper Mississippi river drainages. Larvae drift from the James River into Segment **15** (Muth and Schmulbach 1984). Our sample of 193 blue suckers (179 used for analysis) had many larger specimens (500-800 mm, Figure 6), as is found in many studies (reviewed by Morey and Berry 2003). Young blue suckers may use backwaters such as SCNs as nursery areas (Fisher and Willis 2000), but we did not catch blue suckers in SCNs (Figure 11). About one-third of the total catch was by electrofishing and drifting trammel nets each, and one third captured by other gears in ISBs and SCCs. High total catch sometimes occurred in TRMs (Figure 11).

We found blue suckers in all segments, except **14** (Figure 11, Table 8). The most robust analysis of segment contrasts for trammel net C/E indicated that there were no significant segment effects (P = 0.011, Bonferroni-adjusted alpha = 0.006) for C/E from all years and from BENDs and SCCs (Table A3-1). The IR Segments **10**, **12**, and **14** were removed from the analysis because sample size was too low, so statistics are not needed to indicate that catches in IR segments (excluding Segment **15**) were less than those in either the LA or CH zones. The contrast between Segments **14** and **15** was not done because of "zero" catches in **14**, so obviously catches in **15** were higher than those in **14**.

Regarding physical habitat associations, most blue suckers were captured where turbidity was 10-50 NTUs, and catch increased as temperature increased to 24-26C (Figure 12). Blue sucker catch by velocity had a dome-shaped pattern with most fish captured between 0.2 and 1.0 m/s. Blue suckers were caught at depths up to 4 m, and some fish were captured at 11-12 m with the drifting trammel net. Their association with swift, deep water suggested that higher catches might be associated with sand and gravel, which they were (Figure 12).

These generalizations about habitat associations with total catch made from inspection of Figure 12 were confirmed by one-way ANOVA results (Table 16). Where blue suckers were present, means for physical habitat measures were velocity 0.6 m/s, depth 2.4 m, temperature 23°C, turbidity 51 NTUs, and substrate size geometric mean 4.7 mm. The average proportion of gravel was 7%, sand 60%, and silt 18% where blue suckers were found, and the proportions of gravel and sand were higher and the proportion of silt lower where blue sucker were present compared to where they were absent.

Stepwise multiple regression ($R^2 = 0.1$) indicated that the likelihood of presence of blue suckers increased with increased water velocity, conductivity and substrate size geometric mean (Table 16). Velocity and substrate size were positively correlated (50% of the variability of one explained by the other) but both were retained in the model, whereas depth, temperature, and turbidity fell out of the model even though these features were significant when considered alone in the comparison of means between presence and absence sites.

In summary, the blue sucker sample was composed of larger individuals that were widespread (found in all segments except Segment **14**), and were especially abundant in IR Segment **15** and CH Segment *17*. However, the low catch in other IR segments indicated that blue sucker abundance was lower in the IR than in LA or CH zones. Blue suckers were especially vulnera-

Figure 11. Catch per effort of blue sucker from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-2.

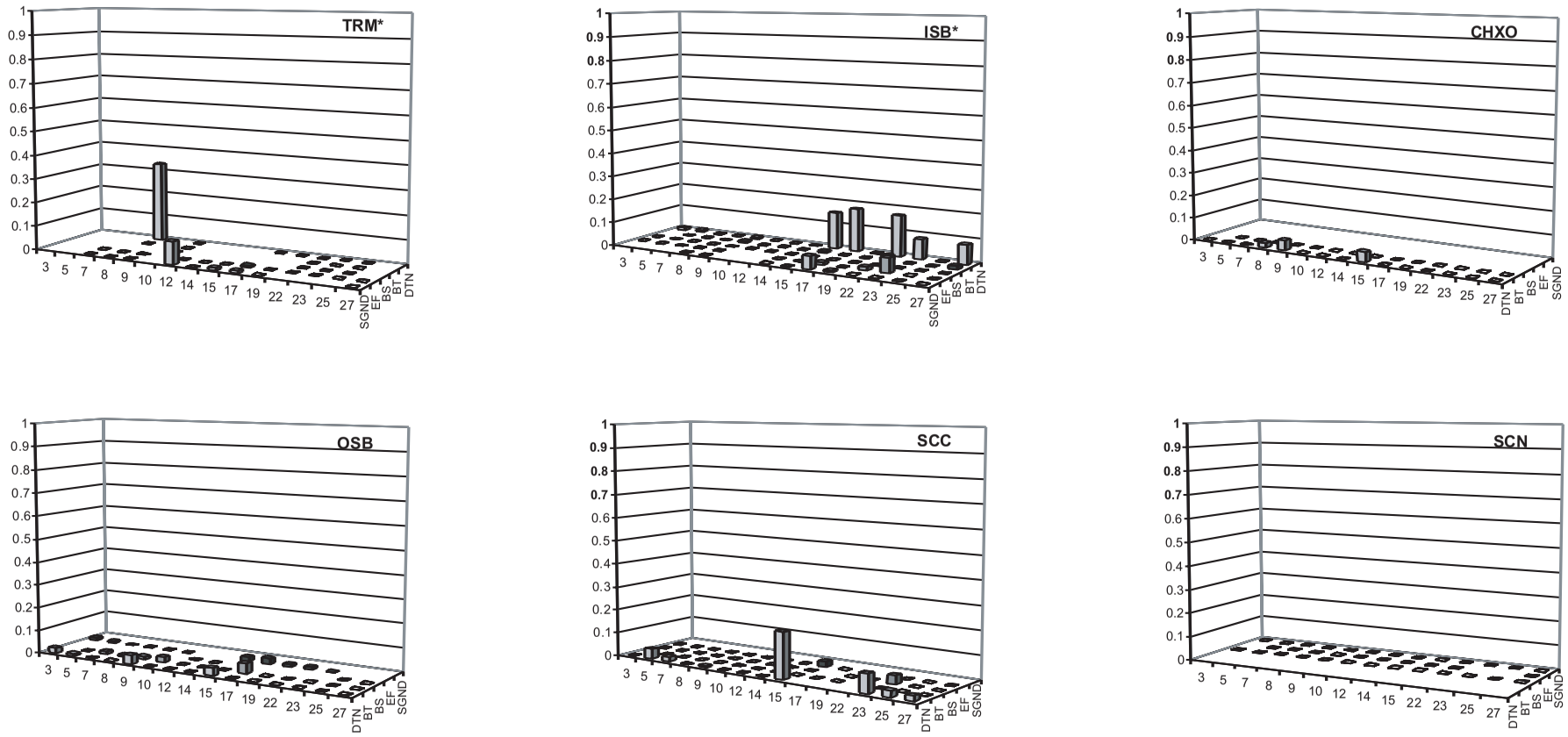
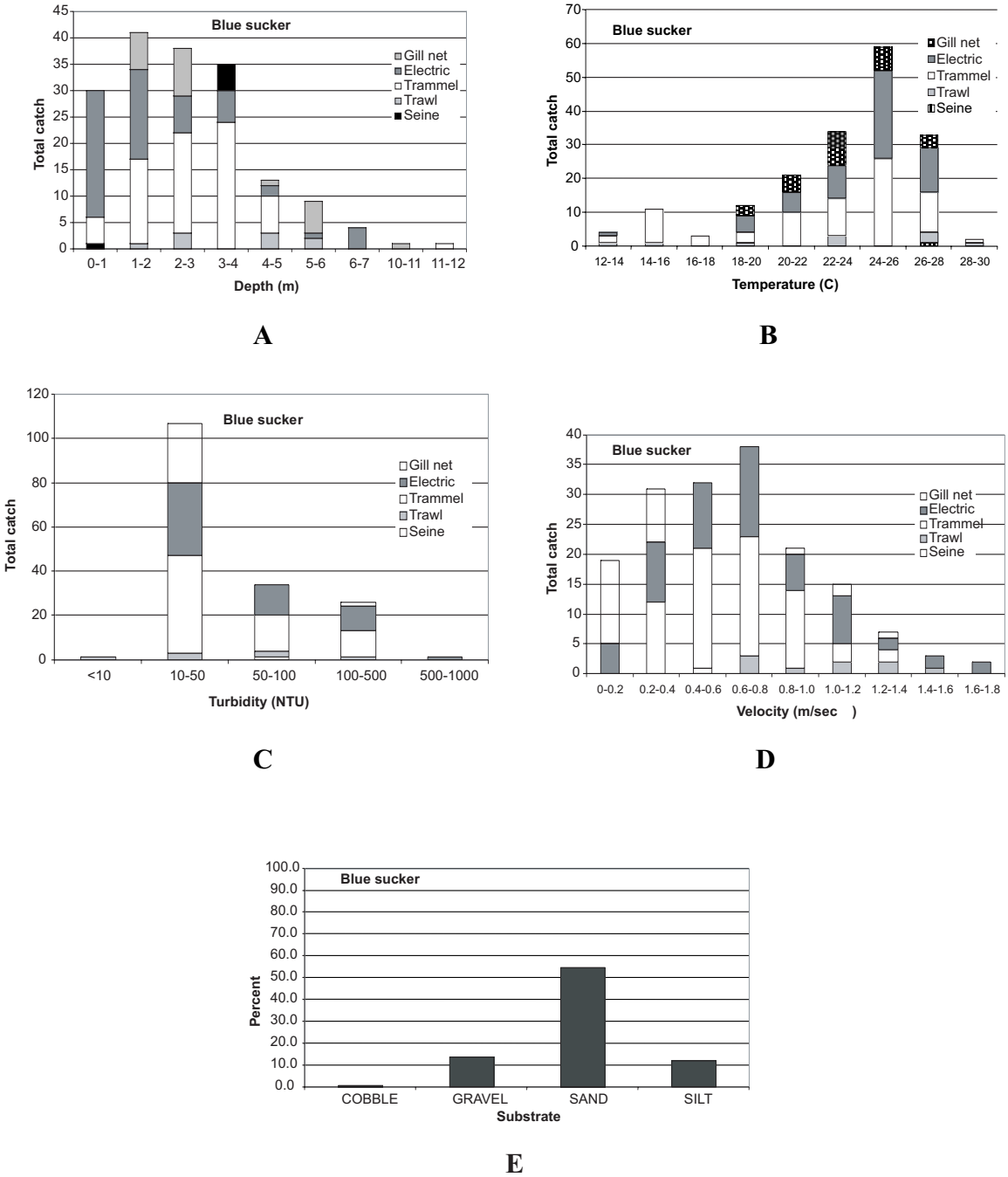


Figure 12. Total catch of blue sucker over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).



ble to drifting trammels and electrofishing in ISBs and SCCs. The species was present where substrate is course (more gravel and sand than silt) and water deeper and swifter than in other locations.

***Burbot***

The burbot is a freshwater cod that is principally a northern species, occurring in the upper Missouri and Mississippi Rivers, Canada, and Alaska (Fisher et al. 1996). Our data confirm this generalization as we found all (except two) of the 220 burbot upstream from Ft Randall Dam in Segments 3-**12** (Figure 13). Burbot usually reach about 1.5 kg (60 cm long) in the Missouri River. Most of the fish we collected were <50 cm long, but a few larger specimens were found in Segment 3 (Figure 6). Ninety percent of the total catch was by electrofishing in BENDs and SCCs (Figure 13). However, the total catch was insufficient for statistical analysis. The C/E declined downstream from Fort Peck Lake (Segment **7**) and Lake Sakakawea (Segment **12**). Also, the trend in total catch and C/E indicated that this species was abundant in the LA and IR zones. There was in increase in C/E between Segments **8** and **10**; the Yellowstone River enters the Missouri River between these two segments.

Most burbot were caught by electrofishing in water depths of 1 – 2 m (Figure 14). The average water depth was 1.8 m at presence sites and 0.8 m at absence sites (Table 16). Mean velocity at presence sites was 0.6 m/sec, which was significantly higher than the mean velocity at absence sites (0.4 m/s), and supported the pattern seen in total catch over velocities up to the 1.0-1.2 velocity category. Present sites were significantly deeper than absence sites, but other differences between presence and absence sites were not significant. However, burbot was among a group of four species (burbot, stonecat, flathead chub, sturgeon chub) that were associated with >10% gravel at presence sites (Table 16). Cobble was ubiquitous at a few burbot presence sites. Most burbot were caught in waters where turbidity was 10-50 NTUs, and most were caught over a 10-degree temperature range (14 – 24º C, Figure 14).

Logistic regression analysis ($R^2 = 0.14$) showed that the presence of burbot increased with increased water velocity and decreased temperature. Depth, velocity, and temperature were correlated (33% of one accounting for the variation in another), which may explain why depth and temperature were significant in the ANOVA and not the regression analyses (Table 16).

In summary, burbot are a fairly common fish of LA zone and Segment **10** (just upstream from Lake Sakakawea). They are vulnerable to electrofishing in SCCs, ISBs and OSBs in deep water and swift current where substrates tended to be sandy to coarse materials, and water turbidity low.

***Channel Catfish***

Channel catfish thrive in a variety of environmental conditions, including warm, turbid water (Hubert 1999). Most of our specimens were <100 mm, but we captured representatives of all size classes including the 750-800 mm size class (Figure 6). Channel catfish were captured in all study segments, with highest C/E in the CH zone (Table 17). The C/E was high in ISB, SCC, and TRM (occasionally) macrohabitats where trawl catches reached about 3 fish/100 m and seine catches were sometimes as high as 8-10 fish/haul (Table 17). There were no significant segment effects using trawl data (P = 0.2) but there were significant segment effects found in data from seines (1,576 fish), electrofishing (1,309 fish) and gill netting (604 fish). Significant contrasts for the three gears were found, but some were misleading because Segments 3, 5, **7**, **8**, **10**, **12**, and **14** were excluded from analysis because of the low total catch. For example, contrasting C/E among LA segments or between LA segments and other segments was difficult because only Segment 9 was available to represent the LA zone and only Segment **15** was used in most analysis to represent the IR zone. Statistical analysis of the contrast between LA segments (3, 5 vs. 9) was not possible, but there seems to be higher catch rates in Segment 9 than in Segments 3 and 5 where total catch was too low for analysis (Table 17).

Significant results from the most robust ANOVAs (Table 18), showed that C/E in beach seines was highest in CH segments (3.3 fish/haul) and lowest in IR segments, but the IR segments were represented only by Segment **15**. On-the-other-hand, several contrasts of C/E in gill nets showed an opposite trend, but data were only from CH Segment *27.* Segment **15** (BL&C, below Lewis and Clark Lake), just downstream from Gavins Point Dam, had lower gillnet C/E (0.17 fish/hr) than did Segment **14** (AL&C, above Lewis and Clark Lake). Electrofishing C/E was higher (0.23 fish/min) downstream from Kansas City compared to C/E upstream (0.1 fish/min). Several trends were apparent after considering the low C/E in Segments 3, 5, **7**, **8**, **10**, **12**, and **14.** The high C/E in Segment 9 (Yellowstone River) was not found in Missouri River Segments **7** and **8** or **10** near the Yellowstone confluence. High catches in the CH segments and low catches in the IR segments were apparent in both the pattern of total catch and C/E data (Table 17).

Total catch increased greatly when temperatures reached 24°C (Figure 15). Mean temperature where fish were captured was greater (24°C) than where fish were not captured (20°C, Table 16). A few channel cat-

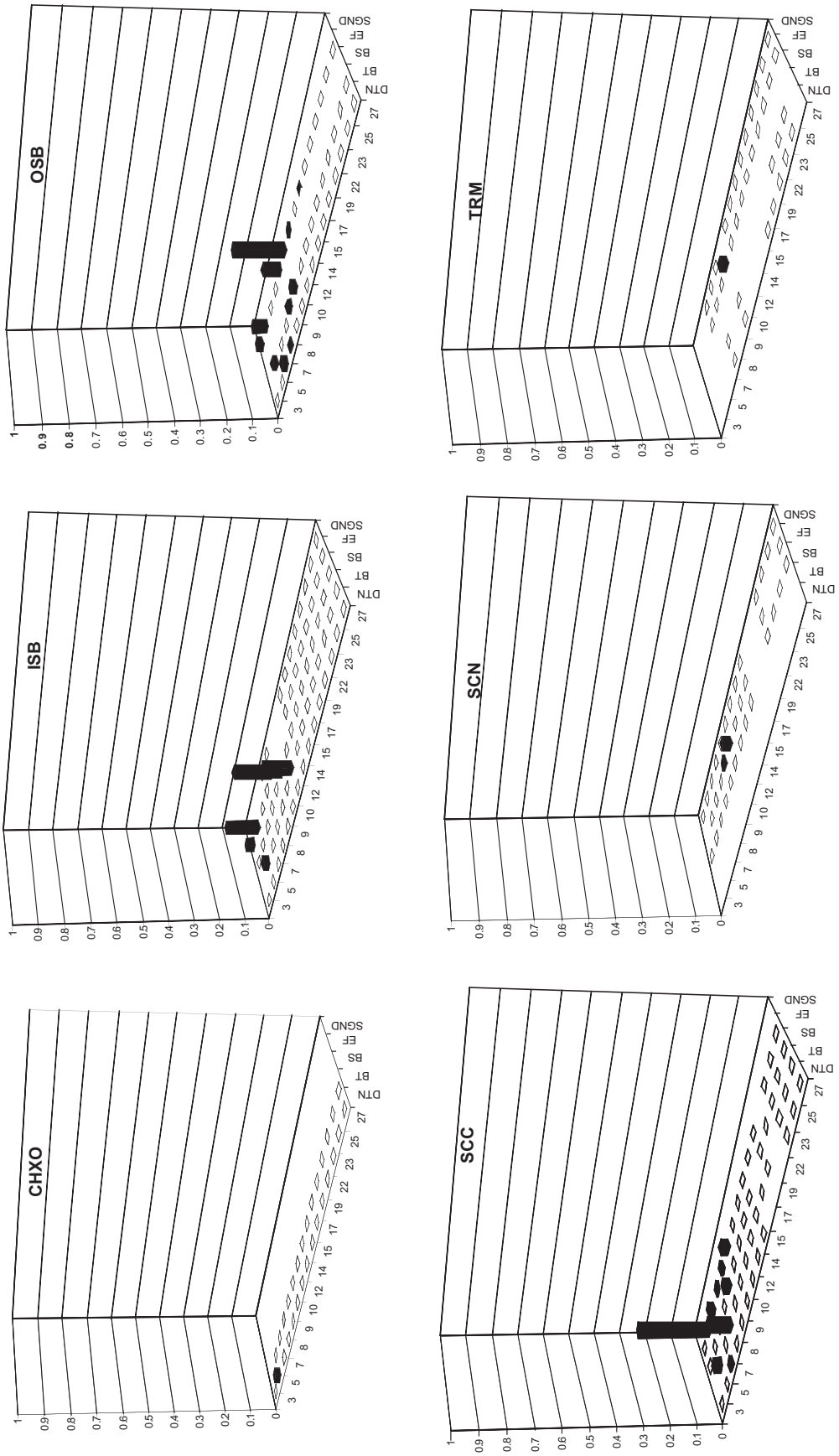



Figure 13. Catch per effort of burbot from 15 segments (3 = Montana, 27 = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). See Table A2-3.

Figure 14. Total catch of burbot over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).

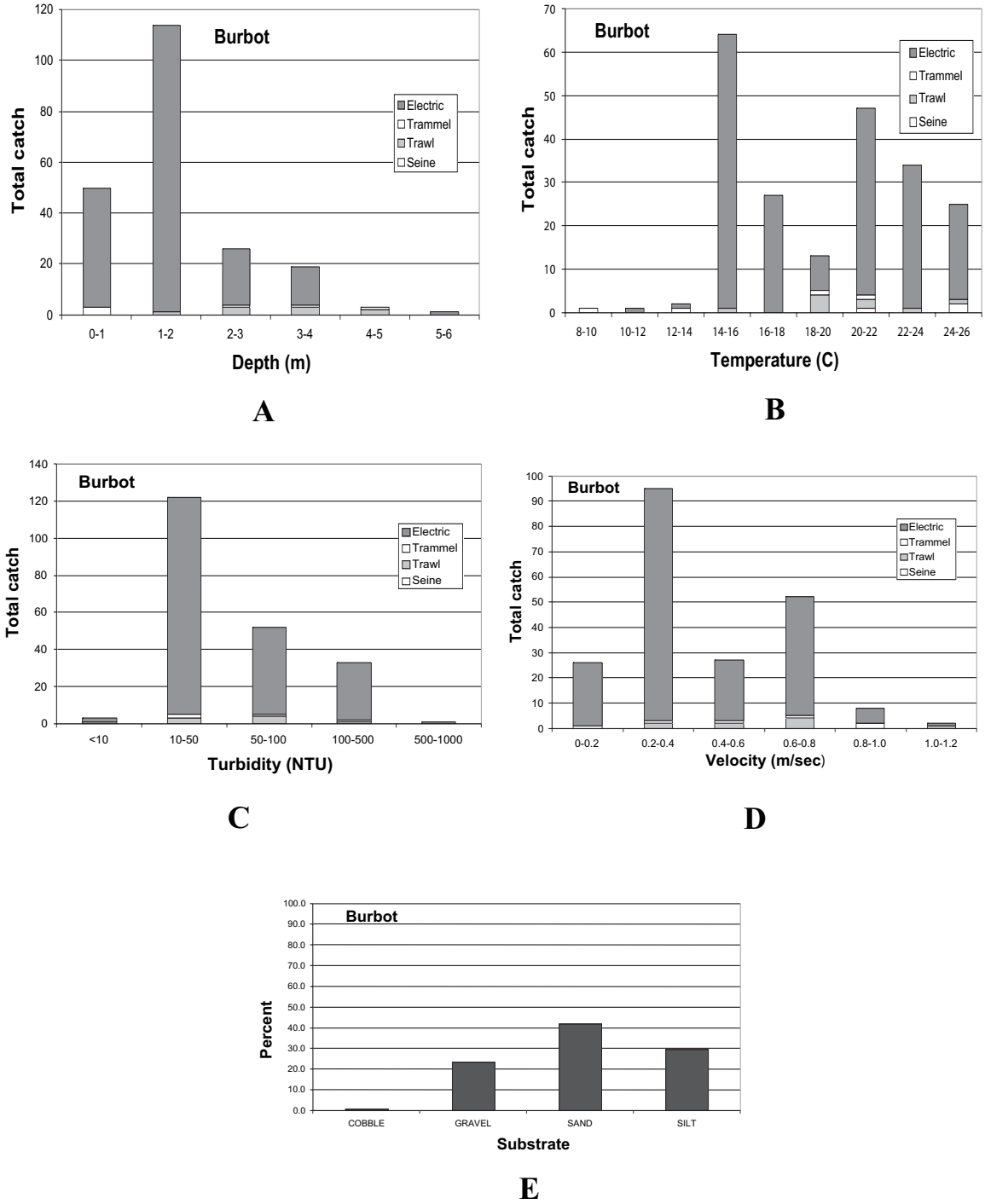


Table 17. Channel catfish catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = benthic seine(fish/haul), EF = electrofishing(fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments. See Figure A2-1.

| Gear and habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0.01 | 0.01 | 0 | 0 | 0.26 | 0.04 | 0 | 0.16 | 0.16 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0 | 0.94 | 0.02 | 0 | 0.22 | 0.31 | 0.04 | 0 | 0.52 | 0.09 | 0 | 0 |
| DTN | OSB | 0 | 0.01 | 0 | 0 | 0.39 | 0.204 | 0 | 0.16 | 0.16 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0.22 | 0.04 | 0 | 0.01 | 0.04 | 0.11 | 0 | 0.61 | 0.23 | | | | 0.03 | 0.02 | 0.01 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0.11 | | 1.89 | | | | 0 | 0 | 0.06 | 0 | 0 | |
| BT | CHXO | | 0.46 | 0 | 0.01 | 0.59 | 0.33 | 0 | 0 | 0.007 | 0.26 | 0.15 | 0.04 | 0.05 | 0.21 | 0 |
| BT | ISB | | 0.14 | 0 | 0 | 0.56 | 0.07 | 0 | 0.007 | 0.007 | 0.72 | 3.79 | 2.59 | 1.29 | 1.66 | 1.87 |
| BT | OSB | | 0.82 | 0 | 0.007 | 0.18 | 0.46 | 0 | 0 | 0 | 0.08 | 0.07 | 0.04 | 0.01 | 0.06 | 0.11 |
| BT | SCC | | 0.12 | 0.01 | 0.04 | 0.35 | 0 | 0 | 0.02 | 0.13 | 3.00 | 8.20 | | 3.64 | 1.43 | 2.23 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0.44 | | 0.89 | | | | | | 3.10 | 7.33 | 0.48 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0 | 0 | 0 | 0 | 1.13 | 0.33 | 0 | 0 | 0.2 | 8.63 | 10.00 | 7.96 | 8.78 | 3.93 | 5.68 |
| BS | OSB | | | 0 | | | | 0 | | | | | | | | |
| BS | SCC | 0.02 | 0 | 0 | 0 | 0.73 | 0.04 | 0 | 0 | 0.41 | | 1.00 | 4.25 | 3.85 | 3.88 | 1.15 |
| BS | SCN | 0 | 0.33 | 0 | 0 | 0.97 | 0 | 0 | 0 | 0 | | | 1.75 | 0.5 | 0 | 1.18 |
| BS | TRM | | | | | | | | | | | | | | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0.28 | 0.04 | 0 | 0 | 0.10 | | | 0 | 0.067 | 0.15 | 0.22 | 0.145 | 0.34 | 0.19 | 0.24 |
| EF | OSB | 0.09 | 0.12 | | 0 | 0.02 | 0 | | 0.01 | 0.104 | 0.04 | 0.08 | 0.39 | 0.50 | 0.09 | 0.18 |
| EF | SCC | 0 | 0.04 | 0 | 0 | 0.04 | 0 | 0 | 0.02 | 0.04 | 0.14 | 0.08 | | 0.29 | 0.12 | 0.16 |
| EF | SCN | | 0 | 0.02 | 0.02 | 0.01 | 0.01 | 0 | 0.01 | 0.035 | | | 0.12 | | | 0.33 |
| EF | TRM | | | 0 | 0 | 0.08 | 0 | 0.02 | 0.04 | 0.185 | 0.05 | 0.04 | 0.11 | 0.07 | 0.05 | 0.11 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0.33 | 0.05 | 0.04 | 0.01 | 0.01 | 0 | 0 | 0.03 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0.12 | 0.77 | 0.06 | 0.17 | 0.46 | 0.39 | 0.09 | 0.81 | 0.15 | | | 0.17 | 0 | 0 | 0.07 |
| SGND | TRM | | | 0.30 | 0.19 | 0.27 | | 0.128 | 0.33 | 0.03 | 0.04 | 0.09 | 0.09 | 0.10 | 0.05 | 0.05 |

Table 18. Mean catch per unit effort data for channel catfish by seining (fish/haul), electrofishing (fish/min), and gill netting (fish/hr) and list of significant contrasts among segments. LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone, AKC = above Kansas City, BKC = below Kansas City, AL&C = above Lewis and Clark Lake (i.e., Segment **14**), BL&C = below Lewis and Clark Lake (i.e., Segment **15**), YSR = Yellowstone River (i.e., Segment 9). For other contrast results see Table A3-2.

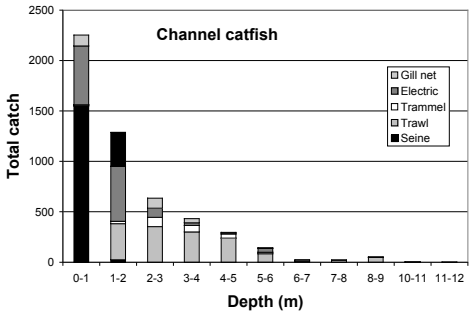
| General Contrast | Segment contrast | | Seining P value Means | Electro Fishing P value Means | Gill Netting P value Means |
|---|---|---|---|---|---|
| Among LA | | | | | |
| LA vs. IR and CH | LA vs. CH | 9 vs. *17, 22-27* | 0.003 0.57, 3.3 | | |
| | LA vs. CH | 5, 9 vs. *27* | | | 0.001 0.4,0.07 |
| | IR vs. CH | **15** vs. *17, 22-27* | 0.0007 0.18, 3.3 | | |
| | IR vs. CH | **7, 8, 10-15** vs. *27* | | | 0.002 0.24,0.07 |
| | LA YSR vs. CH | 9 vs. *17, 23, 25, 27* | 0.003 0.57, 3.3 | | |
| | LA YSR vs. CH | 9 vs. *27* | | | 0.002 0.38,0.07 |
| | IR BL&C vs. CH | **15** vs. *17, 22-27* | 0.0007 0.18, 3.3 | | |
| Among IR | IR W/O BL&C vs. CH | **7, 8, 10-14** vs. *27* | | | 0.0006 0.25,0.07 |
| IR vs. CH | IR AL&C vs. IR BL&C | **14** vs. **15** | | | 0.0001 1.2,0.17 |
| Among CH | AKC vs. BKC | *17, 19* vs. *23-27* | | 0.008 0.1,0.23 | |

fish were captured at depths of 12 m (Figure 15) but the mean depth at presence sites was 1.9 m, which was significantly deeper than the mean depth at absence sites (1.2 m, Table 16). Most of the total catch was at water velocities < 0.6 m/sec (Figure 15), but the mean velocity was similar (0.3 m/sec) at presence and absence sites (Table 16). For water turbidity, total catch was somewhat evenly distributed among categories ranging from 10 to 500 NTUs (Figure 15), but channel catfish presence sites were about twice as turbid as absence sites (Table 16). Silt and sand dominated the substrate where most channel catfish were captured (Figure 15), and there was proportionally more silt and less sand where channel catfish were present compared to where they were absent (Table A4-2).

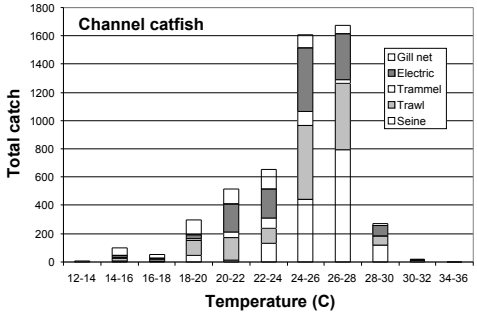
Stepwise multiple regression analysis revealed that the presence of channel catfish increased with water depth and temperature, and decreased with velocity ($R^2 = 0.25$). Turbidity fell out of the regression model perhaps because turbidity was significantly correlated with temperature, and velocity was added to the model even though velocity alone was not significant (P = 0.49, Table A4-2).

In summary, although the channel catfish was widespread, the low abundance in some LA and IR zone segments hampered statistical analysis of many segment contrasts. Significant contrasts indicated that C/E in IR segments was less than in CH segments because several IR segments were excluded from analysis due to low total catch. Channel catfish were caught in all

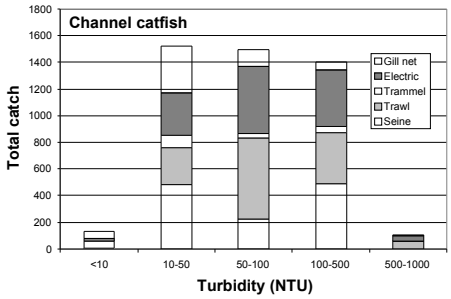
Figure 15. Total catch of channel catfish over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).



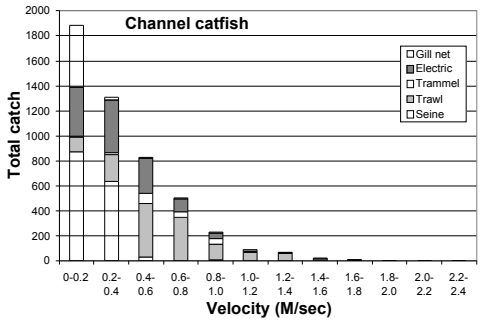

A



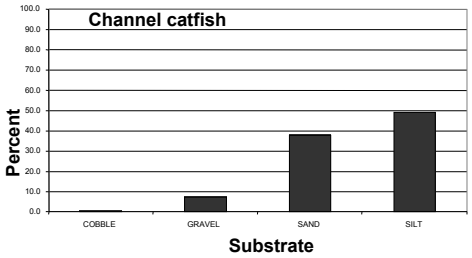

B




C




D




E

gears, but were most vulnerable to seines, trawls and electrofishing (Table 10). In ISB, TRM, and SCC macrohabitats in the CH zone, C/E values were 10x those in other macrohabitats in the same zone. Channel catfish were associated with a broad range of turbidities, and were more likely found over predominantly silt (50%) and sand (33%) substrates. Water velocity at presence and absence sites was about 0.3 m/sec, but channel catfish presence sties were deeper, warmer, and more turbid than absence sites.

***Common Carp***

The common carp is the only exotic species in our benthic fishes assemblage. Most adults usually weigh 0.5-3.6 kg and are 500-1000 mm long. We caught many small carp (<100 mm) and most size classes were well represented up to 750 mm long (Figure 6). The preponderance of fish in the 300-700 mm size class was somewhat similar to the length-frequency pattern of bigmouth buffalo.

This species does well in rivers and reservoirs (Edwards and Twomey 1982b), and we caught common carp in all segments and all macrohabitats (Table 19). Trammel net C/E were low in all macrohabitats in Segments 3-**10**, and declined greatly downstream in CH zone segments, except in TRMs. Conversely, trawl C/E increased in CH zone segments compared to C/E values upstream (Table 19). Total catch of 312 fish by seining was somewhat evenly distributed among zones, but statistical analysis of C/E data was not possible. Gill net C/E tended to be higher in SCNs and TRMs than in other macrohabitats (Table 19), but no segment contrasts were significant for gill net C/E of common carp (P = 0.04, Table A3-3).

The total catch by electrofishing (224 fish) was useful for some contrasts among segments using data from BENDs, SCCs, and TRMs of Segments **10-15**, *17*, *19*, *23-27* (Table 20). Data for LA segments was of minimal use because electrofishing was not used in 1996 and 1997, because there were no TRMs in Segment 5, or because catches in other macrohabitats and gears were too low for analysis. The IR zone vs. CH zone contrast was insignificant (P = 0.034, Table A3-3), except when the high catch (0.4 fish/min) in Segment **15** made several contrasts among IR and CH segments and between IR and CH segments significant (Table 20). Mean C/E downstream from Lake Sakakawea was higher than the catch upstream. Mean C/E below Kansas City was higher (0.17 fish/min) than the catch above (0.13 fish/min). In general, the high catch rate in Segment **15** (0.4 fish/min) dominated the contrasts, making catches upstream in the IR and downstream in the CH significantly lower than catches in Segment **15**.

Total catch of common carp was distributed over a wide range of habitat conditions but most fish were caught where velocity was < 0.4 m/sec (Figure 16), and mean velocity was similar (0.3 m/sec) for both presence and absence sites (Table 16). Most total catch was where substrates were dominated by silt, but total catch was distributed over a wide range of turbidity (10 - 500 NTUs) and temperature (18-30º C) conditions (Figure 16). The proportion of silt was significantly higher (57% vs 30%) and sand significantly less (31% vs 57%) where common carp were caught compared to sites where fish were not caught (Table 16). Water depth at presence sites was higher (1.9 m) than at absence sites (1.3 m, Table 16).

Stepwise logistic regression ($R^2 = 0.14$) indicated that the likelihood of presence of common carp increased with increased water depth, temperature and decreased water velocity and substrate geometric mean. Velocity and substrate geometric mean were added to the model even though the means at presence and absence sites were not significantly different when tested alone with ANOVA. Turbidity may have been eliminated from the regression model because it was correlated with temperature. Temperature likely accounted for enough of the variation in the likelihood of presence of common carp that turbidity accounted for by itself to result in the non-significant turbidity effect in the logistic regression analysis.

In summary, common carp were abundant, widespread, and easily collected by electrofishing in all macrohabitats except CHXO. The C/E in the LA zone was lower than that in other zones, and the high C/E in all macrohabitats of Segment **15** dominated statistical contrasts. The catches downstream from Lake Sakakawea were higher than catches upstream. Substrates had more silt and water was deeper, warmer, and more turbid at common carp presence sites than at absence sites. Velocity was about 0.3 m/sec at both presence and absence sites.

***Emerald Shiner***

This species is not associated with the benthic habitat as much as other species in our benthic fishes assemblage, however it is probably important prey for many species. Adults are about 7 cm long, so all of our catch was in two small size classes (Figure 17). The species was used by Young (2001) to study the possibility of subpopulations (demes) forming in the mainstem. We caught emerald shiners throughout the mainstem and in all segments, with total catch in Segment **15** (below Gavins Point Dam) almost twice the catch in other segments (Table 8). Most fish were captured by seining and electrofishing in all macrohabitats except CHXO (Figure 18). The C/E data showed a general pattern of lower catches in the IR. The unusually high catch in

Table 19. Common carp catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = benthic seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments. See Figure A2-2.

| Gear and habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0.007 | 0.022 | 0 | 0.007 | 0.015 | 0.037 | 0 | 0 | 0 | 0 | 0 | 0.022 | 0 | 0 | 0 |
| DTN | ISB | 0.026 | 0.009 | 0.007 | 0 | 0.080 | 0.019 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0.000 | 0.037 | 0 | 0.007 | 0.015 | 0.037 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0.444 | 0 | 0.015 | 0.052 | 0.022 | 0 | 0 | 0.030 | 0 | | | | 0 | 0 | 0.015 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0.167 | 0.222 | 0.195 | 0.133 | 0.037 | |
| BT | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.064 | 0 | 0.009 | 0 | 0.030 |
| BT | OSB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.022 | 0 |
| BT | SCC | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0.022 | 0 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0.044 | 0 | 0.111 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0.028 | 0.074 | 0 | 0 | 0.07 | 0.67 | 0 | 0 | 0.056 | 0 | 0 | 0 | 0 | 0.044 | 0.022 |
| BS | OSB | | | | | | | | | | | | | | | |
| BS | SCC | 0.04 | 0 | 0.074 | 0 | 0.01 | 0.65 | 0 | 0 | 0.118 | | 0.5 | 0 | 0.167 | 0.017 | 0.011 |
| BS | SCN | 0 | 0.22 | 0.38 | 7.69 | 0.63 | 0.25 | 0 | 0.75 | 0 | | | 0 | 0.5 | 0 | 0.3 |
| BS | TRM | | | | | | | | | | | | | | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0.2 | 0.12 | 0.06 | 0 | 0.05 | | | 0.111 | 0.87 | 0.20 | 0.09 | 0.13 | 0.07 | 0.07 | 0.17 |
| EF | OSB | 0.23 | 0.18 | 0.07 | 0.08 | 0.10 | 0.03 | 0.056 | 0.059 | 0.31 | 0.12 | 0.13 | 0.09 | 0.10 | 0.07 | 0.15 |
| EF | SCC | 0.45 | 0.15 | 0.12 | 0.130 | 0.24 | 0.10 | 0.050 | 0.162 | 0.27 | 0.00 | 0.12 | | 0.18 | 0.10 | 0.13 |
| EF | SCN | | 0.00 | 0.16 | 0.122 | 0.41 | 3.44 | 0.575 | 0.182 | 0.32 | | | 0.25 | | | 0.17 |
| EF | TRM | | | 0.33 | 0.167 | 0.55 | 0.03 | 0.261 | 0.248 | 0.57 | 0.15 | 0.17 | 0.14 | 0.16 | 0.31 | 0.40 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0 | 0.005 | 0 | 0.021 | 0.002 | 0 | 0 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0.345 | 0.093 | 0.040 | 0.052 | 0.220 | 0.017 | 0.658 | 0.105 | | | 0.021 | 0.235 | 0 | 0.087 |
| SGND | TRM | | | 0.011 | 0.054 | 0.035 | | 0.022 | 0.099 | 0.030 | 0.006 | 0.143 | 0.077 | 0.043 | 0.0426 | 0.171 |

Table 20. Mean catch per unit effort data for common carp by electrofishing (fish/min) and list of significant contrasts among segments. LA = least altered zone, IR = inter-reservoir zone, CH = channelized zone, ASAK = above Lake Sakakawea, BSAK = below Lake Sakakawea, AL&C = above Lewis and Clark Lake (i.e., Segment **14**), BL&C = Below Lewis and Clark Lake (i.e., Segment **15**), 1st CHAN = 1st channelized segment (i.e., Segment *17*), AKC = above Kansas City, BKC = below Kansas City. For other contrast results see Table A3-3.

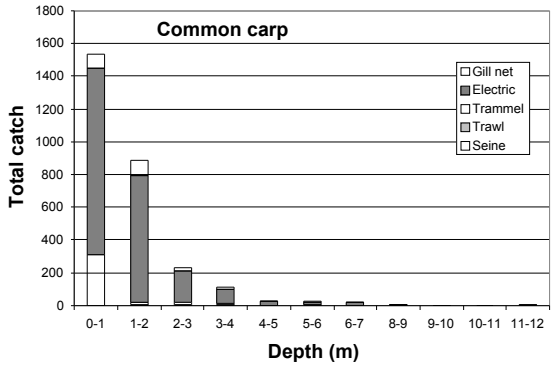
| General Contrast | Segment contrast | | Electro P value Means |
|---|---|---|---|
| Among LA | | | |
| LA vs. IR and CH | | | |
| Among IR | ASAK IR vs. BSAK IR | **10** vs. **12** | 0.01<br>0.05, 0.14 |
| | AL&C IR vs. BL&C IR | **14** vs. **15** | <0.0001<br>0.15, 0.4 |
| | IR W/O BL&C vs. BL&C IR | **10-14** vs. **15** | <0.0001<br>0.12, 0.4 |
| IR vs. CH | BL&C IR vs. CH | **15** vs. *17, 19, 23, 25, 27* | <0.0001<br>0.4, 0.16 |
| | BL&C IR vs. 1st CHAN | **15** vs. *17* | <0.0001<br>0.4, 0.13 |
| Among CH | AKC CH vs. BKC CH | *17, 19* vs. *23, 25, 27* | 0.001<br>0.13,0.17 |

Segment **15** biased statistical comparisons, but catches in other IR segments (Segments **7**, **8**, **10**, and **12**) were too low to include those segments in ANOVA, so concluding that average catch in the IR was lower than in other zones is intuitive.

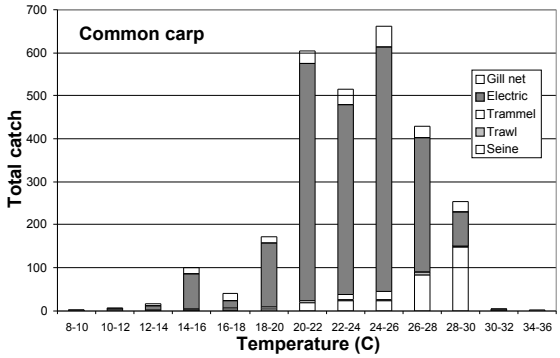
All ANOVAs for seine data have significant segment effects, but we present results from the most robust analysis that included eight segments and three macrohabitats over all years (Table A3-4). Three segment contrasts were significant (Table 21). Beach seine C/E was lower in Segment 9, the Yellowstone River segment, than in Missouri River LA Segments 3 and 5, and lower than the average C/E in the CH segments. Electrofishing catch in Segment **15** was about 3X higher than in the CH segments. Statistics were not needed to see that emerald shiner catch was lower in the Missouri River around the confluence with the Yellowstone (Segment 9) than in the Yellowstone River itself, and that catch in Segment 9 was higher than that in the IR segments, many of which were deleted from the analysis. The trend in total catch and C/E (Table A2-4) was higher above than below Fort Peck Lake and Lake Sakakawea, but the reverse trend was obvious for Lewis and Clark Lake.

The habitat data were not helpful in associating presence with most of the conditions (expect decreased conductivity) that were measured in this study. The stepwise logistic regression $R^2$ was one of the lowest recorded in this study, and there were no significant differences in means of physical habitat measurements

Figure 16. Total catch of common carp over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).




A

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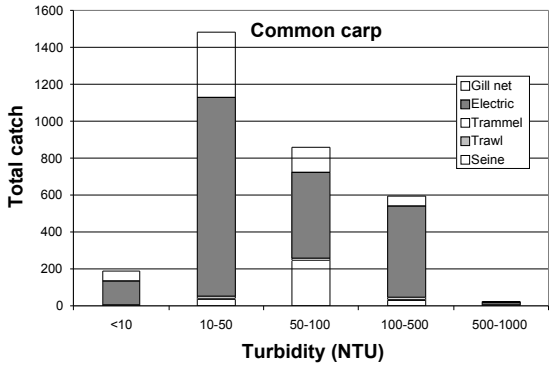


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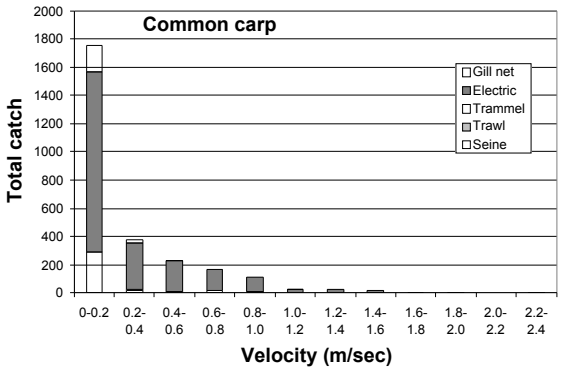


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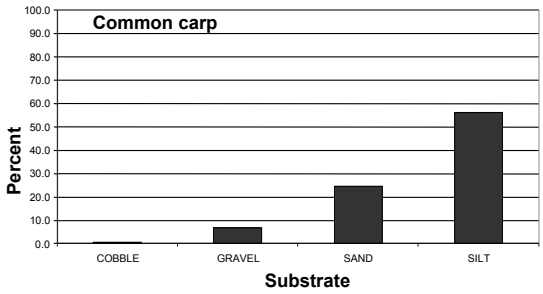


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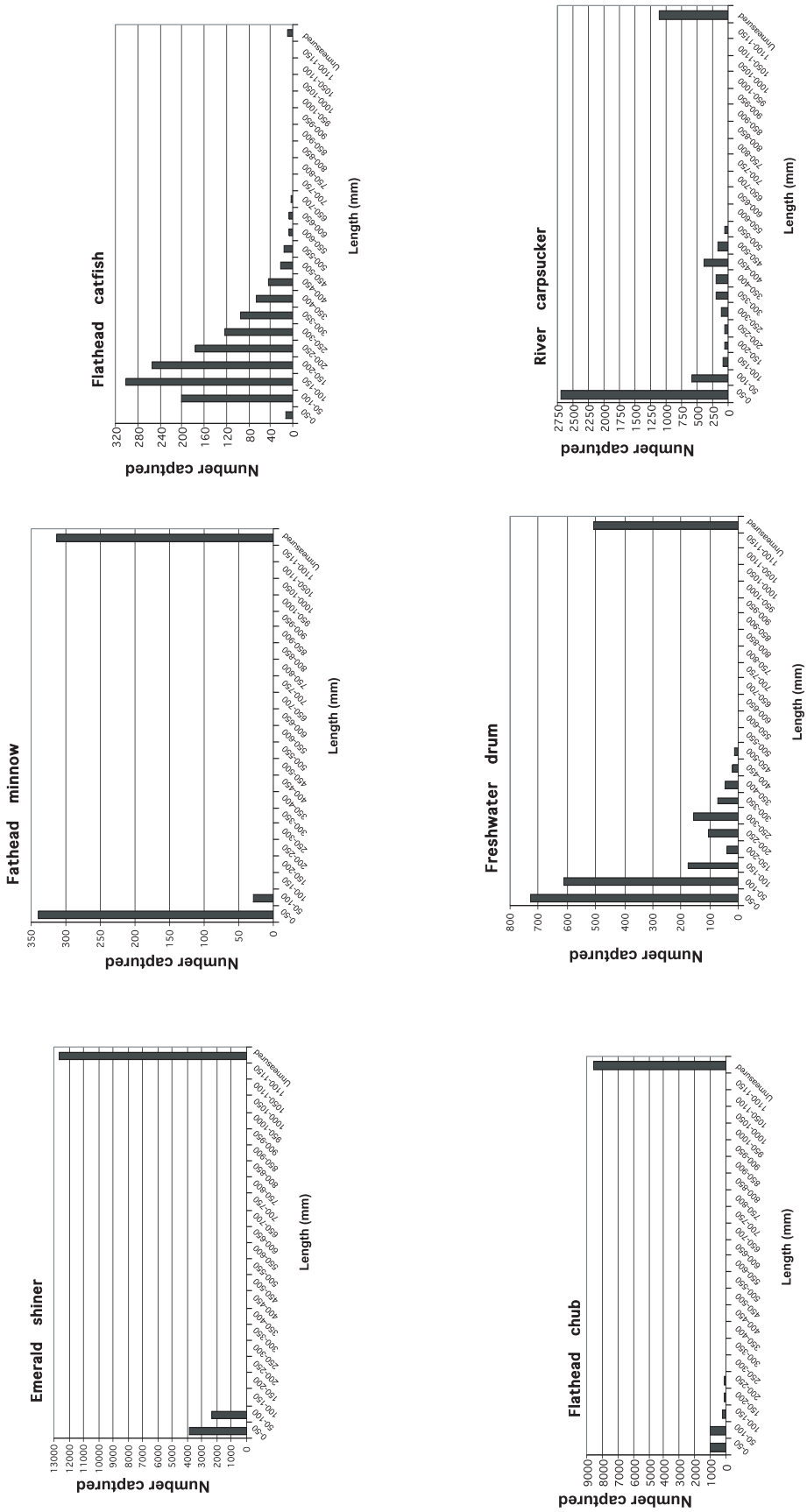



Figure 17. Length, frequency, distribution for six species of benthic fishes collected from 15 segments of the main channel of the Missouri River, 1996-1998. Bar in far right of figure indicates number of fish not measured.

Figure 18. Catch per effort of emerald shiner from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-4.

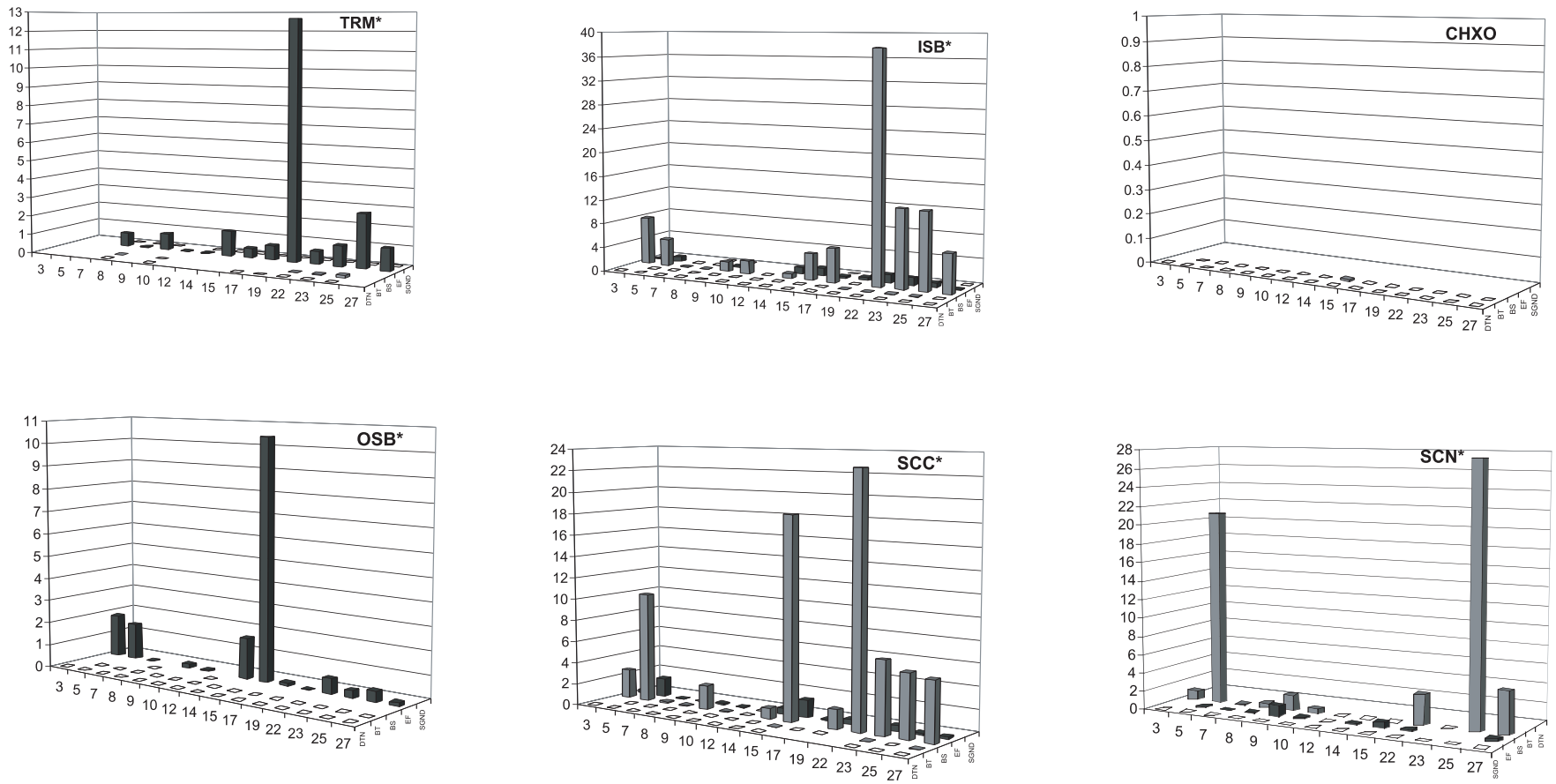


Table 21. Mean catch per unit effort data for emerald shiner by electrofishing (fish/min) and seining (fish/haul) and list of significant contrasts among segments. LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone, BL&C = below Lewis and Clark Lake (i.e., Segment **15**), MOR = Missouri River, YSR = Yellowstone River (i.e., Segment 9). For other contrast results see Table A3-4.

| General Contrast | Segment contrast | | Seining P value Means | Electro Fishing P value Means |
|---|---|---|---|---|
| Among LA | LA MOR vs. LA YSR | 3, 5 vs. 9 | 0.011<br>2.4, 0.8 | |
| LA vs. IR and CH | LA YSR vs. CH | 9 vs. *22, 23, 25, 27* | 0.0001<br>0.8, 2.9 | |
| Among IR | | | | |
| IR vs. CH | BL&C vs. CH | **15** vs. *17, 19, 23, 25, 27* | | 0.008<br>2.1, 0.7 |
| Among CH | | | | |

at presence and absence sites, except the proportion of sand (Table 16). The pattern of total catch at each habitat category may be somewhat helpful. The total catch pattern was skewed toward shallow water where the proportion of silt was higher than sand or gravel (Figure 19). Highest catches occurred where temperature was 20-30°C and turbidity was 10-100 NTUs (Figure 19). Most of the total catch was over a broad (<1.2m) velocity range.

In summary, emerald shiners were vulnerable to seining and electrofishing. Most catches were in ISB, SCC, and SCN habitats, but electrofishing catch was high in OSB and TRM habitats. Catches in the IR segments were lower than those in the LA or CH segments. The LA Segments 3 and 5 differed from LA Segment 9, and a "reservoir effect" was found in two cases (catches upstream from Fort Peck and Lewis and Clark were lower than catches downstream). The species was usually found in shallow, clear, moderate velocity waters over silt substrates, but can be found in a variety of conditions.

***Fathead Minnow***

The fathead minnow grows to about 50-70 mm in length, so all fish we caught were in two size classes (Figure 17). The fathead minnow we collected were distributed throughout the mainstem (except Segment 5), but the largest catches were in segments in the IR, especially Segment **12** where 317 fish were caught and seine C/E reached 7 fish/haul in SCNs (Figure 20). All fish were caught by either electrofishing or seining; most were caught in SCNs, ISBs, and SCCs. Analysis of segment contrasts was possible using 193 fish caught by electrofishing, but there were no significant ($P > 0.43$) segment effects (Table A2-5). However, trends were obvious, especially that C/E in the IR segments exceeded C/E in either the LA segments or CH segments. No fathead minnow were captured in Segment 5, so it is obvious that C/E in the LA Missouri River segments was lower than C/E in the LA Yellowstone River Segment 9.

Habitat associations were not suggested by either ANOVA comparison between mean conditions at presence and absence sites, or by stepwise logistic regression (Table 16, Table A4-2). The fathead minnow was typically caught in shallow water where velocities were <0.4 m/sec (Figure 21). Total catch was higher where turbidity was <50 NTUs and substrates were predominantly silt with some sand than in areas of high turbidity or coarser substrates (Figure 21). The catch curve over the range of sampling temperatures was bimodal, with high catches at 16-18°C and high catches at 22-26°C.

In summary, the total catch pattern of fathead minnow was highest in the IR zone, but the patchy nature of the catch and the few number of segments with suf-

Figure 19. Total catch of emerald shiner over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).

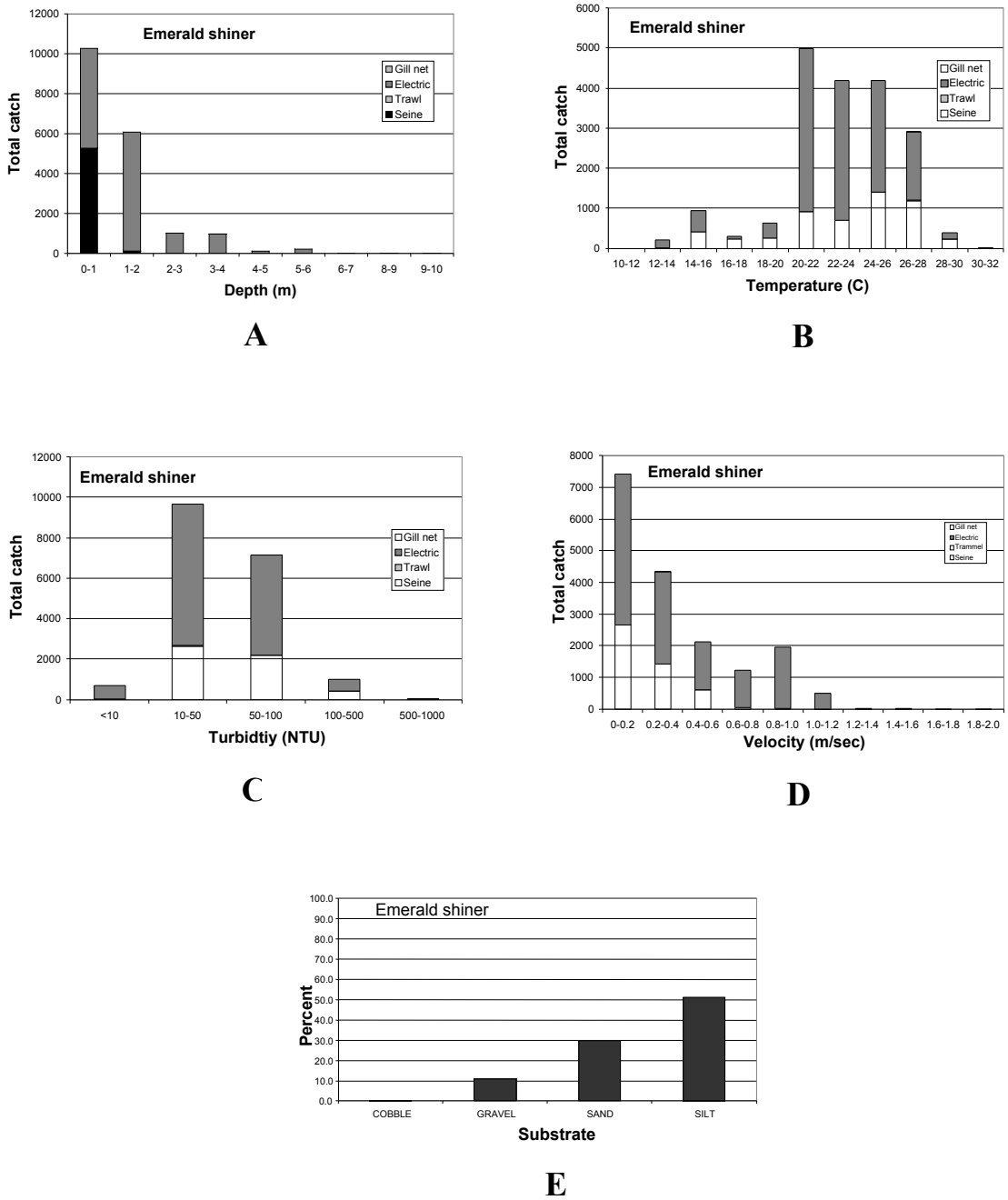


Figure 20. Catch per effort of fathead minnow from 15 segments (3= Montana, 27= Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-5.

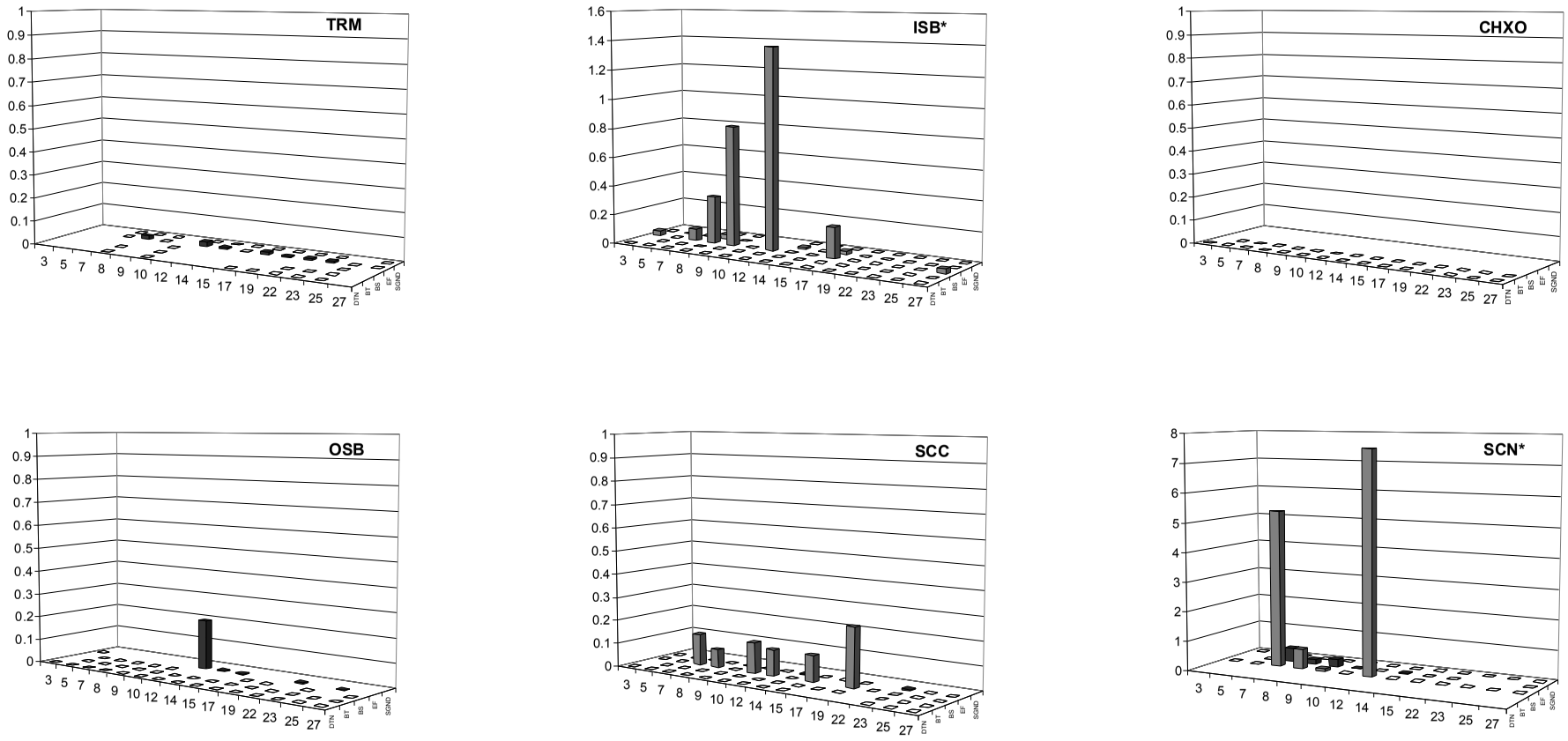
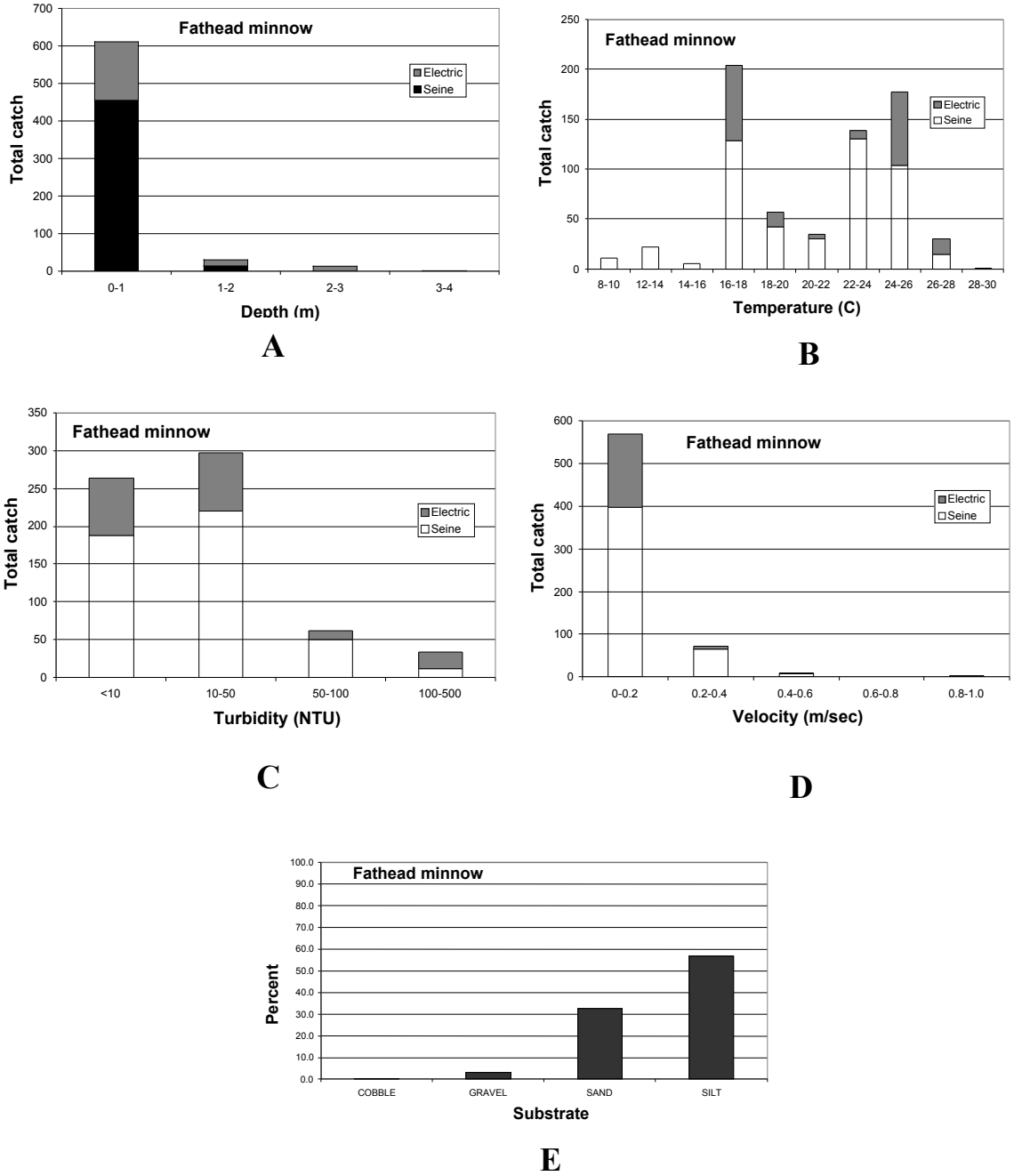


Figure 21. Total catch of fathead minnow over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).



ficient C/E of fathead minnow limited statistical segment contrasts. In general, fathead minnow were found in slowly moving (0.2 – 0.3 m/sec) waters over substrates dominated by silt and sand that are typical of SCNs (Galat et al. 2001) where C/E was as high as 7 fish/haul with seines.

***Flathead Catfish***

This species is native and common in the lower Missouri River, but is only occasionally collected in the upper river (Reigh and Owen 1979, Jackson 1999, Galat et al. 2005). It does well in reservoirs and the main channel. We captured 1267 flathead catfish in a wide size range, with some in the 1100-1150 mm length class (Figure 17).

Flathead catfish were not found upstream from Segment **14** (Figure 22). Three flathead catfish were captured in Segment **14**, which is the 73-km reach between Fort Randall Dam and Lewis and Clark Lake, and the remainder were captured downstream from Gavins Point Dam. Highest C/E was by electrofishing in OSB macrohabitat, with lower catch rates in TRMs, ISBs, and SCCs, and very few fish were caught in CHXOs and SCNs.

Because the catch was mostly in the CH zone, statistics were not needed to show that catch in this zone was greater than in the IR or LA zones. Planned statistical contrasts were possible only for Segment **15** and other segments downstream (Table 22). Possible segment contrasts used electrofishing data for BEND, SCC, and TRM (Table A3-6). Catches in Segment **15** (BL&C) were higher than in CH segments. There was no difference in catch above and below Kansas City (P = 0.8, Table A3-6).

Though limited in distribution, the flathead catfish showed more contrast in habitat conditions between presence and absence sites than other species, as judged by the stepwise logistic regression $R^2$ value and the number of significant habitat differences between sites with and without fish (Table 16). Total catch was associated with a wide range of turbidity levels (10-500 NTUs, Figure 23); but presence sites were more turbid than absence sites (Table 16). Most fish were found at depths of <2 m, but fish were also captured at many depths up to 12 m, and mean depth at presence sites (2.7 m) was among the deeper mean values recorded for all benthic fishes (Table 16). Velocities associated with total catch had a wide range; mean velocities were 0.5 m/sec at presence sites and 0.2 m/sec at absence sites. Silt and sand dominated the substrate (85%, Table 16) where flathead catfish were captured, but some were caught where cobble was present (Figure 23) and sites with fish had more gravel than sites without (Table 16).

Stepwise logistic regression ($R^2$ = 0.37) indicated that the likelihood of presence of flathead catfish increased with increased water depth and geometric mean substrate particle size. There was a significant difference in velocity between sites with and without flathead catfish when only velocity was considered, however, stepwise logistic regression indicated that, after inclusion of depth and substrate into the model, velocity did not account for a significant amount of additional variance. Depth was significantly positively correlated with temperature (28% of the depth effect explained by temperature).

In summary, the range of the flathead catfish is limited to the lower river where it is common in all segments, except Segment *27*. It is vulnerable to electrofishing and is associated with the deep waters and swift currents of OSBs, with much reduced presence in other macrohabitats.

***Flathead Chub***

The flathead chub inhabits streams in the western plains (e.g., Moreau River, Loomis et al. 1999), but has declined in the southern part of the Missouri River basin (Grady and Milligan 1998). We commonly collected this species with four gears in Segments 3-**10**, but further downstream, catches were nil (Figure 24). Fisher et al. (2002) found 5-year-old fish to 267 mm in length and we caught a few in that size range and longer (Figure 17).

We captured most flathead chub by seining (9281 fish) and electrofishing (1502 fish), but some fish were caught with drifting trammel nets and benthic trawls in CHXO habitats (Figure 24). Flathead chub were captured in all macrohabitats, but highest catch rates were in SCCs, ISBs, and SCNs. Our catch rates with the bag seine were highest (occasionally 50 fish/haul) in channel border habitat, which agreed with other recent reports (Welker 2000, Fisher et al. 2002).

Data from seining in BEND, SCC, and SCN and electrofishing in BEND and SCCs were sufficient for segment comparisons, which were significant (P < 0.0001 and P = 0.003 respectively, Table 23). Contrasts were only possible with data from LA Segments 3, 5, and 9, and from IR Segments **8** and **10** (Table A3-7). Catch in seines was greater in the Yellowstone River (C/E = 21.9) than in the Missouri River LA segments (C/E = 6.1), but the data for electrofishing showed the opposite trend. All possible contrasts between LA segments and IR segments for both fishing gears indicated that catches were greater in the LA segments. Too few specimens were collected in the IR Segments **12-15** and in any CH segments to make any segment comparisons, but trends were obvious. From 1-10 flathead

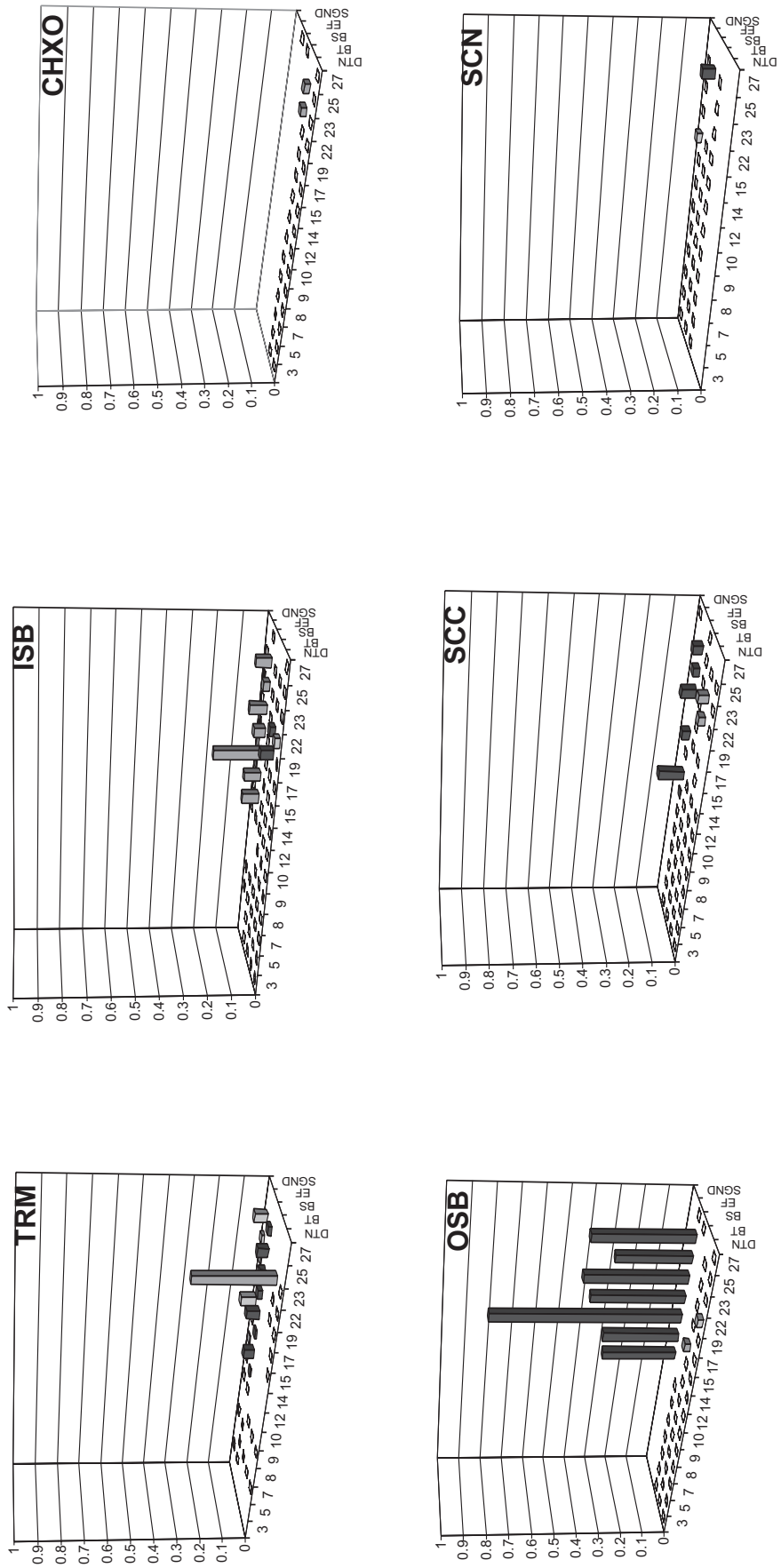



Figure 22. Catch per effort of flathead catfish from 15 segments (3 = Montana, 27 = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). See Table A2-6

Table 22. Mean catch per unit effort data for flathead catfish by electrofishing (fish/min) and list of significant contrasts among segments. LA = least altered zone, IR = inter-reservoir zone, CH = channelized zone, BL&C = below Lewis and Clark Lake (i.e., Segment **15**), 1st CHAN = first segment downstream from the IR zone in the CH zone. For other contrast results, see Table A3-6.

| General Contrast | Segment contrast | | Electro Fishing P value Means |
|---|---|---|---|
| Among LA | | | |
| LA vs. IR and CH | | | |
| Among IR | | | |
| IR vs. CH | BL&C IR vs. 1ST CHAN | **15** vs. 17 | 0.003<br>0.14, 0.07 |
| | BL&C IR vs. CH | **15** vs. 17, 19, 23-27 | 0.005<br>0.14, 0.09 |
| Among CH | | | |

chubs were captured in each of Segments **14**-*27*, so the species was widely distributed, but obviously the density was higher in the LA zone than in the IR zone or CH zone. Two reservoir related contrasts were also obvious: fewer flathead chubs were found downstream from Fort Peck Lake and Lake Sakakawea than were found upstream (i.e., Segments 5 vs. **7** and Segments **8** vs. **10**).

Flathead chub total catch was high in shallow (<1 m) conditions where sand is the dominant substrate, but gravel is also abundant (Figure 25). Most flathead chub were caught in a narrower temperature range (14-26°C) than most other benthic species, but mean temperature was similar at sites with and without fish (Table 16). Most fish were captured where turbidity levels were 10-50 NTUs, but the fish was found at other turbidity levels as well. Mean velocity at presence sites what higher (0.4 m/sec) than at absence sites (0.2 m/sec), and substrate geometric mean was higher (1.4 mm) at presence sites than at absence sites (0.1 m). Presence was positively related to the proportion of gravel and sand and negatively related to the proportion of silt in the bottom substrates.

Stepwise multiple regression indicated that the likelihood of presence of flathead chub increased with increased water velocity and decreased depth ($R^2$= 0.17). Differences between mean depths at presence and absence sites approached significance (P = 0.055, Table A4-3), and depth was recognized as significant by stepwise logistic regression analysis. Depth and velocity were also positively correlated (17%). Substrate geometric mean dropped out of the model.

In summary, the flathead chub is widespread, but much higher densities were found in the LA segments and IR segments upstream from Lake Sakakawea than further downstream. Catch was higher in the LA segments than in the IR and CH segments. The species was found in all macrohabitats, and sites with fish had swifter, shallower water over coarser substrates than did sites without fish. It can be captured by active gears, especially seines and electrofishing.

***Freshwater Drum***

This species is an important commercial and recreational species that is widespread and locally abundant. It is a large (maximum about 22 kg and 80 cm) silvery fish and open-water spawner; larvae drift from the South Dakota portion of the river into the CH zone (Braaten and Guy 2002). We collected freshwater drums distributed in 13 size classes up to 700 mm in length (Figure 17).

Freshwater drums were captured in all segments except Segment **12** (downstream from Garrison Dam). Most fish were caught by beach seine (1820), bottom trawl (553), or electrofishing (1273). Fish were caught in all macrohabitats, with CHXO producing the lowest catch (Figure 26). A one-time, high catch rate in the trawl of about 40 fish/100 m in SCCs in Segment *17*

Figure 23. Total catch of flathead catfish over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).

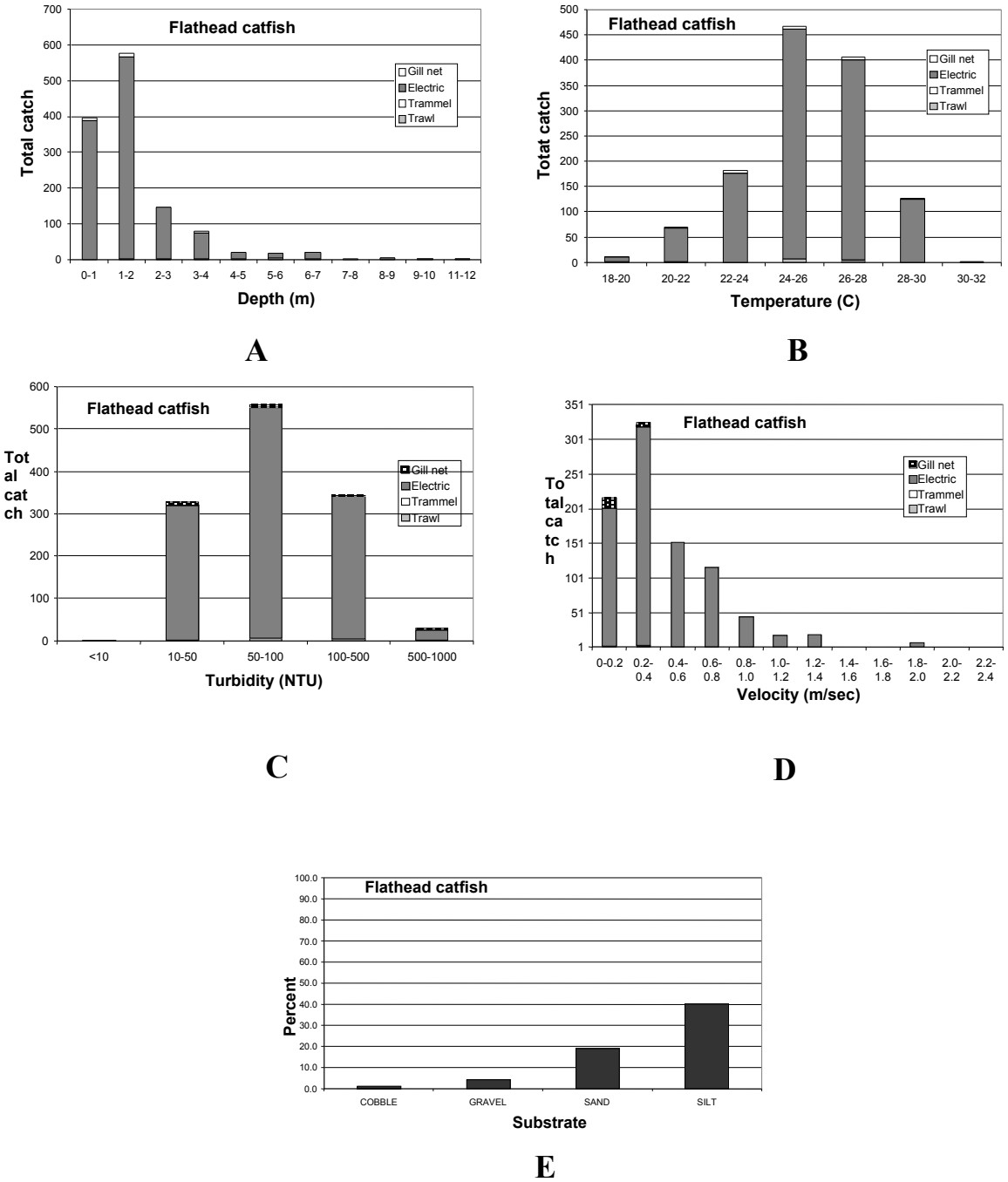


Figure 24. Catch per effort of flathead chub from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-7.

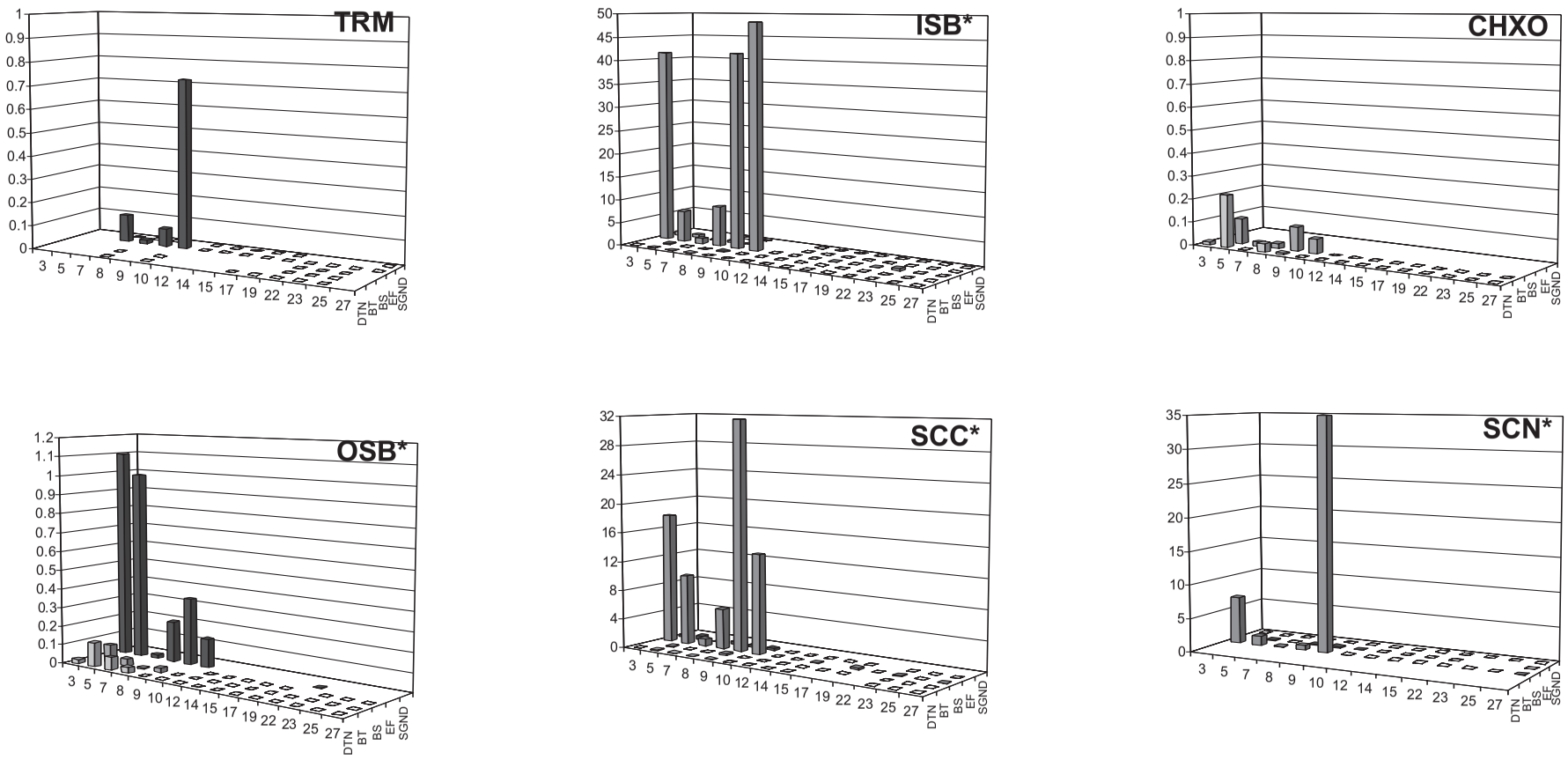


Table 23. Mean catch per unit effort data for flathead chub by electrofishing (fish/min) and seining (fish/haul) and list of significant contrasts among segments. LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone, BL&C = below Lewis and Clark Lake (i.e., Segment **8**), FTP = segments between Fort Peck Dam and YSR confluence, MOR = Missouri River, YSR = Yellowstone River (i.e., Segment 9). For other contrast results see Table A3-7.

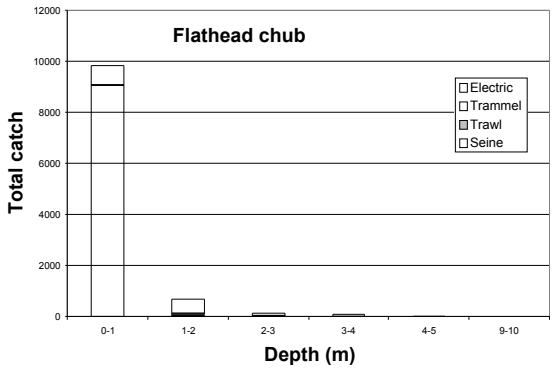
| General Contrast | Segment contrast | | Seining P value Means | Electro Fishing P value Means |
|---|---|---|---|---|
| Among LA | MOR LA vs. YSR LA | 3, 5 vs. 9 | <0.0001 6.1, 21.9 | |
| | MOR LA vs. YSR LA | 5 vs. 9 | | 0.002 1.04, 0.3 |
| LA vs. IR and CH | YSR LA vs. FTP IR | 9 vs. **8** | <0.0001 21.9, 2.8 | |
| | MOR LA vs. FTP IR | 5 vs. **8** | | 0.001 1.04, 0.28 |
| | LA vs. IR | 3, 5 ,9, vs. **8, 10** | 0.003 11.7, 3.8 | |
| | MOR LA vs. IR W/O BL&C | 5 vs. **8, 10** | | 0.0006 1.04, 0.24 |
| | YSR LA vs. IR W/O BL&C | 9 vs. **8, 10** | <0.0001 6.1, 3.8 | |
| Among IR | | | | |
| LA vs. CH | | | | |
| Among CH | | | | |

was unusual, otherwise, trawl catches were about 1-7 fish/100 m in the CH zone in ISBs, SCNs, and TRMs. Seine catches were relatively high (1-7 fish/haul), but there were no significant segment effects (P > 0.1, Table A3-8).

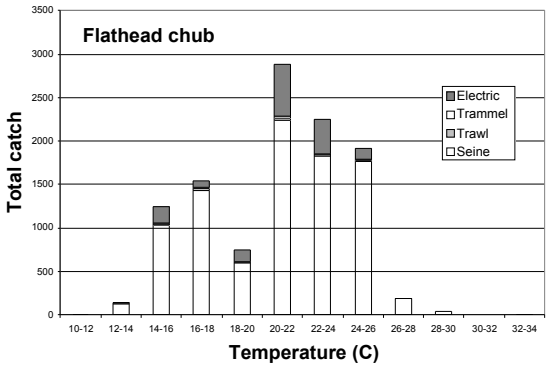
Significant segment effects were found for electrofishing C/E in BENDS (P = 0.003, all years) and trawling C/E in BENDS and SCCs (P = 0.002, 1997 and 1998 only). The C/E values for these gears were higher in LA and CH segments than in IR segments (Table 24), thus agreeing with the general trends seen in total catch (Figure 26). The C/E in LA segments of the Missouri River (Segments 3 and 5) were higher than catches in the Yellowstone River and higher than in both the IR and CH zones. Catches in most IR segments were too low for analysis (except in Segments **14** and **15)**, so C/E of freshwater drums in the CH segments for these gears was obviously higher than catches in IR segments. The one planned contrast (Table 24) among CH segments was possible - trawling catches above Kansas City (C/E = 1.95 fish/100 m) were higher than catches below Kansas City (C/E = 0.14 fish/100 m).

Segments **7**, **8**, 9, **10**, **12**, and **14** were left out of most analyses, so any contrasts dealing with the Yellowstone River and Missouri River segments near the confluence could not be made. Catch was obviously

Figure 25. Total catch of flathead chub over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).




A

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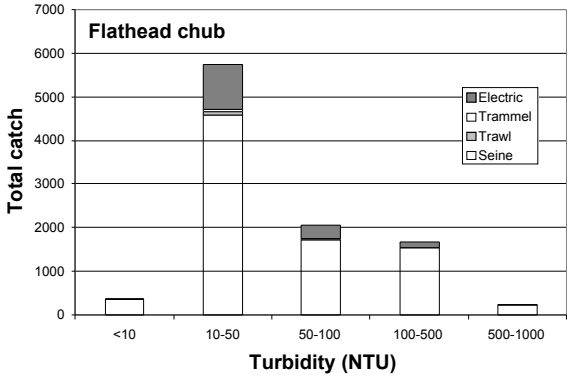


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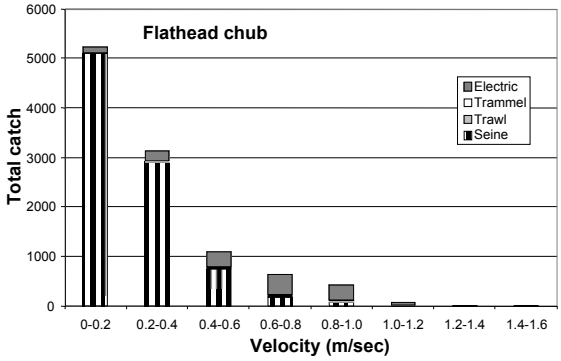


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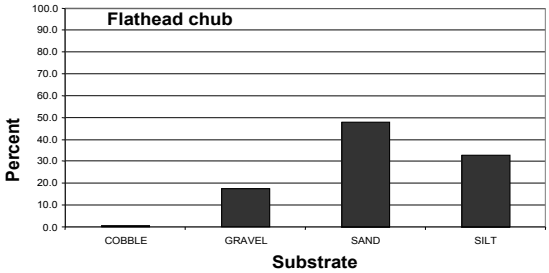



E

Figure 26. Catch per effort of freshwater drum from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-8.

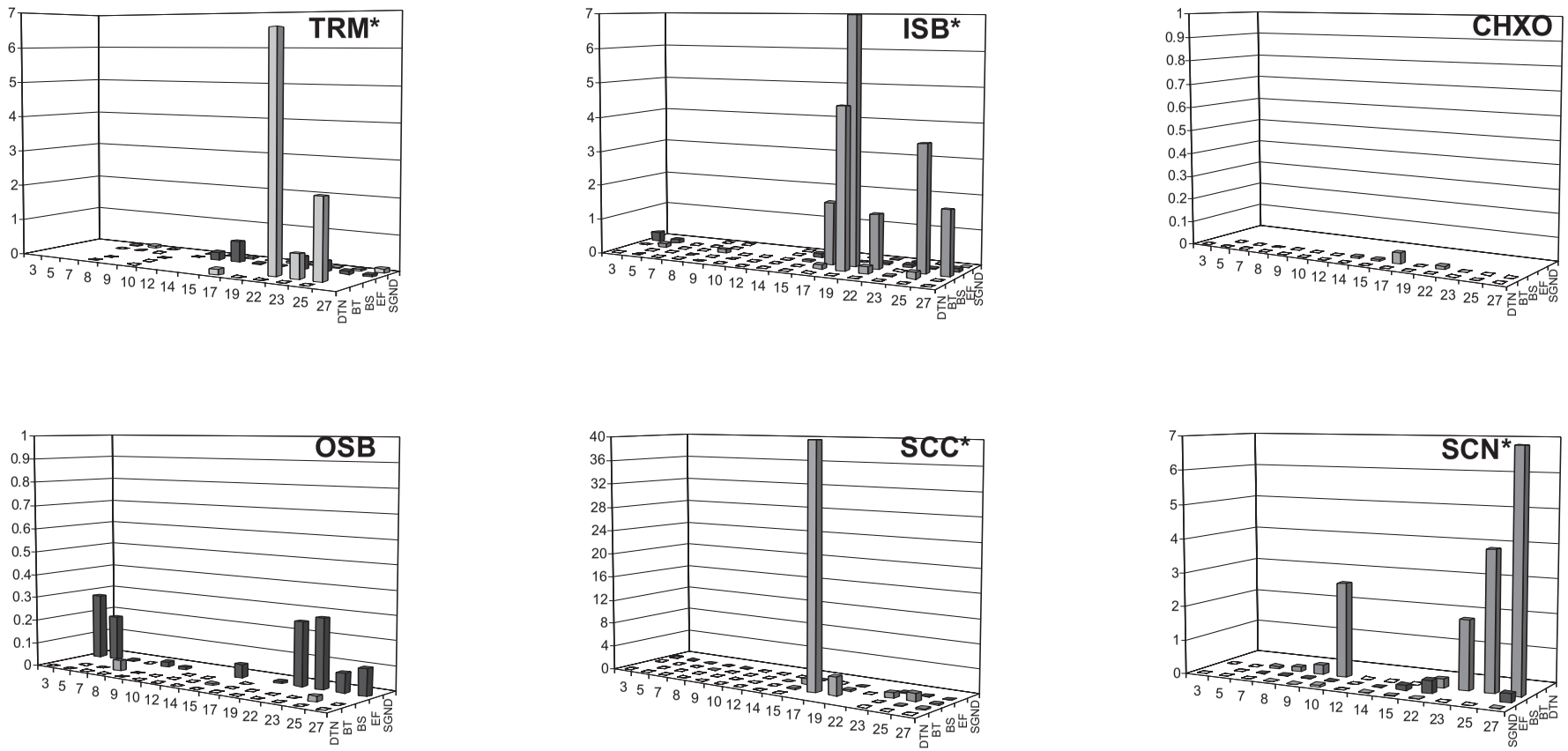


Table 24. Mean catch per unit effort data for freshwater drum by electrofishing (fish/min) and trawling (fish/100m) and list of significant contrasts among segments. LA = least- altered zone, IR = inter-reservoir zone, CH = channelized zone, AKC = above Kansas City, BKC = below Kansas City, BL&C = below Lewis and Clark Lake (i.e., Segment **15**), 1st CHAN = 1st channelized segment (i.e., Segment *17*), MOR = Missouri River. For other contrast results see Table A3-8.

| General Contrast | Segment contrast | | Electro Fishing P value Means | Trawl P value Means |
|---|---|---|---|---|
| Among LA | | | | |
| LA vs. IR and CH | LA vs. IR | 3, 5, vs. **14**, **15** | <0.0001<br>0.2, 0.02 | |
| | MOR LA vs. BL&C IR | 3, 5 vs. **15** | 0.002<br>0.2, 0.05 | |
| | MOR LA vs. IR w/o BL&C | 3, 5 vs. **14** | 0.0002<br>0.2, 0.001 | |
| | LA vs. CH | 3, 5 vs. 22- 27 | 0.006<br>0.2, 0.1 | |
| Among IR | | | | |
| IR vs. CH | IR vs. CH | **14**, **15** vs. 22 -27 | 0.008<br>0.03, 0.1 | |
| | IR w/o BL&C vs. CH | **14** vs. 22 - 27 | 0.008<br>0.001, 0.1 | |
| | IR vs. CH | **15** vs. *17, 19, 25* | | 0.002<br>0.01, 1.08 |
| | BL&C vs. 1st CHAN | **15** vs. *17* | | 0.0009<br>0.01, 2.6 |
| Among CH | AKC vs. BKC | *17, 19* vs. *25* | | 0.0009<br>1.95, 0.14 |

higher above Fort Peak and Lewis and Clark reservoirs than below. There was low C/E in Segments **14** and *17*, so the high C/E in Segment **15** indicated that fish density was higher there without statistical analysis.

The habitat associations with total catch reveal that the freshwater drum were found in shallow to mid-depth sites with substrates dominated by silt and sand (Figure 27). Freshwater drums were caught over a wide range of velocities (<2 m/sec), and at temperatures from 12 to 32°C, but differences between presence and absence sites was not significant (Table 16). One-way ANOVA indicated that mean depth was greater (1.9 m) at sites with fish than at sites without fish (1.5 m). Turbidity at presence sites was about two times that at absence sites (Table 16). There was no difference in substrate geometric mean between presence and absence sites, but the ANOVA results confirmed the total catch pattern that indicated more silt and less sand at presence sites than at absence sites (Table 16). However, stepwise multiple regression indicated that the likelihood of fish presence increased with increasing substrate mean and increasing turbidity. The low stepwise logistic regression $R^2$ (0.06) probably indicates that other factors are important in predicting the likelihood of presence of freshwater drum, and our data accounts for too little of the variability to be biologically useful.

Overall, the freshwater drum was most abundant in the CH zone in most macrohabitats and in a wide range of physical conditions. Results of segment contrasts generally agreed that densities in the LA and CH zones were higher than those in the IR zone. The obvious trend was that catches in the IR zone were lower than in other zones. Segment **15** had high catches and catch was lower below two reservoirs than above. The species was most vulnerable to seining, trawling and electrofishing.

***Hybognathus spp.***

The benthic fishes assemblage has three minnow species (western silvery minnow, *H. argyritis*; plains minnow, *H. placitus*; brassy minnow, *H. hankinsoni*) that are difficult to identify without necropsy. However, a presumptive identification of adults can be made with external characters (e.g., scale pattern, eye size, head length). Few details are known about the biology of these species; however, the western silvery minnow is considered rare in some basin states, whereas the plains and brassy minnow are more common.

We identified 374 western silvery minnow, many in the upper basin where they were the subject of a Ph.D. dissertation associated with our study (Welker 2000). Welker (2000) collected more western silvery minnow along shallow channel borders than in the main channel. Western silvery minnow were not found in our study or by Grady and Milligan (1998) in the lower Missouri River. The species is more common in the upper basin, especially Segment **10**, and is abundant in some tributaries of the upper basin (e.g., Moreau River, Loomis et al. 1999).

Plains minnow inhabit shallow, braided streams where sediment accumulates. Grady and Milligan (1998) collected 676 fish by seining in the lower Missouri River. We collected 57 plains minnow during the study, but may have collected many more and identified them only as *Hybognathus* spp. The small sample size precluded age and growth analysis.

Adult brassy minnow are sometimes distinguishable from the plains and western silvery minnow by their brassy-yellow color, longitudinal stripes on the sides, and rounded dorsal fin. We collected 142 brassy minnow in the South Dakota and Iowa segments.

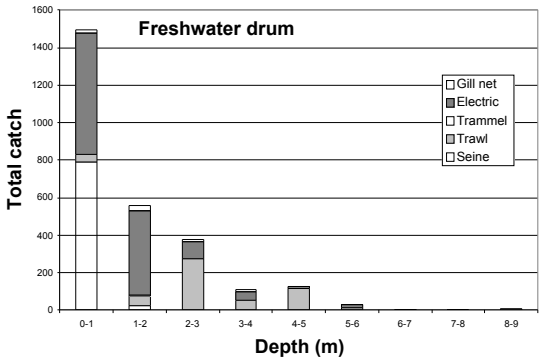
Because these three species were difficult to identify, our protocol stated that we would report data by species only if external characteristics for identification were obvious. We identified about 12,000 specimens as *Hybognathus* spp. The total catch distribution was "U-shaped" in that highest catches were in the upper and lower river (Figure 28). No fish were found in Segment **12** and few were found in other IR segments. Fish were captured in high numbers in all macrohabitats except CHXOs where only eight were collected. About half were collected in SCCs. Trammel nets and gillnets were ineffective; about 75% were captured with beach seines.

In summary, we identified 374 western silvery minnow, 57 plains minnow, and 142 brassy minnow. Most western silvery minnow were found in Segments **7**, **8**, 9, and **10**, which again indicates that the segments in the area of the Yellowstone confluence might support native fishes better than do other IR segments. Plains minnow were also found in Segments **7** and **10** but not in Segment **12** (Table 8). Several plains minnow were found in the CH zone (Segments *19*, *25*, *27*). Brassy minnow were most common in Segment **15**, and Segment *19*.

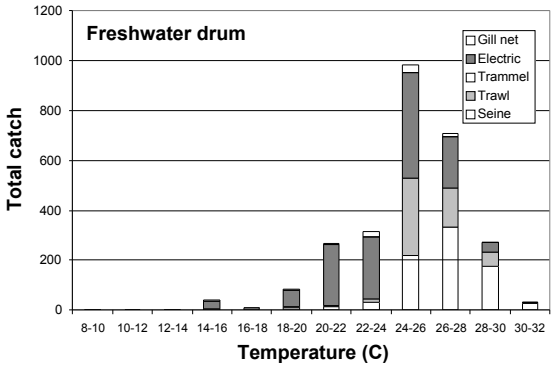
***Pallid Sturgeon***

Pallid sturgeon were caught in Segment 9 (two fish, Sept. 1998), Segment **10** (August 1997), and Segment *22* (August 1998). Three were caught in ISB and one in a TRM macrohabitat, two fish each were collected in a trammel net and trawl (Table A1-8). Capture depth ranged from 1.7 to 4.8 m. Velocity was 0.5-0.9 m/s where trammel nets were used and 1.0 m/s where benthic trawls were used. Turbidity was lower (about 30 NTUs) in Segment 9 than in IR and CH segments (444 - 590 NTUs, Galat et al. 2001). Substrate was mostly

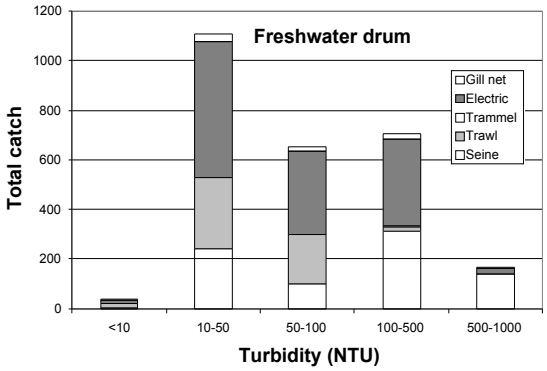
Figure 27. Total catch of freshwater drum over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).



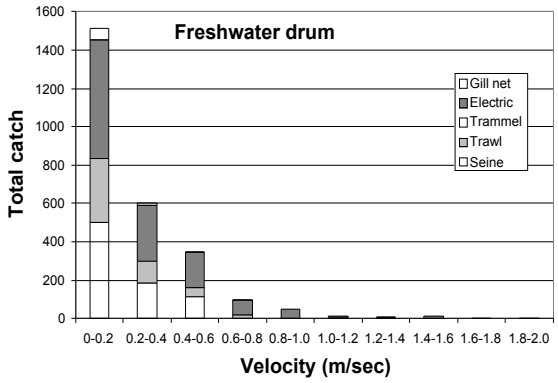

A



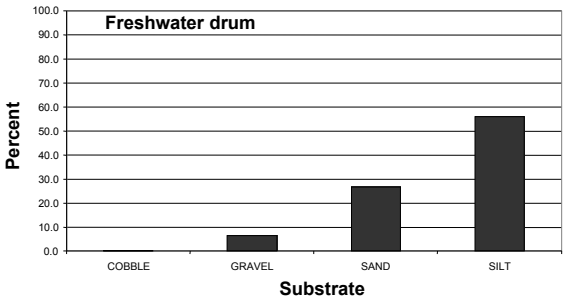

B




C

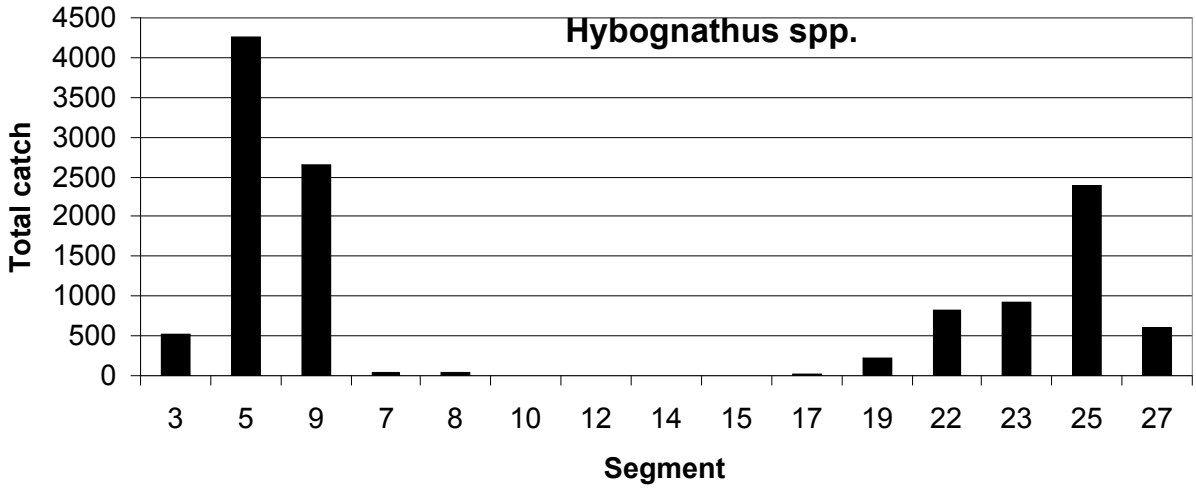



D




E

Figure 28. Total catch of *Hybognathus* spp. (western silvery minnow, *H. argyritis*; brassy minnow, *H. hankansoni*, plains minnow, *H. placitus*) in 15 segments of the Missouri River, 1996-1998. Segments 3, 5, and 9 are least-altered segments, Segments **7-15** are inter-reservoir segments, and Segments *19-27* are channelized segments.




sandy with some gravel (10-60%) and no silt was noted at capture locations.

***River Carpsucker***

River carpsuckers are widespread in the Mississippi River drainage and do well in both rivers and reservoirs. The river carpsucker was studied by students working on the Benthic Fishes Study (Braaten et al. 2002, Welker 2000, Welker and Scarnecchia 2003). Welker found that river carpsuckers were more abundant in moderately altered segments than in highly altered segments (Welker 2000). Adults can grow to 70 cm in length and about 4 kg, but maximum age and length at age >6 years is positively related to latitude. About half of the river carpsuckers we collected were <100 mm long, but we also captured fish in each length category up to the 600-650 mm category (Figure 17).

River carpsuckers were found in all study segments. Highest total catches (>1000) were in the Segments *25* and *27* (Table 25), and high seine catch rates (about 6 fish/haul) dominated statistical analyses involving the CH zone. Most fish were caught with seines (n = 4208) but electrofishing (n = 1184) also produced substantial catches in ISBs, SCCs, and SCNs. River carpsuckers were also commonly found in TRMs, but the C/E values were much lower than in other macrohabitats.

The ANOVA for seine C/E that included seven segments, one macrohabitat (i.e., BEND) and two years (i.e., ANOVA 2, Table A3-9) had no significant segment effects (P = 0.7). A second ANOVA with seven segments, one macrohabitat (SCC), but representing only one year of data did have significant segment effects (P = 0.0001). For that analysis, the Yellowstone seine C/E was lower (P < 0.0001) than the C/E in three CH segments. All possible contrasts between seine C/E in IR and CH segments agreed that C/E in the CH zone were greater than those in the IR zone. Contrasts among LA segments were not possible but seine C/E in Yellowstone Segment 9 (0.5 fish/haul) was obviously higher than C/E in the LA segments on the Missouri River that were too low to be included in the analysis. Seine C/E above Kansas City (Segment *19*) were higher than C/E in Segments *25* and *27* downstream from Kansas City, but this conclusion applied to only SCCs where an unusual catch of 514 fish occurred in one seine haul.

The most robust electrofishing ANOVA resulted in significant segment effects (P = 0.0003, Table A3-9) and included data from eight segments, three macrohabitats (BEND, SCC, TRM) and all years, but LA segments were excluded because of low total catch (Table

Table 25. River carpsucker catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = benthic seine (fish/haul, note very high catches in some segments), EF = electrofishing (fish.;min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments. See Figure A2-3.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHX0 | 0 | 0.052 | 0 | 0 | 0.022 | 0 | 0.028 | 0.028 | 0.059 | 0 | 0 | 0 | 0 | 0 | 0 |
| | ISB | 0 | 0.018 | 0.021 | 0.007 | 0.035 | 0 | 0 | 0 | 0.083 | 0.030 | 0 | 0 | 0 | 0 | 0.022 |
| | OSB | 0 | 0.022 | 0.022 | 0 | 0.015 | 0 | 0 | 0 | 0.044 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SCC | 0 | 0.009 | 0.015 | 0 | 0.010 | 0 | 0 | 0 | 0 | | | | 0.033 | 0 | 0 |
| | SCN | | | | | | | | | | | | | | | |
| | TRM | | | | 0.556 | | 0.111 | | | | 0 | 0 | 0.470 | 0.289 | 0 | |
| BT | CHX0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | ISB | | 0 | 0 | 0 | 0.007 | 0 | 0 | 0 | 0 | 0 | 0.067 | 0.015 | 0 | 0 | 0 |
| | OSB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SCC | | 0 | 0 | 0 | 0 | 0 | 0 | 0.015 | 0.007 | 2 | 0 | | 0 | 0 | 0.028 |
| | SCN | | | | | | | | | | | | | | | |
| | TRM | | | | 0 | | 0 | | | | | | 0.071 | 0.111 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| | ISB | 0.300 | 0.037 | 0.156 | 1.130 | 5.922 | 0 | 0 | 0 | 0.467 | 4.1 | 1 | 0.681 | 1.611 | 12.489 | 2.356 |
| | OSB | | | | | | 0 | | | | | 0 | | | | |
| | SCC | 0.589 | 0.563 | 0.383 | 0.980 | 1.317 | 0.419 | 0.044 | 0.417 | 2.558 | | 111.25 | 0 | 1.898 | 9.489 | 3.362 |
| | SCN | 0 | 0.111 | 3.578 | 0.681 | 11.148 | 0 | 0 | 0.25 | 1.25 | | | 4 | 1 | 0 | 13.178 |
| | TRM | | | | | | | | | | | | | | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| | ISB | 0.033 | 0.053 | 0 | 0 | 0 | | | 0.056 | 0 | 0.039 | 0.050 | 0.050 | 0.027 | 0.004 | 0.007 |
| | OSB | 0.043 | 0.032 | 0.023 | 0.007 | 0 | | 0.025 | 0.052 | 0.305 | 0.011 | | 0.007 | 0.013 | 0.009 | 0.022 |
| | SCC | 0.050 | 0.029 | 0.118 | 0.043 | 0.040 | 0 | 0 | 0.053 | 0.052 | 0 | 0.025 | | 0.045 | 0.056 | 0.053 |
| | SCN | | 0 | 0.621 | 0.222 | 0.659 | 0.16 | 0.12 | 0.187 | 0.879 | | | 1.794 | | | 0.045 |
| | TRM | | | 0.692 | 0.117 | 0.825 | 0.08 | 0.08 | 0.197 | 0.529 | 0.199 | 0.155 | 0.218 | 0.105 | 0.059 | 0.170 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| | ISB | | | | 0 | 0 | | | 0 | 0 | 0.004 | 0 | 0.020 | 0.007 | 0.008 | 0.004 |
| | OSB | | | | | | | | | | | | | | | |
| | SCC | | | | | | | | | | | | | | | |
| | SCN | 0 | 0.137 | 3.514 | 0.075 | 0.546 | 0.059 | 0.205 | 0.413 | 0.223 | | | 0.031 | 0 | 0 | 0.332 |
| | TRM | | | 0.237 | 0.422 | 0.445 | | 0.133 | 0.183 | 0.091 | 0.016 | 0.169 | 0.111 | 0.134 | 0.128 | 0.057 |

26). Two electrofishing contrasts supported seine data indicating that C/E was higher in the CH segments than in the IR segments, but two did not (Table 26). The two contrasts possible between individual segments showed that electrofishing C/E was higher in Segment **15** than in either upstream (**14**) or downstream (*17*) segments.

Trends suggested by segments that were excluded from analysis because of low total catch indicated that LA Segments 3 and 5 had fewer river carpsuckers than did LA Segment 9 and fewer than did IR segments. Electrofishing C/E in Segment **10** was too low for analysis so catches in Segment **8** (upstream from the Yellowstone River confluence) were obviously higher than in Segment **10**. Electrofishing C/E in segments up- and downstream from three reservoirs indicated that downstream catches were higher than those upstream from reservoirs (e.g., Segments 5 < **7**, **10** < **12**, **14** < **15**). This trend was also apparent for other gears (with exceptions), and was opposite that found for other species for Segments **7** and **12**, where catches downstream were usually lower than those upstream from the reservoirs.

Fish were captured over a wide range of habitat conditions (Figure 29), and river carpsucker was one of two benthic fish (also shovelnose sturgeon) that had significant differences for all mean conditions for sites with and without fish (Table 16). The analysis of habitat associations was one of the best examples of agreement among catch, macrohabitat, and physical conditions. High catches were recorded in TRM and SCN macrohabitats where water tends to be slower, warmer and more turbid and substrate geometric mean tends to be smaller than in other macrohabitats (Galat et al. 2001). The ANOVA results showed that where river carpsucker were present, velocity, depth and geometric substrate mean were significantly less, and water temperature and turbidity were significantly higher than at locations without river carpsucker (Table 16). Substrate geometric mean was significantly less for sites with river carpsucker; gravel and sand proportions were significantly less and silt proportions were significantly more than at sites without river carpsucker.

Stepwise logistic regression ($R^2 = 0.11$) indicated that the likelihood of presence of river carpsucker increased with increased water temperature and decreased velocity. Three factors (depth, turbidity, substrate geometric mean) that were significant when considered alone in the ANOVA analysis were not included in the stepwise logistic regression model. Temperature, which was retained, was significantly correlated with turbidity, and therefore likely accounted for enough of the variation that turbidity accounted for by itself to result in the non-significant turbidity effect in the model.

In summary, the river carpsucker was widespread and abundant in shallow, low velocity, silt-dominated areas. Catches by seining and electrofishing were sufficient for some statistical analysis, but analyses were limited to one or two years and sometimes only one macrohabitat. In general, catches were higher downstream from reservoirs and in the Yellowstone River, and lower in IR segments than in other areas.

***Sand Shiner***

The sand shiner is a small (maximum length about 80 mm) minnow that is widespread in the Missouri River basin, but more common in tributaries than in the main channel. All sand shiners in our sample were <100 mm long (Figure 30). Most were caught downstream from Gavins Point Dam, mostly in seines (Figure 31). The C/E for most gears was usually greatest in ISBs, but catches were occasionally high in SCCs and SCNs.

Catches in seines were insufficient for statistical segment comparisons. No sand shiners were caught in Segments 3-**10** and catch was too low in Segments **12**, **14**, *19*, *22*, and *23* for analysis. However, it was obvious that catches in Segment **15** were higher than in other segments and that, in general, catches in the CH zone were higher than in other zones. Of the 631 sand shiners caught in seines, 362 were caught in Segment **15** and 157 in Segment *27*.

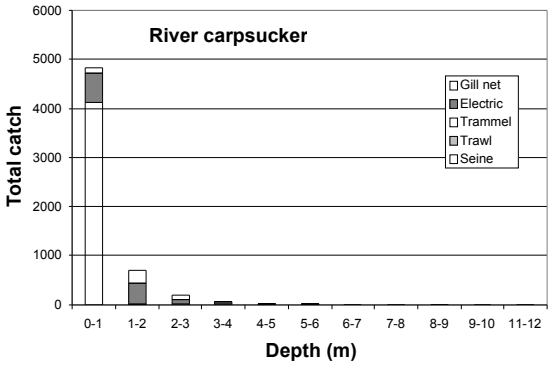
Total catch of sand shiners was highest in temperatures of 22-28°C, temperature was significantly higher at sites with fish than at sites without, and temperature was the only variable included in the stepwise logistic regression as being positively related to the likelihood of presence of sand shiners. Significant differences in mean turbidity and substrate size between sites with and without fish were also found, but these variables were not included in the model that had one of the lowest $R^2$ values (0.04) of any benthic species (Table 16). Though mean turbidity was different at sites with and without fish, turbidity was dropped from the stepwise logistic regression model, probably because turbidity was significantly correlated with temperature. In general, too little of the variability in sand shiner presence was accounted for to be biologically meaningful. Total catch patterns (Figure 32) indicated that most sand shiners were caught in shallow water where mean velocity was about 0.35 m/sec (Table A4-4) and substrates where proportionally more sand and less silt than at sites without fish.

In summary, we caught most sand shiners with seines in ISB, SCC and SCN macrohabitats of the CH zone. Sand shiner presence sites tended to be warmer, more turbid, and more sandy than absence sites, but there were few significant associations between sand shiner presence and habitat conditions.

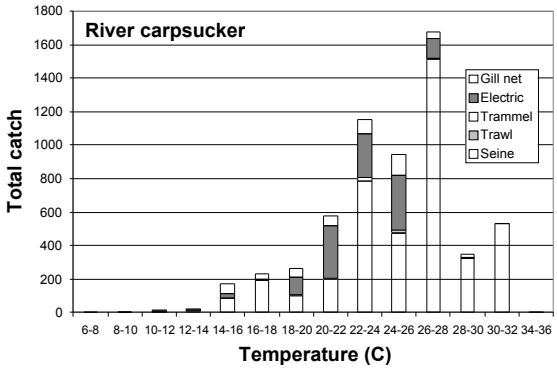
Table 26. Mean catch per unit effort data for river carpsucker by seining (fish/haul) and electrofishing (fish/min) and list of significant contrasts among segments. LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone, AKC = above Kansas City, BKC = below Kansas City, AL&C = above Lewis and Clark Lake, BL&C = below Lewis and Clark Lake (i.e., Segment **15**), 1st CHAN = 1st channelized segment (i.e., Segment *17*), YSR = Yellowstone River. For other contrast results see Table A3-9.

| General Contrast | Segment contrast | | Seining P value Means | Electro Fishing P value Means |
|---|---|---|---|---|
| Among LA | | | | |
| LA vs. IR and CH | YSR LA vs. CH | 9 vs. *19, 25, 27* | <0.0001<br>0.5, 6.5 | |
| Among IR | AL&C vs. BL&C | **14** vs. **15** | | 0.0004<br>0.1, 0.3 |
| IR vs. CH | IR vs. CH | **7, 8, 15** vs. *19, 25, 27* | <0.0001<br>0.16, 6.5 | |
| | IR vs. CH | **12-15** vs. *17, 19, 23-27* | | 0.002<br>0.15, 0.07 |
| | IR W/O BL&C vs. CH | **7, 8** vs. *19, 25, 27* | <0.0001<br>0.2, 6.5 | |
| | IR W/O BL&C vs. BL&C | **12**, **14** vs. **15** | | 0.0001<br>0.07, 0.3 |
| | IR BL&C vs. CH | **15** vs. *19, 25, 27* | <0.0001<br>0.07, 6.5 | |
| | IR BL&C vs. CH | **15** vs. *17*, *19, 23-27* | | <0.0001<br>0.3, 0.07 |
| | IR BL&C vs. 1st CHAN | **15** vs. *17* | | 0.0001<br>0.3, 0.09 |
| Within CH | AKC CH vs. BKC CH | *19* vs. *25, 27* | 0.0007<br>221, 5.2 | |

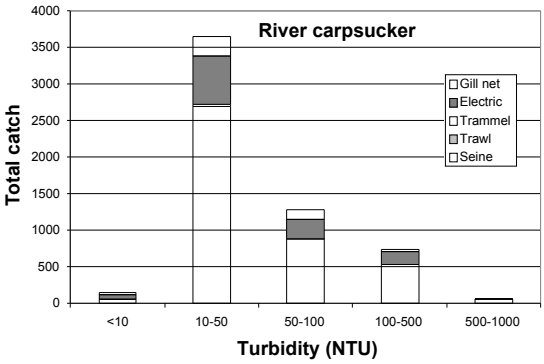
Figure 29. Total catch of river carpsucker over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).



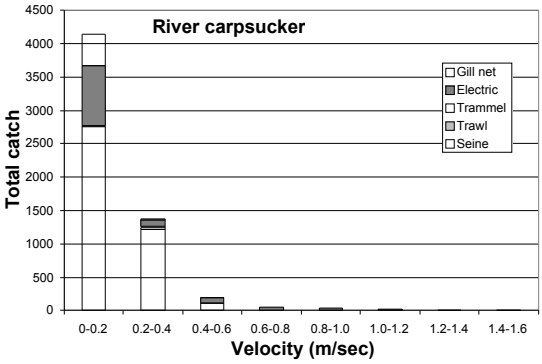

A



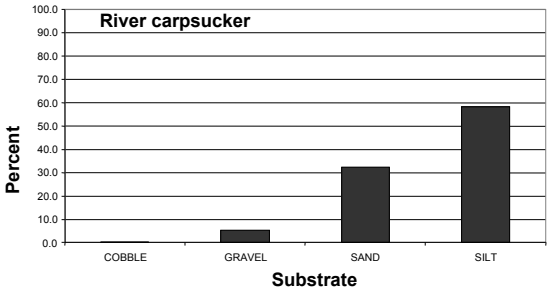

B




C




D




E

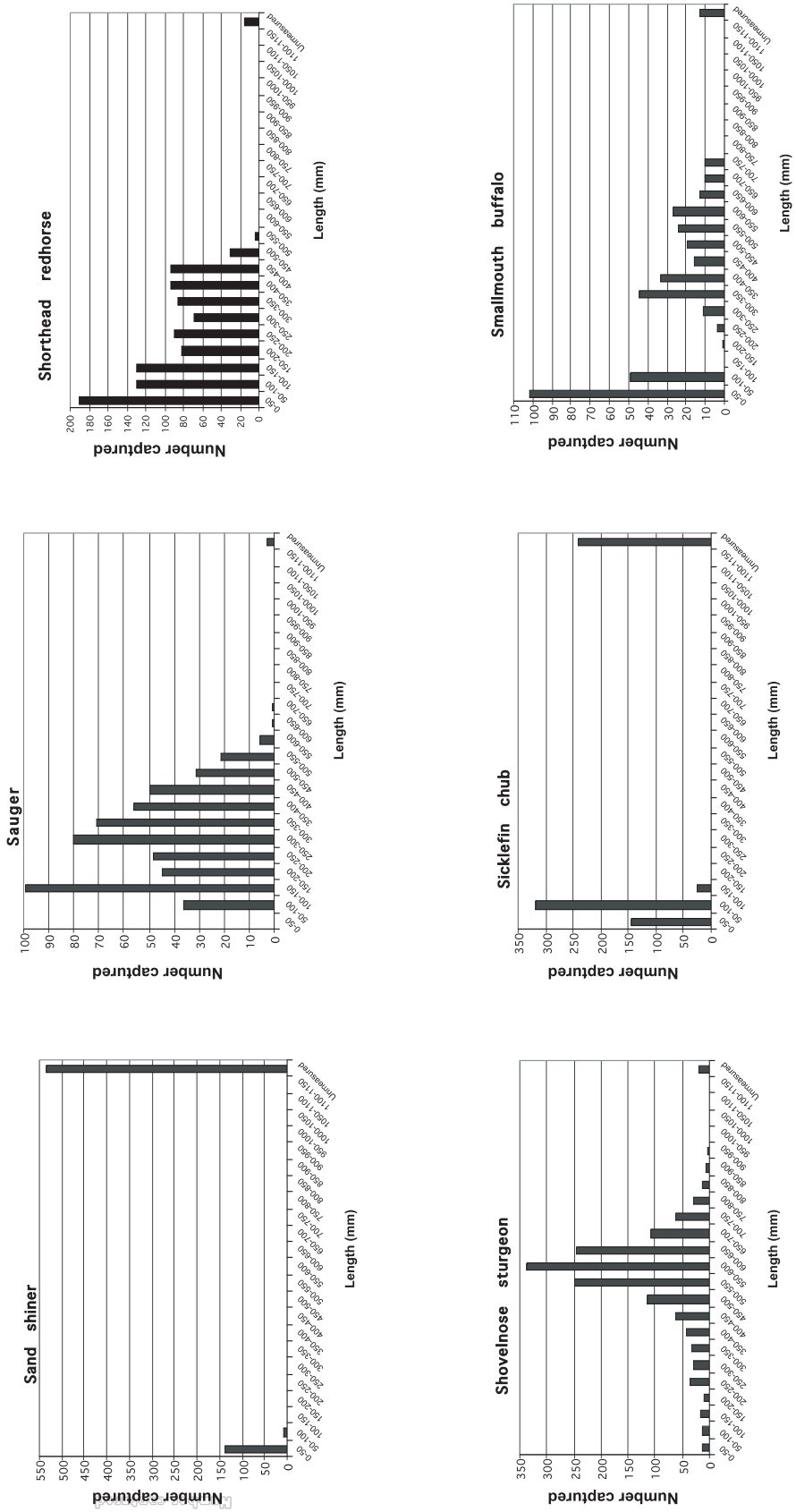



Figure 30. Length, frequency, distribution for six species of benthic fishes collected from 15 segments of the main channel of the Missouri River, 1996-1998. Bar in far right of figure indicates number of fish not measured.

Figure 31. Catch per effort of sand shiner from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-9.

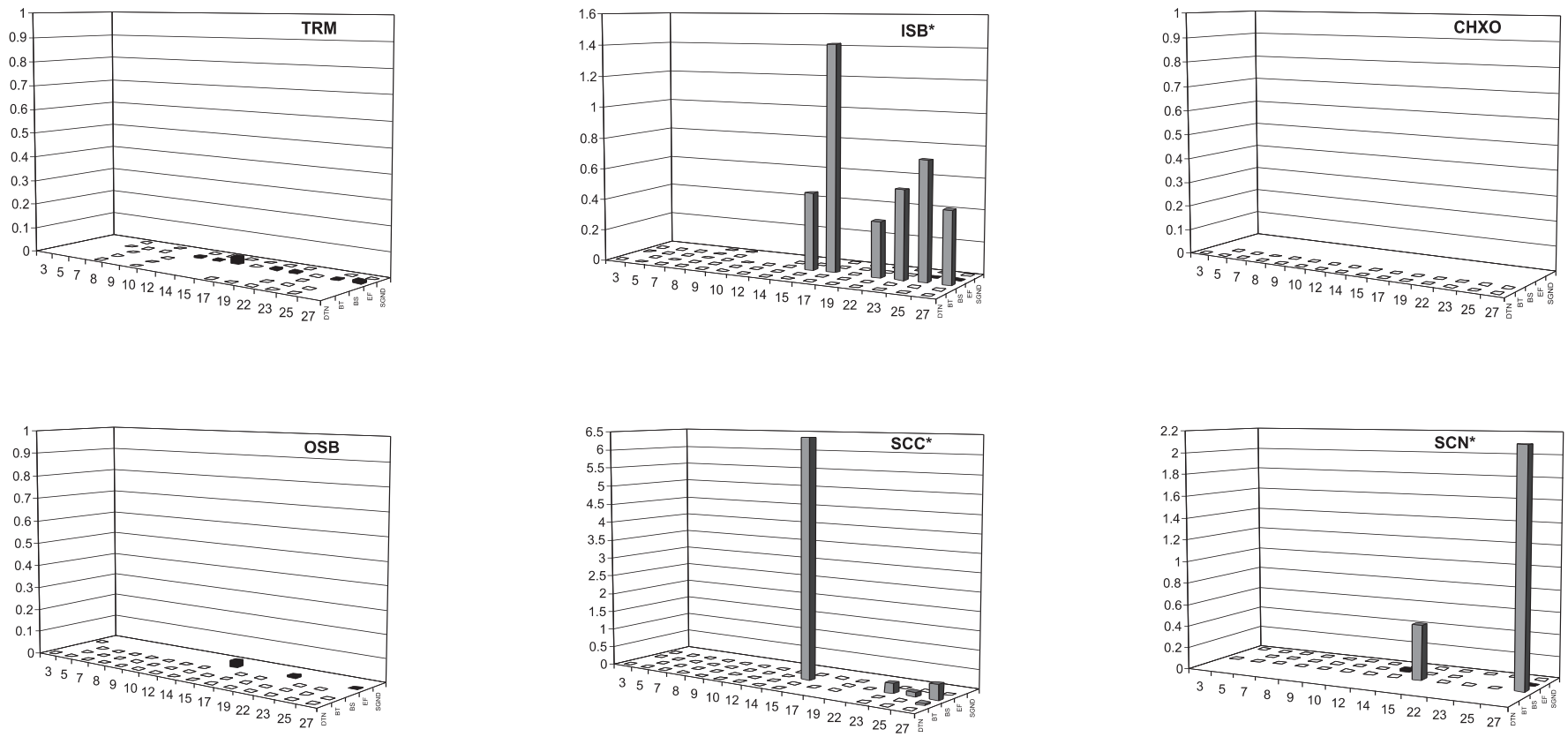
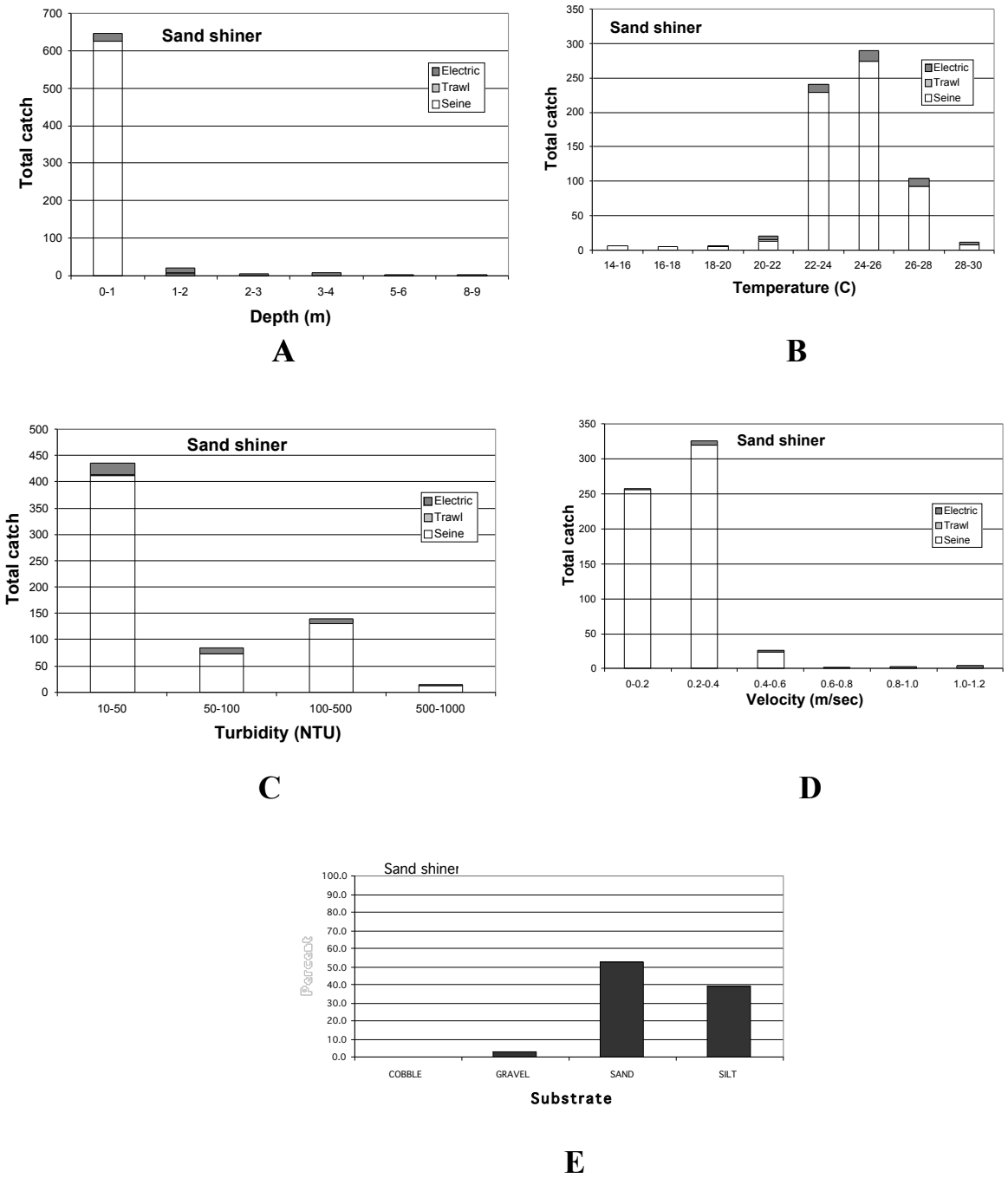


Figure 32. Total catch of sand shiner over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).



***Sauger***

The sauger is native to the Missouri River and inhabits both rivers and lakes. It has been declining in number since the mainstem dams were closed in the lower (Hesse et. al. 1993) and upper Missouri River (McMahon 1999). However, saugers are common in some lakes (Lewis and Clark, Sakakawea) and in the recreational fishery (Mestl et al. 2001). Saugers grow to 700 mm long, and our catch of saugers included numerous specimens in each size class including the 650-700 size class (Figure 30).

We found a few saugers in all study segments and in all macrohabitats (Table 27). Most saugers were caught by electrofishing (346 fish), with much lower total catch in other gears. The C/E for several gears was highest in the OSB macrohabitat in the upper river segments compared to other macrohabitats. Saugers were commonly caught in drifting trammel nets in CHXO, ISB and OSB habitats in all segments upstream from Lake Sakakawea, but rarely caught in these macrohabitats downstream (Table 27).

Significant segment effects (P = 0.004) were found for electrofishing data in BENDS over all years, and the few possible contrasts used Segments 3, 5, **10**, **14**, **15**, *17*, *22*, *23*, and *25* (Table A3-10). The electrofishing C/E in the LA segments was higher than the C/E in either IR or CH segments (Table 28). Trends support the "reservoir effect" in that catches upstream from Fort Peck Lake and Lake Sakakawea were higher than catches downstream, but at Lewis and Clark Lake the trend was opposite as has been found for several other species.

We caught saugers over a wide range of depths and velocities (Figure 33). Silt and sand substrates and turbidity levels (10 – 50 NTU) were dominant conditions where most saugers were caught. Total catch doubled when temperatures reached 20°C; mean temperature at presence sites was 22°C, and was 23°C at absence sites (Table 16). No other habitat measures were significantly different between presence and absence sites except that the proportion of sand was significantly less and the proportion of silt was significantly more at presence sites than absence sites. Stepwise logistic regression indicated that the likelihood of sauger presence increased as temperature decreased, but the $R^2$ was only 0.01, indicating that most of the variability in the presence data was not accounted for.

In summary, saugers where widespread but seemed more common in Segments 3, 5, **7**, **8**, 9, than further downstream, a trend confirmed statistically by electrofishing results. Saugers were also somewhat uniformly distributed among macrohabitats. There was little difference between habitat conditions at presence and absence sites.

***Shorthead Redhorse***

This species and seven other sucker species were the focus of a Ph.D. dissertation written using Benthic Fishes Study data for segments in Montana and North Dakota (Welker 2000). He found that shorthead redhorses were a minor (<1%) part of the sucker catch in that area. When viewed over all segments that we studied, the highest catches were in the LA and IR zones compared to the CH zone (Table 29). The largest fish we captured were in the 500-550 size class, while all smaller size classes were well represented (Figure 30).

The shorthead redhorse were distributed throughout the mainstem, but were most abundant in the LA segments and Segment **15** (Table 29). We captured about 1,000 fish in all macrohabitats, with highest catch rates in ISBs, SCCs, SCNs, and OSBs. Only seven fish were caught by trawling, whereas 67 were caught in gill nets. Catches in the trammel net (114 fish) and by electrofishing (591) had significant segment effects (P = 0.007 and < 0.0001 respectively). Most shorthead redhorse were captured in the LA and IR zones, and data for analysis were limited to segment contrasts in these two zones (Table 30).

Obviously, the C/E was significantly lower in the CH zone than in other zones. Higher trammel C/E was recorded in the Missouri River LA segments (C/E = 0.17 fish/100 m) than in the Yellowstone segment (0.05 fish/100 m). Catches in the LA segments were higher than those is IR segments for all six possible contrasts for both gears (Table 30). The catch in Segment **15** was higher than in other IR segments. While no segments in the LA zone were eliminated because of insufficient catch, three or more segments in the IR zone and CH zone were eliminated. Hence, it was obvious that catches in IR segments **7** and **8** were less than in LA segments, and that catch declined in Segment **10** that was downstream from Yellowstone confluence. Catch upstream from Fort Peck was higher than that downstream, but catches upstream from Lewis and Clark Lake were lower than those downstream (Table 29).

Total catch of the shorthead redhorse in various categories of physical conditions indicated several trends that were confirmed by comparison of mean habitat conditions between sites with and without shorthead redhorses. Shorthead redhorses were caught over a wide range of velocities, with a substantial portion of the total catch at velocities up to 1 m/sec (Figure 34). Most fish were caught in waters of moderate turbidity over a mix of substrate categories that included a noticeable gravel component. Total catch of shorthead redhorses was highest in waters of shallow to mid-depths and occurred over a wide range of water temperatures.

Table 27. Sauger catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = stationary channel not connected, TRM = tributary mount. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments. See Figure A2-4.

| Gear and habitat | | Segments | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0.044 | 0.033 | 0.007 | 0.007 | 0.037 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | ISB | 0.026 | 0.009 | 0.019 | 0.015 | 0.052 | 0.056 | 0 | 0 | 0.037 | 0 | 0 | 0 | 0 | 0 | 0 |
| | OSB | 0.024 | 0.022 | 0.022 | 0 | 0.044 | 0 | 0 | 0.015 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SCC | | 0.009 | 0 | 0 | 0.015 | 0 | 0 | 0 | 0.007 | 0 | 0 | | 0 | 0 | 0 |
| | SCN | | | | | | | | | | | | | | | |
| | TRM | | | 0 | | | | | | 0 | 0 | 0 | 0 | 0 | | |
| BT | CHXO | | 0 | 0 | 0 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | ISB | | 0 | 0.022 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | OSB | | 0.033 | 0 | 0 | 0.022 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SCC | 0 | 0.019 | 0.056 | 0.070 | 0.061 | 0.083 | 0 | 0 | 0.072 | | 0.5 | 0 | 0 | 0 | 0.02963 |
| | SCN | | | | | | | | | | | | | | | |
| | TRM | | | 0 | | 0 | | | | | | 0 | 0 | 0 | | |
| BS | CHXO | | | | | | | | | | | | | | | |
| | ISB | 0 | 0.037 | 0 | 0.056 | 0.033 | 0 | 0 | 0 | 0 | 0.189 | 0 | 0.333 | 0 | 0.022 | 0 |
| | OSB | | | | | | | | | | | | | | | |
| | SCC | 0.05 | 0.0575 | 0.02 | 0.077 | 0.132 | 0.025 | 0 | 0.003 | 0.055 | 0 | 0.0125 | | 0 | 0 | 0 |
| | SCN | 0.333 | 0 | 0 | 0.022 | 0.100 | 0.25 | 0 | 0 | 0 | | | 0.5 | 0.5 | 0 | 0 |
| | TRM | | | | | | | | | | | | | | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| | ISB | 0.033 | 0.128 | 0 | 0.033 | 0 | | | 0 | 0.200 | 0.061 | 0.007 | 0.014 | 0.004 | 0.006 | 0.004 |
| | OSB | 0.094 | 0.082 | 0.017 | 0.047 | 0.070 | 0.091 | 0 | 0.01 | 0.026 | 0 | 0 | 0.009 | 0.007 | 0.004 | 0 |
| | SCC | | | | | | | | | | | | | | | |
| | SCN | | 0 | 0.071 | 0.008 | 0.020 | 0 | 0.013 | 0 | 0.050 | | | 0.033 | | | 0 |
| | TRM | | 0 | 0.017 | 0 | 0 | 0.032 | 0.019 | 0.144 | 0.026 | 0.014 | 0.070 | 0.018 | 0.036 | 0.007 | |
| SGND | CHXO | | | | | | | | | | | | | | | |
| | ISB | | | | 0 | 0 | | | 0 | 0.012 | 0.027 | 0 | 0 | 0 | 0.001635 | 0 |
| | OSB | 0 | 0.122 | 0.007 | 0.025 | 0.037 | 0 | 0 | 0.167 | 0.019 | | | | 0 | 0 | 0 |
| | SCC | | | | | | | | | | | | | | | |
| | SCN | 0 | 0 | 0.008 | 0.025 | 0.057 | 0.118 | 0 | 0.106 | 0.010 | | | 0.021 | 0 | 0 | 0 |
| | TRM | | 0.019 | 0.042 | 0 | | 0 | 0.004 | 0.054 | 0.033 | 0.056 | 0.016 | 0.061 | 0.010 | 0.005 | |

Table 28. Mean catch per unit effort data for sauger by electrofishing (fish/min) and list of significant contrasts among segments. LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone, MOR = Missouri River. For other contrast results see Table A3-10.

| General Contrast | | Segment contrast | Electro Fishing P value Means |
|---|---|---|---|
| Among LA | | | |
| LA vs. IR and CH | LA vs. IR | 3, 5 vs. **10, 14** | 0.005<br>0.1, 0.04 |
| | MOR LA vs. CH | 3, 5, vs. *17, 22, 23, 25* | <0.0001<br>0.1, 0.01 |
| Among IR | | | |
| IR vs. CH | | | |
| Among CH | | | |

Velocity, geometric substrate mean, and proportion of gravel were significantly higher, and turbidity significantly lower at sites with shorthead redhorses, compared to sites where the species was not caught (Table 16). Stepwise logistic regression retained turbidity and substrate geometric mean in the model, but velocity fell out of the model. However, the $R^2$ value of 0.04 indicated that turbidity and substrate size were minor factors in predicting the liklehood of presence of shorthead redhorse.

In summary, shorthead redhorse were wide spread, with highest catches in LA segments and Segment **15**. Most were caught by electrofishing in the LA zone where water was swifter, and clearer, and where substrates were coarser, than at sites where the fish was not caught.

***Shovelnose Sturgeon***

The once abundant shovelnose sturgeon populations have declined (Hesse et al. 1993). It is an important species because it may be a species that indicates river health, it hybridizes with the endangered pallid sturgeon, and it may be a surrogate for smaller sizes of pallid sturgeons (Ruelle and Keenlyne 1994, Bramblett and White 2002). Our sample of 1447 shovelnose sturgeons was dominated by specimens that were 400-800 mm long (Figure 30), and was distributed throughout the mainstem (Table 31). Fish were caught in all macrohabitats except SCNs (Table 31, Figure A2-6). Highest C/E values were for trammel nets used in ISBs (e.g., about 2 fish/100 m), whereas catches of about 1 fish/100 m occurred in CHXOs, TRMs, and SCCs. Trends for trammel net catches shifted from being high in CHXOs and OSBs in LA and IR segments to being high in SCC and ISB habitats in CH Segments *17-27*.

For statistical segment contrasts, total catch in seines and by electrofishing was insufficient, but total catch in trawls (149 fish), gill nets (336 fish), and trammel nets (951 fish) was sufficient for contrasts. There were no significant segment effects for trawls or gill nets, but both ANOVAs for trammel net C/E had significant segment effects (A3-12). We discuss the most robust ANOVA (ANOVA2, P = 0.0006), which had 11 segments, one macrohabitat (BEND), and all years included in the analysis. Trammel C/E values were higher in the Yellowstone segment (C/E = 0.6 fish/100 m) than in several IR segments (C/E = 0.013 fish/100 m, Table 32). The C/E in IR segments was significantly lower than the C/E in CH segments, but only three CH segments were included in the analysis. Two CH segments had high C/E values (e.g., Segment *22* and *23*), and three had low values (i.e., Segments *17*, *19*, and *25*). The C/E for shovelnose sturgeon in CH segments

Figure 33. Total catch of sauger over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).

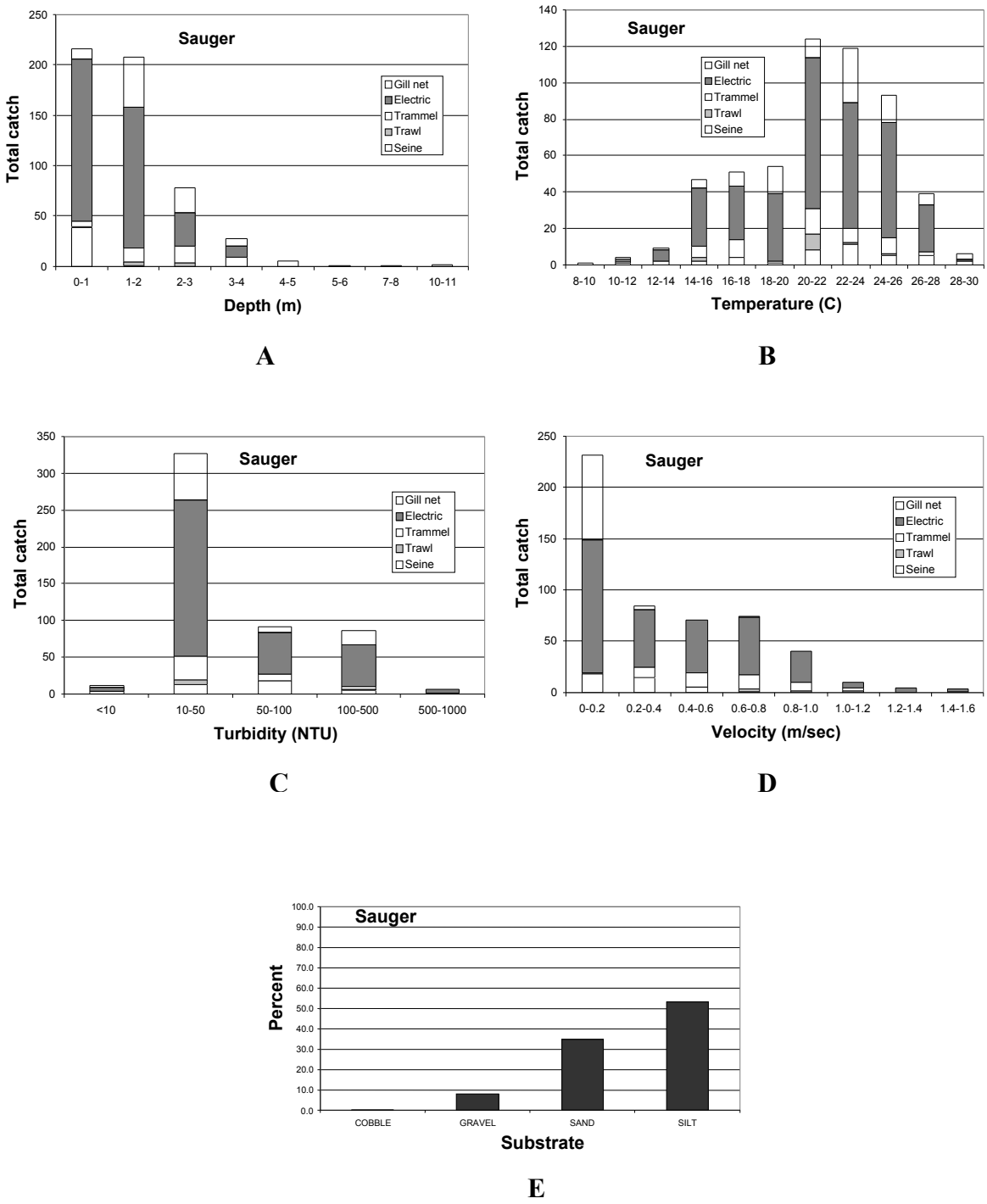


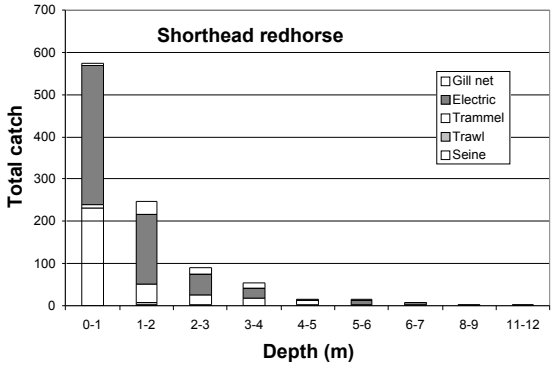
Table 29. Shorthead redhorse catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electro fishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments. See Figure A2-5.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0.111 | 0.007 | 0 | 0.015 | 0.030 | 0 | 0 | 0.015 | 0.015 | 0 | 0 | 0 | 0 | 0 | 0 |
| | ISB | 0.070 | 0.037 | 0.015 | 0.007 | 0.007 | 0 | 0 | 0 | 0.111 | 0 | 0 | 0 | 0 | 0 | 0 |
| | OSB | 0.026 | 0.026 | 0.025 | 0.090 | 0.067 | 0 | 0 | 0.138 | 0.111 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SCC | 1.111 | 0.224 | 0.059 | 0.052 | 0.064 | 0 | 0 | 0.080 | 0.241 | | | | 0 | 0 | 0 |
| | SCN | | | | | | | | | | | | | | | |
| | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | ISB | | 0.022 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | OSB | | 0 | 0.007 | 0.044 | 0 | 0 | 0 | 0 | 0.022 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SCC | | 0.015 | 0 | 0 | 0.007 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| | SCN | | | | | | | | | | | | | | | |
| | TRM | | | | 0 | | 0 | | | | | | 0 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| | ISB | 0.889 | 0.556 | 0 | 0.159 | 0.044 | 0.056 | 0.042 | 0 | 1.156 | 0.022 | 0 | 0 | 0 | 0 | 0 |
| | OSB | | | | | | | | | | | 0 | 0 | 0 | | 0 |
| | SCC | 0.567 | 0.411 | 0.041 | 0.195 | 0.050 | 0 | 0 | 0 | 0.262 | | 0 | 0 | 0 | 0 | 0 |
| | SCN | 1 | 0 | 0.022 | 1.978 | 0.626 | 0 | 0.056 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| | TRM | | | | | | 0 | | | | | | 0 | | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| | ISB | 0.167 | 0.257 | 0 | 0.050 | 0 | | | 0 | 0.133 | 0 | 0 | 0 | 0.004 | 0 | 0.003 |
| | OSB | 0.664 | 0.156 | 0.022 | 0.014 | 0 | 0.014 | 0.008 | 0.004 | 0.194 | 0.013 | | | | 0.002 | |
| | SCC | 0.050 | 0.066 | 0.06 | 0.050 | 0.051 | 0.025 | 0 | 0.015 | 0.155 | 0 | 0 | | 0 | 0 | 0 |
| | SCN | | 0 | 0 | 0.190 | 0.1 | 0.094 | 0 | 0.017 | 0.090 | | | 0 | | | 0.004 |
| | TRM | | | 0 | 0.033 | 0 | | 0.019 | 0.014 | 0.054 | 0.003 | 0 | 0 | 0.014 | 0.005 | 0.003 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| | ISB | | | | 0 | 0 | | | 0.063 | 0.014 | 0.018 | 0 | 0 | 0 | 0 | 0.002 |
| | OSB | | | | | | | | | | | | | | | |
| | SCC | | | | | | | | | | | | | | | |
| | SCN | 0 | 0 | 0.004 | 0.032 | 0 | 0.021 | 0.037 | 0.012 | 0.038 | | | 0 | 0 | 0 | 0.004 |
| | TRM | | | 0.027 | 0.029 | 0 | | 0.126 | 0 | 0.032 | 0.039 | 0 | | 0.007 | 0.008 | 0.011 |

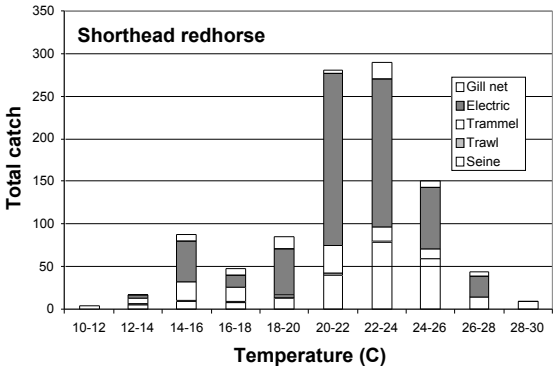
Table 30. Mean catch per unit effort data for shorthead redhorse by electrofishing (fish/min) and drifting trammel net (fish/100m) and list of significant contrasts among segments. LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone, BFTP = below Fort Peck Reservoir, BL&C = below Lewis and Clark Lake, MOR = Missouri River, YSR = Yellowstone River. For other contrast results see Table A3-11.

| General Contrast | Segment contrast | | Trammel P value Means | Electro Fishing P value Means |
|---|---|---|---|---|
| Among LA | MOR LA vs. YSR LA | 3, 5 vs. 9 | 0.001<br>0.17, 0.05 | |
| LA vs. IR and CH | MOR LA vs. BFTP IR | 3, 5 vs. **7, 8** | 0.0004<br>0.17, 0.04 | |
| | LA vs. IR | 3, 5, 9 vs. **7, 8, 14, 15** | 0.003<br>0.12, 0.07 | |
| | LA vs. IR | 3, 5 vs. **10, 15** | | 0.0001<br>0.38, 0.1 |
| | MOR LA vs. IR w/o BL&C | 3, 5 vs. **7**, **8**, **14** | 0.002<br>0.17, 0.05 | |
| | MOR LA vs. IR w/o BL&C | 3, 5 vs. **7**, **8**, **10-14** | | <0.0001<br>0.39, 0.01 |
| | MOR LA vs. BL&C | 3, 5 vs. **15** | | 0.0009<br>0.39, 0.19 |
| Among IR | IR w/o BL&C vs. BL&C IR | **10** vs. **15** | | 0.0035<br>0.01, 0.19 |
| IR vs. CH | | | | |
| Among CH | | | | |

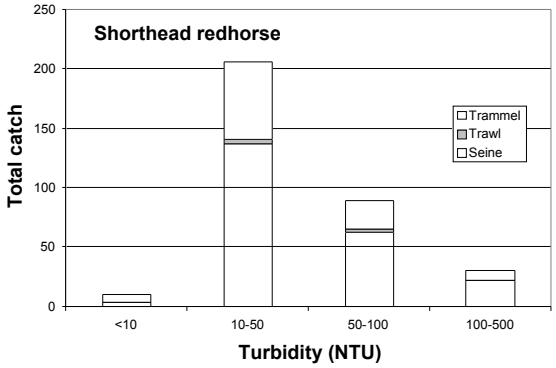
Figure 34. Total catch of shorthead redhorse over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).



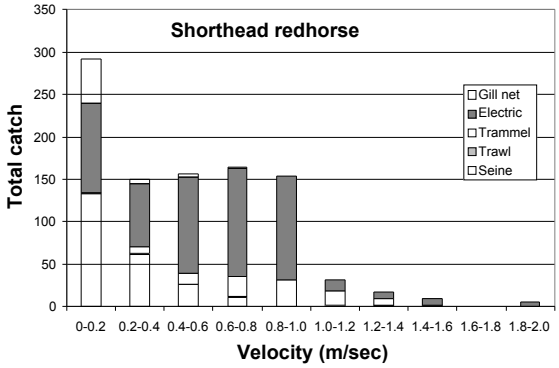

A



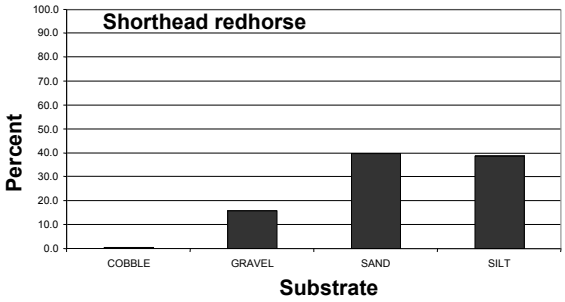

B




C




D




D

Table 31. Shovelnose sturgeon catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fihs/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electro fishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments. See Figure A2-6.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0.148 | 0.463 | 0.196 | 0.044 | 0.803 | 0.296 | 0.405 | 0.022 | 0.213 | 0.022 | 0 | 0 | 0.013 | 0 | 0 |
| | ISB | 0.111 | 0.416 | 0.253 | 0.081 | 0.678 | 0.179 | 0.148 | 0.052 | 0.269 | 0.135 | 0.093 | 2.349 | 1.880 | 0.133 | 0.141 |
| | OSB | 0.104 | 0.491 | 0.146 | 0.057 | 0.346 | 0.303 | 0.213 | 0.077 | 0.173 | 0.022 | 0 | 0 | 0.036 | 0 | 0 |
| | SCC | 0 | 0.152 | 0.406 | 0.106 | 0.463 | 0.259 | 0.111 | 0.098 | 0.422 | | | | 0.872 | 0.056 | 0.232 |
| | SCN | | | | | | | | | | | | | | | |
| | TRM | | | | 0.667 | | 1.333 | | | | 0.500 | 0.500 | 0 | 0.267 | 0 | |
| BT | CHXO | | 0.022 | 0.009 | 0 | 0.044 | 0.091 | 0 | 0 | 0 | 0.044 | 0 | 0 | 0.053 | 0.022 | 0 |
| | ISB | | 0.009 | 0.009 | 0.007 | 0.053 | 0 | 0.037 | 0 | 0.025 | 0 | 0.209 | 0.332 | 0.222 | 0.324 | 0.044 |
| | OSB | | 0.040 | 0.007 | 0.015 | 0.037 | 0.102 | 0 | 0 | 0.030 | 0.044 | 0.022 | 0 | 0.013 | 0.022 | 0.022 |
| | SCC | | 0.021 | 0 | 0.037 | 0.037 | 0.222 | 0 | 0.015 | 0 | 0 | 0.056 | | 0.203 | 0.206 | 0.148 |
| | SCN | | | | | | | | | | | | | | | |
| | TRM | | | | 0.111 | | 0 | | | | | | 0 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.022 | 0 | 0 | 0 | 0 | 0 | 0 |
| | OSB | | | | | | | | | | | | 0 | | | |
| | SCC | 0 | 0 | 0 | 0.012 | 0.011 | 0 | 0 | 0 | 0.011 | | 0 | 0 | 0 | 0 | 0 |
| | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| | TRM | | | | | | | | | | | | 0 | | 0 | |
| EF | CHXO | | | | | | | | | | | | | | | |
| | ISB | 0 | 0.006 | 0 | 0 | 0 | | | 0 | 0 | 0.017 | 0 | 0 | 0 | 0 | 0 |
| | OSB | 0.002 | 0.002 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| | SCC | 0 | 0 | 0 | 0.005 | 0 | 0 | 0 | 0 | 0 | 0 | 0.018 | | 0 | 0 | 0 |
| | SCN | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | | | 0 |
| | TRM | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| | ISB | | | | 0 | 0 | | | 0 | 0.024 | 0.138 | 0.161 | 0.218 | 0.190 | 0.242 | 0.075 |
| | OSB | | | | | | | | | | | | | | | |
| | SCC | | | | | | | | | | | | | | | |
| | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0.009 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| | TRM | | | 0.004 | 0 | 0 | | 0.029 | 0 | 0.022 | 0.045 | 0.092 | | 0 | | 0 |

Table 32. Mean catch per unit effort data for shovelnose sturgeon by drifting trammel net (fish/100 m) and list of significant contrasts among segments. LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone, AKC = above Kansas City, BKC = below Kansas City, BFTP = below Fort Peck Reservoir, BL&C = below Lewis and Clark Lake, YSR = Yellowstone River. For other contrast results see Table A3-12.

| General Contrast | Segment contrast | | Trammel P value Means |
|---|---|---|---|
| Among LA | | | |
| LA vs. IR and CH | YSR LA vs. BFTP IR | 9 vs. **7, 8** | 0.001<br>0.62, 0.13 |
| | YSR LA vs. IR w/o BL&C | 9 vs. **7, 8, 10, 12** | 0.002<br>0.62, 0.19 |
| IR vs. CH | IR vs. CH | **7, 8, 10, 12, 15** vs. *22, 23, 27* | 0.002<br>0.19, 0.45 |
| | IR w/o BL&C vs. CH | **7, 8, 10, 12** vs. *22, 23, 27* | 0.003<br>0.19, 0.45 |
| Among IR | | | |
| Among CH | AKC vs. BKC | *22* vs. *23,27* | 0.005<br>0.77, 0.31 |

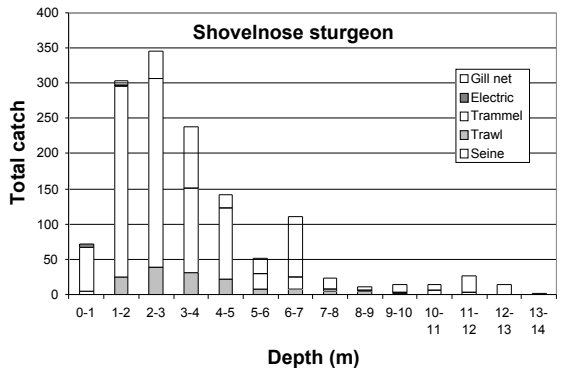
upstream from Kansas City (mean = 0.77 fish/100 m) was greater than the C/E for segments downstream (mean = 0.3 fish/100 m). Total catches in Segment **14** upstream from Gavins Point Dam were too low to include this segment in the analysis, so C/E in Segment **14** were obviously lower than the C/E in Segment **15** downstream from Gavins Point Dam.

Most shovelnose sturgeon were caught at depths of 1-7 m, but some were captured in water of 13-14-m (Figure 35), and depth was identified by ANOVA and stepwise logistic regression as significant to the presence of this species. Total catch was much higher where sand dominated the substrate, which agreed with the results of the ANOVA that showed larger substrates at sites where fish were caught compared to where there was no catch (Table 16). The velocity range associated with the total catch was dome-shaped with the center in the 0.6-0.8 m/sec category, and the mean at presence sites was 0.6 m/sec compared to an mean of 0.3 m/sec at sites without shovelnose sturgeon. Total catch tended to be higher in higher temperatures but there was no significant difference in mean temperatures at presence and absence sites. Total catch was spread over a wide range of turbidity levels. Unlike many species, some shovelnose sturgeon were caught at turbidities in the 500-1000 NTU category, and about as many in the <10 NTU category.

Stepwise logistic regression indicated that the likelihood of shovelnose sturgeon presence increased with depth and velocity, and the model had one of the higher $R^2$ values (0.27) obtained for any species (Table 16). Substrate geometric mean and turbidity were significant when considered alone in the ANOVA but dropped from the model because of significant correlations with velocity (substrate mean), or perhaps the effect was marginal (turbidity).

In summary, shovelnose sturgeon data were important because of their close relationship to the endangered pallid sturgeon. Shovelnose sturgeon were common and widely spread but many planned contrasts

Figure 35. Total catch of shovelnose sturgeon over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).

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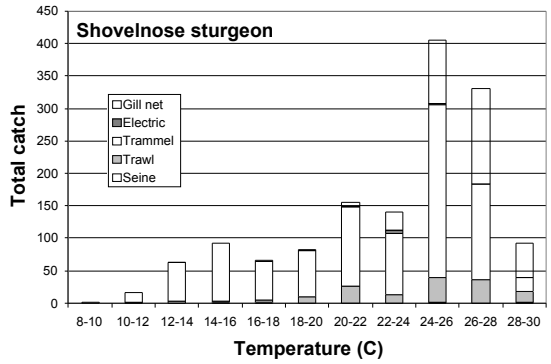


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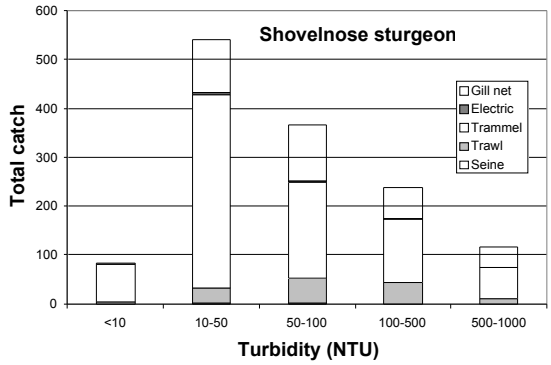
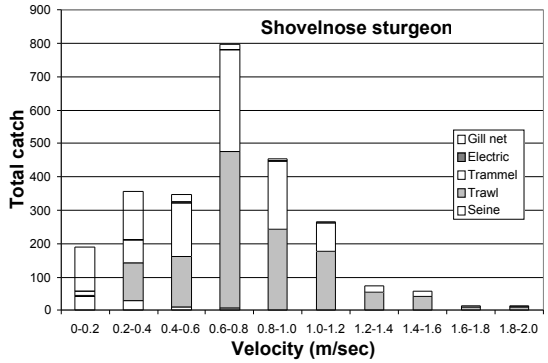
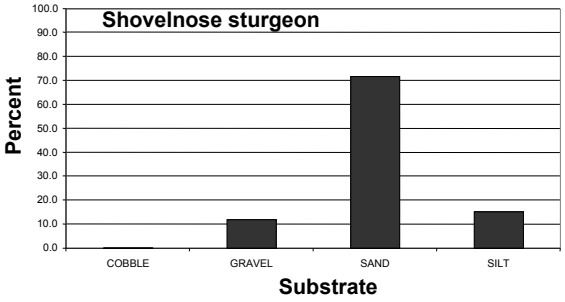



C




D




E

were not posisble because of low total catch, or were not significant. In general, C/E was lower in the IR zone than in the LA or CH zones, and most of the catch was by drifting trammel nets (64% of catch) used in macrohabitats with higher water velocity than other macrohabitats. Catch was positively associated with velocity, depth, turbidity, and substrate size.

***Sicklefin Chub***

The sicklefin chub is listed by several states as imperiled, and has a G3 conservation status (NatureServe 2003). It may be more abundant than previously thought because the new methods of bottom trawling seem to be more effective than gears used in previous studies (Grady and Milligan 1998). The ecomorphology, habitat associations, and catch rates of the sicklefin chub were presented in Ph.D. dissertations done concurrently with our study (Dieterman 2000, Welker 2000, Welker and Scarnecchia 2004).

The sicklefin chub grows to about 110 mm long, and all of the 704 fish that we collected were in this size range (Figure 30). The total catch showed a "U-shaped" distribution with most fish in the LA and lower CH segments (Figure A2-7). Sicklefin chubs were usually collected in the benthic trawl in all macrohabitats except SCN (Table 33). Three gears (trammel net, electrofishing, gill net) caught no fish. The benthic trawl catch data were suitable for analyzing C/E for BEND and SCC for all years among Segments 5, **8**, 9, **10**, *25*, and *27*.

In general, the ANOVA results (Table 34) confirmed that C/E was higher in LA segments than in altered segments (IR or CH). The high C/E in Segment 5 was important for contrasts between this segment and selected IR and CH segments. Segments **8** and **10** upstream from Lake Sakakawea had higher C/E than did other IR segments (Table 34). The C/E downstream from the Yellowstone River confluence was higher (Segment **10**, C/E = 0.4 fish/100 m) than the catch above in Segment **8** (C/E = 0.14).

Some statistical comparisons were not made because total catch was insufficient in several segments in the IR and CH zones. However, it is obvious that the high C/E in Segments 5 and 9 would be significantly higher than the average catch in the IR and CH segments (e.g., Segment 9 vs. Segments **7** and **8**). Additionally, segments downstream from two reservoirs (Fort Peck, Segment **7**; Lake Sakakawea, Segment **12**) could not be included in the analysis because of low total catch in trawls, so obviously C/E that ranged from 0.4 to 0.5 fish/100 m in segments upstream from the reservoirs were higher. Finally, total catch in trawls in CH segments upstream from Kansas City was too low to compare these segments with segments downstream from Kansas City, but it was obvious that the C/E downstream (Segments *25*, *27*) was greater than that from upstream segments (Table 33).

We captured sicklefin chubs over a wide temperature (14-30°C) and turbidity range (10-500 NTU) over substrates dominated usually by sand and gravel. Sicklefin chub were associated with higher velocities (0.4-1.2 m/s) than most other benthic species, and were frequently found at depths of 1-4 m (Figure 36). Logistic regression indicated that the likelihood of presence of the sicklefin chub increased with increased water velocity and depth, and decreased temperature ($R^2$ = 0.34). There was a significant positive correlation between water velocity and depth, but both factors were important enough to be retained in the model.

Mean velocity, depth , and substrate geometric mean were greater, and mean temperature lower at sites with fish compared to sites where fish were not caught (Table 16). Substrate geometric mean was significantly greater (2.1 mm) where sicklefin chub were present compared to absence sites (1.2 mm). Sand appeared to be common in proportion to total catch (Figure 36), but differences in the mean proportions of gravel, sand, and silt were similar at presence and absence sites (Table 16). Our findings agree with those from the Yellowstone River area, where the presence of sicklefin chub increased with increasing depth and velocity (Everett 1999).

In summary, the sicklefin chub was more vulnerable to the benthic trawl than to other gears. It is found in all macrohabitats except SCN. While it was common in CHXO and OSB in the LA segments, it is rarely found in these habitats in CH segments. The C/E contrasts and trends among segments indicated that catch was higher in the LA zone than in other zones, and higher upstream from two of three reservoirs. Catch rates increased below Kansas City. The likelihood of presence increased with velocity and depth and decreased with temperature.

***Smallmouth Buffalo***

The species typically inhabits large rivers, frequenting deep, clear, warm-waters with a current, but is also found in backwater areas and reservoirs (Edwards and Twomey 1982a). It is, therefore, not surprising that we found this species in every segment. Detailed studies of its distribution, catch rate and diet were done as part of the Ph.D. research associated with the Benthic Fishes Study (Welker 2000). Individuals can reach 1000 mm in length, but the largest fish that we collected were in the 700-750 size class (Figure 30).

The C/E for all gears was nil in CHXO and OSB macrohabitats (Figure 37). Only one fish was caught in the benthic trawl and 23 in the drifting trammel net.

Table 33. Sicklefin chub catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electro fishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments. See Figure A2-7.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | IBS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | OBS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| | SCN | | | | | | | | | | | | | | | |
| | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0.824 | 0 | 0.222 | 0.233 | 0.304 | 0 | 0 | 0 | 0 | 0.022 | 0 | 0 | 0.027 | 0 |
| | IBS | | 1.009 | 0 | 0.133 | 0.330 | 0.198 | 0 | 0 | 0 | 0 | 0 | 0.131 | 0.053 | 0.430 | 0.622 |
| | OBS | | 0.724 | 0 | 0.119 | 0.136 | 0.793 | 0 | 0 | 0.022 | 0 | 0 | 0 | 0.013 | 0 | 0.111 |
| | SCC | | 1.178 | 0 | 0.170 | 0.348 | 1.111 | 0 | 0 | 0 | 0 | 0 | | 0.037 | 0.356 | 0.644 |
| | SCN | | | | | | | | | | | | | | | |
| | TRM | | | | 0.556 | | 0.222 | | | | | | 0.022 | 0 | 0.815 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| | IBS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.078 | 0.044 |
| | OBS | | | 0 | | | | 0 | 0 | | 0 | 0 | 0 | | 0 | |
| | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0.022 | 0.133 |
| | SCN | 0 | 0 | 0 | 0 | 0.022 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| | TRM | | | | | | | | | | | | | 0 | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| | IBS | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | OBS | 0 | 0 | | 0 | 0 | 0 | | | 0 | | | | 0 | | 0 |
| | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| | SCN | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | | | 0 |
| | TRM | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| | IBS | | | | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | OBS | | | | | | | | | | | | | | | |
| | SCC | | | | | | | | | | | | | | | |
| | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| | TRM | | | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |

Table 34. Mean catch per unit effort data for sicklefin chub by benthic trawl (fish/100m) and list of significant contrasts among segments. LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone, ASAK = above Lake Sakakawea, BFTP = below Fort Peck Reservoir, BL&C = below Lewis and Clark Lake, FTP = segments between Fort Peck Dam and YSR confluence, MOR = Missouri River, YSR = Yellowstone River. For other contrast results see Table A3-13.

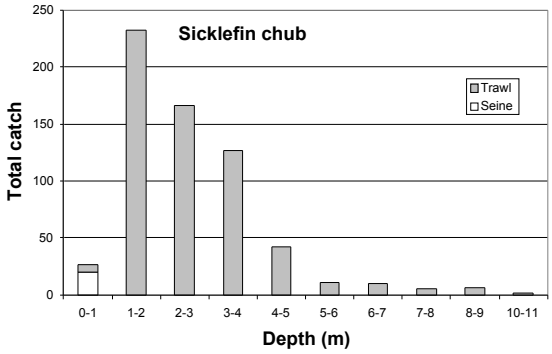
| General Contrast | Segment contrast | | Trawl<br>P value<br>Means |
|---|---|---|---|
| Among LA | MOR LA vs. YSR LA | 5 vs. 9 | <0.0001<br>0.8, 0.28 |
| LA vs. IR and CH | MOR LA vs. FTP IR | 5 vs. **8** | <0.0001<br>0.8, 0.14 |
| | LA vs. CH | 5, 9 vs. *25, 27* | 0.0003<br>0. 5, 0.21 |
| | LA MOR vs. CH | 5 vs. *25, 27* | <0.0001<br>0.8, 0.2 |
| | MOR LA vs. IR w/o BL&C | 5 vs. **8, 10** | 0.0005<br>0.8, 0.25 |
| Among IR | IR BFTP vs. ASAK IR | **8** vs. **10** | 0.003<br>0.14, 0.4 |
| IR vs. CH | | | |
| Among CH | | | |

Electrofishing caught the most fish (216) while gill nets and seines captured 98-131 specimens each. Analyses of data from trammel nets, beach seines, gill nets, and electrofishing was possible, but there was no significant segment effect for any of the four gears (P > 0.17, Table A3-14).

Our highest catches were upstream from Lake Sakakawea in Segments **8** and **10**, but identifying trends in the C/E by segment was difficult because of the low total catch. Few smallmouth buffalo were captured in Segment 9, so any contrasts with this segment were obvious (e.g., catch in Segments 3 and 5 were greater than those in Segment 9). Half of the IR segments were excluded from analysis of electrofishing C/E, whereas only one CH segment was excluded, so the general trend was that C/E was lower in the IR zone, and especially low in Segment **12** downstream from Garrison Dam. For Lewis and Clark Lake catch was higher in Segment **15** (below) than in Segment **14** (above).

Total catch was highest in shallow waters where velocities were low and silt dominated the substrate (Figure 38). This general pattern was supported by ANOVA that showed lower water velocity and finer substrate sizes at sites with fish compared to sites where no fish were caught (Table 16). About half of the fish were captured where turbidity was 10-50 NTUs, and average turbidity at presence and absence sites was similar (46 NTUs). Most fish were caught at temperatures in the 20-30°C range. Temperature was signifi-

Figure 36. Total catch of sicklefin chub over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).

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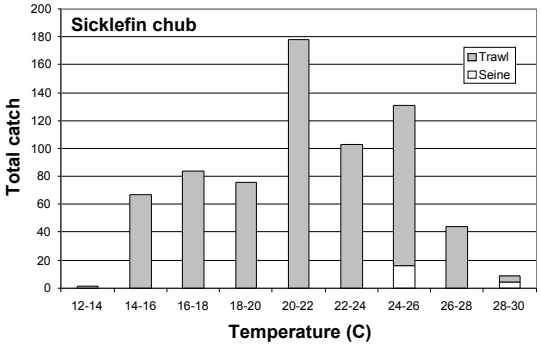


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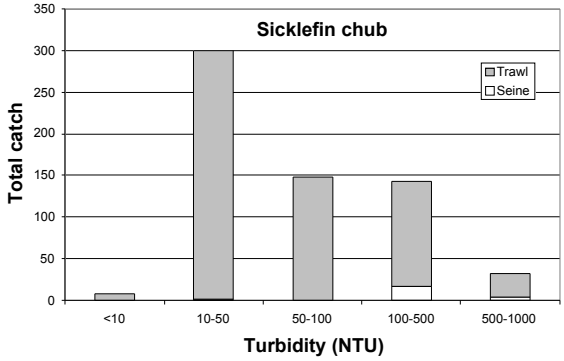


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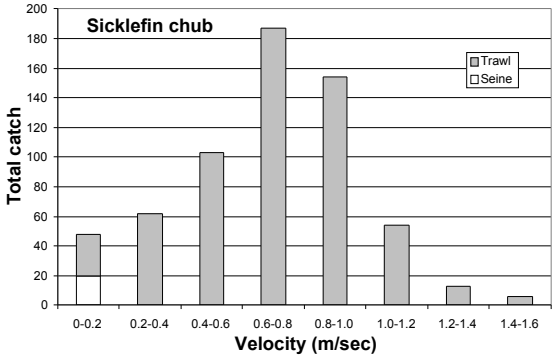


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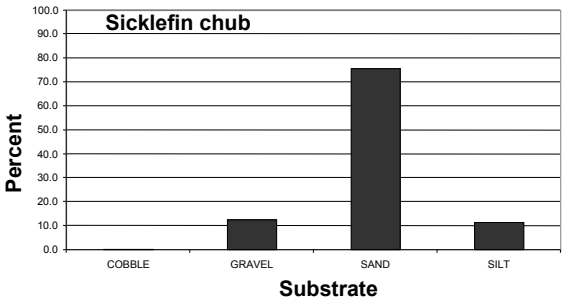


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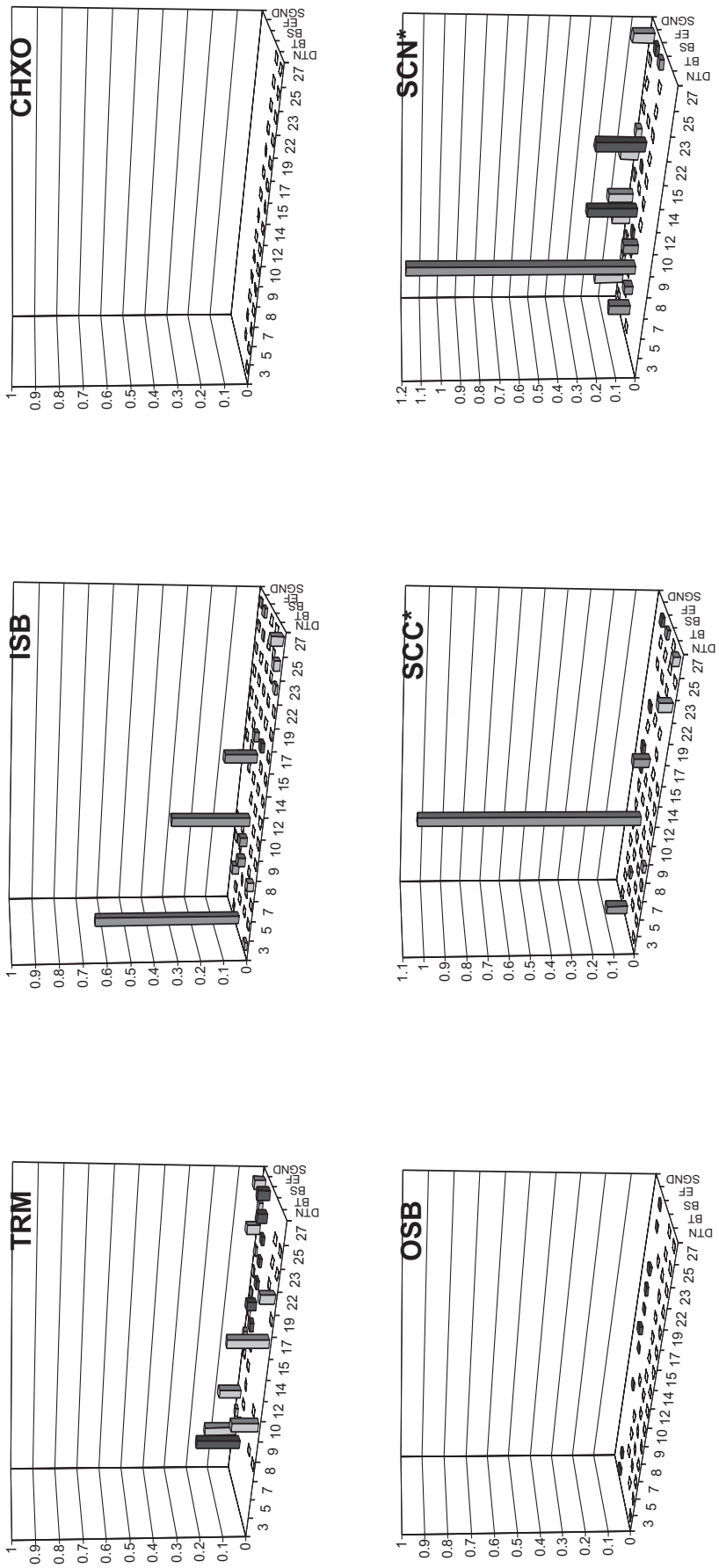
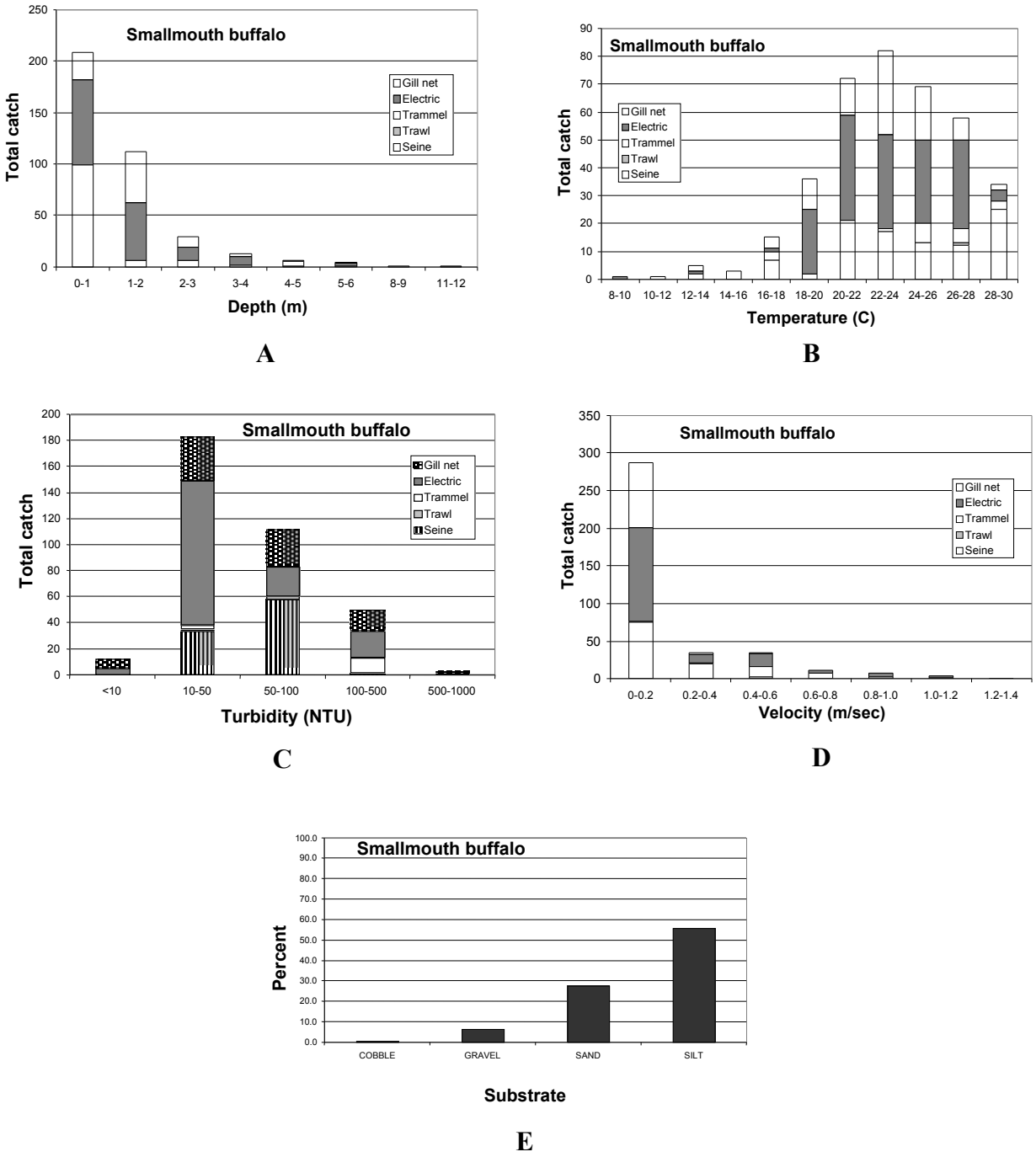



Figure 37. Catch per effort of smallmouth buffalo from 15 segments (3 = Montana, 27 = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), BT = benthic trawl (fish/100m). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-10.

Figure 38. Total catch of smallmouth buffalo chub over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).



cantly higher at presence sites (23°C) than at absence sites (22°C), but temperature was not retained in the stepwise logistic regression model predicting the likelihood of presence of smallmouth buffalo. Stepwise logistic regression indicated that the likelihood of presence of smallmouth buffalo increased with decreased water velocity and substrate geometric mean, but with an $R^2$ of 0.05, the information has little biological significance.

In summary, smallmouth buffalos were collected by all gears, especially electrofishing, and although widespread, the species was not particularly abundant in our samples. It was rarely found in high velocity habitats (e.g., CHXO, OSB) and usually found in TRMs and SCNs where velocity and turbidity were low and silt percentage and temperature were high. No segment contrasts were significant and too few fish were caught to show meaningful trends, except possibly that catches were lower in the IR segments than in the LA and CH segments, and lower in Segment **12** downstream from Garrison Dam than upstream.

***Stonecat***

The stonecat takes refuge between stones or beneath litter and is therefore difficult to capture so it is may be more common than indicated by the 342 fish that we caught. The largest species of the *Noturus* genus, the stonecat can reach 230 mm in length, and our sample spanned this range (Figure 39).

The stonecat was present in all segments, except Segment **12**. Highest catches were in the LA zone and in OSBs (Figure 40). This species was one of the few species that was abundant in OSB macrohabitat, but it was also found in other macrohabitats. Seventy-six percent were caught in the trawl but no statistical analysis was possible for the trawl data because of the disproportionately higher catch in Segments 5 and 9. There were no significant segment effects for electrofishing data ($P > 0.57$, Table A3-15). Obviously, catch rate in the LA zone was higher than in other zones. Catches above Fort Peck Lake and Lake Sakakawea were higher than those below. In general, higher catch rates in the area of the Yellowstone confluence (Segments 9, **8**, and **10**) were higher than further upstream (Segment **7**) or downstream (Segment **12**).

Total catch was associated with a broad depth and velocity range (Figure 41) that included some of the deepest depths recorded (e.g., 11-12 m) and swift velocities (1.8-2.0 m/sec). Total catch occurred over a broad range of turbidity levels. The temperature pattern associated with total catch was somewhat bi-modal with high catches at 20-22°C and at 24-26°C. Substrate usually included about 20% gravel and cobble but was made up of more sand (56%) than silt (16%). These patterns were confirmed by one-way ANOVA of mean habitat conditions at sites with and without stonecat, which indicated that velocity, depth, and coarse substrate percentages were significantly higher for locations with stonecat (Table 16). Stepwise logistic regression also indicated higher velocities as associated with the likelihood of stonecat presence ($R^2 = 0.15$). Depth was significant when considered alone, but it fell out of the stepwise regression model, probably because depth was significantly correlated with velocity (40% of the variation that depth accounted for was also accounted for by velocity).

In summary, the stonecat was widely distributed but more abundant in the upper (LA segments and Segments **7** and **8** of the IR zone) than in the CH zone segments. However, segment contrasts were not possible, or were insignificant (electrofishing). Stonecat were caught in all gears, but was most vulnerable to trawling in macrohabitats such as CHXO, OSB, ISB, and SCC. Stonecat were usually found in coarse substrates and in deep water where water velocity was high.

***Sturgeon Chub***

The sturgeon chub is thought to be declining throughout its range (Everett 1999, Galat et al. 2005). This small minnow is caught by seining in riffles in tributaries to the Missouri River in the Dakotas (e.g., Cheyenne River, Hampton and Berry 1997) and by trawling in the lower Missouri River main channel (Grady and Milligan (1998). The association of the sturgeon chub with various macrohabitats and a comparative niche analyses among species were part of a Ph.D. Dissertation done by a student with the Benthic Fishes Study (Welker 2000).

We collected sturgeon chubs in 12 segments; most were collected in Segments 3 through **10** and none in IR Segments **12**, **14**, and **15**. Most fish were caught in CHXOs, OSBs, and ISBs, but occasionally high catches were also made in TRM and SCN. The benthic trawl captured 95% of the fish and for trawl data there was a significant segment effect ($P < 0.0001$). However, segment contrasts were limited to a few segments in the upper mainstem (e.g., 5, 9, **8**) for BEND and SCC data (Table 35). The high catch in Segment 9 dominated the analyses, and greatly influenced ANOVA results. Although catches in Segment 5 were lower than those in Segment 9, catches in both segments were higher than those in Segment **8** ($P = < 0.0001$) and in other segments where catches in either Segment 9 or 5 were higher than those in Segment **8**.

Statistics were not needed to determine that catches in the LA zone were greater than those in the IR and CH zones. It was obvious that C/E was higher above Fort Peck Lake than below (Segment **7**), and higher

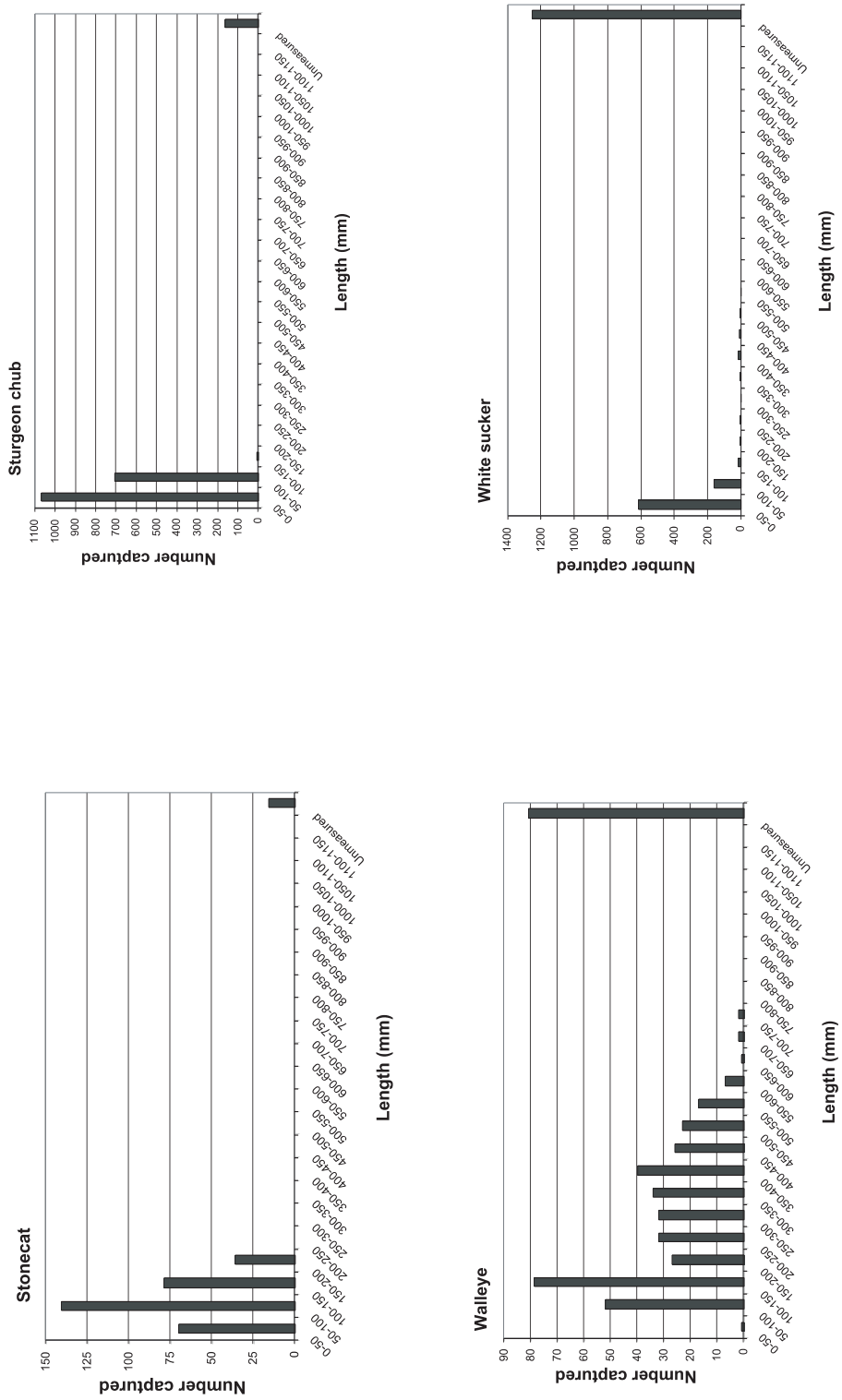



Figure 39. Length, frequency, distribution for four species of benthic fishes collected from 15 segments of the main channel of the Missouri River, 1996-1998. Bar in far right of figure indicates number of fish not measured.

Figure 40. Catch per effort of stonecat from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), BT = benthic trawl (fish/100m). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-11.

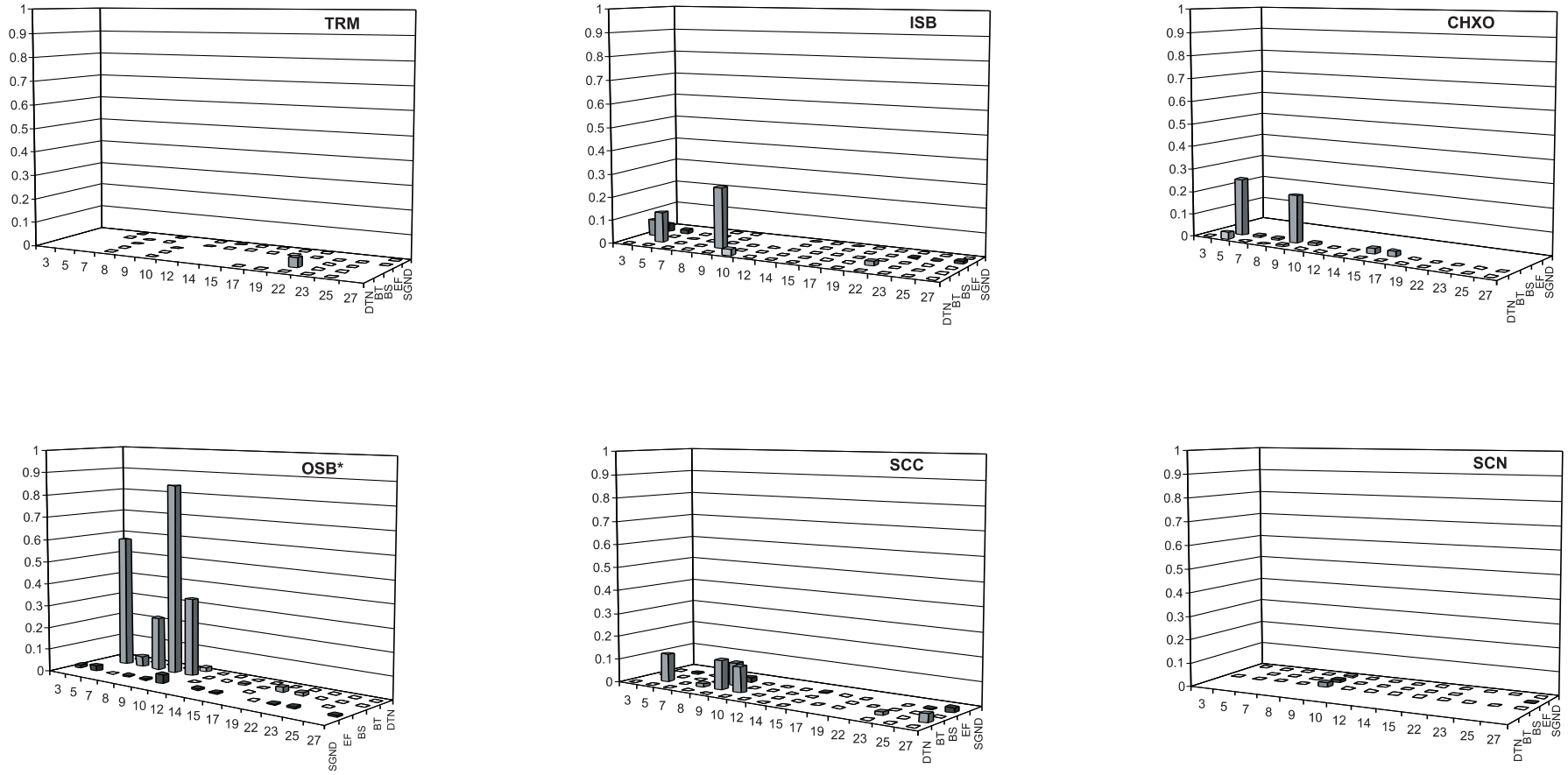
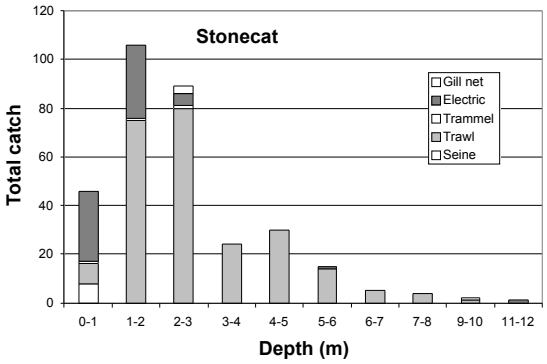


Figure 41. Total catch of stonecat over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).

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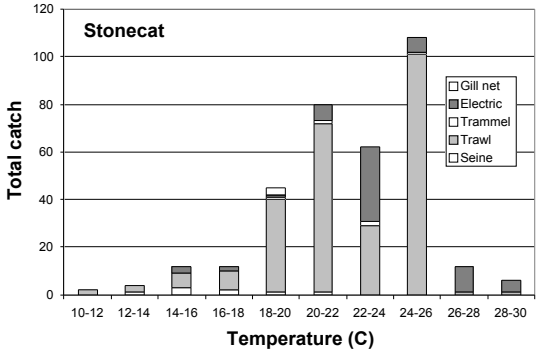


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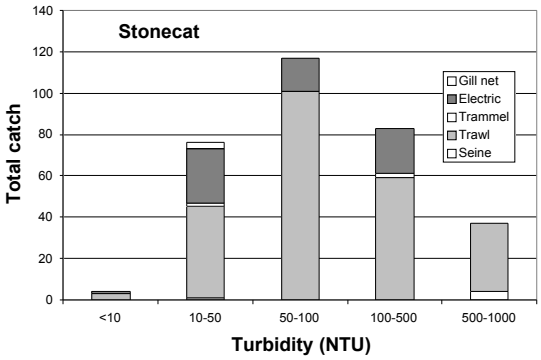


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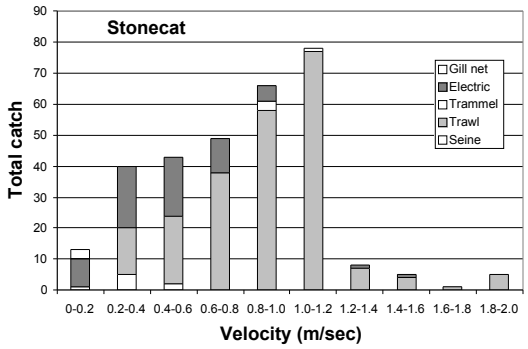
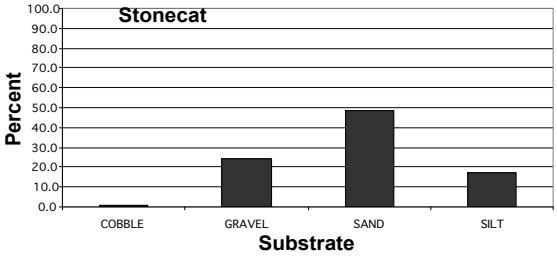



D




E

Table 35. Mean catch per unit effort data for sturgeon chub by benthic trawl (fish/100m) and list of significant contrasts among segments. LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone, BFTP = below Fort Peck Reservoir, BL&C = below Lewis and Clark Lake, MOR = Missouri River, YSR = Yellowstone River. For other contrast results see Table A3-16.

| General Contrast | Segment contrast | | Trawl<br>P value<br>Means |
|---|---|---|---|
| Among LA | MOR LA vs. YSR LA | 5 vs. 9 | 0.008<br>1.4, 2.2 |
| LA vs. IR and CH | LA vs. IR | 5, 9 vs. **8** | 0.0001<br>1.8, 0.3 |
| | YSR LA vs. IR BFTP | 9 vs. **8** | <0.0001<br>2.2, 0.3 |
| | MOR LA vs. IR W/O BL&C | 5 vs. **8** | <0.0001<br>1.4, 0.3 |
| | YSR LA vs. IR W/O BL&C | 9 vs. **8** | <0.0001<br>2.2, 0.3 |
| Among IR | | | |
| IR vs. CH | | | |
| Among CH | | | |

upstream from the Yellowstone confluence (Segment **8**) than below. The Yellowstone River catches were quite high (total catch = 1,835 fish, trawl C/E = 2.2 fish/100 m), and similar catches were not found in the Missouri River segments (i.e., Segments **8** and **10**) near the confluence (Figure 42). Although both Segments **10** and **12** were withheld from analysis, 32 fish were caught in Segment **10** whereas none were caught in Segment **12**, thus supporting the trend that catches downstream from Lake Sakakawea were generally lower than catches above.

Catch trends across physical habitat categories indicated that the sturgeon chub was associated with sandy substrates with more gravel than silt (Figure 43). Most sturgeon chubs were captured in 1-4 m depths where velocity was relatively high (dome shaped pattern with peak at 0.6-0.8 m/sec). Mean velocity was higher (0.6 m/sec) at sites with fish than at sites without (Table 16). Total catch had a bi-modal distribution over the temperature range, with most fish caught in the 20-26°C range; mean temperatures at sites with and without fish were similar (Table 16). About half of the catch was in water where turbidities were 10-50 NTUs, with the remainder of the catch distributed among other turbidity categories. Where sturgeon chub were captured, silt was significantly less and substrate geometric mean size was significantly higher than at sites without fish.

The stepwise logistic regression model ($R^2$ = 0.25) indicated that the likelihood of presence of sturgeon chub increased with increased water velocity and increased depth, but left geometric substrate mean out, probably because it was marginally important (P = 0.048, Table A4-5). Velocity and depth were correlated.

In summary, the high catch of sturgeon chubs was unexpected because of reports about their declining status. They may be declining in the lower mainstem because most of the specimens we collected were in the LA and upper IR segments. We collected most fish in the trawl in deep (<3 m) and swift (0.6 m/sec) water conductions over sand and gravel substrates.

Figure 42. Catch per effort of sturgeon chub from 15 segments (3 = Montana, 27 = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), BT = benthic trawl (fish/100m). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-12.

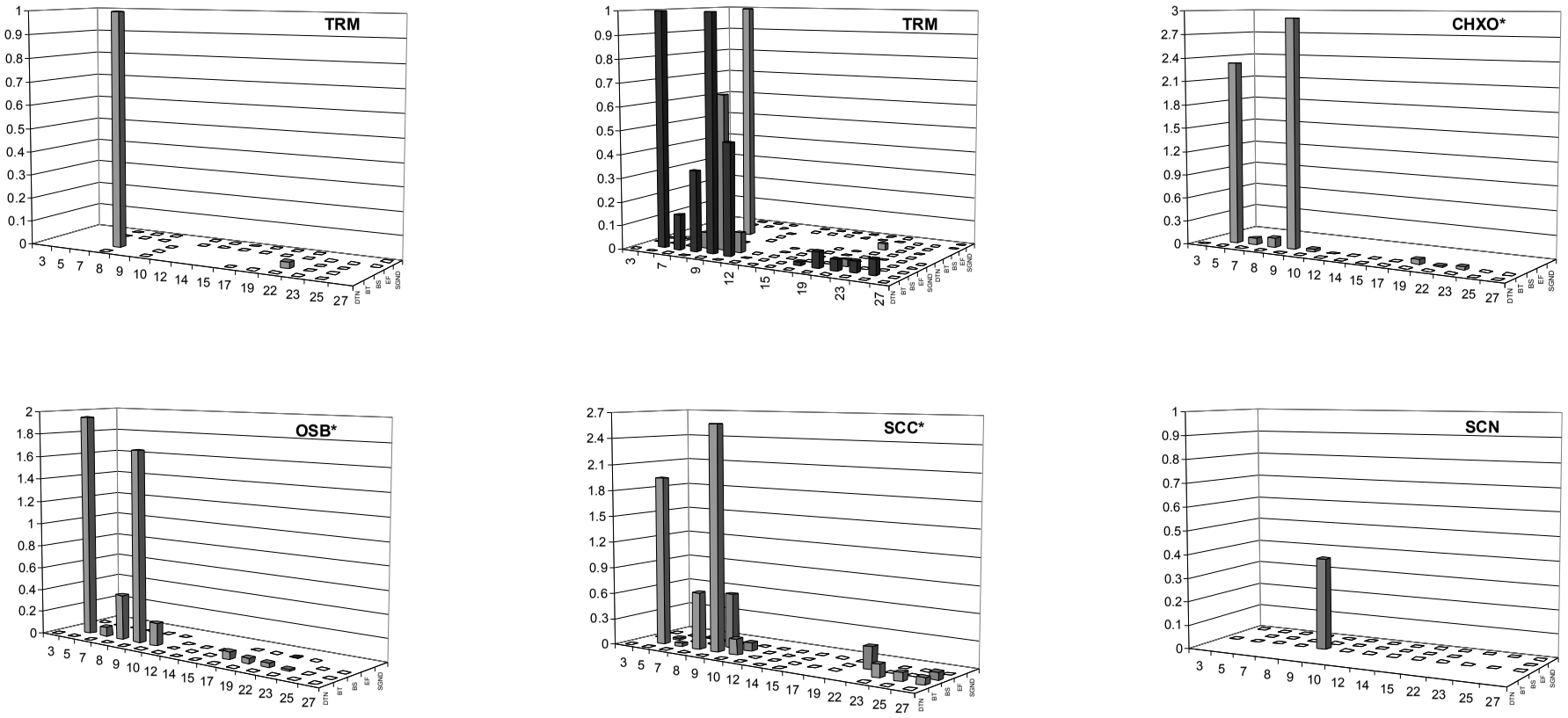
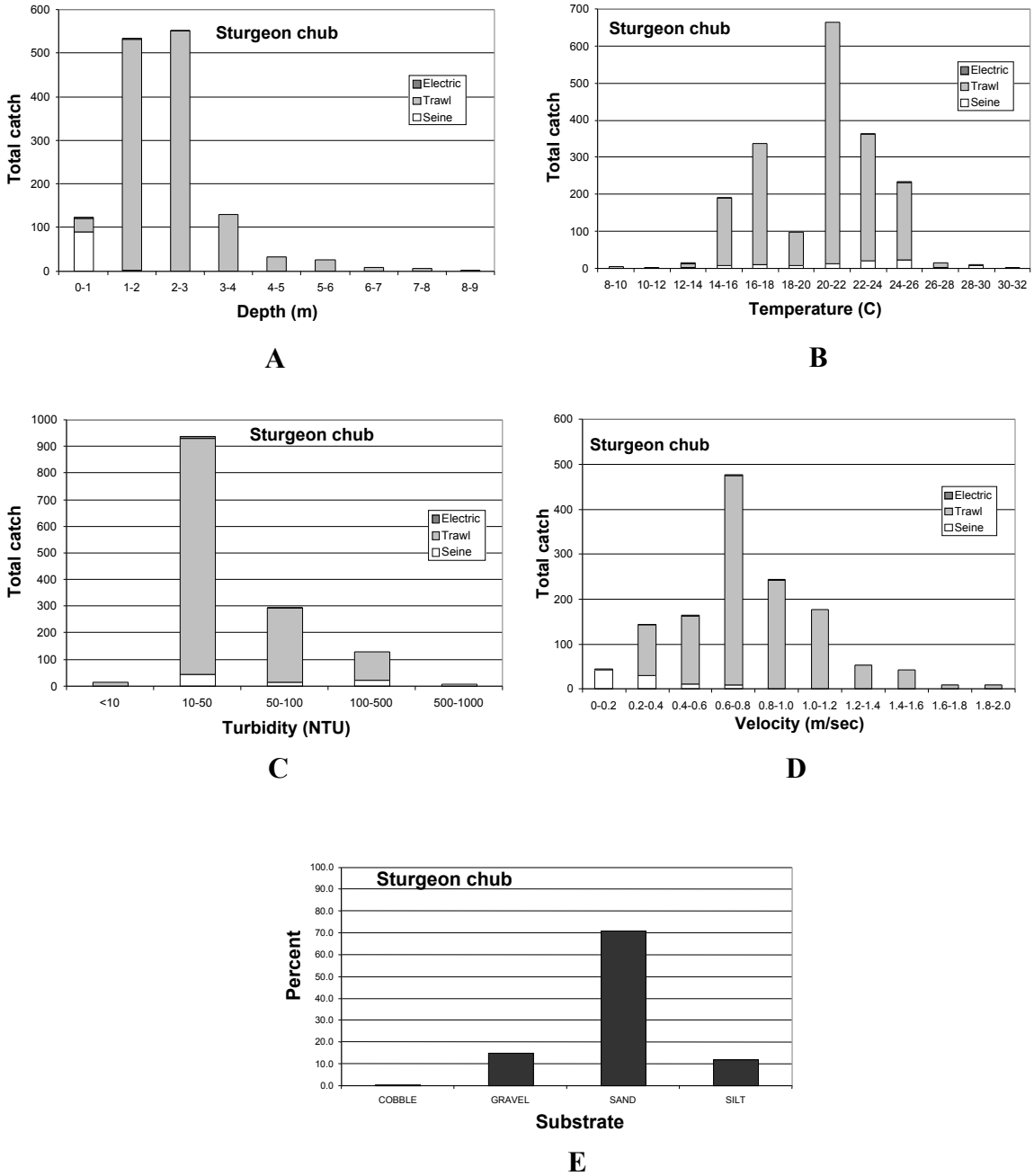


Figure 43. Total catch of sturgeon chub over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).



***Walleye***

The walleye is a popular game fish that inhabits the reservoirs and main channel of the Missouri River and is stocked in Missouri River reservoirs. The walleye was included in the benthic fishes assemblage because it is associated with deep-water substrates near steeply sloping banks or bars, and spawns over rocky substrates. Large adults reach about 800 mm in length and we captured some in this size range (Figure 39). Our sample included some fish in each size class except the smallest (0-50 mm). We caught walleyes in all macrohabitats except CHXO (Figure 44).

Walleyes were distributed among all study segments, but the catch in CH segments was relatively low for total catch and C/E (Figure 44). Total catches in the CH segments was low, so these segments were excluded from analysis. Most fish were caught by electrofishing (271 fish caught) but segment effects were not found ($P > 0.29$, Table A3-17). Trends were obvious for several contrasts, for example, the catch of walleye was greater in the LA and IR segments than in CH segments, and the higher walleye catch in Segment **12** than in Segment **10** was a rare case of catches downstream from Lake Sakakawea being higher than those upstream.

Catch of most walleyes was at moderate depths and low velocities (Figure 45). Most walleyes were caught in a 10-degree temperature range (18-28°C) an where turbidity was 10-50 NTU. The ANOVA results indicated that velocity was slower, and temperature and turbidity higher at sites with walleyes than at sites where walleyes were not caught (Table 16). Mean depth at presence and absence sites was similar (1.5 m). Stepwise logistic regression indicated that the likelihood of walleye presence was increased with increased temperature and decreased water velocity ($R^2 = 0.05$). Substrate geometric mean and turbidity were significant when considered alone, but fell out of the regression model, perhaps because of correlations with temperature (turbidity) and velocity (proportion of silt).

In summary, the walleye was a fish of the IR and LA segments, but catches were too variable and small to determine trends in C/E or make planned segment comparisons. Representatives of all size classes were captured. Walleyes were caught in all gears but were especially vulnerable to electrofishing and gill netting in TRMs, SCCs, and SCNs where velocity was lower, temperature higher, and substrate size was smaller than at sites where walleye were not caught.

***White Sucker***

This species is widespread and common in rivers and lakes in the Mississippi River basin, but was absent in our samples from the CH zone (Figure 46). The species reaches 450 mm and may live 15 years, but we caught a few that were larger than expected (e.g., 500-550 size class). Small fish dominated our catch, but there were specimens in each length class (Figure 39). A Ph.D. project by Welker (2000) included detailed analyses of diet and distribution, especially in Segment **12** where they were very abundant compared to other upper basin segments.

White suckers have been labeled "generalists", but optimum stream habitat depends on life stage, in that white suckers make upstream spawning runs to rocky areas, eggs incubate in clean gravel, and fry drift downstream (Twomey et al. 1984). We found white suckers in all macrohabitats, but had high C/E values in ISBs and SCCs (Figure 46). There was an unusual distribution of total catch in that 337, 223, and 1304 white suckers were caught in Segments **7**, **8** and **12** respectively. Most white suckers were caught with the beach seine. Because of the unusual catch distribution, no statistical analyses were possible for the seine or any other gear. The only obvious general trend in seine C/E was the higher abundance in IR segments **7**, **8**, and **12**, than in other nearby segments (e.g., 5, 9, **10**).

Most fish were caught in shallow areas (Figure 47) with low velocities when water temperatures were <20°C, but there were no differences for the measured habitat conditions between sites with and without white suckers (Table 16). Stepwise logistic regression indicated that the likelihood of presence of white sucker increased with decreased water temperature and depth ($R^2 = 0.05$).

In summary, the white sucker was absent from the CH and the uneven catch and distribution made segment comparisons impossible. Most fish were caught in beach seines, which may explain the preponderance of small fish in the sample. Habitat associations were weak but generally, catches were in shallow, slow, clear water over sand and silt substrates.

**Nonindigenous Species**

Nonindigenous species are those species that are exotic or introduced. Exotic species are from outside of North America, whereas introduced species are from outside of the Missouri River basin. We did not list as nonindigenous those species that were native to part of the Missouri River drainage, but had expanded into our study area. Four warmwater exotics were found: two species of Asian carp, common carp and goldfish (Table 36). All Asian carp (e.g., grass carp, bighead carp) were found downstream from Gavins Point Dam. The brown trout is also an exotic; one was one found in Segment 5.

Coldwater species were Chinook salmon, brown trout, and rainbow trout, and whitefish, all found in

Figure 44. Catch per effort of walleye from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), BT = benthic trawl (fish/100m). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-13.

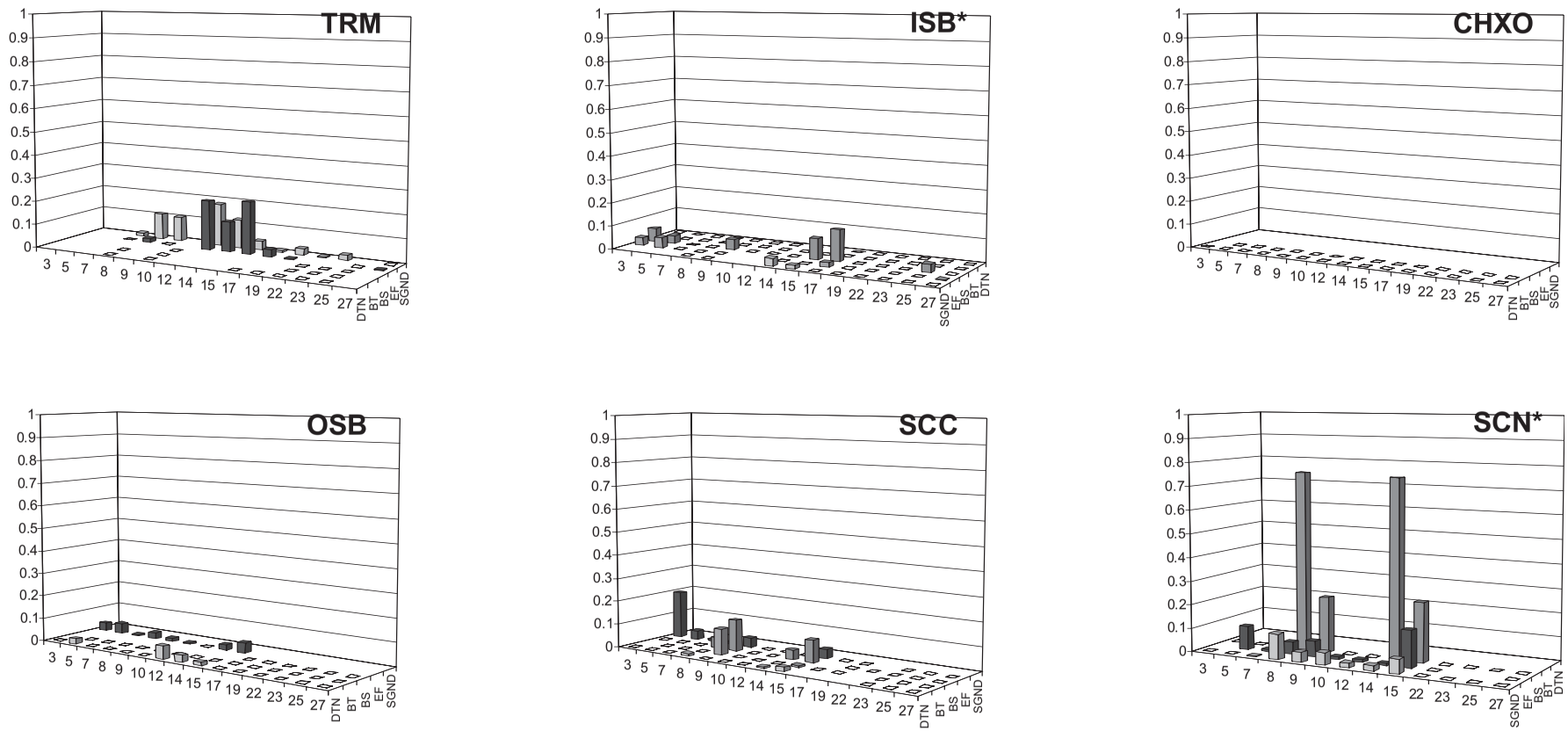
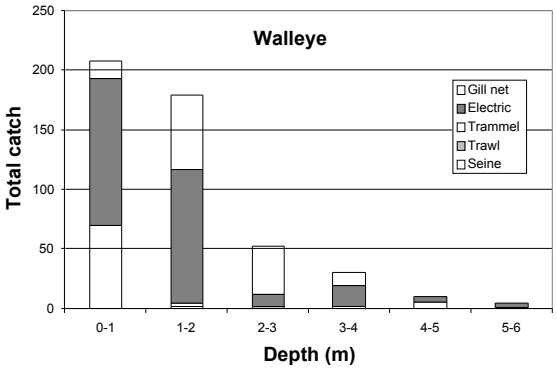
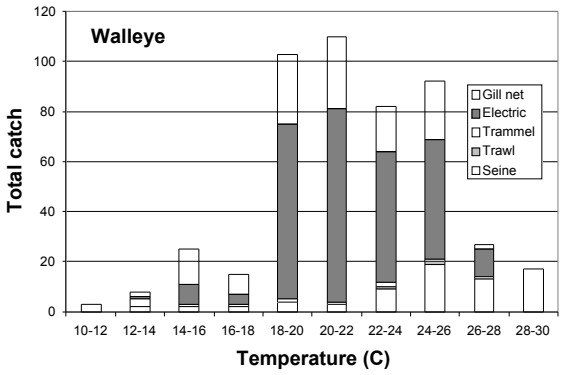


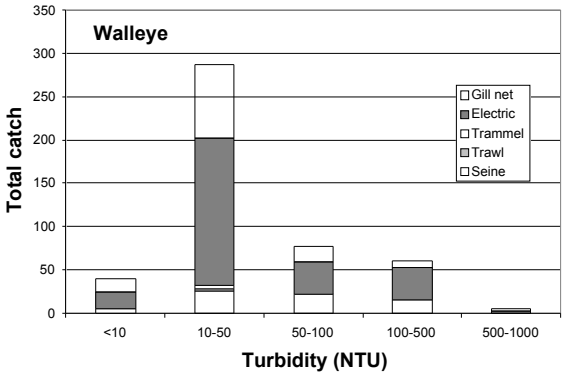
Figure 45. Total catch of walleye over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).



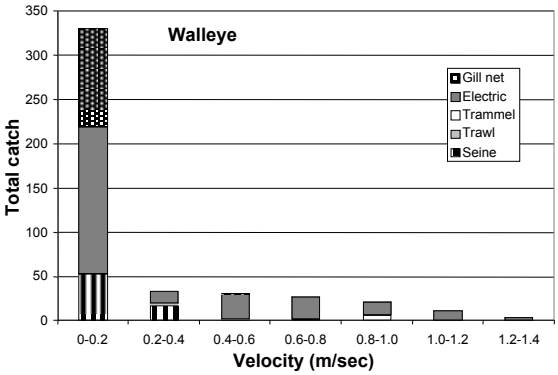

A



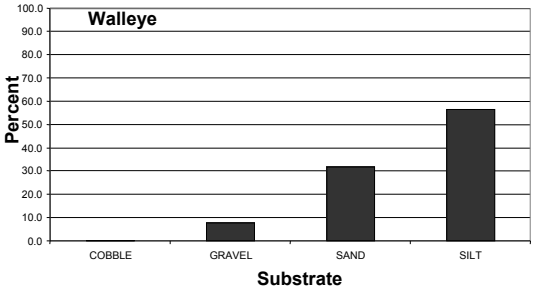

B




C




D




E

Figure 46. Catch per effort of white sucker from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), BT = benthic trawl (fish/100m). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability. See Table A2-14.

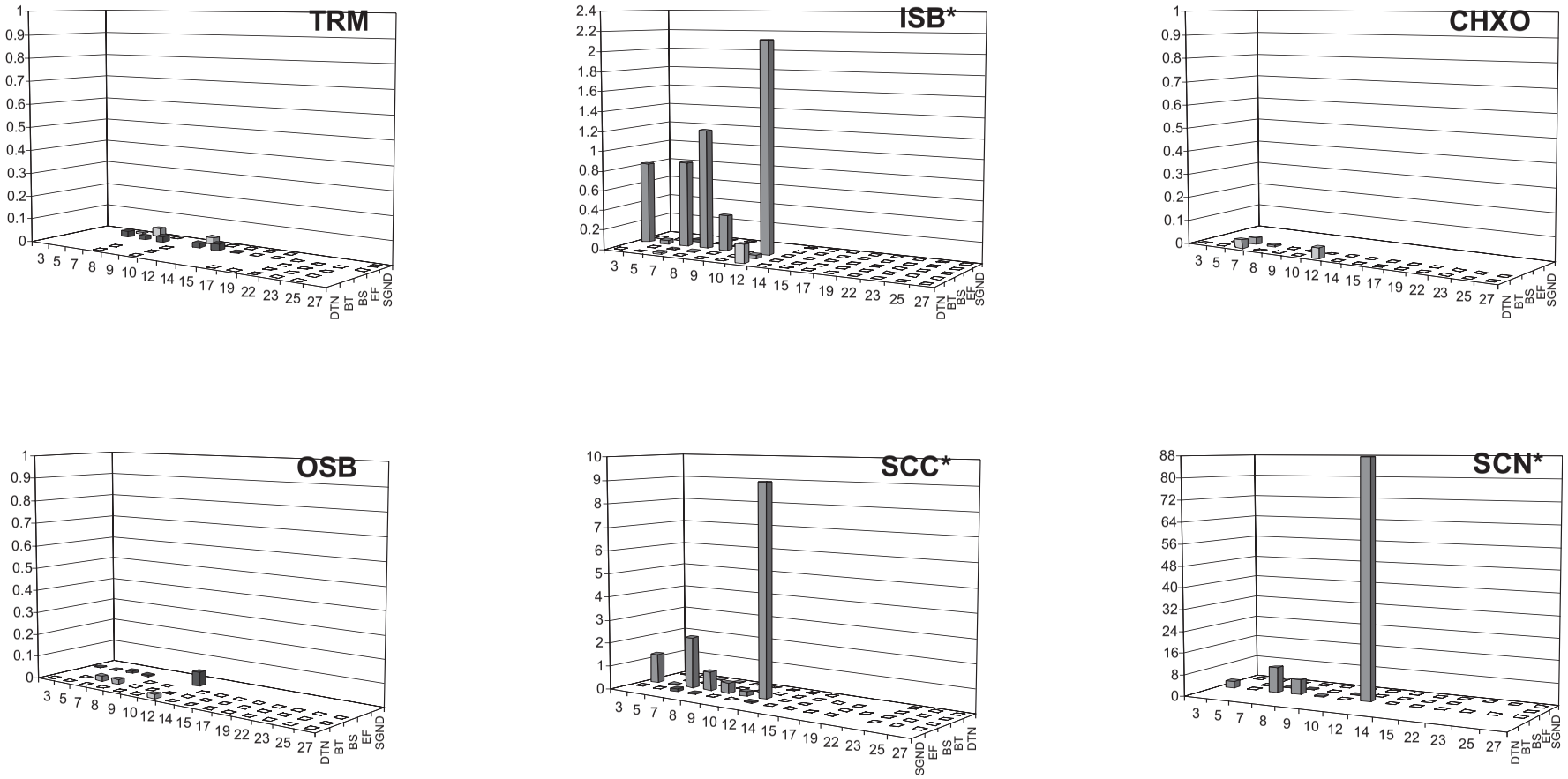
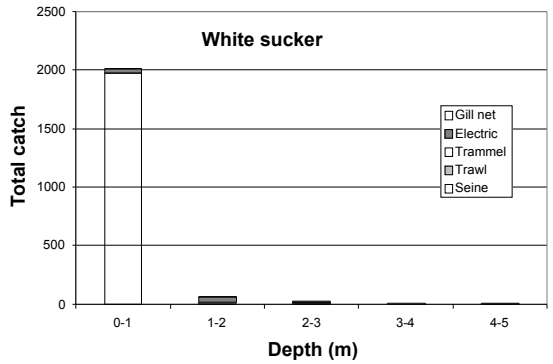
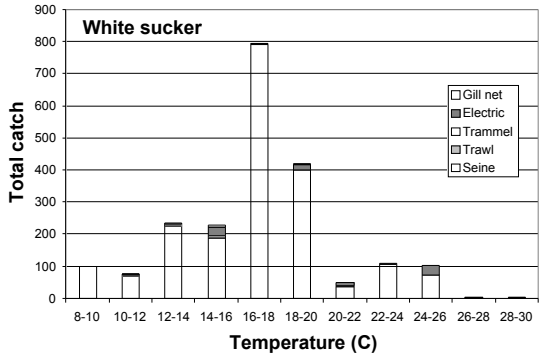


Figure 47. Total catch of white sucker over three years (1996-1998) in association with depth (A), temperature (B), turbidity (C), velocity (D), and percent of catch over four substrates (E).




A

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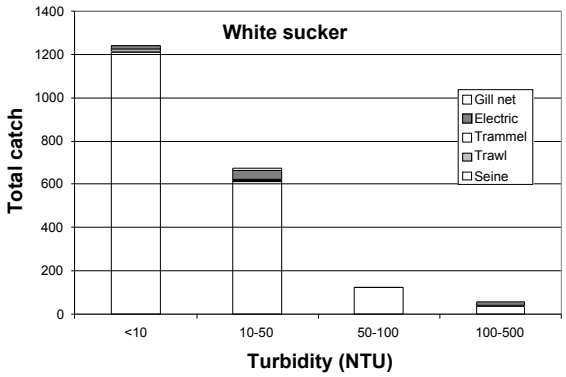


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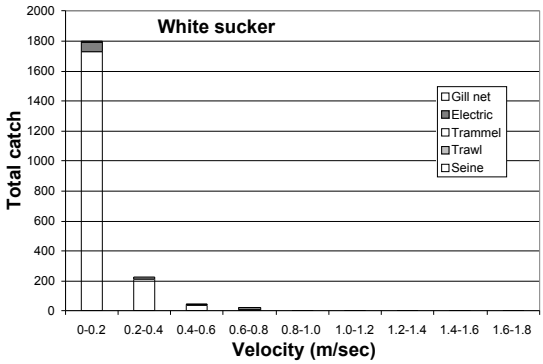


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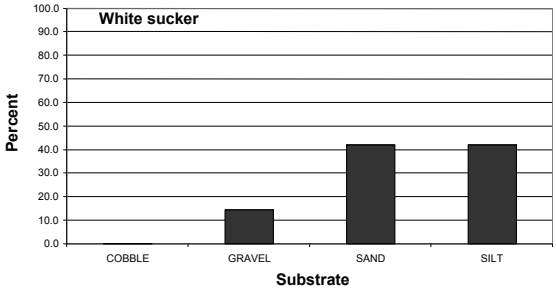



E

segments in Montana (Table 36). Cisco (lake herring) and lake whitefish were found in Montana segments and downstream from Garrison Dam in North Dakota (Segment **12**). Seven other introduced species were cool- or warm-water species. Striped bass were few (n = 18) and found only in Missouri (Segments *25* and *27*). Muskellunge and rock bass were found in North and South Dakota. We collected 227 mosquitofish in the Missouri portion of the river (Segments *23-27*).

**Other Species**

The 65 other species included a group of incidental species (<10 caught), a group of more commonly caught species with limited distribution, and a group that were common and widely distributed in at least two zones. None of the 28 incidental species (Table 37) have ever been common or widespread in the Missouri River mainstem, which is on the edge of their range (Lee et al. 1980). An exception was the yellow bull-

Table 36. Number of exotic and introduced fish species, including salmonids, caught each year of the Benthic Fishes Study in the riverine portions of the Missouri River from Montana to Missouri. Native range comments are from Page and Burr (1991) and Lee et al. (1980).

| Species | 1996 | 1997 | 1998 | Total | Comment and segment number where found |
|---|---|---|---|---|---|
| | | | Exotic species | | |
| Common carp | 481 | 1,235 | 1,321 | 3,037 | ubiquitous |
| Grass carp | 3 | 10 | 3 | 16 | *19* downstream |
| Bighead carp | 3 | 0 | 19 | 22 | *19* downstream |
| Goldfish | 0 | 0 | 5 | 5 | |
| Brown trout | 0 | 0 | 1 | 1 | 5 |
| | | | Introduced cool and warm water species | | |
| Spottail shiner | 257 | 100 | 136 | 493[e] | *19* upstream |
| Mosquitofish[b] | 7 | 115 | 105 | 227 | *23-27* (MO) |
| Rainbow smelt | 6 | 17 | 0 | 23 | **6**, **12**, **14**, **15**, *25* |
| Rock bass[d] | 2 | 14 | 6 | 22 | **14**, **15** |
| Striped bass | 12 | 6 | 0 | 18 | *25*, *27* |
| Muskellunge[a] | 0 | 1 | 0 | 1 | **12** (ND) |
| White perch | 2 | 0 | 0 | 2 | *19* |
| | | | Introduced coldwater species | | |
| Cisco[c] | 13 | 8 | 3 | 24 | **6**, **7**, **12** (Mt, ND) |
| Rainbow trout | 6 | 4 | 11 | 21 | 3, **7** (Mt) |
| Chinook salmon | 0 | 1 | 0 | 1 | **7** (Mt) |
| Lake whitefish | 0 | 2 | 0 | 2 | **8** (Mt) |

[a]Native to upper Mississippi River south to Iowa.
[b]Native to central Mississippi River basin south.
[c]Also called lake herring, native to upper Mississippi River basin south to Minnesota and Illinois.
[d]Native to Mississippi River Basin but not the Missouri River Basin
[e]121 spottail sampled in Segments 4 and **6** in 1996.

head, which has been widely reported from Missouri to North Dakota, and which we also found over this range. We found 24 species (Table 38) that were more common, some with distributions that were restricted to either the upper (e..g., mottled sculpin, longnose sucker, longnose dace) or lower river (e.g., spotted bass, skipjack herring, bullhead minnow.

Thirteen species were found in more than six segments and usually in each zone (Table 39). The goldeye was common at every segment. White and black crappie, northern pike, and smallmouth bass are natives that have been widely stocked and are now common in the IR and LA segments. Green sunfish and shortnose gar are natives, but are more abundant in the lower river than in the upper. Spottail shiner, yellow perch, and black bullhead were not found in the last 5 downstream segments (Segments *19-27*).

**Summary of Zone and Segment Contrasts**

Catches of five species (bigmouth buffalo, burbot, sand shiner, white sucker, pallid sturgeon) were too limited for any statistical analysis of the planned segment contrasts. A few species (e.g., blue catfish, flathead catfish) were found only in one or two zones in our study so data from these species were not useful for zone contrasts, but were useful for certain segment contrasts. Overall, data from 18 species were useful for addressing the 22 planned contrasts (Tables 40 and 41).

A summary of the individual species data for each planned contrast indicates that possible contrasts were more likely when data from several segments were involved (e.g., zone contrasts D, E, F, Table 41) than when the contrast was between only two segments (e.g., upstream compared to downstream from a dam, contrasts H, S, T, Table 41). For some species, data from only one gear were useful (e.g., sturgeon chub, benthic trawl C/E) and therefore there were 22 possible tests for segment differences for that species (Table 40). Data from as many as four gears was useful for some species (e.g., channel catfish, electrofishing, gill net, seine, benthic trawl), and therefore the total number of possible tests for segment differences was 88 for the channel catfish. A total of 924 tests were possible for the 18 species, depending on how many gears provided useful data for analysis.

Much of the data did not meet our data filter criteria, so 478 possible contrasts were not performed (Table 40). However, some of these contrasts were not performed because patterns in the data were obvious (zero catch). In the discussion section we summarize overall trends among segments by combining the obvious "trends" with the possible statistical contrasts. Of the 446 possible contrasts, 85 were significant. Common, widespread species (e.g., channel catfish, freshwater drum, river carpsucker, shorthead redhorse) had more statistically significant results throughout the study area than did species with limited distributions (Table 40). Five species had adequate data for contrasts, but no contrasts were significant (blue catfish, fathead minnow, smallmouth buffalo, stonecat, walleye).

**Summary of Habitat Associations**

The CCA ordination plot summarizes the general trends for benthic fishes at the segment scale (Figure 48). Segments in the LA zone, and Segment **10** just downstream from the confluence of the Yellowstone River are grouped with sturgeon chubs, sicklefin chubs, flathead chubs, burbot, sauger, and other fish that were found in abundance in the LA zone. Segments **7**, **8**, and **12** grouped together with the species that tended to have high catch rates in the IR zone (e.g., white sucker, bigmouth buffalo, walleye, fathead minnow). Segments **14-***27* grouped with the fishes that were abundant (e.g., channel catfish, emerald shiner) or only found in the lower IR and CH zone segments (e.g., flathead catfish, blue catfish, sand shiner).

All macrohabitats were used by one or more species and all species were common in three or more macrohabitats. Channel catfish was the only species commonly found in abundance in all macrohabitats. All benthic species were subjectively judged as abundant in ISB and SCC macrohabitats. In SCNs, 68% of the benthic fish species were abundant, 63% in TRMs, 45% is OSBs and 23% in CHXOs. Three of the four pallid sturgeon were captured in ISBs.

The ordination plot (Figure 49) shows a summary of the species associations at the macrohabitat scale. The four macrohabitats were widely separated from one another with the slow-water macrohabitats (i.e., SCN and TRM) grouped together. Fishes (e.g., bigmouth buffalo, smallmouth buffalo, sauger, walleye, freshwater drum) associated with silt substrates and slow velocity conditions were grouped with SCNs and TRMs. In the high-velocity BEND habitat were fishes with the highest catch rates and total catch in OSBs and CHXOs, such as shovelnose sturgeon, sicklefin chub, blue sucker, sturgeon chub, and flathead catfish.

Of the physical habitat characteristics (i.e., water temperature, velocity, depth, conductivity, turbidity, substrate composition and size), from one to four characteristics were significant in the logistic regression models for each species, except the fathead minnow. The fathead minnow had no significant habitat associations. Most associations were weak as most $R^2$ values ranged from 0.006 to 0.36 (Table 42). Velocity, temperature, and depth were physical habitat variables that most often (9-13 times) entered regression models that distinguished between presense and absence sites in

Table 37. Total catch of incidental (<10 individuals) species caught during the Benthic Fishes Study of the Missouri River, 1996-1998. Montana-Yellowstone (YS) segments (3, 5, 9) are in the LA; segments **7**, **8**, **10**, **12**, **14**, **15** are in the IR; Iowa-Missouri segments (*17*, *19*, *22*, *23*, *25*, *27*) are in the CH. Segment **15** is blocked upstream by a dam, but is open downstream. YSR = Yellowstone River.

| | Missouri River Segment | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | MT | MT | YSR | MT | MT | ND | ND | SD | SD | IA | IA-KS | MO | MO | MO | MO | |
| Common name | 3 | 5 | 9 | **7** | **8** | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | Total |
| Lake chub | 1 | | | | | | | | | | | | | | | 1 |
| Pearl dace | | | 1 | | | | | | | | | | | | | 1 |
| N. redbelly dace | | | | 1 | | | | | | | | | | | | 1 |
| Brook stickleback | | | | | 1 | | 1 | | | | | | | | | 2 |
| Banded killifish | | | | | | | 4 | | | | | | | | | 4 |
| Yellow bullhead | | | | | | 1 | | | | 1 | 3 | 1 | | | | 6 |
| Grass pickerel | | | | | | | | | 1 | | | | | | | 1 |
| Highfin carpsucker | | | | | | | | | 1 | | | 1 | | 1 | 2 | 5 |
| River redhorse | | | | | | | | | | 1 | | 1 | | | | 2 |
| Northern hogsucker | | | | | | | | | | 1 | | | | | | 1 |
| Threadfin shad | | | | | | | | | | 1 | | | | | | 1 |
| Bigeye shiner | | | | | | | | | | | | 1 | | | 4 | 5 |
| Silverband shiner | | | | | | | | | | | | 1 | | | 1 | 2 |
| Slender madtom | | | | | | | | | | | | 1 | | | | 1 |
| Tadpole madtom | | | | | | | | | | | | 1 | | | | 1 |
| Black buffalo | | | | | | | | | | | | 2 | | | | 2 |
| Logperch | | | | | | | | | | | | | 1 | 4 | | 5 |
| Largescal. stoner. | | | | | | | | | | | | | | 2 | | 2 |
| Longear sunfish | | | | | | | | | | | | | | 1 | | 1 |
| Chestnut lamprey | | | | | | | | | | | | | | 2 | | 2 |
| Lake sturgeon | | | | | | | | | | | | | | 4 | 1 | 5 |
| Spotted gar | | | | | | | | | | | | | | 1 | | 1 |
| Yellow bass | | | | | | | | | | | | | | 1 | 5 | 6 |
| Striped shiner | | | | | | | | | | | | | | | 1 | 1 |
| Bowfin | | | | | | | | | | | | | | | 1 | 1 |
| Common shiner | | | | | | | | | | | | | | | 2 | 2 |
| Freckled madtom | | | | | | | | | | | | | | | 8 | 8 |
| Total | 1 | 0 | 1 | 1 | 3 | 1 | 5 | 0 | 2 | 4 | 3 | 9 | 1 | 16 | 25 | 82 |

* Ghost shiners (2) probably another species

Table 38. Total catch of fishes with restricted distribution caught during the Benthic Fishes Study of riverine portions of the Missouri River, 1996-1998. Montana-Yellowstone (YS) segments (3, 5, 9) are in the LA zone; segments **7**, **8**, **10**, **12**, **14**, **15** are in the IR zone; Iowa-Missouri segments (*17*, *19*, *22*, *23*, *25*, *27*) are in the CH zone.

| Species | MT 3 | MT 5 | YSR 9 | MT **7** | MT **8** | ND **10** | ND **12** | SD **14** | SD **15** | IA *17* | IA-KS *19* | MO *22* | MO *23* | MO *25* | MO *27* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mottled sculpin | 7 | 6 | | | | | | | | | | | | | | 13 |
| Longnose dace | 113 | 89 | 217 | 10 | 13 | 5 | | | | | | | | | | 447 |
| Longnose sucker | 150 | 21 | 8 | 39 | 14 | 7 | 4734 | | | | | | | | | 4973 |
| Bluegill | | | | | | | 1 | 103 | 39 | 32 | 14 | 87 | 89 | 187 | 115 | 667 |
| Red shiner | | | | | | | 4 | 55 | 254 | 81 | 19 | 95 | 144 | 272 | 1436 | 2360 |
| Johnny darter | | | | | | | 20 | 80 | 22 | 4 | 3 | | | | 1 | 130 |
| Quillback | | | | | | | | 42 | 1875 | 11 | 4 | 9 | 11 | 3 | 6 | 1961 |
| River shiner | | | | | | | | 23 | 200 | 180 | 144 | 89 | 77 | 105 | 30 | 848 |
| Silver chub | | | | | | | | 8 | 1 | 13 | 49 | 158 | 55 | 37 | 66 | 387 |
| Largemouth bass | | | | | | | | 164 | 46 | 22 | 8 | 30 | 13 | 28 | 3 | 314 |
| Spotfin shiner | | | | | | | | 718 | 768 | 144 | 114 | 1 | 2 | | | 1747 |
| Gizzard shad | | | | | | | | 174 | 4360 | 2469 | 2330 | 5026 | 1887 | 2048 | 6889 | 25183 |
| Mimic shiner | | | | | | | | 1 | 4 | 2 | | 3 | | | 90 | 100 |
| Bluntnose minnow | | | | | | | | 3 | 1 | | | | | 15 | 23 | 42 |
| Bigmouth shiner | | | | | | | | | 68 | 17 | | 2 | | 15 | 6 | 108 |
| Longnose gar | | | | | | | | | 38 | 7 | 5 | 28 | 23 | 43 | 36 | 180 |
| Orangespotted sunfish | | | | | | | | | 4 | | 2 | 79 | 12 | 5 | 18 | 120 |
| Golden redhorse | | | | | | | | | | 1 | | 2 | 14 | | | 17 |
| Speckled chub | | | | | | | | | | | 43 | | 24 | 61 | 191 | 319 |
| Brook silverside | | | | | | | | | | | 7 | | | 8 | 1 | 16 |
| Suckermouth minnow | | | | | | | | | | | | | 4 | 2 | 4 | 10 |
| Bullhead minnow | | | | | | | | | | | | 3 | 4 | 1 | 3 | 11 |
| Skipjack herring | | | | | | | | | | | | | 1 | 4 | 5 | 10 |
| Spotted bass | | | | | | | | | | | | | 3 | 36 | 19 | 58 |

Table 39. Total catch of widely distributed fish species caught during the Benthic Fishes Study of riverine portions of the Missouri River, 1996-1998. Montana-Yellowstone (YS) segments (3, 5, 9) are in the LA zone; segments **7**, **8**, **10**, **12**, **14**, **15** are in the IR zone; Iowa-Missouri segments (*17*, *19*, *22*, *23*, *25*, *27*) are in the CH zone.

| Species | MT | MT | YSR | MT | MT | ND | ND | SD | SD | IA | IA-KA | MO | MO | MO | MO | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 5 | 9 | **7** | **8** | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | |
| Yellow perch | 2 | 58 | | 13 | 26 | 7 | 23 | 492 | 140 | 7 | | | | | | 768 |
| Black bullhead | | | 2 | | | 5 | 1 | 5 | | 2 | | | | | | 15 |
| Smallmouth bass | | | 1 | | 2 | | 19 | 147 | 230 | 5 | | | | | | 404 |
| Creek chub | | | 29 | 5 | 30 | | 1 | | | | | 2 | | | | 67 |
| Paddlefish | | | | | 1 | 1 | | 1 | 2 | 2 | 2 | | | | | 9 |
| Golden shiner | | | | | | 4 | 1 | 1 | 55 | | 1 | | 4 | | | 66 |
| Green sunfish | | | 7 | | | 1 | | 11 | 16 | 2 | 4 | 65 | 64 | 13 | 21 | 204 |
| Shortnose gar | | | 1 | | 1 | | | 9 | 44 | 30 | 58 | 105 | 125 | 93 | 138 | 604 |
| Black crappie | 9 | 137 | | | | 3 | 2 | 17 | 10 | 2 | 4 | 7 | 1 | 6 | | 198 |
| Northern pike | 13 | 38 | 44 | 58 | 60 | 86 | 12 | 17 | 17 | 4 | 3 | | | 1 | | 353 |
| White crappie | 23 | 69 | 52 | 3 | 66 | 229 | | 925 | 38 | 4 | 15 | 21 | 5 | 18 | 6 | 1474 |
| Goldeye | 136 | 327 | 606 | 445 | 774 | 452 | 61 | 56 | 188 | 319 | 112 | 68 | 77 | 132 | 83 | 3836 |
| White Bass | | | 8 | | | | 1 | 40 | 197 | 14 | 20 | 46 | 75 | 43 | 65 | 514 |

either a positive or negative relation depending on species. Conductivity, geometric means, and turbidity were used in 7, 6, and 2 models respectively.

An example is the blue catfish: the likelihood of presence increased with increased velocity, depth, and temperature and decreased turbidity ($R^2 = 0.34$) compared to absence sites. To place quantitative values on these features one must inspect the total catch bar charts to find the range of habitat conditions where the species was found, and then find the mean condition at presence sites. In the case of the blue catfish, most fish were caught where velocity ranged from 0.2-1.0 m/s. However, the mean velocity at presence sites was 0.47 m/sec. Total catch was distributed over depth categories from the 0-1 m category up to the 12-13 m category, and the mean depth where blue catfish were caught was 2.6 m.

An ordination plot provides an approximate synthesis of the results of the habitat association information (Figure 50). Silt separated about 180 degrees from sand, gravel, and velocity vectors as expected. Fishes associated with silt substrates, and with TRM and SCN macrohabitats presented above (Figure 49) grouped along the silt vector. Nine species (e.g., walleye, fathead minnow, emerald shiner, bigmouth buffalo) were found over substrates dominated by silt. When the percentage of gravel and sand was correlated with velocity, the association was always positive, as illustrated by the ordination plot. The stonecat, sturgeon chub, burbot, and other species that were generally associated with BENDS (Figure 49) were grouped with the sand, gravel, and velocity vectors (Figure 50). Most species were caught in water depths of <3 m, but some were also caught at depths to 14 m (e.g., blue catfish, flathead catfish, freshwater drum, shovelnose sturgeon, blue sucker) and these species generally grouped in the quadrant with the temperature and depth vectors.

Table 40. Total possible outcomes for statistical tests of catch/effort of benthic fishes for 5 gears that captured a sufficient sample for making 22 planned contrasts (Table 41 lists contrasts) among Missouri River segments.

| Species | Fishing gears | Number significant | Number insignificant | Number not possible | Total |
|---|---|---|---|---|---|
| Blue catfish | Trawl | 0 | 1 | 21 | 22 |
| Blue sucker | Trammel, electro. | 0 | 25 | 19 | 44 |
| Channel catfish | Electro, gill net, Seine, trawl | 10 | 27 | 51 | 88 |
| Common carp | Electro, gill net | 6 | 23 | 15 | 44 |
| Emerald shiner | Seine, electro | 3 | 16 | 26 | 44 |
| Fathead minnow | Electro | 0 | 3 | 19 | 22 |
| Flathead catfish | Electro | 3 | 1 | 18 | 22 |
| Flathead chub | Electro, seine | 9 | 7 | 28 | 44 |
| Freshwater drum | Trawl, electro, seine | 11 | 7 | 48 | 66 |
| River carpsucker | Electro, seine, gill net | 11 | 19 | 36 | 66 |
| Sauger | Electro, seine, trawl, gill net | 3 | 47 | 38 | 88 |
| Shorthead redhorse | Electro, trammel, seine, gill net | 9 | 51 | 28 | 88 |
| Shovelnose sturgeon | Trammel, gill net, trawl | 5 | 36 | 25 | 66 |
| Sicklefin chub | Trawl | 7 | 6 | 9 | 22 |
| Smallmouth buffalo | Gill net, electro, seine, trammel | 1 | 42 | 45 | 88 |
| Stonecat | Electro | 0 | 10 | 12 | 22 |
| Sturgeon chub | Trawl | 7 | 0 | 15 | 22 |
| Walleye | Gill net, electro, seine | 0 | 40 | 26 | 66 |
| | Total | 85 | 361 | 478 | 924 |

Table 41. List of 22 planned contrasts and number of significant and insignificant contrasts with species that had significant results; 924 contrasts were possible and 477 had insufficient data for statistical treatment. Statistical tests were not possible for four species (bigmouth buffalo, burbot, sand shiner, white sucker). LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone.

| Contrast | Key | Number significant | Number insignificant | Species with significant results |
|---|---|---|---|---|
| Least-altered MOR vs. least-altered YSR (3,5 vs. 9) **MOR_LA_VS_YSR_LA** | A | 6 | 12 | Emerald shiner, flathead chub, shorthead redhorse, sicklefin chub, sturgeon chub |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.7, 8) **FTP_IR_VS_YSR_LA** | B | 3 | 19 | Flathead chub, shovelnose sturgeon, sturgeon chub |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs.**7**, **8**) **MOR_LA_VS_FTP_IR** | C | 4 | 13 | Flathead chub, shorthead redhorse, sicklefin chub, sturgeon chub |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | D | 6 | 25 | Flathead chub, freshwater drum, sauger, shorthead redhorse, sturgeon chub |
| Least-altered vs. channelized (3,5,9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | E | 6 | 18 | Channel catfish, freshwater drum, river carpsucker, sauger, sicklefin chub |
| Inter-reservoir vs. channelized(**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | F | 8 | 23 | Channel catfish, flathead catfish, freshwater drum, river carp sucker, shovelnose sturgeon |
| Least-altered MOR vs. least-altered YSR (3,5 vs. 9) **MOR_LA_VS_YSR_LA** | G | 6 | 12 | Flathead chub, shorthead redhorse, sicklefin chub, sturgeon chub, emerald shiner |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. inter-reservoir MOR from YSR to Lake Sakakawea headwaters(**8** vs. **10**) **BWFP IR vs. ASAK IR** | H | 1 | 13 | Sicklefin chub |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | I | 6 | 15 | Flathead chub, freshwater drum, shorthead redhorse, sicklefin chub, sturgeon chub |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | J | 2 | 17 | Freshwater drum, shorthead redhorse |
| Least-altered lower MOR vs. channelized zones segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | K | 3 | 18 | Freshwater drum, sauger, sicklefin chub |

| Contrast | Key | Number significant | Number insignificant | Species with significant results |
|---|---|---|---|---|
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | L | 3 | 19 | Flathead chub, shovelnose sturgeon, sturgeon chub |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR LA vs. BL&C IR** | M | 0 | 18 | none |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR LA vs. CH** | N | 4 | 16 | Channel catfish, emerald shiner, river carpsucker |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR W/O BL&C vs. BL&C IR** | O | 3 | 19 | Common carp, river carpsucker, shorthead redhorse |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR W/O BL&C vs. CH** | P | 5 | 18 | Channel catfish, freshwater drum, river carpsucker, shovelnose sturgeon, smallmouth buffalo |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C IR vs. CH** | Q | 7 | 22 | Channel catfish, common carp, emerald shiner, flathead catfish, freshwater drum, river carpsucker |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP LA vs. BFTP IR** | R | 0 | 11 | None |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters **(10 vs. 12) ASAK vs. BSAK** | S | 1 | 7 | Common carp |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam **(14 vs. 15) AL&C IR vs. BL&C IR** | T | 3 | 13 | Channel catfish, common carp, river carpsucker |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1$^{ST}$_CHAN** | U | 4 | 14 | Common carp, flathead catfish, freshwater drum, river carpsucker |
| Channelized above Kansas City vs. channelized below Kansas City (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | V | 5 | 19 | Channel catfish, common carp, freshwater drum, river carpsucker, shovelnose sturgeon |
| Total | | 85 | 361 | |

Figure 48. Ordination plot for partial CCA of benthic fishes species with 15 Missouri River segments. Vectors show segments but segment numbers are moved to the box for clarity. Symbol shows species location in the plot. BMBF = bigmouth buffalo, BLCF = blue catfish, BUSK = blue sucker, BRBT = burbot, CNCF = channel catfish, CARP = common carp, ERSN = emerald shiner, FHCB =flathead chub, FHCF = flathead catfish, FHMW = fathead minnow, FWDM = freshwater drum, RVCS = river carpsucker, SNSN = sand shiner, SGER = sauger, SHRH = shorthead redhorse, SNSG = shovelnose sturgeon, SFCB = sicklefin chub, STCT = sturgeon chub, SMBF = smallmouth buffalo, STCT = stonecat, WLYE = walleye, WTSK = white sucker.

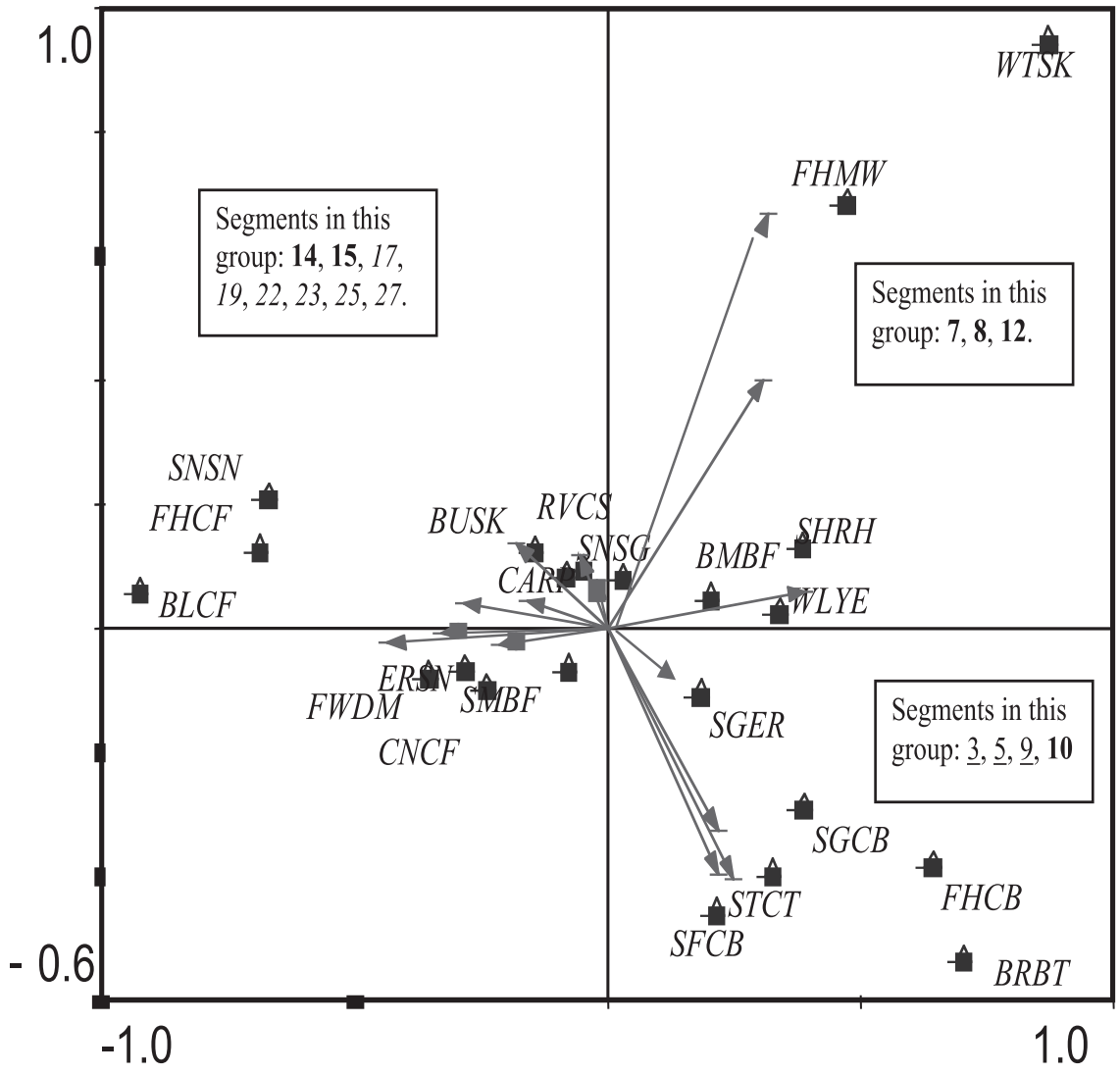


Figure 49. Ordination plot for partial CCA of benthic fishes species with macrohabitats sampled in 15 segments of the Missouri River. SCC = secondary channel connected, SCN = secondary channel not-connected, BEND = river bend that includes an adjacent inside bend, outside bend, and channel crossover, TRM = tributary mouth. BMBF = bigmouth buffalo, BLCF = blue catfish, BUSK = blue sucker, BRBT = burbot, CNCF = channel catfish, CARP = common carp, ERSN = emerald shiner, FHCB = flathead chub, FHCF = flathead catfish, FHMW = fathead minnow, FWDM = freshwater drum, RVCS = river carpsucker, SNSN = sand shiner, SGER = sauger, SHRH = shorthead redhorse, SNSG = shovelnose sturgeon, SFCB = sicklefin chub, STCT = sturgeon chub, SMBF = smallmouth buffalo, STCT = stonecat, WLYE = walleye, WTSK = white sucker.

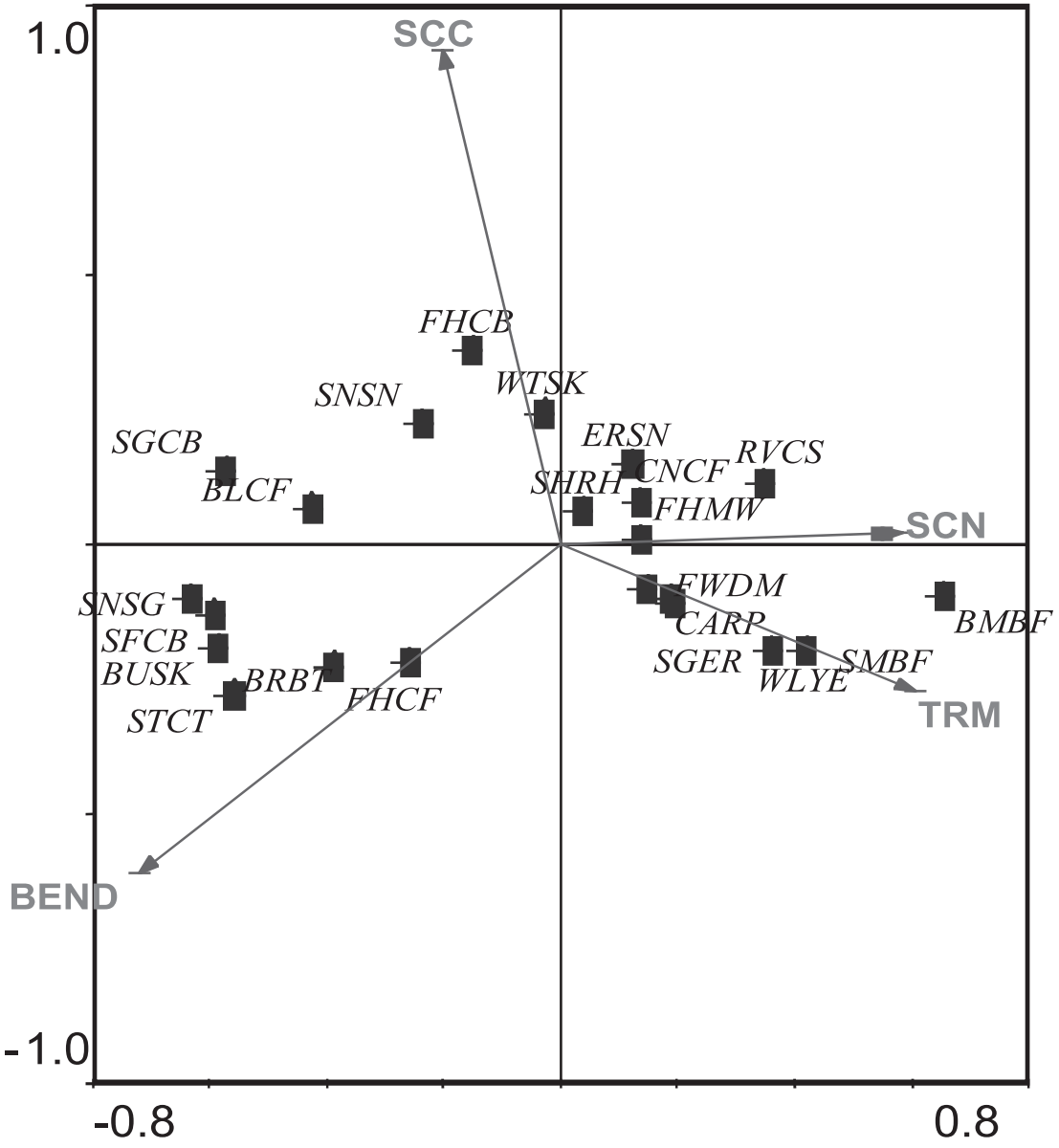
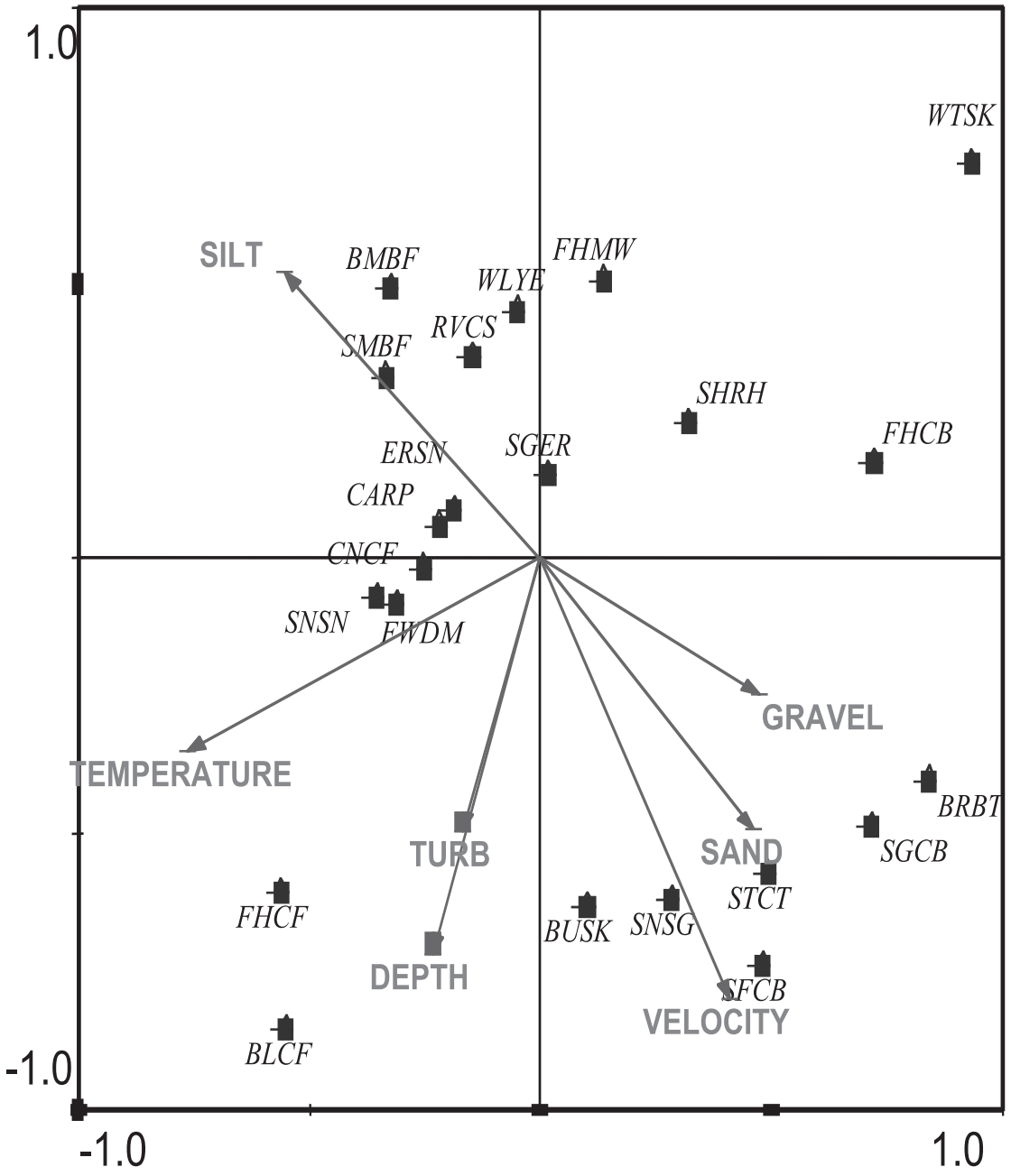


Table 42. List of benthic species and physical habitat variables (Summary of Table 16) identified with stepwise logistic regression and $R^2$ value for each model.

| Species | Variables | $R^2$ |
|---|---|---|
| Bigmouth buffalo | increased with increased temperature | 0.0494 |
| Blue catfish | increased with increased velocity, depth, and temperature and decreased with conductivity | 0.3355 |
| Blue sucker | increased with increased velocity, conductivity, and substrate geometric mean | 0.1000 |
| Burbot | increased with increased velocity and decreased temperature | 0.1435 |
| Common carp | increased with increased depth and temperature, and decreased substrate geometric mean, and velocity | 0.1402 |
| Channel catfish | increased with increased depth and temperature and decreased velocity | 0.248 |
| Emerald shiner | increased with decreased conductivity | 0.0101 |
| Fathead minnow | no habitat covariates were significant | -- |
| Flathead catfish | increased with increased depth and substrate geometric mean | 0.3683 |
| Flathead chub | increased with increased velocity and decreased depth and conductivity | 0.1742 |
| Freshwater drum | increased with increased turbidity and substrate geometric mean | 0.0584 |
| River carpsucker | increased with increased temperature and conductivity and decreased with velocity | 0.1144 |
| Sand shiner | increased with increased temperature | 0.0412 |
| Sauger | increased with decreased temperature | 0.0059 |
| Shorthead redhorse | increased with increased substrate geometric mean and decreased turbidity | 0.0434 |
| Shovelnose sturgeon | increased with increased depth and velocity | 0.2674 |
| Sicklefin chub | increased with increased velocity and depth and decreased temperature and conductivity | 0.3396 |
| Smallmouth buffalo | increased with decreased substrate geometric mean and velocity | 0.0469 |
| Stonecat | increased with increased velocity and decreased conductivity | 0.1499 |
| Sturgeon chub | increased with increased velocity and depth | 0.2528 |
| Walleye | increased with increased temperature and decreased velocity | 0.0476 |
| White sucker | increased with decreased temperature and depth | 0.0487 |

Figure 50. Ordination plot for CCA of benthic fishes species with environmental variables measured at fish capture sites. BMBF = bigmouth buffalo, BLCF = blue catfish, BUSK = blue sucker, BRBT = burbot, CNCF = channel catfish, CARP = common carp, ERSN = emerald shiner, FHCB = lathead chub, FHCF = flathead catfish, FHMW = fathead minnow, FWDM = freshwater drum, RVCS = river carpsucker, SNSN = sand shiner, SGER = sauger, SHRH = shorthead redhorse, SNSG = shovelnose sturgeon, SFCB = sicklefin chub, STCT = sturgeon chub, SMBF = smallmouth buffalo, STCT = stonecat, WLYE = walleye, WTSK = white sucker.



## DISCUSSION

The purpose of this volume is to report on the distribution, abundance and habitat associations of 26 benthic fishes and on the distribution of 80 other species that were caught during the study. Distribution data are often presence/absence data that can show spatial and temporal trends in large rivers (Strayer 1999) and many of the trends on the Missouri River have also been found in other large rivers. For example, in the Tennessee River 12 species were absent after reservoirs were constructed (Voightlander and Poppe 1989). On the Colorado River presence of native species declined as introduced species invaded (Holden and Stalnaker 1975). On the Mississippi River distribution of 241 fishes in the mainstem was influenced by glaciation, natural barriers, and human activities (Fremling et al. 1989). Our discussion of results focuses on the planned contrasts among river zones and segments and on the geophysical conditions associated with fish presence and abundance.

### Pallid Sturgeon

We found pallid sturgeon (4 total) in Segments 9, **10**, and *22*. Certainly the absence from other segments and the low catch support its endangered designation. Our capture of pallid sturgeons in Segments 9, **10**, and *22* suggests that the Yellowstone confluence area and the lower Missouri River area may have characteristics that support the pallid sturgeon. These segments were also the approximate locations where other biologists captured wild juvenile pallid sturgeons after our study concluded (Steve Krantz, Pallid Sturgeon Project Leader, personal communication by phone, February 15, 2005). Several small wild pallid sturgeons (presumptive identification based on morphological characteristics) were found in the lower Missouri River (near our Segments *22* and *25*) and two larval pallid sturgeon (presumptive identification based on morphological characteristics) were found near the headwaters of Lake Sakakawea (our Segment **10**). Since our study, adult and juvenile fish were implanted with sonic transmitters and released and hatchery-reared yearlings were released at several locations (Steve Krantz, Pallid Sturgeon Project Leader, personal communication by phone, February 15, 2005). Researchers sampling especially for the pallid sturgeon from 1996 to 2004 collected 23 adults and three larvae in Missouri (Segments *23-27,* W. Doyle, Biologist, U. S. Fish and Wildlife Service, Columbia Fisheries Resources Office, personal communication email), one possible adult in the Nebraska reach (Segment **15**), and 14 adults (7 tagged, 7 new) in the Yellowstone River confluence area (Segments **8-10,** Steve Krantz, Pallid Sturgeon Project Leader, personal communication by phone, February 15, 2005).

### Zoogeographical Influences on Five Benthic Species

Ecological factors are important to fish distribution in the Missouri River, which flows through about 10º latitude and four freshwater ecoregions (Rocky Mountain, Great Plains, Central Lowlands, Interior Highlands; Abell et al. 2000), and receives water from 47 major tributaries (Cross et al. 1986). Tributary species became more abundant in the main channel in the lower Missouri River between 1940 and 1983 (our Segments *22-27*, Pflieger and Grace 1987). Other ecological factors probably influence the distribution of burbot, blue catfish, flathead catfish, sand shiner, and perhaps the white sucker.

The burbot is the "northern" species. Its native range extends only to the northern portion of the Missouri River basin. Some burbot have been found in the lower basin, but they probably represent vagrants, not an established population (Lee et al. 1980). The range of the white sucker includes the lower basin (Lee et al. 1980, Page and Burr 1991), but it is probably more abundant in tributaries than in the lower mainstem. Pflieger (1997) called it a "small creek" species and reported that it became abundant in a situation where a dam changed a tributary stream from warm and turbid to clear and cool. We found the highest catch in clear, cool IR Segment **12** (downstream from Lake Sakakawea) where there were few other native large river suckers.

Other limited-distribution species are also "southern species". The native range of the flathead and blue catfish extends upstream as far as South Dakota (Lee et al. 1980), which coincides with the distribution we found. The native range of the sand shiner is downstream from Montana, which is where we found this species. In the northern portion of its range it is more common in tributaries than in the mainstem. These southern species were also absent during earlier studies of the Yellowstone River (Schwehr 1977, Peterman 1980).

### Zone Contrasts

Of the 26 benthic species, data for eight species were not useful for contrasts (3 *Hybognathus* species, pallid sturgeon, burbot, bigmouth buffalo, sand shiner, white sucker), thus leaving the combination of five gears for 18 species with which to address the 22 planned contrasts (18 x 5 x 22 = 1,980 possible tests). Total catch for some gears was inadequate, leaving 42 species/gear combinations available to test the 22 contrasts (42 x 22 = 924 possible tests). Catches were sometimes inadequate for making certain contrasts (e.g., when only two segments were compared), thus resulting in a total of 446 statistical tests of which 85 were significant and 361 insignificant. The characteristics of the data set

from this study, which is unique in its large spatial and temporal scale, can be a guide for planning other great river studies or for monitoring the Missouri River fishes.

As a working hypothesis, we speculated that there would be differences in fish community and population metrics among three major zones and we planned several contrasts to test this hypothesis (Contrasts D, E, F, Table 41). The hypotheses were formed based on our review of the literature on fish distribution and abundance and because physical habitat conditions differed among zones (Galat et al. 2001). Sixty-six contrasts indicated insignificant differences in catch among zones and 20 contrasts indicated significant differences (Table 41), but summarizing the data was difficult. All possible zone contrasts were insignificant for blue sucker, common carp, emerald shiner, fathead minnow, stonecat, smallmouth buffalo and walleye.

One or more zone contrasts were significant for 9 species (Table 43). Sometimes contrasts were significant for several gears, but individual gears do not show the same pattern in C/E. For example, channel catfish seine C/E was lower in the LA zone than in other zone(s), but the gill net C/E was higher (Table 18). Many significant zone contrasts were usually supported by one or more partial contrasts [e.g., LA zone segments compared to IR zone segments, without Segment **15**, or LA zone segments (Segments 3, 5) compared to IR zone segments below Fort Peck Lake, Segments **7** and **8**], because for many partial contrasts the same numbers were used as for the full zone contrast (e.g., channel catfish, Table 18). Three zone contrasts were examined: LA vs. IR, LA vs. CH, and IR vs. CH (Table 41).

***LA vs.Other Zones***

Ten contrasts for seven species indicated higher catch rates in the LA zone compared to the two zones where habitat (e.g., hydrological regime, sediment transport, macrohabitat diversity) has been altered (Table 43). The group included important native species such as the flathead chub, sturgeon chub, and sicklefin chub. The mean C/E for flathead chub in the LA zone was 11.7 fish/seine haul compared to 3.8 fish/seine haul in the IR zone (Table 23) and this trend was reflected in the total catch. We collected only 15 flathead chubs from the CH zone and over 10,000 specimens from the LA zone. Pflieger (1997) documented the decline in relative abundance of flathead chubs from 31% of small fishes in the mainstem Missouri River (in Missouri) to 1.1% over 50 years. He also documented

Table 43. Number of significant contrasts in catch per unit effort among zones for species/gear combinations. LA = least-altered zone, IR = inter-reservoir zone, CH = channelized zone.

| Contrast | Number | Species showing pattern |
|---|---|---|
| LA > IR or CH (or both) | 10 | Sauger, shorthead redhorse (2), sicklefin chub, flathead chub, freshwater drum (2), sturgeon chub, channel catfish (gillnet) |
| LA < IR or CH (or both) | 2 | Channel catfish (seine), river carpsucker (seine) |
| IR < CH | 5 | Channel catfish (seine), freshwater drum (trawl, electrofishing), river carpsucker (seine), shovelnose sturgeon (trammel) |
| IR > CH | 2 | Channel catfish (gill net), river carpsucker (electrofishing) |

the concurrent increase in relative abundance of the emerald shiner and proposed that competition with sight feeders that flourished after mainstem impoundments were built upstream led to the decline of the flathead chub. Welker (2000) found most flathead chubs in shallow, channel border habitat in the Yellowstone River (Segment 9), which has been reduced in area in the CH zone (Galat et al. 2001).

Most flathead chubs are found in the mainstem in the lower basin, but in the upper basin the species is also common in western tributaries (Lee et al. 1980). In general, tributaries in the upper basin have higher turbidity and conductivity and lower velocity than tributaries in the lower basin (Galat et al. 2001). Most western tributaries to the Missouri River in South Dakota and North Dakota are now isolated because they enter large reservoirs. Consequently, there is less opportunity for flathead chub emigration from tributaries to augment mainstem populations in Segments **12, 14**, and **15**, which had few flathead chubs present.

Data from other species show a weaker trend of higher C/E in the LA zone. For sauger and sicklefin chub, catches in the LA zone were higher than those in the IR and CH zones, and many individual segment contrasts supported this finding. Pegg and Pierce (2002a) showed that white sucker and sicklefin chub were most associated with the upper and inter-reservoir segments; whereas emerald shiner, flathead catfish, and freshwater drum were most associated with the lower channelized river.

Two species showed a trend toward reduced populations (many zero catches) in the IR and CH zones, but the pattern was not supported by statistics. For walleye, the total catch pattern supported the working hypothesis, but all statistical contrasts of C/E data for four gears were insignificant. Only 483 walleyes were used for analysis, so a higher catch was needed to improve statistical power. For the stonecat, the total catch of 343 fish was too small for meaningful interpretation, even though contrasts among zones for electrofishing data from BENDS was possible. Moreover, the CH zone is toward the southern edge of the range for stonecats, and stonecats are usually described as a small-stream species rather than a large river fish (Pflieger 1997). Consequently, the low abundance in the CH zone may be a zoogeographical pattern rather than a response to habitat alteration of the mainstem.

***LA > IR < CH Catch Trend***

Total catch was lower in the IR zone and fish assemblages more dissimilar among segments in the IR zone compared to similar data from either the CH or LA zones. The statistical contrasts of C/E for several species supported this trend. There was a trend toward lower catches in the IR zone than in either the LA or CH zones for several species (Table 43). For example, C/E for shovelnose sturgeon in trammel nets (fish/100 m) was LA = 0.38, IR = 0.19, and CH = 0.45, and the IR vs. CH contrast was significant (P = 0.002). For the freshwater drum, all contrasts showed a significantly lower catch in the IR zone for electrofishing data and the trawling data partially supported the trend (Table 24). Catch of river carpsucker, and channel catfish showed the IR < CH pattern. Only 179 blue suckers were analyzed, but it too showed the general pattern of lower total catch in the IR zone.

Several conditions in the IR zone might negatively impact population density for many riverine species. Hypolimnetic release dams have been implicated in lack of recruitment (Wolf et al. 1996, Galat and Clark 2002). Reduction in channel complexity and changes to the natural flow regime are other factors that may decrease the density of these species in the IR zone. In general, most studies of impounded rivers do not address fish assemblages in isolated riverine segments (Petts 1984), so our study is unique in this regard. Pegg and Pierce (2002a) showed that IR communities had more generalist species. Bergstedt et al. (2004) summarized our data in another way - as an index of biotic integrity – and came to conclusions that were similar to ours. Based on their index of biotic integrity, the LA segments were rated excellent to good; the IR segments showed the greatest variability in ratings with some segments being fair, poor, and very poor; and the CH segments rated good (31%), fair (58%), and poor (11%).

Conclusions using channel catfish harvest depended on gear. Channel catfish harvest has been controlled, so both fishing regulations and habitat change influence our results. Catch of channel catfish in the CH zone decreased 61% over four decades between 1944 and 1983 from over-fishing, but catch increased after a moratorium that was imposed in 1992 (Mestl 1999a).

The working hypothesis that system changes reduced fish abundance was generally supported by this study. Causes for the reduced abundance could be systemic (i.e., climate, latitude, zoogeography) or regional change (e.g., dams, tributary influences). Our evidence indicates that systemic factors were important in determining distribution and abundance for some benthic fishes. The only latitudinal change in geophysical river characteristics that we measured was increased temperature (Galat et. al. 2001). We considered the natural range of each species when interpreting possible distribution and catch differences among zones. Consequently, regional alterations because of impoundment and channelization, which influence biophysical properties of the river (Galat et al. 2001), may have

also influenced fish distribution and abundance. For example, some IR zone segments had reduced turbidity and temperature and coarser substrates that would influence production of certain fishes. In the CH zone, the most pervasive effect of channelization and bank stabilization was to increase water depths and velocities in macrohabitats in the CH zone compared to the IR and LA zones (Galat et al. 2001). Tributaries have local control on habitat because they restore some of the natural hydrograph to mainstem segments, deliver sediment, and are sources of fish immigration.

**Segment Contrasts**

Certain segments or groups of segments were interesting because they had unique physical conditions that might affect fish catch and interpretations of the results of this study (e.g., segments upstream from reservoirs compared to segments downstream from reservoirs). Segment contrasts might also be useful for understanding the ecology of the Missouri River and large rivers in general. For example, the influence of tributaries on the mainstem could be assessed by comparing segments in the area of the Yellowstone River confluence (e.g., Segments **7, 8**, 9, **10**). Galat et al. (2001) showed that tributaries greatly influenced physical habitat and water quality of the mainstem.

For segment contrasts there were less opportunities to apply statistics than for zone contrasts because C/E means included data from only one segment or segment group (e.g., MOR LA vs. YSR LA; Segments 3, 5 vs. Segment 9). Segment contrasts of interest were:

Among LA segments (i.e., MOR LA vs. YSR LA).
Among CH segments (i.e., AKC vs. BKC).
Effect of impoundments (e.g., ASAK vs. BSAK).
Effect of Segment **15** (e.g., BL&C IR vs. 1st CHAN).
Influence of Yellowstone River (e.g., YSR LA vs. ASAK).

***Among LA Segments ( MOR LA vs. YSR LA)***

We lumped Segments 9, 3, and 5 as the LA zone, understanding that the term "least-altered" meant "relative to the other parts of the river". Cross et al. (1986) showed a close phenetic relationship between Yellowstone and Upper Missouri fish communities, but we expected differences in fish abundance among benthic species because of the differences in physical habi-

Table 44. Number of significant contrasts for catch per unit effort for species/gear combinations in the least-altered segments of the Missouri River (MOR LA, Segments 3 and 5) vs. the least-altered segment on the Yellowstone River (YSR LA, Segment 9). When a contrast was not made because of zero catch, but a trend in presence/absence data was obvious, then we listed the species (italics) as "supporting" the pattern determined from statistical results.

| Among LA Contrasts | Number | Species showing pattern |
|---|---|---|
| MOR LA > YSR LA | 4 | Emerald shiner (seine), flathead chub (electrofishing), shorthead redhorse (trammel), sicklefin chub |
| YSR LA > MOR LA | 2 | Flathead chub (seine), sturgeon chub, *channel catfish* (3 gears), *river carpsucker* (3 gears) |
| YSR LA vs MOR LA Not significant | 12 | Blue sucker, channel catfish, common carp (2 gears), sauger (2 gears), shovelnose sturgeon (2 gears), smallmouth buffalo, shorthead redhorse (2 gears), walleye |

tat among the LA zone segments (Galat et al. 2001) and because of changes in C/E over a 20-year interval for certain species in Segments 3 and 5 (reviewed by Galat et al. 2005). Only Contrast A (Table 41) was possible (i.e., Segment 3 and 5 vs. Segment 9). A complicating factor was the lack of electrofishing data for 1996 and 1997 in Segment 9 because of the possibility of harming the rare pallid sturgeon and the lack of trawling data in Segment 3 because of the rocky bottom.

Analysis (ANOVA) was possible for 18 species/gear combinations; 12 contrasts were insignificant and 6 were significant (Table 41, 44). Catches were statistically greater in the YSR segment for two species/gear combinations and less in the YSR segment for four species/gear combinations compared to catches in the MOR LA segments (Table 44). Best examples of species with higher catch rates in the YSR than in the MOR LA segments were sturgeon chub and flathead chub (seine data). Electrofishing data for the flathead chub showed the opposite trend of the seine data and catches of emerald shiner, shorthead redhorse, and sicklefin chub were also higher in Segments 3 and 5 than in Segment 9.

Statistical analysis was not done for four species that were absent from the LA segments or for seven species that did not meet data requirements. An obvious trend toward higher catches in Segment 9 than in Segments 3 and 5 could be seen in the C/E data for three gears each for river carpsucker and channel catfish.

The interspecific differences in C/E between the LA segments in Missouri and Yellowstone Rivers are perhaps related to the subtle differences in habitat and species preferences. For example, the higher C/E of sturgeon chub in the Yellowstone River may be related to the riverbed form (Wildhaber et al. 2003). Sturgeon chub presence was associated with smooth bedform, and Segment 9 generally had a smoother bedform than did Segments 3 and 5 in the Missouri River mainstem.

***Among CH Segments (AKC vs. BKC)***

Concerning the contrast (Contrast V, Table 41) between catches in the segments upstream (*17, 19, 22*) and downstream (*23, 25, 27*) from Kansas City, we hypothesized that some fish populations may increase in the lower segments because of immigration from the Mississippi River and because flow regimes become more natural (Pegg and Pierce 2002b). Grady and Milligan (1998) reported a decrease for five species, an increase for five species, and 11 species remained about the same over time in this area of the river.

Contrasts in C/E above and below Kansas City were

Table 45. Number of statistical contrasts and contrasts showing obvious trends for catch per unit effort for species/gear combinations above Kansas City (AKC, Segments *17, 19, 22*) vs. below Kansas City (BKC, Segments *23, 25, 27*). CH = channelized segments. When a contrast was not made because of zero catch, but a trend in presence/absence data was obvious, then we listed the species as "supporting" the pattern determined from statistical results in italics.

| Among CH Segments Contrast | Number | Species examples |
|---|---|---|
| AKC > BKC | 3 | Freshwater drum (benthic trawl), river carpsucker (seine), shovelnose sturgeon (trammel) |
| AKC < BKC | 2 | Channel catfish (electrofishing), common carp (electrofishing), *sicklefin chub* |
| AKC vs BKC Not significant | 19 | Blue catfish, blue sucker, channel catfish (seine), common carp (gill net), emerald shiner (2 gears), flathead catfish (electrofishing), freshwater drum (electrofishing), river carpsucker (2 gears), sauger (2 gears), shorthead redhorse (gill net), shovelnose sturgeon (2 gears), smallmouth buffalo (2) |

not possible for 11 species. The sicklefin chub was the only species not analyzed that showed obvious trends – catch was much higher in Segments *25* and *27* than elsewhere in the CH zone. In general, there is no trend between the two areas of the river (Table 45). Of the significantly different species, the C/E of channel catfish and common carp was higher and C/E of freshwater drum, river carpsucker and shovelnose sturgeon was lower downstream from Kansas City compared to upstream. All five species that showed significant differences in C/E for the AKC vs BKC contrast for one gear also had data showing insignificant differences in C/E for that contrast for another gear.

***Effect of Segment 15***

Segment **15** is said to look somewhat like the river seen by Lewis and Clark and for this reason it is protected as a National Recreational River (Berry and Young 2004). However, the hydrology and many riverine processes are greatly modified in Segment **15**. Hesse et al. (1993) reported declines in C/E from 1983 to 1991 for six species in our Segment **15**, whereas increasing trends occurred for three species and other species showed no clear pattern.

In our study, 103 of the 122 planned contrasts that were statistically possible (Contrasts J, M, O, Q, T, U, Table 41) indicated that catches in Segment **15** were similar to the catch in other segments or groups of segments. Catches of shorthead redhorse and freshwater drum were higher in the LA zone segments than in Segment **15**, but most comparisons were insignificant. Catches in Segment **15** were higher than catches in IR or CH zone segments (or segment groups) for 11 species/gear combinations, and lower for 6 species/gear combinations (Table 46).

Most constrasts (5 of 6 constrasts, Table 46) indicated higher C/E in Segment **15** than in upstream segments in the IR zone (Contrasts T, O). The trend toward higher catches in Segment **15** was also supported by other species (e.g., blue sucker, sand shiner, sauger, shovelnose sturgeon, smallmouth buffalo, walleye) that had zero catch or very low catch in several gears used in Segment **14**. The most important distinction between Segments **14** and **15** is that Segment **14** is isolated between two reservoirs and there are no major tributaries, whereas Segment **15** is open downstream and receives water from the James and Vermillion rivers, otherwise, the segments have similar physical habitat features (Galat et al. 2001, Berry and Young 2004). After closure of Gavins Pt Dam, fish abundance and richness declined in Lewis and Clark Lake and increased downstream from the dam (Walburg 1976). The 53 species collected during our study were combined with fishes recorded by routine sampling by state agencies to compose an ichthyofaunal list of 92 species (reviewed by Berry and Young 2004). All species found

Table 46. Number of significant contrasts in catch per unit effort for species/gear combinations in Segment **15** compared to individual segments and segment groups in the LA, IR, CH zones. When a contrast was not made because of zero catch, but a trend in presence/absence data was obvious, then we listed the species as "supporting" the pattern determined from statistical results in italics, (2) = 2 gears or 2 contrasts.

| Contrasts | Number | Species showing trend |
|---|---|---|
| Segment **15** > LA | 0 | none |
| Segment **15** < LA | 2 | Shorthead redhorse, freshwater drum |
| Segment **15** > IR or Segment **14** | 5 | Common carp (2), river carpsucker (2), shorthead redhorse, *blue sucker, emerald shiner, sand shiner, shovelnose sturgeon, smallmouth buffalo, walleye* |
| Segment **15** < IR or Segment **14** | 1 | Channel catfish |
| Segment **15** > CH or Segment *17* | 7 | Common carp (2), emerald shiner (electrofishing), flathead catfish (2), river carpsucker (2), *sand shiner, shorthead redhorse, walleye* |
| Segment **15** < CH or Segment *17* | 4 | Channel catfish, freshwater drum (2), river carpsucker, *fathead minnow* |

in Segment **14** were found in Segment **15**, except black bullhead. Movement of grass carp is apparently stopped by Gavins Point Dam, as several were found in Segment **15**, but none in Segment **14**.

For Contrasts involving Segments **15** and CH zone segments, four species had higher C/E in Segment **15** and three species had lower (Table 46). The C/E values were usually higher in Segment **15** when compared to Segment **17** alone, but there was no trend when other CH segments were included. Segments **15** and *17* provide a contrast in *channel form* from Segment **15** to channelized conditions in Segment *17*. For example, Segment **15** has lower water velocity and more habitat diversity (e.g., SCCs, SCNs) than does Segment *17* (Galat et al. 2001). Several studies have documented reduced fish abundance in Segment *17* compared to Segment **15** (Groen and Schmulbach 1978, Kallemeyn and Novotny 1977, Hesse et al. 1993). Sauger declined in abundance after the dams were closed in the 1950s (Walburg 1976, Hesse et al. 1993); we collected 21 in Segment **14**, 79 in Segment **15**, and 31 in Segment *17*. Anglers catch several thousand sauger yearly (Mestl et al. 2001) and natural reproduction is occurring (Van Zee 1996). Catch of sicklefin and sturgeon chubs has also declined (Hesse et al. 1993) and these species were also absent or rare in our samples. Conversely, emerald shiners have increased in abundance (Hesse et al. 1993); our highest catch of emerald shiners was in Segment **15**.

***Effect of Impoundments***

Data on C/E upstream and downstream from Fort Peck Lake and Lake Sakakawea were used in three contrasts (Contrasts C, R, S, Table 41). We hypothesized reduced fish abundance in IR segments and further that Segment **12** would be more impacted than Segment **10** because the Yellowstone River discharge ameliorated physical conditions in Segment **10**. Catch data for only one segment were usually too low for most species to compare one segment upstream with one segment downstream, so only 36 contrasts were possible (Table 41).

For Fort Peck Lake, all four significant contrasts indicated that C/E was higher upstream than downstream from the Reservoir (Table 47). Analysis was not done for 11 species, but there was an obvious trend in C/E for emerald shiner in several gears (seine, electrofishing) that supported the statistical results of other species, whereas fathead minnow C/E data suggested the opposite trend (higher C/E downstream than upstream).

For Lake Sakakawea, catches were sufficient for three species to make Contrast S; C/E for channel catfish and shovelnose sturgeon were similar up- and downstream from the Lake whereas C/E for common carp were higher downstream than upstream (Table 47). For other species, there were many cases where C/E upstream was obviously higher because no fish or very few fish were caught in Segment **10**. However, fathead minnow and white sucker C/E showed the opposite trend (more fish downstream). In general, catch rate was usually higher upstream from Fort Peck Lake and Lake Sakakawea than downstream. The opposite trend was found at Lewis and Clark Lake, where the catch in the downstream segment (Segment **15**) was similar to or higher than the catch in the upstream Segment **14**.

Segment **12** between Lake Sakakawea and Lake Oahe was distinctive because catches of most species that were common in other segments in the IR zone were lower in Segment **12** (Table 47) and the relative abundance was quite dissimilar from that of Segment **10**. Segment **12** was often eliminated from analyses because of low catch rates for most species. Low abundance and diversity of fishes in this segment have been noted by others, who attributed the problems to low numbers of larval fish being discharged from Garrison Dam (Wolf et al. 1996, Everett 1999). Electrofishing C/E of common carp was significantly higher in Segment **12** than in Segment **10**. Two species that dominated our catches in Segment **12** were white sucker and fathead minnow, which are generalist species that tend to increase in IR segments, as do other generalist species (Pegg and Pierce 2002a). Both species also dominated catches in a concomitant study done in backwaters and floodplain wetlands in this segment (Powell 2002).

The Segment **12** mainstem is now a high-velocity habitat that is disconnected from floodplain wetlands and backwaters (Powell 2002, Welker 2000). Average temperature in Segment **12** during our study was about 9°C lower than might be found in the unaltered river (Galat et al. 2001). Growth of shovelnose sturgeon is much slower in Segment **12** than in the Yellowstone River (Everett et al. 2002), and condition of shovelnose sturgeon was low in Segment **12** (Pierce et al. 2003).

***Influence of Yellowstone River***

Contrasts B, H, and L (Table 41) focused on the influence of the Yellowstone River Segment 9 on the Missouri River Segments **8** and **10**, which are just up- and downstream from the confluence of the Yellowstone River. Major tributaries to the Missouri River may be more suitable as fish habitat than the modified main channel (Brown and Coon 1994, Latka et al. 1995, Welker and Scarnecchia 2004). Contrasts were not possible for 16 species, but 58 statistical contrasts were possible. Most contrasts (51) were not significant. The most important contrast for testing the

Table 47. Number of significant contrasts and contrasts showing obvious trends in catch per unit effort for species/gear combinations up and downstream from Fort Peck and Lake Sakakawea reservoirs. Species showing difference up- and downstream from Lake Sakakawea followed by (**10** vs **12**). When a contrast was not made because of zero catch, but a trend in presence/absence data was obvious, then we listed the species as "supporting" the pattern determined from statistical results in italics. (Number) = multiple gears or contrasts.

| Contrast<br>Upstream vs. downstream<br>Segment 3, 5 vs. **7, 8**;5 vs. **7**; and **10** vs. **12** | Number | Species showing pattern |
|---|---|---|
| Up > down | 4 | Flathead chub (electrofishing), shorthead redhorse (trammel), sicklefin chub, sturgeon chub *emerald shiner, burbot* (**10** vs **12**), *flathead chub* (**10** vs **12**), *sauger* (**10** vs **12**), *sicklefin chub* (**10** vs **12**), *smallmouth buffalo* (**10** vs **12**), *stonecat* (**10** vs **12**), *sturgeon chub*(**10** vs **12**) |
| Up < down | 1 | Common carp (electrofishing, **10** vs **12**), *white sucker, fathead minnow* |
| Up vs down<br>Not significant | 31 | Blue sucker (2), channel catfish (2), flathead catfish, commom carp (4), sauger (4), shorthead redhorse (9), shovelnose sturgeon (5), small-mouth buffalo (3), walleye |

effect of the Yellowstone River influence on the Missouri River was Contrast H (Segment **8** vs Segment **10**), but only one species showed a significant difference for this contrast - C/E for sicklefin chub was higher in Segment **10** than in Segment **8** (Table 41).

There was no support for the possibility that the Yellowstone River influence might also affect Segment **8**, which was upstream from the confluence (Contrast B). Of the three significant contrasts (flathead chub, shovelnose sturgeon, sturgeon chub), the C/E values were higher in the Yellowstone than in Segment 8. Shovelnose sturgeon and pallid sturgeon rarely use Segments **7** and **8**, but are often found in Segments 9 and **10** (Bramblett and White 2001). Segments 9 and **10** have more natural physical habitat than do Segments **7** and **8** (Bramblett and White 2001, Galat et al. 2001). The addition of the Yellowstone River flows may be an influence on the physical habitat, but fish abundance also increased with distance from Fort Peck Dam. Thirteen species increased in abundance between Fort Peck Dam (Segment **7**) and the upper end of Lake Sakakawea (Segment **10**). Best examples were catches of common carp, channel catfish, freshwater drum, sauger, smallmouth buffalo, stonecat, and sicklefin chub. Total catch of sicklefin chub increased from zero near the dam to 81 fish at Segment **8** and 70 fish at

Segment **10**, a trend also noted by Dieterman and Galat (2004) below other impoundments.

**Fish Habitat Associations**

Habitat and its physical attributes of rivers are fundamental determinants of composition and abundance of fish assemblages, and data on fish associations with habitat is fundamental to planning river restoration and management. Berry and Young (2001) discuss the justification for including fish associations with habitat as part of this study and examples are provided in work by Ph.D. students associated with our study. For example, sicklefin chub presence was associated with water flow variability and turbidity (Dieterman and Galat 2004). Other findings from studies unrelated to ours also indicate the value of benthic fishes habitat information. For example, Hurley et al. (2004) found that pallid sturgeon were most often found in main-channel and main-channel border habitats independent of temperature and discharge. The benthic fishes that we studied have a wide range of habitat associations, reproductive types, diets, and tolerance to environmental degredation (reviewed by Bergstedt et al. 2004 in their Appendix A).

In our study the diversity of habitats within segments was addressed by sampling six macrohabitats: CHXO, ISB, OSB (these were grouped into a BEND category for statistical analysis), SCC, SCN, and TRM. Our data represent only the late summer season, so conclusions about macrohabitat use by individual species are for this period only. Also, our data span a range of fish sizes that includes both juvenile and adult fish, so our averages might be of little use for recommendations of spawning habitat for example. In regulated rivers, managers usually request information that relates system operations (e.g., dam discharges) to fish habitat. Habitat management of the Missouri River should not be for a certain species or a certain fish size group if conservation of fish biodiversity is a goal. However, the benthic fishes assemblage as a group may help formulate general objectives for habitat restoration.

The macrohabitats can be grouped into three categories: slow velocity macrohabitats (e.g., TRM, SCN) that certain fish species might use as a velocity refuge and feeding area, moderate velocity areas (e.g., ISB, SCC) that other species might prefer to use for refuge or migration, and high velocity areas (e.g., CHXO, OSB) that a few species might prefer and that all species might use for migration. Species use of a macrohabitat depends on morphological, functional, and life-history differences (Pegg and Pierce 2002a). For example, streamlined species use swift velocity habitats more often than deep-bodied species (Welker 2000). Most species were not present or abundant in swift water conditions of the CHXOs and OSBs, but some species were frequently collected in swift water; a finding that agreed with results from the upper Mississippi River system (Dettmers et al. 2001). Five species were common in CHXO (channel catfish, shovelnose sturgeon, sicklefin chub, stonecat, sturgeon chub). These same species were also judged common in OSBs, but other species commonly found in OSBs were flathead catfish, flathead chub, emerald shiner, and shorthead redhorse.

We hypothesized that all macrohabitats are potentially used during the lifetime of the species and species richness and abundance is positively associated with macrohabitat diversity. This conclusion was also made after analysis of Missouri River "science" (NRC 2002), for other major rivers (Galat and Zweimuller 2001), and for the upper Mississippi River system (Koel 2004). Koel (2004) concluded that remnants of natural riverine dynamics and habitats should be preserved and enhanced.

We measured physical variables to better describe macrohabitats (Galat et al. 2001). In general, CHXOs and OSBs had the deepest water, fastest current velocity, and largest mean particle size. Tributary mouths were relatively warm and turbid in some segments, whereas SCNs were primarily shallow, low-velocity habitats with fine substrates. The SCCs did not show a consistent multivariate distribution among physical habitat variables compared to other macrohabitats. The diversity of conditions in SCCs may explain why all species were judged abundant there and supports continuing efforts directed toward their rehabilitation. Physical habitat conditions varied by segment and macrohabitat. For example, turbidity was usually higher in SCNs than in other macrohabitats and declined in BENDS if a clear-water tributary entered the main channel upstream from the BEND (Galat et al. 2001).

The data on physical habitat conditions at each fish sampling site revealed species-specific habitat associations. Our independent variable was presence or absence of each species, so our data covers all physical habitat conditions regardless of macrohabitat or segment. Of course, there are several caveats for using this habitat information. The data do not represent species "preferences". Theoretically preferences are determined by offering a species a wide variety of choices and monitoring their responses. Our data from one season and over a limited temperature range apply only to those conditions. A well-supported working hypothesis about fish-habitat associations is that they change seasonally (Dettmers et al. 2001). We lumped catches for all gears, but gears were selective for certain sizes of fish. Finally, other abiotic aspects of habitat (temperature, light, oxygen, structure) that we did not measure are also important to fishes. Also, biotic factors (e.g.,

predation, competition, food webs) that we did not measure further influence habitat use (Poff et al. 1997).

Most logistic regression models were not very powerful, but most benthic species (except fathead minnow) were associated with one to four habitat features. Mean habitat conditions (e.g., mean water velocity) at sites where fish were present were statistically evaluated for each species. For the benthic fish assemblage, we summarized the total catch with habitat to show the range of habitat conditions used by the assemblage.

We identified three catch patterns in the velocity data. The catch of five species, represented by the sicklefin chub, occurred over a wide range of velocities (Figure 51). These species tended to be caught in gears used in the main channel (i.e., drifting trammel net, benthic trawl) where the highest water velocities were recorded. Our results generally agreed with reviews of habitat suitability indices for selected benthic fishes (Berry and Young 2001, Bergstedt et al. 2004) and with studies that investigated fish-habitat associations by monitoring movements of radio-tagged fish (e.g., Hurley et al. 2004). Curtis et al. (1997) reported that radio-tagged shovelnose sturgeon were typically found in areas with sand substrates, mean water depth of 5.8 m, and mean bottom current velocity of 0.23 m/s. Velocities where juveniles were observed were less.

Two patterns were apparent for fish caught in slower water. A wide-range pattern was exhibited by 13 species (Figure 51). Most fish in this group were caught at velocities <0.5 m/sec, but some were caught at velocities up to 2.4 m/sec. The stacked bars in the figures show that catch was distributed among four fishing gears, thus indicating that fish were caught in a wide variety of habitats where velocities varied greatly. Although velocity preferences are not known for most species, our results agree with general habitat associations published for smallmouth buffalo and bigmouth buffalo, which are characterized as inhabiting both high velocity (<1.6 m/sec) main channels and pools, but also using backwaters with low (<0.2 m/s) velocity (Edwards and Twomey 1982). In contrast, four other species (bigmouth buffalo, sand shiner, fathead minnow, white sucker) had a narrow-range catch pattern (Figure 51). Most of these fishes were caught by electrofishing SCCs and SCNs where velocity was low or with seines that were used in low velocity habitats. White suckers use pools with flows of about 0.15 m/s (Twomey and Nelson 1984), but can ascend high velocity fishways during the spring spawning migration (reviewed by Cooke et al. 2004). The adverse consequences of regulated flows on riverine fish communities have been well documented. Generally, fluvial specialists (e.g., redhorse suckers) are more abundant in unregulated reaches of rivers compared to regulated reaches (reviewed by Cooke et al. 2004).

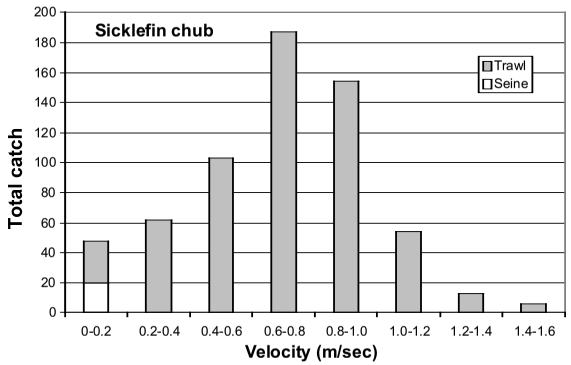
There were three general catch patterns for fishes that were related to turbidity (Figure 52). Three pairs of species (Figure 53) exemplify the relation of turbidity and fish ecology. Turbidity categories for the total catch of walleye and sauger were similar, as both were mostly caught by electrofishing and mostly in turbidities of 10-50 NTUs (Figure 53). Other authors have suggested that sauger prefer more turbid water than do walleye (Goldstein et al. 1996). Sturgeon chub and sicklefin chub were mostly caught in the trawl, but more sicklefin chubs were found in a broader range of turbidities than were sturgeon chubs. This finding agrees with that of Everett (1999), who found sturgeon chubs in less turbid water than sicklefin chubs. Finally, two species (fathead minnow, white sucker) were captured more than other species in the <10 NTU turbidity class (Figure 53). For the white sucker, this finding agrees well with the literature (Twomey et al. 1984). Overall, however, a species by species assessment of association with turbidity is not the main value of our results. The general conclusion regarding turbidity findings, as with other physical habitat, is that the native species assemblage was associated with (and may prefer) a variety of turbidity conditions.

Total catch by depth results indicate that most fish were captured at <3 m, but the wide range of capture depths was also an obvious trend. The deepest capture depth was 14 m for a shovelnose sturgeon. Three general patterns of depth association are apparent (Figure 54). In the shallow water group are small-bodied fish such as the flathead chub and sand shiner, but also two species that grow larger - the white sucker and bigmouth buffalo (Figure 54). Most white suckers and sand shiners were captured by seining. Another group (shallow to mid-depth) was also abundant at <1 m, but much of the catch also occurred at higher velocities. All species in this group tended to have a higher electrofishing component to the total catch than did the shallow-water group. The five species making up the deep-water group had a broad association with depth (up to 14 m), but were mostly caught at depths from 1-4 m (Figure 54). The bottom trawl accounted for most of the catch of sturgeon chub, sicklefin chub, blue catfish, and stonecat; whereas shovelnose sturgeon were mostly caught in the drifting trammel net and in gill nets.

The study was planned to reduce the seasonal effects of temperature on fish collections, because our main focus was comparing catch among zones and segments. Nevertheless fish were collected over a fairly broad temperature range because of differences in climate among years, latitude, reservoir releases, and macrohabitat conditions. Latitude and reservoir releases were

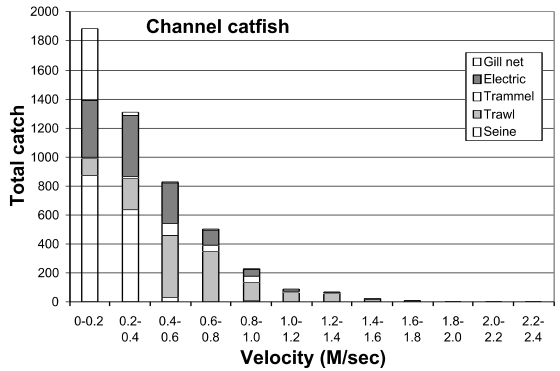
Figure 51. Three patterns of association between total catch of Missouri River benthic fishes and water velocity and a list of species with each pattern. Figures show the diversity of habitat associations among the benthic fishes, not the mean condition present at sites where a species was collected.

Mid-velocities group



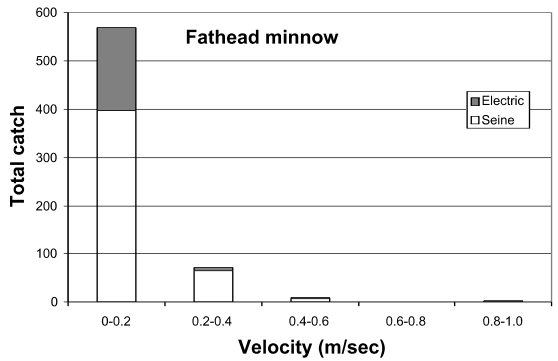

Species with similar results –
- blue sucker
- sturgeon chub
- stonecat
- shovelnose sturgeon

Slow velocities group – wide range




Species with similar results –
- blue catfish
- burbot
- common carp
- emerald shiner
- fathead chub
- flathead catfish
- freshwater drum
- river carpsucker
- sauger
- shorthead redhorse
- smallmouth buffalo
- walleye

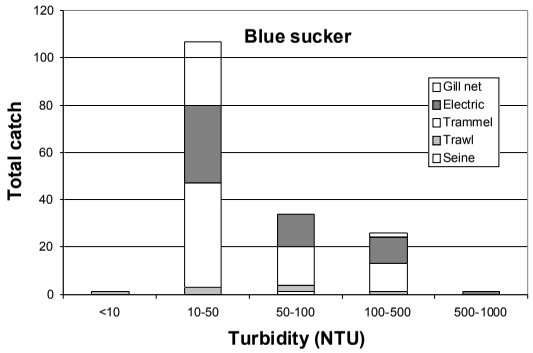
Slow velocities group – narrow range




Species with similar results –
- bigmouth buffalo
- sand shiner
- white sucker

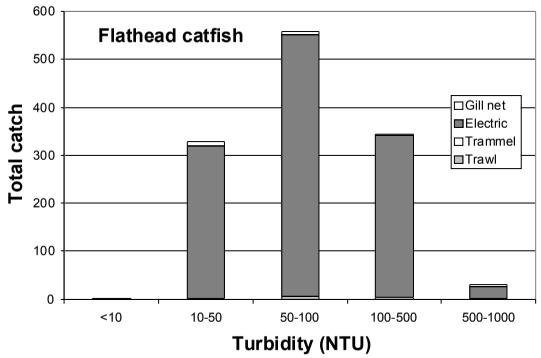
Figure 52. Three patterns of association between total catch of Missouri River benthic fishes and turbidity and a list of species with each pattern. Figures show the diversity of habitat associations among the benthic fishes, not the mean condition present at sites where a species was collected.

Low turbidity group




Species with similar results –
- burbot
- common carp
- emerald shiner
- fathead chub
- fathead minnow
- river carpsucker
- sand shiner
- sauger
- shorthead redhorse
- shovelnose sturgeon
- sicklefin chub
- smallmouth buffalo
- sturgeon chub
- walleye

Moderate turbidity group




Species with similar results –
- bigmouth buffalo
- channel catfish
- freshwater drum
- stonecat

High turbidity group

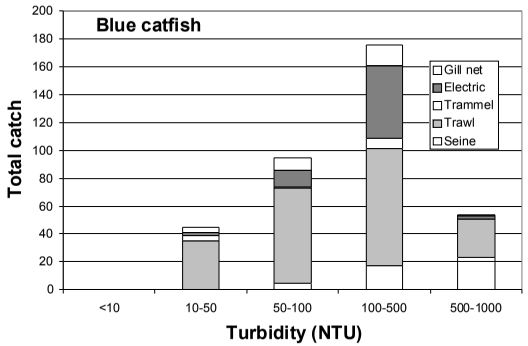


Figure 53. Total catch for 1996, 1997, and 1998 in multiple gears of three pairs of species among turbidity catagories. The pairs were selected because of their ecological similarity (sturgeon chub, sicklefin chub, walleye, and sauger) or association with turbidity <10 NTUs (fathead minnow and white sucker).

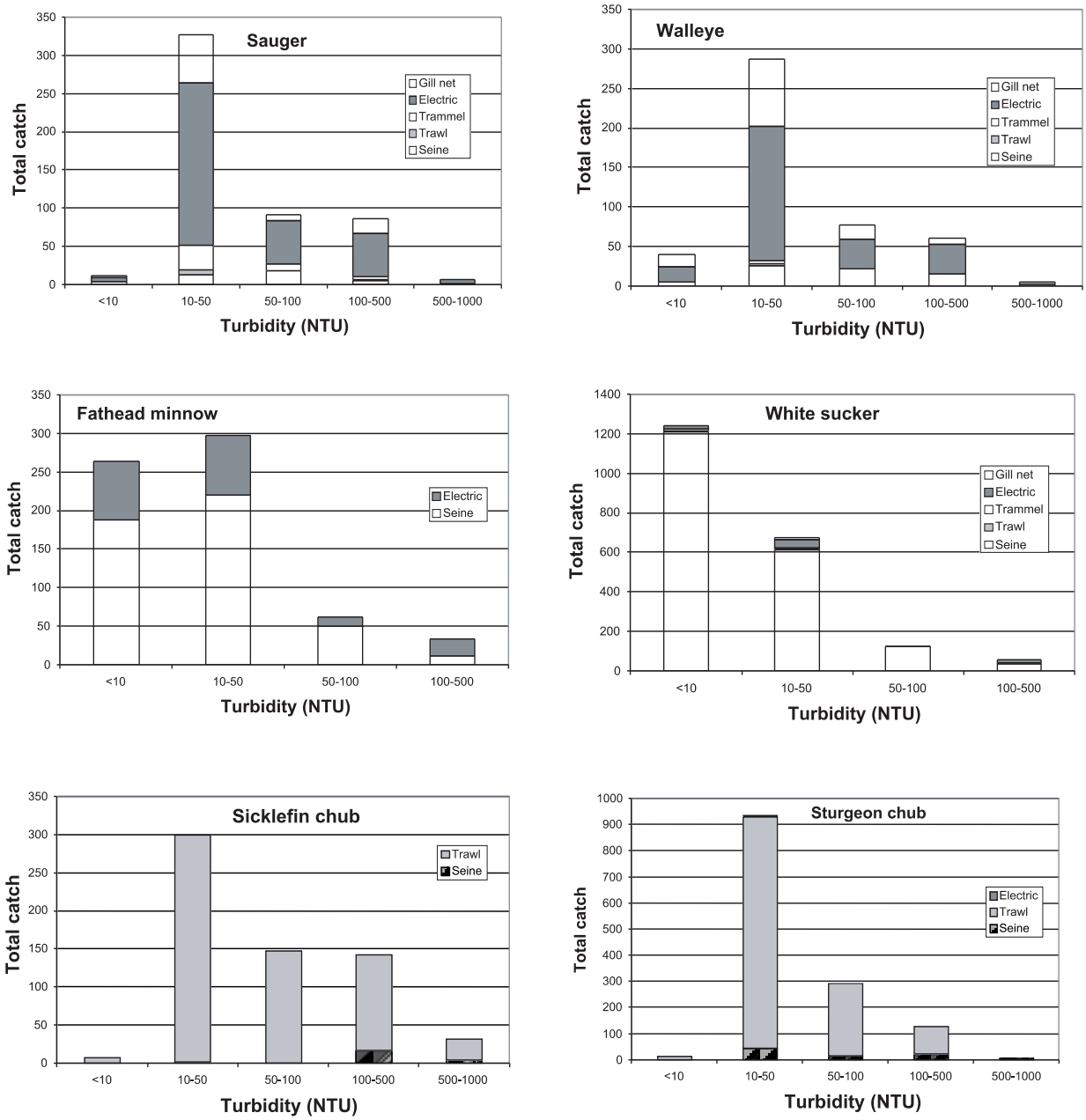
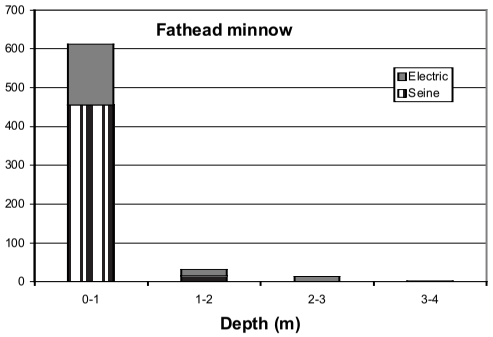


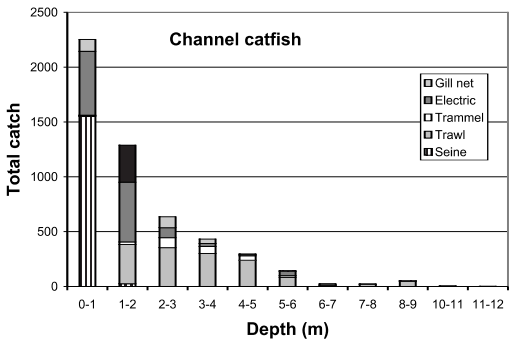
Figure 54. Three patterns of association between total catch of Missouri River benthic fishes and water depth and a list of species with each pattern. Figures show the diversity of habitat associations among the benthic fishes, not the mean condition present at sites where a species was collected.

Shallow water group



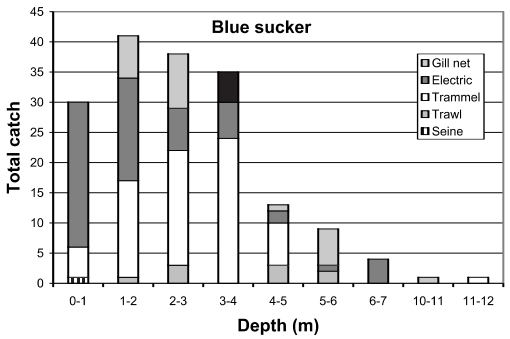

Species with similar results –
bigmouth buffalo
flathead chub
sand shiner
white sucker

Shallow to mid-depth water group




Species with similar results –
burbot
common carp
emerald shiner
flathead catfish
freshwater drum
river carpsucker
sauger
shorthead redhorse
smallmouth buffalo
walleye

Deep water group




Species with similar results –
blue catfish
shovelnose sturgeon
sicklefin chub
stonecat
sturgeon chub

the most important factors determining temperature (Galat et al. 2001). Catch data displayed three general patterns of association with temperature (Figure 55).

Substrate was characterized at the midpoint of the area where fishing gears were deployed. Missouri River substrates are predominantly sandy (Galat et al. 2001), so sand was a major component in each of three groups (Figure 56). Our assignment of a species to one of three substrate groups obscures subtle individual differences. For example, we report that sturgeon chub were found where substrate geometric mean was lower than where sicklefin chubs were found, which agreed with findings by Everett (1999). However, compared to other benthic species they both fall into our "gravel" group.

The sand shiner and blue catfish were placed in the "sand" group because their catch pattern had the highest percentage of sand and <10% gravel. As its name applies, the sand shiner has a strong affinity to sandy substrates (Pflieger 1997). Nine species in a gravel group were distinguished from sand group because gravel percentages were >10%. Most specimens in the gravel group were collected by trawling or electrofishing. Trawling was usually done in the channel, whereas electrofishing was done along the shoreline where riprap and other large substrates were located. Higher gravel (and cobble) percentages are found where velocity is high (Galat et al. 2001). Where velocity is low, substrates tend to have more silt (Galat et al. 2001).

A group of eleven species was found over substrates dominated by silt (Figure 56), including the common carp. Our results for common carp agree with a summary of the literature that indicates that carp habitat suitability is highest when up to 80% of riverine habitat is pools, backwaters, and marsh areas during average summer flows (Edwards and Twomey 1982b). Most specimens in the "silt" group were captured by seining and electrofishing in SCNs and TRMs. The TRMs were usually at the confluence of small tributaries where velocity was low and silt substrates common, especially in the LA and IR zones (Galat et al. 2001).

Substrate size requirements for spawning are associated with fish abundance (Pegg and Pierce 2002b). They found that fishes that use coarse substrates (e.g., white sucker, shovelnose sturgeon, river carpsuckers) for spawning predominate in IR segments, whereas a high percentage of general and pelagic spawners (e.g., freshwater drum) occur in the CH segments. In the Red River of the North the number of substrate types was positively associated with fish community composition (Goldstein et al. 1996). In the Missouri River, habitat is created by human engineering, by natural hydrology, by sediment dynamics, or a combination (e.g., chute restoration). The goal should be to provide a diversity of habitats focusing on velocity and depth. Others (e.g., Wissman and Bission 2003) have recommended implementing natural flows to restore habitat, creating or acquiring shallow-water, low velocity channel and floodplain habitats and sandbars, and carrying out adaptive management (NAS 2002) to restore Missouri and river ecosystems in general.

The fish community of the Missouri River is diverse and characteristic of the unique geological history of the basin (e.g., presence of ancestral species). Becker and Gorton (1995) suggested "Mother Nature's Formula for the Missouri River". The natural formula includes the following dynamics

NF = PF + ER + AG + SE + BC

Where: PF = peak flow, ER = erosion, AG = aggradation, SE = seasonality, BD = biologic or chemical activity.

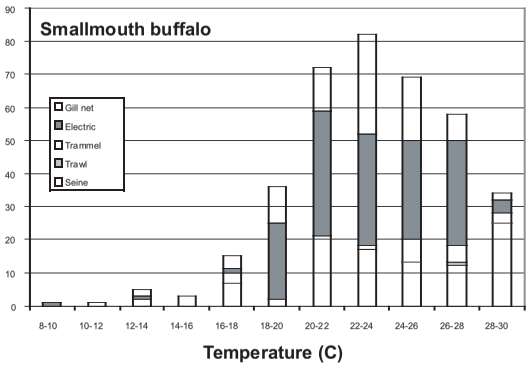
**Other Fishes**

We also collected about 36,800 specimens representing 80 other species. These other species were not the focus of our study, but the information may be useful in several ways. Our data have been used to update ichthyofaunal lists for the basin (Galat et al. 2005) and for the National Recreational River sections on the South Dakota-Nebraska border (Berry and Young 2004). We found 12 species that had not been reported in the open literature for the mainstem (spotted gar, threadfin shad, grass pickerel, bullhead minnow, river redhorse, slender madtom, Chinook salmon, yellow bass, logperch, lake whitefish, muskellunge, striped bass). Galat et al. (2005) included these species (except river redhorse) in the list of 108 species in the mainstem (136 species from 25 families in the mainstem, flood plain, and reservoirs).

We missed 30 species that had been reported by others. Their absence from our collection does not mean they are rare. All have Global Heritage (NatureServe 2002) ranks of G5 (secure) except the Alabama shad, *Alosa alabamae* (G3, vulnerable), speckled chub, *Macrohybopsis aestivalis* (G3-G4, apparently secure), and chestnut lamprey, *Ichthyomyzon castaneus* (G4, apparently secure). We collected a few specimens of lake sturgeon, paddlefish, silver chub, and highfin carpsucker, which are ranked as imperiled or vulnerable. The Missouri River has the lowest proportion of imperiled fishes of eight north temperate rivers reviewed by Galat and Zweimuller (2001). The native fish fauna is relatively intact despite the history of habitat change but there are declines in some species — about 25% of the native fish according to a recent review (Galat et al. 2005). Several benthic species were the focus of our study because they are ranked as vulnerable or imperiled: sturgeon chub (G3), sicklefin

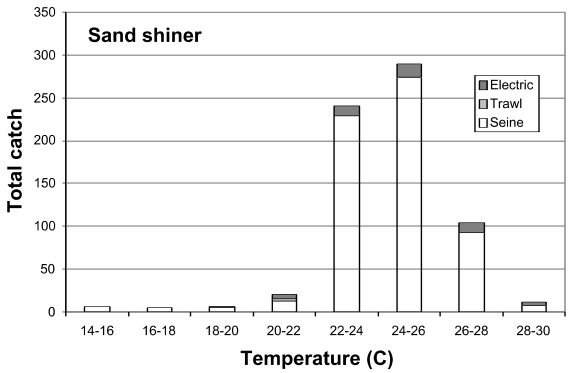
Figure 55. Three patterns of association between total catch of Missouri River benthic fishes and water temperature and a list of species with each pattern. Figures show the diversity of habitat associations among the benthic fishes, not the mean condition present at sites where a species was collected.

Wide Range



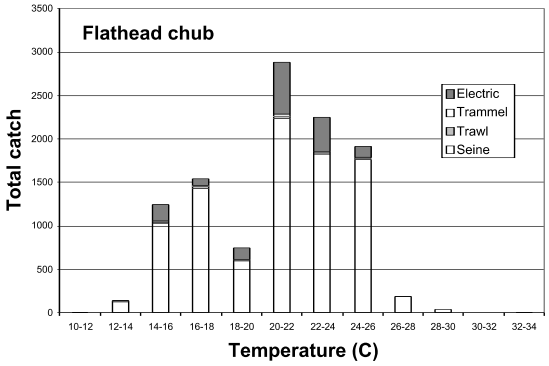

Species with similar results –
- blue sucker
- channel catfish
- common carp
- emerald shiner
- freshwater drum
- river carpsucker
- walleye

Narrow Range




Species with similar results –
- bigmouth buffalo
- blue catfish
- flathead catfish

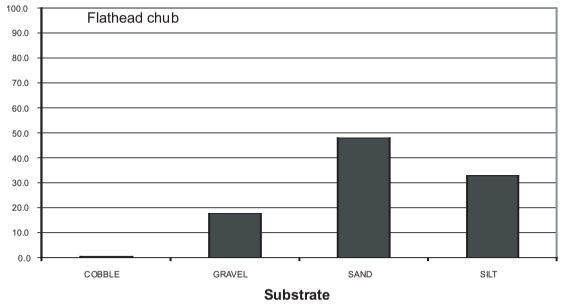
Bi-modal Range




Species with similar results –
- burbot
- fathead minnow
- sauger
- shorthead redhorse
- shovelnose sturgeon
- sicklefin chub
- stonecat
- sturgeon chub
- white sucker

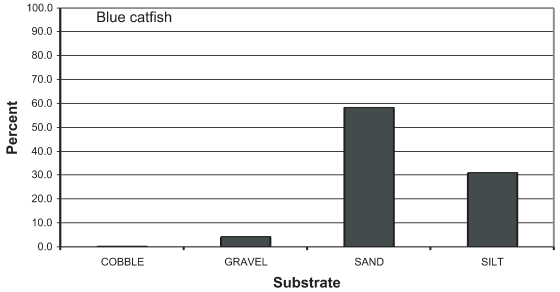
Figure 56. Three patterns of association between total catch of Missouri River benthic fishes and substrate and a list of species with each pattern. Figures show the diversity of habitat associations among the benthic fishes, not the mean condition present at sites where a species was collected.

Gravel group



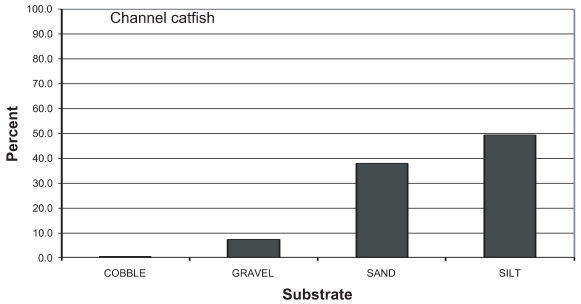

Species with similar results –
- blue sucker
- burbot
- shorthead redhorse
- shovelnose sturgeon
- sicklefin chub
- stonecat
- sturgeon chub
- white sucker

Sand group




Species with similar results –
- sand shiner

Silt group




Species with similar results –
- bigmouth buffalo
- common carp
- emerald shiner
- fathead minnow
- flathead catfish
- freshwater drum
- river carpsucker
- sauger
- smallmouth buffalo
- walleye

chub (G3), blue sucker (G3G4), shovelnose sturgeon (G4), western silvery minnow (G4), plains minnow (G4), flathead chub (G4), and pallid sturgeon (G1).

Number of species increased in the downstream direction, as might be predicted by the River Continuum Concept, and illustrates the classic phenomenon of longitudinal zonation in riverine fish assemblages (Hawks 1975, Matthews 1998). In other Mississippi River tributaries (e.g., Limbird 1993), species richness increases in a downstream direction because of the addition of habitats. In the case of the Missouri River mainstem, the additional species are present because of the presence of the Mississippi River, added species from the Ozark Plateau Physiographic Region, and replacement of coolwater species by warmwater species.

Total catch of all 106 species supported several conclusions about differences among zones and segments that were shown by the catch of the benthic assemblage. The total catch appeared to be lower in the IR zone than in other zones. In the LA zone highest total catch was in the Yellowstone. In the IR zone, Segment **12** had the lowest total catch, and the catch of 4,734 longnose suckers made up most of the catch of 6,955 fish in that segment. The highest total catch was in Segment **15**, but two species (gizzard shad, emerald shiner) made up half of this total. In the CH zone, total catch increased linearly downstream, as did the catch of some benthic fishes (e.g., channel catfish, river carpsucker, sicklefin chub).

The goldeye was a common native species (3,836 collected) found in every segment. Lowest catches were in Segments **12** and **14**. Goldeye is a native species that would be useful in assessing longitudinal change in the river, but it is a pelagic species, and therefore not a primary focus of our study. It was more common (136-774 collected) in Segments 3-**10** than in other segments.

A group of nonbenthic native species were rarely collected. In this group were fish that are termed "strays" or "waifs" that are more common in floodplain wetlands, reservoirs, and tributaries than in the mainstem. Examples are banded killifish, brook stickleback, grass pickerel, longear sunfish, largescale stoneroller, and northern redbelly dace. Examples of "strays' from tributaries are the two river redhorse found in the CH zone.

Another group that is part of the Missouri River fish community are species on the edge of their range, such as those generally restricted to Canada (e.g., lake chub, lake whitefish) or Great Lakes states and upper Mississippi River basin. Just as the native range of some benthic species were limited to a portion of the basin, a similar distribution pattern was found among the other species collected. Species with distributions that were restricted to the upper river were the mottled sculpin, longnose sucker, and longnose dace. The distribution of most species generally agrees with published reports (Lee et al. 1980). Exceptions were the paddlefish and golden shiner, which were not found in the LA zone, but are present there (White and Bramblett 1993, Galat et al. 2005).

Rock bass were found in Segments **14** and **15**, which are near to the only tributary in the Missouri River basin (Big Sioux River) in which rock bass are considered native to headwater streams. The species is a representative of several dozen species (e.g., northern redbelly dace, bluegill, sand shiner, black crappie) that invaded the central Missouri River basin from the upper Mississippi through connections between the Minnesota River drainage and drainages in North and South Dakota and Iowa, such as the Big Sioux River drainage (Bailey and Allum 1962). Rock bass typically inhabit small, rocky rivers where waters are clear and vegetated, so the species is considered a waif in the Missouri River main channel habitats (Galat et al. 2005).

Exotic or introduced species made up 15% of the 106 species we documented. Exotic species were Asian carp (grass carp, bighead carp), common carp, goldfish, and brown trout. The common carp and goldfish were introduced to North America long ago (Cooper 1987) and the common carp has had a major detrimental impact on many water bodies and fisheries (Verrill and Berry 1995). Brown trout were introduced from Europe long ago. Asian carp were imported to Arkansas and Alabama for aquaculture purposes between 1963 and 1973, and escaped into the wild soon after introduction. Grass carp were widely reported in the lower Missouri basin in the 1970s (Stanley et al. 1978, Brown and Coon 1991), whereas bighead carp began appearing in the 1980s. Reproducing populations are established. No Asian carp were found upstream from Gavins Point Dam. In the past the dam has been faulted because it stops migration of native fish, but the dam is now being praised for stopping the invasion of the Asian carp.

Bighead carp in the lower Missouri River exhibit fast growth (Schrank and Guy 2002). Bighead carp feed on plankton and may compete with native planktivorous fishes such as the paddlefish (Shrank et al. 2003). Capturing Asian carp requires specific sampling protocols that we did not use, but our finding of 16 grass carp and 22 bighead carp confirm their presence and can be used in the future as baseline data when our sampling protocols are used.

The introduced predator species (such as centrarchids, salmonids, esocids, and percids) or forage

species (lake herring, rainbow smelt, spottail shiner, golden shiner) were intentionally stocked to provide recreational fishing in the mainstem reservoirs and tailraces. Twenty-seven game fish or prey fish have been stocked in the Missouri River Basin since 1940 (Hesse et al. 1989). We found several introduced species, including a few coldwater species (e.g., Chinook salmon, rainbow trout, and whitefish). These species were stocked in reservoirs to inhabit the deep, coldwater zone in lakes like Sakakawea and Oahe, so their presence is incidental in the warmwater portions of the river where we sampled. We encountered introduced salmonids only in Montana (Segments 3,**7**,**8**); although they are found in tailrace fisheries downstream from Garrison and Oahe Dams, but not further downstream (Wickstrom 1999, Mestl 1999b).

A muskellunge was found in Segment **12** downstream from Lake Sakakewea. The native range is the upper Mississippi River and Great Lakes basins, but the culture and stocking for recreational fishing has expanded the range of this species (reviewed by Crossman 1986). Muskellunge are a large, predatory member of the pike family (Esocidae) that were stocked in the Missouri River to occupy habitat created downstream from dams. Muskellunge have also been recorded in Missouri River segments in South Dakota, but angler catches are very rare (Berry and Young 2004).

White bass were ubiquitous and common. White bass are native to the Lower Missouri River, but their populations increased greatly in the 1960s after the reservoirs were built (Pflieger 1997). On the other hand, striped bass were few (n = 18) and found only in Missouri (Segments *25* and *27*). Striped bass are a marine species that can be managed in landlocked populations in reservoirs (Axon and Whitehurst 1985). They were stocked in reservoirs in Missouri in the 1960s and were washed through dams into rivers that are tributaries to the Missouri River (Pflieger 1997).

Forage species for introduced predators have also been stocked. Cisco (lake herring) and lake whitefish are primarily found in the Hudson Bay and Great Lakes drainages (Lee et al. 1980), but were stocked in Fort Peck, Sakakawea, and Oahe reservoirs as prey fish. We found them in Montana segments and downstream from Garrison Dam in North Dakota (Segment **12**).

Rainbow smelt were introduced in the Missouri River in 1971 through stocking of 7,100 Lake Superior strain fish into Lake Sakakawea (Frieburger 1992). Rainbow smelt populations expanded greatly and by 1977 they had established a reproducing population in Lake Oahe and had dispersed downstream into other reservoirs and the unimpounded Missouri River and upstream into Montana (Gould and Schmulbach 1981). The smelt pass through hydroelectric turbines in Missouri River dams (Unkenholz 1998), so they were expected in samples from the IR zone. We found them as far downstream as Missouri.

Mosquitofish are native to the Mississippi basin, but have been widely stocked in the lower Missouri basin in quiet ponds and backwaters (Page and Burr 1991). We collected 227 mosquito fish, but only from the Missouri portion of the river (Segments *23-27).*

**Applications**

Presence/absence information, distribution patterns, and quantitative abundance data (species richness, relative abundance, catch/effort) have been used to assess temporal change in large rivers (Berry and Galat 1993, Simon and Emery 1995), in portions of the Missouri mainstem (Pflieger and Grace 1987, Hesse et al. 1993, Grady and Milligan 1998, Mestl 1999, Berry and Young 2004), and in tributaries to the Missouri River (e.g., Cross and Moss 1987, Patton et al. 1998, McMahon and Gardner 2001, Shearer and Berry 2003). Also, use of fish community data for large-scale assessments of river heath has been done with synthetic indices such as the Index of Biotic Integrity (Harris and Silveira 1999), which was also the focus of a Ph.D. project associated with the Benthic Fishes Study (Bergstedt et al. 2004).

Monitoring is necessary to assess progress towards river restoration and species recovery goals (FWS 2000, NRC 2002). Smallscale habitat restoration projects on the Missouri River have sometimes been biologically assessed (e.g., Atchison et al. 1986) and the Corps of Engineers supports fisheries studies to evaluate constructed chutes, river widening projects, backwaters development, and other projects under the Missouri River Fish and Wildlife Mitigation Project (Mestl 2000). However, many restoration or mitigation projects have not had adequate biomonitoring and methods and data for future environmental assessments are needed.

A monitoring program would allow adaptive management (NRC 2002) as projects are evaluated. Fishes have been used for "biomonitoring" in rivers because fish are socially relevant and respond to habitat change (Karr and Chu 1998). Fishes were useful for this study because some species are long-lived and migratory, thus reflecting environmental conditions over the temporal and spatial scales of a great river such as the Missouri River. Additionally, fishes use several macrohabitats depending on life stage and season, and some species are top predators, so their analysis can reflect trophic conditions. The term "big river fishes" describes the assemblage of fishes that includes many benthic specialists (inferior mouth, dorsoventral flattening of the head, streamlined or deep humpbacked body shape, sickle-shaped or enlarged pec-

toral fins, reduced eyes, developed electrosensory and chemosensory organs). Warren et al. (1997) found the most decline in southeastern fishes was in the benthic assemblage. High levels of imperilment in fishes with multiple niche axes converges on the benthic species as benthic habitat becomes degraded from pollution and hydrological change.

This Benthic Fishes Study was unique for its scope, conduct and educational objectives (Berry and Young 2001). The analysis of physical habitat is possibly the most robust and comprehensive ever assembled for the Missouri River (Galat et al. 2001). Emphasis was placed on how flow regime has changed and how the current regime can be used to describe fish community structure throughout the river system (Pegg 2000). When distribution and abundance results for the benthic fish assemblage presented here are combined with results on growth, mortality, condition and size structure data presented by Pierce et al. (2004), patterns may appear that show how these species have responded to natural and anthropogenic factors in the riverscape. The new life history information presented by Braaten (2000), Dieterman (2000), Young (2001) and Welker (2000) for sicklefin chub, sturgeon chub, emerald shiner, river carpsucker, freshwater drum, bigmouth buffalo, smallmouth buffalo, white sucker, and flathead chub help interpret population trends and add to the sparse information on these species in large regulated river environments. The fish community-level analyses were innovative, unique for their scale and hold a great deal of promise in aiding researchers and managers determine effectiveness of mitigation and rehabilitation efforts (Pegg 2000, Bergstedt et al. 2004). Our experiences and data have supported many technical assistance efforts to date, and will continue to be important as the Voyage of Recovery$^{SM}$ proceeds to restore the rivers of Lewis and Clark.

## CONCLUSIONS

The goal of the Benthic Fishes Study was to evaluate the Missouri River fish community on a large spatial scale and produce results that would assist agencies and the public to interpret current conditions and make decisions about how to manage the river. In Volume 1, Table 3, Berry and Young (2001) provided a list of 42 concomitant fish studies on the Missouri River, but none were at the basin scale, as was ours.

- Our data are the first for the Missouri River at such a broad spatial scale and our focus on distribution and population abundance data for benthic species leads to several conclusions that have not been previously possible.
- Our results were unique in its large spatial scale, but generally agreed with presence/absence results from local studies and with temporal trend data from these local studies (e.g., Montana, Nebraska, Missouri).
- Significant year effects in C/E were found in 9 of 42 possible ANOVAs, mostly for data from benthic trawls and electrofishing, which might be gears most affected by discharge variations among years.
- Catch of 77,196 benthic fishes was dominated by emerald shiner, flathead chub, river carpsucker, and channel catfish. Total catch was lowest in the IR segments and generally increased downstream in the CH segments.
- The native range of five benthic species (burbot, blue catfish, flathead catfish, sand shiner, white sucker) did not include the entire mainstem.
- The benthic fishes assemblage was similar among segments in the CH and LA zones, but dissimilar among segments in the IR zone, with Segment **12** being the most dissimilar.
- Data from 18 species was useful for making 22 planned contrasts, but 51% of the 924 contrasts were not statistically possible, usually because of low total catch, which indicates that greater effort will be needed for future studies of this scale if statistical comparisons are to be made. Alternatively, use of statistical approaches less affected by sample size is encouraged.
- Two-thirds of the contrasts among zones were insignificant; most significant contrasts indicated that catches in the LA zone were greater than in altered zones.
- In Segment **15** catch of most species was higher than or similar to catches in Segment **14**; the trend was less obvious between Segments **15** and *17.*
- There were no trends in catches among segments in the LA or CH zones. Many contrasts were insignificant and there were about as many significant increases in catch as decreases for planned contrasts among segments in these zones.
- Catches upstream from two reservoirs (Lake Sakakawea, Fort Peck Lake) were generally higher than catches downstream, perhaps because downstream segments **7**, **8**, and **12** were isolated between dams.
- Segment **12** stood out because of its depauparate fish community; changes in kinds of fish compared to other segments, and depressed catches.
- Channel catfish was the only species judged common in all macrohabitats; no species was a “macrohabitat specialist”; catches were high for all species in at least three macrohabitats; catches were high for all species in ISB and SCC macrohabitats.

- Catches were high for certain species in BEND macrohabitats; six species had high total catches in CHXOs and the catches in CHXOs tended to be higher in the LA zone segments than in IR or CH zone segments for species present in each segment (sicklefin chub, shovelnose sturgeon, sauger).
- Conclusions about macrohabitat use are for the sampling period only; we assume that fish use more than one habitat depending on season and life stage.
- Catch of individual species (expect fathead minnows) was weakly associated with one to four habitat features; the associations were useful for speculating on individual fish habitat needs during the July–October period.
- The benthic fishes assemblage used a wide variety of habitat conditions, which implies that managing the river for variety would foster fish diversity conservation.
- More sturgeon chubs (n = 2,051) were caught than expected; most were caught in the benthic trawl in deep (<3 m) and swift (0.6-0.8 m/s) water conditions; more sicklefin chubs (n = 709) were caught than expected, also in the benthic trawl, but in somewhat different habitat conditions than were associated with sturgeon chub catches.
- Four pallid sturgeons were caught: three in the Yellowstone River and a Missouri River segment near the Yellowstone confluence, and one in the lower CH zone. The adult-sized fish were found in deep (1.7 to 4.8 m) and swift (0.5 – 1.0 m/sec) water conditions.
- Shovelnose sturgeon (n = 1,560) were caught in all segments; most by drifting trammel nets; presence sites tended to be deeper, with faster water velocity and coarser substrates than found at absence sites.
- Species in the genus *Hybognathus* were difficult to identify and most were grouped, thus reducing the information gained from these fishes, but the distribution of the group supported some of the general conclusions of the study.
- Eighty other species brought the ichthyofaunal list to 106 species; 12 species had not been reported in the open literature; 30 species reported by others were not collected.
- Exotic or introduced species made up 15% of species richness; most were recreational species or forage fish introduced to improve angling; exotic Asian carp were found in the CH zone.
- The goldeye a pelagic native species was common (3,836 collected) and found in every segment; lowest catches were in Segments **12** and **14**.
- The main objectives of the study were accomplished and with the additional data from six Dissertations, our study was unique in its scale and design.

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## APPENDIX 1
## TOTAL CATCH FOR ALL YEARS

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Table A1-1. Number of unidentified specimens and hybrids collected during the Benthic Fishes Study of the Missouri River.

| Category | 1996 | 1997 | 1998 | Total |
|---|---|---|---|---|
| Partially identified and unidentified | | | | |
| *Hybognathus* sp. | 1,759 | 5,436 | 5,523 | 12,718 |
| *Lepomis* sp. | 6 | 26 | 0 | 32 |
| *Sander* sp. | 20 | 41 | 70 | 131 |
| *Ictiobus* sp. | 17 | 0 | 2 | 19 |
| *Carpiodes* sp. | 2 | 2 | 339 | 343 |
| *Notropis* sp. | 90 | 247 | 101 | 438 |
| *Moxostoma* sp. | 2 | 1 | 1 | 4 |
| *Macrhybopsis* sp. | 0 | 7 | 9 | 16 |
| Centrarchidae | 14 | 50 | 14 | 78 |
| Cyprinidae | 313 | 225 | 183 | 721 |
| Catostomidae | 1,195 | 259 | 534 | 1,988 |
| Unidentified fish[a] | 12 | 52 | 67 | 131 |
| Larval fish | 32 | 0 | 4 | 36 |
| Age-O fish | 627 | 6 | 393 | 1,026 |
| Hybrids[b] | | | | |
| Saugeye | 1 | 10 | 1 | 12 |
| GSFxOSF | 1 | 2 | 0 | 3 |
| GSFxunknown | 0 | 1 | 0 | 1 |
| GSFxBG | 0 | 8 | 2 | 10 |
| Wiper | 0 | 1 | 4 | 5 |

[a]Some fish crushed in the trawl or other accident.
[b]GSF = green sunfish, OSF = orangespotted sunfish, BG = bluegill, wiper = white bass x striped bass, saugeye = sauger x walleye.

Table A1-2. Total catch (n = 134,163) of all fishes during the Benthic Fishes Study of the mainstem of the Missouri River, 1996-1998. Segments 4, **6**, *18*, and *21* were sampled only 1996. Segments 3, 4, 5, and 9 are in the least altered zone. Segments **7-15** are in the inter-reservoir zone. Segments *17-27* are in the channelized zone.

| Common name | Scientific name | 3 | 4 | 5 | **6** | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *18* | *19* | *21* | *22* | *23* | *25* | *27* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Banded killifish | Fundulus diaphanus | | | | | | | | | 4 | | | | | | | | | | | 4 |
| Bigeye shiner | Notropis boops | | | | | | | | | | | | | | | | 1 | | | 4 | 5 |
| Bighead carp | Hypopthalmichthys nobilis | | | | | | | | | | | | | | 1 | 3 | 3 | 1 | 2 | 12 | 22 |
| Bigmouth buffalo | Ictiobus cyprinellus | | | 3 | | 7 | 102 | 4 | 299 | 34 | 6 | 23 | 19 | | 9 | | 3 | 1 | 6 | 1 | 517 |
| Bigmouth shiner | Notropis dorsalis | | | | | | | | | | | 68 | 17 | | | 1 | 2 | | 15 | 6 | 109 |
| Black buffalo | Ictiobus niger | | | | | | | | | | | | | | | | | 2 | | | 2 |
| Black bullhead | Ameiurus melas | | | | | | | 2 | 5 | 1 | 5 | | 2 | | | 1 | | | | | 16 |
| Black crappie | Pomoxis nigromaculatus | 9 | 1 | 137 | | | | | 3 | 2 | 17 | 10 | 2 | | 4 | | 7 | 1 | 6 | | 199 |
| Blue catfish | Ictalurus furcatus | | | | | | | | | | | | | | 1 | | 79 | 92 | 109 | 101 | 382 |
| Blue sucker | Cycleptus elongatus | 8 | | 7 | 1 | 8 | 6 | 11 | 1 | 4 | | 36 | 53 | 3 | 9 | 3 | 19 | 24 | 1 | 6 | 200 |
| Bluegill | Lepomis macrochirus | | | | | | | | | 1 | 103 | 39 | 32 | 3 | 14 | 1 | 87 | 89 | 187 | 115 | 671 |
| Bluntnose minnow | Pimephales notatus | | | | | | | | | | 3 | 1 | | | | | | | 15 | 23 | 42 |
| Bowfin | Amia calva | | | | | | | | | | | | | | | | | | | 1 | 1 |
| Brassy minnow | Hybognathus hankinsoni | | | | | | | | | | 2 | 82 | 3 | | 55 | | | | | | 142 |
| Brook silverside | Labidesthes sicculus | | | | | | | | | | | | | | 7 | | | | 8 | 1 | 16 |
| Brook stickleback | Culaea inconstans | | | | | | 1 | | | 1 | | | | | | | | | | | 2 |
| Brown trout | Salmo trutta | | | 1 | | | | | | | | | | | | | | | | | 1 |
| Bullhead minnow | Pimephales vigilas | | | | | | | | | | | | | | | | 3 | 4 | 1 | 3 | 11 |
| Burbot | Lota lota | 11 | | 113 | | 4 | 5 | 18 | 63 | 4 | 1 | 1 | | | | | | | | | 220 |
| Channel catfish | Ictalurus punctatus | 60 | 4 | 196 | 1 | 62 | 78 | 526 | 148 | 29 | 403 | 257 | 551 | 71 | 334 | 79 | 733 | 846 | 569 | 709 | 5656 |
| Chestnut lamprey | Ichthyomyzon castaneus | | | | | | | | | | | | | | | | | | 2 | | 2 |
| Chinook salmon | Oncor. tshawytscha | | | | | 1 | | | | | | | | | | | | | | | 1 |
| Cisco | Coregonus artedi | 1 | | | 11 | 7 | | | | 5 | | | | | | | | | | | 24 |
| Common carp | Cyprinus carpio | 132 | 9 | 157 | | 102 | 282 | 164 | 352 | 97 | 234 | 413 | 108 | 15 | 152 | 49 | 162 | 160 | 208 | 241 | 3037 |
| Common shiner | Luxilus cornutus | | | | | | | | | | | | | | | | | | | 2 | 2 |
| Creek chub | Semotilus atromaculatus | | | | | 5 | 30 | 29 | | 1 | | | | | | | 2 | | | | 67 |
| Emerald shiner | Notropis atherinoides | 1277 | 6 | 2502 | | 84 | 41 | 623 | 104 | 7 | 1137 | 4965 | 544 | 166 | 2322 | 206 | 1201 | 1113 | 2594 | 1470 | 20362 |
| Fathead minnow | Pimephales promelas | 1 | | | 5 | 201 | 66 | 94 | 6 | 317 | 8 | 8 | 12 | | 13 | | 4 | 2 | 1 | 1 | 739 |
| Flathead catfish | Pylodictus olivaris | | | | | | | | | | 3 | 133 | 130 | 82 | 298 | 104 | 163 | 210 | 145 | 188 | 1456 |
| Flathead chub | Platygobio gracilis | 3015 | 138 | 2322 | | 170 | 868 | 5487 | 804 | | 10 | 7 | 1 | | 1 | 2 | 4 | 5 | 2 | 2 | 12838 |
| Freckled madtom | Noturus nocturnus | | | | | | | | | | | | | | | | | | | 8 | 8 |
| Freshwater drum | Aplodinotus grunniens | 129 | 7 | 121 | | 10 | 16 | 23 | 23 | | 47 | 374 | 130 | 5 | 321 | 26 | 528 | 303 | 360 | 347 | 2770 |
| Ghost shiner | Notropis buchanani | | | | | | | | | | | | | | | | 1 | | | 1 | 2 |

| Common name | Scientific name | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 15 | 17 | 18 | 19 | 21 | 22 | 23 | 25 | 27 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gizzard shad | Dorosoma cepedianum | | | | | | | | | | 174 | 4360 | 2469 | 489 | 2330 | 258 | 5026 | 1887 | 2048 | 6886 | 25927 |
| Golden redhorse | Moxostoma erythrurum | | | | | | | | | | | | 1 | | | | 2 | 14 | | | 17 |
| Golden shiner | Notemigonus crysoleucas | | | | | | | | 4 | 1 | 1 | 55 | | | 1 | | | 4 | | | 66 |
| Goldeye | Hiodon alosoides | 136 | 4 | 327 | 13 | 445 | 774 | 606 | 452 | 61 | 56 | 188 | 319 | 132 | 112 | 29 | 68 | 77 | 132 | 83 | 4014 |
| Goldfish | Carassius auratus | | | | | | | | | | | | | | | | 3 | 2 | | | 5 |
| Grass carp | Ctenopharyngodon idella | | | | | | | | | | | 6 | 1 | | 3 | | 1 | 1 | 2 | 2 | 16 |
| Grass pickerel | E. amer. vermiculatus | | | | | | | | | | | 1 | | | | | | | | | 1 |
| Green sunfish | Lepomis cyanellus | | | | | | | 7 | 1 | | 11 | 16 | 2 | | 4 | 6 | 65 | 64 | 13 | 21 | 210 |
| Green sunfish x sp | Lepomis cyanellus x sp. | | | | | | | | | | | | | | 1 | | | | | | 1 |
| Gsunfish x Bluegill | L. cyanel.x macrochirus | | | | | | | | | | 2 | | | | 8 | | | | | | 10 |
| Gsunfish x Oranges. | L. cyanellus x L. humilis | | | | | | | | | | | 2 | | | | | | | | | 2 |
| Highfin carpsucker | Carpiodes velifer | | | | | | | | | | | 1 | | | | 1 | 1 | | 1 | 2 | 6 |
| Hybognathus spp. | Hyybognathus sp. | 518 | 13 | 4259 | | 38 | 34 | 2648 | 3 | | 5 | 1 | 23 | | 227 | 182 | 828 | 931 | 2398 | 610 | 12718 |
| Johnny darter | Etheostoma nigrum | | | | | | | | | 20 | 80 | 22 | 4 | | 3 | | | | | 1 | 130 |
| L. stoneroller | Campostoma oligolepis | | | | | | | | | | | | | | | | | | 2 | | 2 |
| Lake chub | Couesius plumbeus | 1 | | | | | | | | | | | | | | | | | | | 1 |
| Lake sturgeon | Acipenser fulvescens | | | | | | | | | | | | | | | | | | 4 | 1 | 5 |
| Lake whitefish | Coregonus clupeaformis | | | | | | 2 | | | | | | | | | | | | | | 2 |
| Largemouth bass | Micropterus salmoides | | | | | | | | | | 164 | 46 | 22 | | 8 | | 30 | 13 | 28 | 3 | 314 |
| Logperch | Percina caprodes | | | | | | | | | | | | | | | | | 1 | 4 | | 5 |
| Longear sunfish | Lepomis megalotis | | | | | | | | | | | | | | | | | | 1 | | 1 |
| Longnose dace | Rhinichthys cataractae | 113 | 6 | 89 | | 10 | 13 | 217 | 5 | | | | | | | | | | | | 453 |
| Longnose gar | Lepisosteus osseus | | | | | | | | | | | 38 | 7 | | 5 | 5 | 28 | 23 | 43 | 36 | 185 |
| Longnose sucker | Catostomus catostomus | 150 | | 21 | 7 | 39 | 14 | 8 | 7 | 4734 | | | | | | | | | | | 4980 |
| Mimic shiner | Notropis volucellus | | | | | | | | | | 1 | 4 | 2 | | | | 3 | | | 90 | 100 |
| Mosquitofish | Gambusia affinis | | | | | | | | | | | | | | | | 3 | 16 | 29 | 179 | 227 |
| Mottled sculpin | Cottus bairdi | 7 | 2 | 6 | | | | | | | | | | | | | | | | | 15 |
| Muskellunge | Esox masquinongy | | | | | | | | | 1 | | | | | | | | | | | 1 |
| No. hog sucker | Hypentelium nigricans | | | | | | | | | | | | 1 | | | | | | | | 1 |
| No. redbelly dace | Phoxinus eos | | | | | 1 | | | | | | | | | | | | | | | 1 |
| Northern pike | Esox lucius | 13 | 4 | 38 | 10 | 58 | 60 | 44 | 86 | 12 | 17 | 17 | 4 | | 3 | 1 | | | 1 | | 368 |
| Orangesp. sunfish | Lepomis humilis | | | | | | | | | | | 4 | | | 2 | 7 | 79 | 12 | 5 | 18 | 127 |
| Paddlefish | Polyodon spathula | | | | | | 1 | | 1 | | 1 | 2 | 2 | | 2 | | | 1 | 2 | 3 | 15 |
| Pallid sturgeon | Scaphirhynchus albus | | | | | | | 2 | 1 | | | | | | | | 1 | | | | 4 |
| Pearl dace | Margariscus margarita | | | | | | | 1 | | | | | | | | | | | | | 1 |
| Plains minnow | Hybognathus placitus | | | | | 2 | | | 23 | | | | | | 12 | | | | 14 | 6 | 57 |
| Quillback | Carpiodes cyprinus | | | | | | | | | | 42 | 1875 | 11 | 1 | 4 | | 9 | 11 | 3 | 6 | 1962 |

| Common name | Scientific name | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 15 | 17 | 18 | 19 | 21 | 22 | 23 | 25 | 27 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainbow smelt | Osmerus mordax | | | | 1 | | | | | 19 | 1 | 1 | | | | | | | 1 | | 23 |
| Rainbow trout | Oncorhynchus mykiss | 1 | | | 6 | 14 | | | | | | | | | | | | | | | 21 |
| Red shiner | Cyprinella lutrensis | | | | | | | | | 4 | 55 | 254 | 81 | 2 | 19 | 20 | 95 | 144 | 272 | 1436 | 2382 |
| River carpsucker | Carpiodes carpio | 58 | | 129 | 2 | 387 | 232 | 1164 | 58 | 60 | 212 | 516 | 256 | 12 | 716 | 44 | 234 | 142 | 1397 | 1069 | 6688 |
| River redhorse | Moxostoma carinatum | | | | | | | | | | | | 1 | 1 | | | 1 | | | | 3 |
| River shiner | Notropis blennius | | | | | | | | | | 23 | 200 | 180 | 11 | 144 | 17 | 89 | 77 | 105 | 30 | 876 |
| Rock bass | Ambloplites rupestris | | | | | | | | | | 13 | 9 | | | | | | | | | 22 |
| Sand shiner | Notropis stramineus | | | | | | | | | 1 | 12 | 383 | 56 | | 4 | 3 | 19 | 11 | 38 | 166 | 693 |
| Sauger | Sander canadense | 53 | 4 | 106 | | 24 | 47 | 68 | 55 | 5 | 21 | 79 | 31 | 4 | 26 | 10 | 37 | 17 | 21 | 6 | 614 |
| Sauger x Walleye | S. canadense x vit. | | | | | | | | | 1 | | 6 | | | 5 | | | | | | 12 |
| Shorthead redhorse | Mox. macrolepidotum | 357 | 29 | 226 | 1 | 30 | 125 | 69 | 18 | 22 | 22 | 237 | 44 | | | 1 | | 8 | 5 | 6 | 1200 |
| Shortnose gar | L. platostomus | | | | | | 1 | 1 | | | 9 | 44 | 30 | 1 | 58 | 9 | 105 | 125 | 93 | 138 | 614 |
| Shovelnose sturgeon | Scaphirhynchus platorynchus | 31 | 5 | 123 | 3 | 100 | 51 | 253 | 63 | 50 | 17 | 62 | 103 | 7 | 70 | 30 | 190 | 218 | 126 | 58 | 1560 |
| Sicklefin chub | Macrhybopsis meeki | | | 267 | | | 81 | 124 | 70 | | | 1 | | | 1 | 5 | 9 | 6 | 70 | 75 | 709 |
| Silver chub | Macrhybop. storeriana | | | | | | | | | | 8 | 1 | 13 | | 49 | 36 | 158 | 55 | 37 | 66 | 423 |
| Silverband shiner | Notropis shumardi | | | | | | | | | | | | | | | | 1 | | | 1 | 2 |
| Skipjack herring | Alosa chrysochloris | | | | | | | | | | | | | | | | | 1 | 4 | 5 | 10 |
| Slender madtom | Noturus exilis | | | | | | | | | | | | | | | | 1 | | | | 1 |
| Smallmouth bass | Micropterus dolomieu | 2 | | | 1 | | 2 | 1 | | 19 | 147 | 230 | 5 | | | | | | | | 407 |
| Smallmouth buffalo | Ictiobus bubalus | 27 | | 9 | 1 | 34 | 43 | 21 | 110 | 1 | 17 | 97 | 14 | | 10 | 1 | 12 | 16 | 25 | 47 | 485 |
| Speckled chub | Macrhybop. aestivalis | | | | | | | | | | | | | 5 | 43 | 2 | | 24 | 61 | 191 | 326 |
| Spotfin shiner | Cyprinella spiloptera | | | | | | | | | | 718 | 768 | 144 | 3 | 114 | 1 | 1 | 2 | | | 1751 |
| Spottail shiner | Notropis hudsonius | 46 | | 170 | 119 | 17 | 62 | 35 | 20 | 4 | 3 | 13 | 2 | 2 | | | | | | | 493 |
| Spotted bass | M. punctulatus | | | | | | | | | | | | | | | | | 3 | 36 | 19 | 58 |
| Spotted gar | Lepisosteus oculatus | | | | | | | | | | | | | | | 1 | | | 1 | | 2 |
| Stonecat | Noturus flavus | 9 | 1 | 92 | | 5 | 28 | 140 | 34 | | 4 | 4 | 1 | | 1 | | 6 | 6 | 2 | 9 | 342 |
| Striped bass | Morone saxatilis | | | | | | | | | | | | | | | | | 1 | 6 | 14 | 21 |
| Striped shiner | L. chrysocephalus | | | | | | | | | | | | | | | | | | | 1 | 1 |
| StripedxWhite bass | M. saxatilis x chrysops | | | | | | | | | | | | | | | | | 5 | | | 5 |
| Sturgeon chub | Macrhybopsis gelida | 1 | 3 | 577 | | 28 | 125 | 1228 | 32 | | | | 4 | 1 | 7 | 3 | 12 | 16 | 10 | 4 | 2051 |
| Suckermouth min. | Phenacobius mirabilis | | | | | | | | | | | | | | | | | 4 | 2 | 4 | 10 |
| Tadpole madtom | Noturus gyrinus | | | | | | | | | | | | | | | | 1 | | | | 1 |
| Threadfin shad | Dorosoma petenense | | | | | | | | | | | | 1 | | | | | | | | 1 |
| Unid. buffalo | Ictiobus sp. | 17 | | | | | | 2 | | | | | | | | | | | | | 19 |
| Unid. carpsucker | Carpiodes sp. | | | | | | | | | | 38 | 299 | 3 | | 3 | | | | | | 343 |
| Unid. chub | Macrhybopsis sp. | | | | | | | | 5 | | | | | | | | | | 10 | 1 | 16 |
| Unid. Lepomis | Lepomis sp. | | | | | | | | 1 | 3 | 2 | 1 | | | | 2 | 27 | 1 | | | 37 |
| Unid. minnow | Unid. Cyprinidae | 49 | | 32 | 2 | 3 | 5 | 208 | 37 | 24 | 3 | | 5 | | 146 | | 83 | 71 | 12 | 41 | 721 |
| Unid. redhorse | Moxostoma sp. | | | | | | | | | | | | 4 | | | | | | | | 4 |

| Common name | Scientific name | 3 | 4 | 5 | **6** | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *18* | *19* | *21* | *22* | *23* | *25* | *27* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unid. shiner | Notropis sp. | | | | | | | | | | 42 | 41 | 35 | | 221 | | 1 | | 2 | 54 | 396 |
| Unid. Stizostedion | Stizostedion sp. | 2 | | 7 | | 3 | 26 | 3 | 87 | 3 | | | | | | | | | | | 131 |
| Unid. sucker | Unid. Catostomidae | 139 | | 4 | 2 | 11 | 4 | 327 | 233 | 988 | 27 | 249 | 2 | | | | 1 | 1 | | | 1988 |
| Unid. sunfish | Unid. Centrarchidae | | | | | | | | | | 14 | | | | | | 59 | 5 | | | 78 |
| Unidentified | Unidentified | 22 | | 14 | | 44 | 3 | 460 | | | 48 | 508 | 12 | | 18 | | 1 | 6 | 31 | 37 | 1204 |
| W. silvery minnow | Hybognathus argyritis | | | | | 8 | 2 | 5 | 356 | | | 1 | | | 2 | | | | | | 374 |
| Walleye | Sander vitreum | 28 | | 41 | 2 | 8 | 79 | 57 | 21 | 48 | 76 | 161 | 21 | 1 | 9 | 1 | 1 | 4 | 1 | 2 | 561 |
| White bass | Morone chrysops | | | | | | 3 | 8 | | 1 | 40 | 197 | 19 | 7 | 20 | 18 | 46 | 75 | 43 | 65 | 542 |
| White crappie | Pomoxis annularis | 23 | | 69 | | 3 | 66 | 52 | 229 | | 925 | 38 | 4 | 4 | 15 | 2 | 21 | 5 | 18 | 6 | 1480 |
| White perch | Morone americana | | | | | | | | | | | | | 1 | 1 | | | | | | 2 |
| White sucker | Catosto. commersoni | 80 | 40 | 3 | 19 | 376 | 270 | 40 | 6 | 1362 | 6 | 2 | | | | | | | | | 2204 |
| Yellow bass | Mor. mississippiensis | | | | | | | | | | | | | | | | | | 1 | 5 | 6 |
| Yellow bullhead | Ameiurus natalis | | | | | | | | 1 | | | | 1 | | 3 | | 1 | | | | 6 |
| Yellow perch | Perca flavescens | 2 | | 58 | | 13 | 26 | | 7 | 23 | 492 | 140 | 7 | | | | | | | | 768 |
| | | | | | | | | | | | | | | | | | | | | | Total = 134,163 |

Table A1-3. Year 1996: total fish and unidentified specimens collected from the warm water, mainstem Missouri River during the Benthic Fishes Study. Segments 4, **6**, *18*, and *21* were sampled only 1996. Segments 3, 4, 5, and 9 are in the least altered zone. Segments **7-15** are in the inter-reservoir zone. Segments *17-27* are in the channelized zone.

| Common name | Scientific name | 3 | 4 | 5 | **6** | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *18* | *19* | *21* | *22* | *23* | *25* | *27* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Banded killifish | Fundulus diaphanus | | | | | | | | | 4 | | | | | | | | | | | 4 |
| Bighead carp | Hypopthalmichthys nobilis | | | | | | | | | | | | | | 1 | 3 | | 1 | | 2 | 7 |
| Bullhead minnow | Pimephales vigilax | | | | | | | | | | | | | | | | | 1 | | | 1 |
| Black bullhead | Ameiurus melas | | | | | | | | | 1 | 2 | | 2 | | | 1 | | | | | 6 |
| Black crappie | Pomoxis nigromaculatus | | 1 | 17 | | | | | 3 | 2 | 9 | 3 | | | 2 | | | | | | 37 |
| Brook stickleback | Culaea inconstans | | | | | | | | | 1 | | | | | | | | | | | 1 |
| Brook silverside | Labidesthes sicculus | | | | | | | | | | | | | | 1 | | | | | | 1 |
| Blue catfish | Ictalurus furcatus | | | | | | | | | | | | | | | | 15 | 8 | 58 | 23 | 104 |
| Bluegill | Lepomis macrochirus | | | | | | | | | 1 | 54 | 16 | 2 | 3 | 2 | 1 | 3 | 15 | 29 | 15 | 141 |
| Bigmouth buffalo | Ictiobus cyprinellus | | | 1 | | | | 1 | 3 | 1 | | 4 | 2 | | 1 | | | | | 1 | 14 |
| Bigmouth shiner | Notropis dorsalis | | | | | | | | | | | 4 | 1 | | | 1 | | | | | 6 |
| Bluntnose minnow | Pimephales notatus | | | | | | | | | | | | | | | | | | 2 | 1 | 3 |
| Burbot | Lota lota | 1 | | 32 | | 1 | 2 | | 29 | | | | | | | | | | | | 65 |
| Brassy minnow | Hybognathus hankinsoni | | | | | | | | | | 1 | 69 | 3 | | 55 | | | | | | 128 |
| Blue sucker | Cycleptus elongatus | 2 | | 2 | 1 | | 1 | 2 | 1 | 3 | | 3 | 1 | 3 | | 3 | 3 | 7 | | | 32 |
| Common carp | Cyprinus carpio | 14 | 9 | 22 | | 1 | 5 | 7 | 9 | 21 | 54 | 93 | 25 | 15 | 23 | 49 | 23 | 31 | 40 | 53 | 494 |
| Creek chub | Semotilus atromaculatus | | | | | | | 1 | | | | | | | | | | | | | 1 |
| Channel catfish | Ictalurus punctatus | 6 | 4 | 23 | 1 | | 3 | 82 | 29 | 2 | 29 | 19 | 13 | 71 | 53 | 79 | 131 | 193 | 121 | 133 | 992 |
| Cisco | Coregonus artedi | | | | 11 | | | | | 2 | | | | | | | | | | | 13 |
| Emerald shiner | Notropis atherinoides | 78 | 6 | 309 | | | | 13 | 2 | 2 | 44 | 2199 | 119 | 166 | 1440 | 206 | 288 | 164 | 287 | 14 | 5337 |
| Flathead chub | Platygobio gracilis | 1337 | 138 | 136 | | 5 | 67 | 1189 | 125 | | 6 | | | | | 2 | | 3 | 1 | | 3009 |
| Flathead catfish | Pylodictis olivaris | | | | | | | | | | | 30 | 27 | 82 | 127 | 104 | 41 | 34 | 46 | 56 | 547 |
| Fathead minnow | Pimephales promelas | 1 | | | 5 | 11 | 4 | | | 221 | | | 1 | | 1 | | | | | 1 | 245 |
| Freshwater drum | Aplodinotus grunniens | 19 | 7 | 31 | | | 4 | 9 | 12 | | | 32 | 1 | 5 | 5 | 26 | 37 | 42 | 107 | 149 | 486 |
| Goldeye | Hiodon alosoides | 24 | 4 | 34 | 13 | 25 | 100 | 41 | 34 | 1 | 5 | 18 | 39 | 132 | 15 | 29 | 13 | 8 | 67 | 14 | 616 |
| Golden shiner | Notemig. crysoleucas | | | | | | | | | 1 | | | | | | | | 3 | | | 4 |

| Common name | Scientific name | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 15 | 17 | 18 | 19 | 21 | 22 | 23 | 25 | 27 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Green sunfish | Lepomis cyanellus | | | | | | | 4 | 1 | | 6 | 4 | 1 | | 2 | 6 | 4 | 1 | 1 | 2 | 32 |
| Grass carp | Ctenopharyngodon idella | | | | | | | | | | | 1 | | | 1 | | | 1 | | | 3 |
| G.Sunf.xOrange | L. cyanellus x L. humilis | | | | | | | | | | | 1 | | | | | | | | | 1 |
| Ghost shiner | Notropis buchanani | | | | | | | | | | | | | | | | | | | 1 | 1 |
| Gizzard shad | Dorosoma cepedianum | | | | | | | | | | 170 | 657 | 96 | 489 | 565 | 258 | 612 | 825 | 348 | 1181 | 5201 |
| Hybognathus spp. | Hybognathus sp. | 102 | 13 | 396 | | | 6 | 359 | 3 | | | | | | | 182 | 291 | 153 | 115 | 49 | 1669 |
| Highfin carpsucker | Carpiodes velifer | | | | | | | | | | | | | | | 1 | | | | | 1 |
| Johnny darter | Etheostoma nigrum | | | | | | | | | 7 | 20 | 2 | | | | | | | | | 29 |
| Longear sunfish | Lepomis megalotis | | | | | | | | | | | | | | | | | | 1 | | 1 |
| Lake chub | Couesius plumbeus | 1 | | | | | | | | | | | | | | | | | | | 1 |
| Largemouth bass | Micropterus salmoides | | | | | | | | | | 103 | 19 | 2 | | | | | 6 | 11 | | 141 |
| Longnose dace | Rhinichthys cataractae | 34 | 6 | 15 | | 5 | 1 | 38 | | | | | | | | | | | | | 99 |
| Longnose gar | Lepisosteus osseus | | | | | | | | | | | 3 | | | | 5 | 5 | 1 | 6 | 10 | 30 |
| Longnose sucker | Catostomus catostomus | 5 | | 1 | 7 | 4 | 11 | 3 | 1 | 74 | | | | | | | | | | | 106 |
| Larval fish | Unidentified | | | | | 4 | | | | | | | 9 | | 18 | | | | | | 31 |
| Mottled sculpin | Cottus bairdi | 1 | 2 | 1 | | | | | | | | | | | | | | | | | 4 |
| West. Mosquitofish | Gambusia affinis | | | | | | | | | | | | | | | | | 2 | 3 | 2 | 7 |
| N. hog sucker | Hypentelium nigricans | | | | | | | | | | | | 1 | | | | | | | | 1 |
| N. redbelly dace | Phoxinus eos | | | | | 1 | | | | | | | | | | | | | | | 1 |
| Northern pike | Esox lucius | 8 | 4 | 16 | 10 | 6 | 14 | 6 | 31 | 7 | 2 | 2 | | | 1 | 1 | | | | | 108 |
| Orangespot. sunfish | Lepomis humilis | | | | | | | | | | | | | | | 7 | 9 | 4 | | 3 | 23 |
| Paddlefish | Polyodon spathula | | | | | | | | | | | 2 | | | 1 | | | | | | 3 |
| Pearl dace | Margariscus margarita | | | | | | | 1 | | | | | | | | | | | | | 1 |
| Quillback | Carpiodes cyprinus | | | | | | | | | | 2 | 30 | 3 | 1 | | | 1 | | | | 37 |
| Rainbow smelt | Osmerus mordax | | | | 1 | | | | | 5 | | | | | | | | | | | 6 |
| Rainbow trout | Oncorhynchus mykiss | | | | 6 | | | | | | | | | | | | | | | | 6 |
| Red shiner | Cyprinella lutrensis | | | | | | | | | | 10 | 41 | 6 | 2 | 5 | 20 | 21 | 29 | 38 | 43 | 215 |
| Rock bass | Ambloplites rupestris | | | | | | | | | | 1 | 1 | | | | | | | | | 2 |
| River carpsucker | Carpiodes carpio | 14 | | 8 | 2 | 6 | 12 | 279 | 2 | 16 | 35 | 194 | 10 | 12 | 26 | 44 | 34 | 22 | 22 | 24 | 762 |
| River redhorse | Moxostoma carinatum | | | | | | | | | | | | 1 | 1 | | | | | | | 2 |

| Common name | Scientific name | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 15 | 17 | 18 | 19 | 21 | 22 | 23 | 25 | 27 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River shiner | Notropis blennius | | | | | | | | | | 15 | 7 | 4 | 11 | 94 | 17 | 4 | 29 | | 1 | 182 |
| Striped bass | Morone saxatilis | | | | | | | | | | | | | | | | | | 5 | 10 | 15 |
| Sicklefin chub | Macrhybopsis meeki | | | 21 | | | 6 | 6 | 27 | | | 1 | | | 1 | 5 | 4 | 2 | 4 | 11 | 88 |
| Spotfin shiner | Cyprinella spiloptera | | | | | | | | | | 71 | 21 | | 3 | 83 | 1 | 1 | | | | 180 |
| Sturgeon chub | Macrhybopsis gelida | | 3 | 43 | | 5 | 37 | 231 | 11 | | | | 2 | 1 | 6 | 3 | 1 | 3 | 1 | 1 | 348 |
| Sauger | Sander canadense | 6 | 4 | 16 | | 3 | 1 | 8 | 7 | | 6 | 11 | 4 | 4 | 4 | 10 | 16 | 8 | 6 | | 114 |
| Sauger x Walleye | S. canadense x vitrieum | | | | | | | | | | | 1 | | | | | | | | | 1 |
| Shorthead redhorse | Mox. macrolepidotum | 82 | 29 | 44 | 1 | | 7 | 2 | 3 | 5 | 8 | 52 | 1 | | | 1 | | | | | 235 |
| Speckled chub | Macrhybopsis aestivalis | | | | | | | | | | | | | 5 | 20 | 2 | | 5 | 2 | 3 | 37 |
| Smallmouth buffalo | Ichthiobus bubalus | 22 | | 3 | 1 | | 3 | 4 | 4 | | 5 | 3 | | | | 1 | 3 | 5 | 2 | 4 | 60 |
| Smallmouth bass | Micropterus dolomieu | | | | 1 | | | 1 | | 19 | 36 | 52 | 1 | | | | | | | | 110 |
| Suckermouth min. | Phenacobius mirabilis | | | | | | | | | | | | | | | | | | 2 | | 2 |
| Shortnose gar | Lepisosteus platostomus | | | | | | | | | | 2 | 10 | 4 | 1 | 9 | 9 | 16 | 32 | 32 | 13 | 128 |
| Shovelnose sturg. | Scaphir. platorynchus | 2 | 5 | 12 | 3 | 9 | 4 | 28 | 24 | | 1 | 12 | 8 | 7 | 3 | 30 | 47 | 40 | 7 | 6 | 248 |
| Sand shiner | Notropis stramineus | | | | | | | | | 1 | 5 | 115 | | | 1 | 3 | 1 | 4 | 18 | 1 | 149 |
| Spotted bass | Micropterus punctulatus | | | | | | | | | | | | | | | | | 2 | | | 2 |
| Stonecat | Noturus flavus | 3 | 1 | 1 | | 1 | | 22 | 14 | | 1 | 1 | 1 | | | | | | | | 45 |
| Spotted gar | Lepisosteus oculatus | | | | | | | | | | | | | | | 1 | | | | | 1 |
| Spottail shiner | Notropis hudsonius | 36 | | 86 | 119 | 4 | 4 | | | 1 | | 6 | | 2 | | | | | | | 258 |
| Silver chub | Macrhybopsis storeriana | | | | | | | | | | | | | | 7 | 36 | 61 | 16 | 15 | 13 | 148 |
| Threadfin shad | Dorosoma petenense | | | | | | | | | | | | 1 | | | | | | | | 1 |
| Unidentified buffalo | Ichthiobus sp. | 15 | | | | | | 2 | | | | | | | | | | | | | 17 |
| Unident. sunfish | Unident. Centrarchidae | | | | | | | | | | 14 | | | | | | 2 | | | | 16 |
| Unident. carpsucker | Carpiodes sp. | | | | | | | | | | | | 1 | | 1 | | | | | | 2 |
| Unident. sucker | Unident. Catostomidae | 113 | | 2 | 2 | 4 | 3 | 325 | 10 | 442 | 27 | 245 | | | | | | 1 | | | 1174 |
| Unident. minnow | Unident. Cyprinidae | 3 | | 31 | 2 | 1 | 5 | 185 | 13 | 22 | | | 4 | | 136 | | 4 | | 1 | | 407 |
| Unident. Lepomis | Lepomis sp. | | | | | | | | | 3 | 2 | 1 | | | | 2 | 2 | 1 | | | 11 |

| Common name | Scientific name | 3 | 4 | 5 | **6** | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *18* | *19* | *21* | *22* | *23* | *25* | *27* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unident. shiner | Notropis sp. | | | | | | | | | | 42 | 41 | | | 7 | | | | | | 90 |
| Unident. redhorse | Moxostoma sp. | | | | | | | | | | | | 2 | | | | | | | | 2 |
| Unid. Stizostedion | Stizostedion sp. | 2 | | 7 | | | 1 | | 10 | | | | | | | | | | | | 20 |
| Unidentified | Unidentified | | | 7 | | 12 | 2 | 4 | | | | | 2 | | | | | | | | 27 |
| Walleye | Sander vitreum | | | 5 | 2 | | 2 | 1 | | 16 | 15 | 6 | 2 | 1 | 1 | 1 | | 1 | 1 | | 54 |
| W. silvery minnow | Hybognathus argyritis | | | | | | | | | | | 1 | | | 2 | | | | | | 3 |
| White bass | Morone chrysops | | | | | | | | | 1 | | 83 | | 7 | 6 | 18 | 10 | 16 | 2 | 4 | 147 |
| White crappie | Pomoxis annularis | 15 | | 11 | | 1 | 37 | 20 | 213 | | 764 | 12 | 1 | 4 | 10 | 2 | 2 | | 9 | 4 | 1105 |
| White perch | Morone americana | | | | | | | | | | | | | 1 | 1 | | | | | | 2 |
| White sucker | Catostomus commersoni | 35 | 40 | | 19 | 103 | 101 | 13 | 2 | 137 | | | | | | | | | | | 450 |
| Age-0 fish | Unidentified | | | 5 | | | | 380 | | | 39 | 194 | | | | | | | | | 618 |
| Yellow perch | Perca flavescens | | | 33 | | | 2 | | | 13 | 62 | 18 | | | | | | | | | 128 |
| | | 1981 | 276 | 1371 | 207 | 212 | 445 | 3267 | 623 | 1032 | 1668 | 4340 | 403 | 1029 | 2737 | 1170 | 1705 | 1719 | 1410 | 1848 | |
| | | | | | | | | | | | | | | | | | | | | | Total = 27,443 |

Table A1-4. Year 1997: total fish and unidentified specimens collected from the warm water, mainstem Missouri River during the Benthic Fishes Study. Segments 3, 5, and 9 are in the least altered zone. Segments **7-15** are in the inter-reservoir zone. Segments *17-27* are in the channelized zone.

| Common name | Scientific name | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bigeye shiner | Notropis boops | | | | | | | | | | | | 1 | | | 1 | 2 |
| Bighead carp | Hypopthalmichthys nobilis | | | | | | | | | | | | | | 1 | 2 | 3 |
| Bullhead minnow | Pimephales vigilax | | | | | | | | | | | | 2 | | 1 | 3 | 6 |
| Black buffalo | Ichthiobus niger | | | | | | | | | | | | | 2 | | | 2 |
| Black bullhead | Ameiurus melas | | | | | | 1 | | 3 | | | | | | | | 4 |
| Black crappie | Pomoxis nigromaculatus | 1 | 52 | | | | | | 2 | 7 | 2 | 2 | 5 | | 5 | | 76 |
| Brook stickleback | Culaea inconstans | | | | 1 | | | | | | | | | | | | 1 |
| Brook silverside | Labidesthes sicculus | | | | | | | | | | | 6 | | | 1 | 1 | 8 |
| Blue catfish | Ictalurus furcatus | | | | | | | | | | | | 20 | 33 | 12 | 22 | 87 |
| Bluegill | Lepomis macrochirus | | | | | | | | 3 | 12 | 28 | 11 | 67 | 53 | 124 | 81 | 379 |
| Bigmouth buffalo | Ichthiobus cyprinellus | | 2 | 1 | 97 | | 112 | 32 | 2 | 14 | 15 | 7 | 2 | 1 | 5 | | 290 |
| Bigmouth shiner | Notropis dorsalis | | | | | | | | | 50 | 15 | | | | 13 | 5 | 83 |
| Bluntnose minnow | Pimephales notatus | | | | | | | | | 1 | | | | | 6 | 13 | 20 |
| Burbot | Lota lota | 3 | 66 | | 1 | 2 | 13 | | 1 | 1 | | | | | | | 87 |
| Brassy minnow | Hybognathus hankinsoni | | | | | | | | 1 | 13 | | | | | | | 14 |
| Blue sucker | Cycleptus elongatus | 3 | 3 | 6 | 1 | 6 | | 1 | | 15 | 31 | 7 | 11 | 11 | 1 | | 96 |
| Common carp | Cyprinus carpio | 62 | 63 | 20 | 209 | 8 | 29 | 46 | 137 | 176 | 20 | 59 | 90 | 98 | 113 | 105 | 1235 |
| Creek chub | Semotilus atromaculatus | | | | | 3 | | 1 | | | | | 2 | | | | 6 |
| Common shiner | Luxilus cornutus | | | | | | | | | | | | | | | 2 | 2 |
| Channel catfish | Ictalurus punctatus | 28 | 124 | 22 | 42 | 190 | 67 | 16 | 210 | 161 | 112 | 47 | 210 | 374 | 173 | 333 | 2109 |
| Chestnut lamprey | Ichthyomyzon castaneus | | | | | | | | | | | | | | 2 | | 2 |
| Chinook salmon | Oncorhy. tshawytscha | | | 1 | | | | | | | | | | | | | 1 |
| Cisco | Coregonus artedi | | | 6 | | | | 2 | | | | | | | | | 8 |
| Emerald shiner | Notropis atherinoides | 343 | 636 | 1 | | 143 | 28 | | 241 | 1598 | 204 | 514 | 647 | 685 | 1175 | 676 | 6891 |
| Flathead chub | Platygobio gracilis | 509 | 1360 | 69 | 124 | 2602 | 371 | | 4 | 7 | 1 | 1 | 2 | 2 | 1 | 1 | 5054 |
| Flathead catfish | Pylodictus olivaris | | | | | | | | 2 | 57 | 42 | 61 | 74 | 80 | 32 | 50 | 398 |
| Fathead minnow | Pimephales promelas | | | 102 | | 2 | | 84 | 5 | 7 | 5 | 9 | 3 | 1 | 1 | | 219 |
| Freckled madtom | Noturus nocturnus | | | | | | | | | | | | | | | 3 | 3 |
| Freshwater drum | Aplodinotus grunniens | 69 | 44 | 1 | 2 | 2 | 2 | | 7 | 70 | 5 | 17 | 331 | 186 | 95 | 115 | 946 |
| Goldeye | Hiodon alosoides | 43 | 206 | 121 | 274 | 133 | 249 | 25 | 37 | 112 | 221 | 77 | 34 | 50 | 33 | 50 | 1665 |
| Golden redhorse | Moxostoma erythrurum | | | | | | | | | | 1 | | 2 | 14 | | | 17 |

| Common name | Scientific name | 3 | 5 | 7 | 8 | 9 | 10 | 12 | 14 | 15 | 17 | 19 | 22 | 23 | 25 | 27 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Golden shiner | Notemigonus crysoleucas | | | | | | 2 | | | | | 1 | | | | | 3 |
| Gr. sunfish x unknown | Lepomis cyanellus x sp. | | | | | | | | | | | 1 | | | | | 1 |
| Green sunfish | Lepomis cyanellus | | | | | 2 | | | 1 | 9 | | 2 | 55 | 48 | 9 | 9 | 135 |
| Gr. sunfish x bluegill | L. cyanellus x macrochirus | | | | | | | | | | | 8 | | | | | 8 |
| Grass carp | Ctenopharyngodon idella | | | | | | | | | 3 | 1 | 2 | 1 | | 2 | 1 | 10 |
| Gr. sunfish x Orange. | L. cyanellus x humilis | | | | | | | | | 1 | | | | | | | 1 |
| Ghost shiner | Notropis buchanani | | | | | | | | | | | | 1 | | | | 1 |
| Gizzard shad | Dorosoma cepedianum | | | | | | | | | 3264 | 2175 | 1644 | 371 | 580 | 831 | 3700 | 12565 |
| Hybognathus spp. | Hybognathus sp. | 64 | 1559 | 15 | 8 | 716 | | | | | 23 | 227 | 342 | 397 | 1784 | 296 | 5431 |
| Highfin carpsucker | Carpiodes velifer | | | | | | | | | 1 | | | 1 | | | 2 | 4 |
| Johnny darter | Etheostoma nigrum | | | | | | | 7 | 35 | 16 | 2 | 3 | | | | 1 | 64 |
| Logperch | Percina caprodes | | | | | | | | | | | | | 1 | 4 | | 5 |
| Lake sturgeon | Acipenser fulvescens | | | | | | | | | | | | | | 3 | 1 | 4 |
| Lake whitefish | Coregonus clupeaformis | | | | 2 | | | | | | | | | | | | 2 |
| Largemouth bass | Micropterus salmoides | | | | | | | | 49 | 24 | 19 | 8 | 26 | 5 | 16 | 3 | 150 |
| Longnose dace | Rhinichthys cataractae | 69 | 46 | 3 | 12 | 91 | 4 | | | | | | | | | | 225 |
| Longnose gar | Lepisosteus osseus | | | | | | | | | 18 | 2 | 3 | 4 | 15 | 13 | 15 | 70 |
| Longnose sucker | Catostomus catostomus | 129 | 9 | 23 | 2 | 2 | 1 | 2383 | | | | | | | | | 2549 |
| Largescale stoneroller | Campostoma oligolepis | | | | | | | | | | | | | | 2 | | 2 |
| Mottled sculpin | Cottus bairdi | 1 | 4 | | | | | | | | | | | | | | 5 |
| Mimic shiner | Notropis volucellus | | | | | | | | | 3 | 2 | | 3 | | | 57 | 65 |
| West. Mosquitofish | Gambusia affinis | | | | | | | | | | | | | 8 | 6 | 101 | 115 |
| Muskellunge | Esox masquinongy | | | | | | | 1 | | | | | | | | | 1 |
| Northern pike | Esox lucius | 3 | 20 | 20 | 18 | 8 | 27 | 4 | 7 | 12 | 3 | 2 | | | | | 124 |
| Orangespotted sunfish | Lepomis humilis | | | | | | | | | 2 | | 2 | 65 | 4 | 4 | 7 | 84 |
| Paddlefish | Polyodon spathula | | | | | | 1 | | 1 | | 2 | 1 | | | | 1 | 6 |
| Pallid sturgeon | Scaphirhynchus albus | | | | | | 1 | | | | | | | | | | 1 |
| Plains minnow | Hybognathus placitus | | | 2 | | | 20 | | | | | | | | 14 | 6 | 42 |
| Quillback | Carpiodes cyprinus | | | | | | | | 21 | 642 | 8 | 4 | 7 | 11 | 1 | 6 | 700 |
| Rainbow smelt | Osmerus mordax | | | | | | | 14 | 1 | 1 | | | | | 1 | | 17 |
| Rainbow trout | Oncorhynchus mykiss | 1 | | 3 | | | | | | | | | | | | | 4 |
| Red shiner | Cyprinella lutrensis | | | | | | | 4 | 19 | 144 | 65 | 13 | 65 | 101 | 162 | 510 | 1083 |

| Common name | Scientific name | 3 | 5 | 7 | 8 | 9 | 10 | 12 | 14 | 15 | 17 | 19 | 22 | 23 | 25 | 27 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rock bass | Ambloplites rupestris | | | | | | | | 6 | 8 | | | | | | | 14 |
| River carpsucker | Carpiodes carpio | 17 | 54 | 36 | 23 | 135 | 44 | 24 | 72 | 181 | 38 | 483 | 151 | 59 | 1286 | 915 | 3518 |
| River redhorse | Moxostoma carinatum | | | | | | | | | | | | 1 | | | | 1 |
| River shiner | Notropis blennius | | | | | | | | 1 | 166 | 125 | 28 | 55 | 38 | 95 | 29 | 537 |
| Silverband shiner | Notropis shumardi | | | | | | | | | | | | 1 | | | 1 | 2 |
| Striped bass x W. bass | M. saxatilis x chrysops | | | | | | | | | | | | | 1 | | | 1 |
| Striped bass | Morone saxatilis | | | | | | | | | | | | | 1 | 1 | 4 | 6 |
| Sicklefin chub | Macrhybopsis meeki | | 109 | | 18 | 34 | 7 | | | | | | 3 | 4 | 13 | 24 | 212 |
| Spotfin shiner | Cyprinella spiloptera | | | | | | | | 513 | 554 | 94 | 8 | | 2 | | | 1171 |
| Sturgeon chub | Macrhybopsis gelida | | 161 | 9 | 48 | 285 | 17 | | | | 2 | | 4 | 11 | 8 | 1 | 546 |
| Sauger | Sander canadense | 16 | 36 | 6 | 7 | 10 | 30 | 3 | 11 | 10 | 15 | 21 | 17 | 6 | 11 | 4 | 203 |
| Sauger x Walleye | S. canadense x vitrieum | | | | | | | 1 | | 4 | | 5 | | | | | 10 |
| Shorthead redhorse | Moxostoma macrolepidotum | 114 | 121 | 8 | 29 | 13 | 6 | 13 | 3 | 149 | 33 | | | 6 | 4 | 3 | 502 |
| Skipjack herring | Alosa chrysochloris | | | | | | | | | | | | | 1 | 3 | 4 | 8 |
| Speckled chub | Macrhybopsis aestivalis | | | | | | | | | | | 23 | | 13 | 39 | 176 | 251 |
| Smallmouth buffalo | Ichthiobus bubalus | 3 | | 4 | 34 | 6 | 45 | 1 | 10 | 93 | 12 | 2 | 6 | 8 | 18 | 28 | 270 |
| Smallmouth bass | Micropterus dolomieu | 1 | | | | | | | 77 | 138 | 2 | | | | | | 218 |
| Suckermouth minnow | Phenacobius mirabilis | | | | | | | | | | | | | 4 | | 4 | 8 |
| Shortnose gar | Lepisosteus platostomus | | | | | 1 | | | | 19 | 16 | 22 | 42 | 53 | 38 | 93 | 284 |
| Shovelnose sturgeon | Scaphirhyn. platorynchus | 16 | 55 | 43 | 22 | 93 | 20 | 6 | 4 | 11 | 78 | 24 | 68 | 63 | 43 | 19 | 565 |
| Sand shiner | Notropis stramineus | | | | | | | | 7 | 236 | 27 | 1 | 4 | 1 | 5 | 85 | 366 |
| Striped shiner | Luxilus chrysocephalus | | | | | | | | | | | | | | | 1 | 1 |
| Spotted bass | Micropterus punctulatus | | | | | | | | | | | | | 1 | 24 | 17 | 42 |
| Stonecat | Noturus flavus | 2 | 71 | 2 | 4 | 39 | 5 | | 3 | | | | 2 | 2 | | | 130 |
| Spotted gar | Lepisosteus oculatus | | | | | | | | | | | | | | 1 | | 1 |
| Spottail shiner | Notropis hudsonius | 5 | 81 | | 2 | 1 | 1 | 3 | 1 | 4 | 2 | | | | | | 100 |
| Silver chub | Macrhybopsis storeriana | | | | | | | | | | 4 | 39 | 76 | 32 | 11 | 53 | 215 |
| Unidentified buffalo | Ictiobus sp. | 2 | | | | | | | | | | | | | | | 2 |
| Unidentified sunfish | Unident. Centrarchidae | | | | | | | | | | | | 49 | 1 | | | 50 |
| Unident. carpsucker | Carpiodes sp. | | | | | | | | | | 2 | | | | | | 2 |
| Unidentified sucker | Unident. Catostomidae | 7 | | | 1 | 2 | 156 | 86 | | 4 | 2 | | 1 | | | | 259 |
| Unidentified minnow | Unidentified Cyprinidae | 46 | | | | 1 | 21 | 2 | | | | 1 | 70 | 61 | 7 | 16 | 225 |
| Unidentified chub | Macrhybopsis sp. | | | | | | 5 | | | | | | | | 2 | | 7 |

| Common name | Scientific name | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unidentified Lepomis | Lepomis sp. | | | | | | 1 | | | | | | 25 | | | | 26 |
| Unidentified shiner | Notropis sp. | | | | | | | | | | 29 | 212 | 1 | | 1 | 4 | 247 |
| Unidentified redhorse | Moxostoma sp. | | | | | | | | | | 1 | | | | | | 1 |
| Unident. Stizostedion | Stizostedion sp. | | | | 6 | | 34 | 1 | | | | | | | | | 41 |
| Unidentified | Unidentified | 22 | 2 | | | | | | | | | | | | 28 | | 52 |
| Walleye | Sander vitreum | 11 | 23 | 5 | 45 | 10 | 16 | 23 | 38 | 137 | 12 | 8 | 1 | 2 | | 2 | 333 |
| West. silvery minnow | Hybognathus argyritis | | | 8 | 2 | 5 | 280 | | | | | | | | | | 295 |
| White bass | Morone chrysops | | | | 2 | | | | 9 | 94 | 9 | 6 | 32 | 47 | 33 | 53 | 285 |
| White crappie | Pomoxis annularis | 4 | 54 | | 3 | 6 | 9 | | 137 | 9 | 3 | 5 | 18 | 5 | 9 | | 262 |
| White sucker | Catostomus commersoni | 44 | 2 | 64 | 45 | | 1 | 1108 | 1 | 1 | | | | | | | 1266 |
| Yellow bullhead | Ameiurus natalis | | | | | | | | | | 1 | 2 | 1 | | | | 4 |
| Age-0 fish | Unidentified | | | | | 2 | | | | | | | | 4 | | | 6 |
| Yellow bass | Morone mississippiensis | | | | | | | | | | | | | | | 4 | 4 |
| Yellow perch | Perca flavescens | 2 | 23 | | | | 1 | 6 | 289 | 118 | 7 | | | | | | 446 |
| | | 1640 | 4986 | 601 | 1084 | 4553 | 1627 | 3897 | 1971 | 8377 | 3518 | 3629 | 3072 | 3186 | 6326 | 7719 | |

Table A1-5. Year 1998: total fish and unidentified specimens collected from the warm water, mainstem Missouri River during the Benthic Fishes Study. Segments 3, 5, and 9 are in the least altered zone. Segments **7-15** are in the inter-reservoir zone. Segments *17-27* are in the channelized zone.

| Common name | Scientific name | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bigeye shiner | Notropis boops | | | | | | | | | | | | | | | 3 | 3 |
| Bighead carp | Hypopthalmichthys nobilis | | | | | | | | | | | | 3 | | 1 | 8 | 12 |
| Bullhead minnow | Pimephales vigilax | | | | | | | | | | | | 1 | 3 | | | 4 |
| Black bullhead | Ameiurus melas | | | | | 2 | 4 | | | | | | | | | | 6 |
| Black crappie | Pomoxis nigromaculatus | 8 | 68 | | | | | | 6 | | | | 2 | 1 | 1 | | 86 |
| Brook silverside | Labidesthes sicculus | | | | | | | | | | | | | | 7 | | 7 |
| Blue catfish | Ictalurus furcatus | | | | | | | | | | | 1 | 44 | 51 | 39 | 56 | 191 |
| Bluegill | Lepomis macrochirus | | | | | | | | 46 | 11 | 2 | 1 | 17 | 21 | 34 | 19 | 151 |
| Bigmouth buffalo | Ichthiobus cyprinellus | | | 6 | 5 | 3 | 184 | 1 | 4 | 5 | 2 | 1 | 1 | | 1 | | 213 |
| Bigmouth shiner | Notropis dorsalis | | | | | | | | | 14 | 1 | | 2 | | 2 | 1 | 20 |
| Bluntnose minnow | Pimephales notatus | | | | | | | | 3 | | | | | | 7 | 9 | 19 |
| Brown trout | Salmo trutta | | 1 | | | | | | | | | | | | | | 1 |
| Burbot | Lota lota | 7 | 15 | 3 | 2 | 16 | 21 | 4 | | | | | | | | | 68 |
| Blue sucker | Cycleptus elongatus | 3 | 2 | 2 | 4 | 3 | | | | 18 | 21 | 2 | 5 | 6 | | 6 | 72 |
| Bowfin | Amia calva | | | | | | | | | | | | | | | 1 | 1 |
| Common carp | Cyprinus carpio | 56 | 72 | 81 | 68 | 149 | 314 | 30 | 43 | 144 | 63 | 70 | 49 | 31 | 55 | 83 | 1308 |
| Creek chub | Semotilus atromaculatus | | | 5 | 30 | 25 | | | | | | | | | | | 60 |
| Channel catfish | Ictalurus punctatus | 26 | 49 | 40 | 33 | 254 | 52 | 11 | 164 | 77 | 426 | 234 | 392 | 279 | 275 | 243 | 2555 |
| Cisco | Coregonus artedi | 1 | | 1 | | | | 1 | | | | | | | | | 3 |
| Emerald shiner | Notropis atherinoides | 856 | 1557 | 83 | 41 | 467 | 74 | 5 | 852 | 1168 | 221 | 368 | 266 | 264 | 1132 | 780 | 8134 |
| Flathead chub | Platygobio gracilis | 1169 | 826 | 96 | 677 | 1696 | 308 | | | | | | 2 | | | 1 | 4775 |
| Flathead catfish | Pylodictus olivaris | | | | | | | | 1 | 46 | 61 | 110 | 48 | 96 | 67 | 82 | 511 |
| Fathead minnow | Pimephales promelas | | | 88 | 62 | 92 | 6 | 12 | 3 | 1 | 6 | 3 | 1 | 1 | | | 275 |
| Freckled madtom | Noturus nocturnus | | | | | | | | | | | | | | | 5 | 5 |
| Freshwater drum | Aplodinotus grunniens | 41 | 46 | 9 | 10 | 12 | 9 | | 40 | 272 | 124 | 299 | 160 | 75 | 158 | 83 | 1338 |
| Goldeye | Hiodon alosoides | 69 | 87 | 299 | 400 | 432 | 169 | 35 | 14 | 58 | 59 | 20 | 21 | 19 | 32 | 19 | 1733 |
| Goldfish | Carassius auratus | | | | | | | | | | | | 3 | 2 | | | 5 |
| Golden shiner | Notemigonus crysoleucas | | | | | | 2 | | 1 | 55 | | | | 1 | | | 59 |
| Green sunfish | Lepomis cyanellus | | | | | 1 | | | 4 | 3 | 1 | | 6 | 15 | 3 | 10 | 43 |
| Gr. sunfish x Bluegill | L. cyanellus x macrochirus | | | | | | | | 2 | | | | | | | | 2 |
| Grass carp | Ctenopharyngodon idella | | | | | | | | | 2 | | | | | | 1 | 3 |

| Common name | Scientific name | 3 | 5 | 7 | 8 | 9 | 10 | 12 | 14 | 15 | 17 | 19 | 22 | 23 | 25 | 27 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grass pickerel | Esox amer. vermiculatus | | | | | | | | | 1 | | | | | | | 1 |
| Gizzard shad | Dorosoma cepedianum | | | | | | | | 4 | 439 | 198 | 121 | 4043 | 482 | 869 | 2005 | 8161 |
| Hybognathus spp. | Hybognathus sp. | 352 | 2304 | 23 | 20 | 1573 | | | 5 | 1 | | | 195 | 381 | 499 | 265 | 5618 |
| Highfin carpsucker | Carpiodes velifer | | | | | | | | | | | | | | 1 | | 1 |
| Johnny darter | Etheostoma nigrum | | | | | | | 6 | 25 | 4 | 2 | | | | | | 37 |
| Lake sturgeon | Acipenser fulvescens | | | | | | | | | | | | | | 1 | | 1 |
| Largemouth bass | Micropterus salmoides | | | | | | | | 12 | 3 | 1 | | 4 | 2 | 1 | | 23 |
| Longnose dace | Rhinichthys cataractae | 10 | 28 | 2 | | 88 | 1 | | | | | | | | | | 129 |
| Longnose gar | Lepisosteus osseus | | | | | | | | | 17 | 5 | 2 | 19 | 7 | 24 | 11 | 85 |
| Longnose sucker | Catostomus catostomus | 16 | 11 | 12 | 1 | 3 | 5 | 2277 | | | | | | | | | 2325 |
| Larval fish | Unidentified | | | 14 | | | | | | | 1 | | | | | 1 | 16 |
| Mottled sculpin | Cottus bairdi | 5 | 1 | | | | | | | | | | | | | | 6 |
| Mimic shiner | Notropis volucellus | | | | | | | | 1 | 1 | | | | | | 33 | 35 |
| West. Mosquitofish | Gambusia affinis | | | | | | | | | | | | 3 | 6 | 20 | 76 | 105 |
| Northern pike | Esox lucius | 2 | 2 | 32 | 28 | 30 | 28 | 1 | 8 | 3 | 1 | | | | 1 | | 136 |
| Orangespotted sunfish | Lepomis humilis | | | | | | | | | 2 | | | 5 | 4 | 1 | 8 | 20 |
| Paddlefish | Polyodon spathula | | | | 1 | | | | | | | | | 1 | 2 | 2 | 6 |
| Pallid sturgeon | Scaphirhynchus albus | | | | | 2 | | | | | | | 1 | | | | 3 |
| Plains minnow | Hybognathus placitus | | | | | | 3 | | | | | 12 | | | | | 15 |
| Quillback | Carpiodes cyprinus | | | | | | | | 19 | 1203 | | | 1 | | 2 | | 1225 |
| Rainbow trout | Oncorhynchus mykiss | | | 11 | | | | | | | | | | | | | 11 |
| Red shiner | Cyprinella lutrensis | | | | | | | | 26 | 69 | 10 | 1 | 9 | 14 | 72 | 883 | 1084 |
| Rock bass | Ambloplites rupestris | | | | | | | | 6 | | | | | | | | 6 |
| River carpsucker | Carpiodes carpio | 27 | 67 | 345 | 197 | 750 | 12 | 20 | 105 | 141 | 208 | 207 | 49 | 61 | 89 | 130 | 2408 |
| River shiner | Notropis blennius | | | | | | | | 7 | 27 | 51 | 22 | 30 | 10 | 10 | | 157 |
| Striped bass x W. bass | Morone saxatilis x chrysops | | | | | | | | | | | | | 4 | | | 4 |
| Slender madtom | Noturus exilis | | | | | | | | | | | | 1 | | | | 1 |
| Sicklefin chub | Macrhybopsis meeki | | 137 | | 57 | 84 | 36 | | | | | | 2 | | 53 | 40 | 409 |
| Spotfin shiner | Cyprinella spiloptera | | | | | | | | 134 | 193 | 50 | 23 | | | | | 400 |
| Sturgeon chub | Macrhybopsis gelida | 1 | 373 | 14 | 40 | 712 | 4 | | | | | 1 | 7 | 2 | 1 | 2 | 1157 |
| Sauger | Sander canadense | 31 | 54 | 15 | 39 | 50 | 18 | 2 | 4 | 58 | 12 | 1 | 4 | 3 | 4 | 2 | 297 |
| Sauger x Walleye | S. canadense x vitrieum | | | | | | | | | 1 | | | | | | | 1 |
| Shorthead redhorse | Moxost. macrolepidotum | 161 | 61 | 22 | 89 | 54 | 9 | 4 | 11 | 36 | 10 | | | 2 | 1 | 3 | 463 |
| Skipjack herring | Alosa chrysochloris | | | | | | | | | | | | | | 1 | 1 | 2 |

| Common name | Scientific name | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Speckled chub | Macrhybopsis aestivalis | | | | | | | | | | | | | 6 | 20 | 12 | 38 |
| Smallmouth buffalo | Ichthiobus bubalus | 2 | 6 | 30 | 6 | 11 | 61 | | 2 | 1 | 2 | 8 | 3 | 3 | 5 | 15 | 155 |
| Smallmouth bass | Micropterus dolomieu | 1 | | | 2 | | | | 34 | 40 | 2 | | | | | | 79 |
| Shortnose gar | Lepisosteus platostomus | | | | 1 | | | | 7 | 15 | 10 | 27 | 47 | 40 | 23 | 32 | 202 |
| Shovelnose sturgeon | Scaphirhynchus platorynchus | 13 | 56 | 48 | 25 | 132 | 19 | 44 | 12 | 39 | 17 | 43 | 75 | 115 | 76 | 33 | 747 |
| Sand shiner | Notropis stramineus | | | | | | | | | 32 | 29 | 2 | 14 | 6 | 15 | 80 | 178 |
| Spotted bass | Micropterus punctulatus | | | | | | | | | | | | | | 12 | 2 | 14 |
| Stonecat | Noturus flavus | 4 | 20 | 2 | 24 | 79 | 15 | | | 3 | | 1 | 4 | 4 | 2 | 9 | 167 |
| Spottail shiner | Notropis hudsonius | 5 | 3 | 13 | 56 | 34 | 19 | | 2 | 3 | | | | | | | 135 |
| Silver chub | Macrhybopsis storeriana | | | | | | | | 8 | 1 | 9 | 3 | 21 | 7 | 11 | | 60 |
| Tadpole madtom | Noturus gyrinus | | | | | | | | | | | | 1 | | | | 1 |
| Unidentified sunfish | Unidentified Centrarchidae | | | | | | | | | | | | 8 | 4 | | | 12 |
| Unident. carpsucker | Carpiodes sp. | | | | | | | | 38 | 299 | | 2 | | | | | 339 |
| Unidentified sucker | Unidentified Catostomidae | 19 | 2 | 7 | | | 67 | 460 | | | | | | | | | 555 |
| Unidentified minnow | Unidentified Cyprinidae | | 1 | 2 | | 22 | 3 | | 3 | | 1 | 9 | 9 | 10 | 4 | 25 | 89 |
| Unidentified chub | Macrhybopsis sp. | | | | | | | | | | | | | | 8 | 1 | 9 |
| Unidentified shiner | Notropis sp. | | | | | | | | | | 6 | 2 | | | 1 | 50 | 59 |
| Unidentified redhorse | Moxostoma sp. | | | | | | | | | | 1 | | | | | | 1 |
| Unid. Stizostedion | Stizostedion sp. | | | 3 | 19 | 3 | 43 | 2 | | | | | | | | | 70 |
| Unidentified | Unidentified | | | 13 | | | | | | | | | | | 3 | 36 | 52 |
| Walleye | Sander vitreum | 17 | 13 | 3 | 32 | 46 | 5 | 9 | 23 | 18 | 7 | | | 1 | | | 174 |
| West. silvery minnow | Hybognathus argyritis | | | | | | 76 | | | | | | | | | | 76 |
| White bass | Morone chrysops | | | | 1 | 8 | | | 31 | 20 | 10 | 8 | 4 | 12 | 8 | 8 | 110 |
| White crappie | Pomoxis annularis | 4 | 4 | 2 | 26 | 26 | 7 | | 24 | 17 | | | 1 | | | 2 | 113 |
| White sucker | Catostomus commersoni | 1 | 1 | 209 | 124 | 27 | 3 | 117 | 5 | 1 | | | | | | | 488 |
| Yellow bullhead | Ameiurus natalis | | | | | | 1 | | | | | 1 | | | | | 2 |
| Age-0 fish | Unidentified | | | 1 | 1 | 74 | | | 9 | 314 | | | 1 | 2 | | | 402 |
| Yellow bass | Morone mississippiensis | | | | | | | | | | | | | | 1 | 1 | 2 |
| Yellow perch | Perca flavescens | | 2 | 13 | 24 | | 6 | 4 | 141 | 4 | | | | | | | 194 |
| | | 2907 | 5869 | 1549 | 2145 | 6960 | 1584 | 3045 | 1889 | 4880 | 1630 | 1605 | 5584 | 2054 | 3655 | 5178 | |

Table A1-6. Total catch (132,914) of mainstem Missouri River fishes in five gear types, 1996-1998. Total does not include fish caught with other gear or larval or age-0 fish (n = 1,073).

| Common name | Scientific name | Seine | Trawl | Trammel | Gill Net | Electro | Total | Percent |
|---|---|---|---|---|---|---|---|---|
| Banded killifish | Fundulus diaphanus | 4 | 0 | 0 | 0 | 0 | 4 | 0.003 |
| Bigeye shiner | Notropis boops | 3 | 0 | 0 | 0 | 2 | 5 | 0.004 |
| Bighead carp | Hypopthalmichthys nobilis | 5 | 1 | 5 | 0 | 11 | 22 | 0.016 |
| Bullhead minnow | Pimephales vigilas | 4 | 0 | 0 | 0 | 7 | 11 | 0.008 |
| Black buffalo | Ictiobus niger | 0 | 0 | 1 | 1 | 0 | 2 | 0.001 |
| Black bullhead | Ameiurus melas | 2 | 0 | 0 | 6 | 8 | 16 | 0.012 |
| Black crappie | Pomoxis nigromaculatus | 10 | 0 | 1 | 34 | 153 | 198 | 0.148 |
| Brook stickleback | Culaea inconstans | 2 | 0 | 0 | 0 | 0 | 2 | 0.001 |
| Brook silverside | Labidesthes sicculus | 2 | 0 | 0 | 0 | 14 | 16 | 0.012 |
| Blue catfish | Ictalurus furcatus | 43 | 229 | 13 | 30 | 67 | 382 | 0.285 |
| Bluegill | Lepomis macrochirus | 122 | 6 | 0 | 8 | 534 | 670 | 0.499 |
| Bigmouth buffalo | Ictiobus cyprinellus | 167 | 1 | 0 | 13 | 331 | 512 | 0.382 |
| Bigmouth shiner | Notropis dorsalis | 108 | 0 | 0 | 0 | 1 | 109 | 0.081 |
| Bluntnose minnow | Pimephales notatus | 20 | 1 | 0 | 0 | 21 | 42 | 0.031 |
| Brown trout | Salmo trutta | 0 | 0 | 0 | 1 | 0 | 1 | 0.001 |
| Burbot | Lota lota | 3 | 9 | 4 | 0 | 204 | 220 | 0.164 |
| Brassy minnow | Hybognathus hankinsoni | 84 | 1 | 0 | 0 | 57 | 142 | 0.106 |
| Blue sucker | Cycleptus elongatus | 1 | 10 | 94 | 30 | 64 | 199 | 0.148 |
| Bowfin | Amia calva | 0 | 0 | 0 | 0 | 1 | 1 | 0.001 |
| Common carp | Cyprinus carpio | 326 | 13 | 52 | 254 | 2389 | 3034 | 2.261 |
| Creek chub | Semotilus atromaculatus | 62 | 2 | 0 | 0 | 3 | 67 | 0.050 |
| Common shiner | Luxilus cornutus | 0 | 0 | 0 | 0 | 2 | 2 | 0.001 |
| Channel catfish | Ictalurus punctatus | 1720 | 1415 | 297 | 764 | 1438 | 5634 | 4.199 |
| Chestnut lamprey | Ichthyomyzon castaneus | 0 | 0 | 0 | 0 | 2 | 2 | 0.001 |
| Chinook salmon | Oncorhynchus tshawytscha | 0 | 0 | 0 | 1 | 0 | 1 | 0.001 |
| Cisco | Coregonus artedi | 0 | 0 | 2 | 19 | 3 | 24 | 0.018 |
| Emerald shiner | Notropis atherinoides | 5841 | 20 | 0 | 0 | 14501 | 20362 | 15.177 |
| Flathead chub | Platygobio gracilis | 10767 | 112 | 78 | 0 | 1881 | 12838 | 9.569 |
| Flathead catfish | Pylodictis olivaris | 0 | 11 | 2 | 25 | 1418 | 1456 | 1.085 |
| Fathead minnow | Pimephales promelas | 537 | 0 | 0 | 0 | 202 | 739 | 0.551 |
| Freckled madtom | Noturus nocturnus | 0 | 0 | 0 | 0 | 8 | 8 | 0.006 |
| Freshwater drum | Aplodinotus grunniens | 822 | 556 | 1 | 97 | 1293 | 2769 | 2.064 |
| Goldeye | Hiodon alosoides | 536 | 10 | 290 | 2059 | 1100 | 3995 | 2.978 |
| Goldfish | Carassius auratus | 1 | 0 | 0 | 0 | 4 | 5 | 0.004 |
| Golden redhorse | Moxostoma erythrurum | 0 | 0 | 0 | 1 | 16 | 17 | 0.013 |
| Golden shiner | Notemigonus crysoleucas | 1 | 0 | 0 | 1 | 64 | 66 | 0.049 |
| Green sunfish x unk. | Lepomis cyanellus x sp. | 1 | 0 | 0 | 0 | 0 | 1 | 0.001 |

| Common name | Scientific name | Seine | Trawl | Trammel | Gill Net | Electro | Total | Percent |
|---|---|---|---|---|---|---|---|---|
| Green sunfish | Lepomis cyanellus | 17 | 0 | 0 | 4 | 189 | 210 | 0.157 |
| Gr. sunfish x Bluegill | L. cyanellus x macrochirus | 7 | 0 | 0 | 0 | 3 | 10 | 0.007 |
| Grass carp | Ctenopharyngodon idella | 0 | 0 | 1 | 3 | 12 | 16 | 0.012 |
| Gr. sunfish x Orangesp. | L. cyanellus x L. humilis | 0 | 0 | 0 | 0 | 2 | 2 | 0.001 |
| Grass pickerel | Esox americanus vermiculatus | 0 | 0 | 0 | 0 | 1 | 1 | 0.001 |
| Ghost shiner | Notropis buchanani | 1 | 0 | 0 | 0 | 1 | 2 | 0.001 |
| Gizzard shad | Dorosoma cepedianum | 5549 | 7 | 9 | 385 | 19977 | 25927 | 19.325 |
| Hybognathus spp. | Hybognathus sp. | 10545 | 18 | 0 | 0 | 2155 | 12718 | 9.480 |
| Highfin carpsucker | Carpiodes velifer | 0 | 0 | 2 | 1 | 3 | 6 | 0.004 |
| Johnny darter | Etheostoma nigrum | 59 | 3 | 0 | 0 | 68 | 130 | 0.097 |
| Longear sunfish | Lepomis megalotis | 0 | 0 | 0 | 1 | 0 | 1 | 0.001 |
| Logperch | Percina caprodes | 0 | 0 | 0 | 0 | 5 | 5 | 0.004 |
| Lake chub | Couesius plumbeus | 1 | 0 | 0 | 0 | 0 | 1 | 0.001 |
| Lake sturgeon | Acipenser fulvescens | 0 | 0 | 0 | 5 | 0 | 5 | 0.004 |
| Lake whitefish | Coregonus clupeaformis | 1 | 0 | 1 | 0 | 0 | 2 | 0.001 |
| Largemouth bass | Micropterus salmoides | 110 | 0 | 0 | 3 | 201 | 314 | 0.234 |
| Longnose dace | Rhinichthys cataractae | 156 | 272 | 0 | 0 | 25 | 453 | 0.338 |
| Longnose gar | Lepisosteus osseus | 7 | 0 | 29 | 128 | 19 | 183 | 0.136 |
| Longnose sucker | Catostomus catostomus | 4888 | 5 | 60 | 4 | 23 | 4980 | 3.712 |
| Largescale stoneroller | Campostoma oligolepis | 0 | 0 | 0 | 0 | 2 | 2 | 0.001 |
| Mottled sculpin | Cottus bairdi | 0 | 5 | 0 | 0 | 10 | 15 | 0.011 |
| Mimic shiner | Notropis volucellus | 68 | 2 | 0 | 0 | 30 | 100 | 0.075 |
| Mosquitofish | Gambusia affinis | 152 | 0 | 0 | 0 | 75 | 227 | 0.169 |
| Muskellunge | Esox masquinongy | 0 | 0 | 0 | 0 | 1 | 1 | 0.001 |
| Northern hog sucker | Hypentelium nigricans | 0 | 0 | 0 | 0 | 1 | 1 | 0.001 |
| Northern redbelly dace | Phoxinus eos | 1 | 0 | 0 | 0 | 0 | 1 | 0.001 |
| Northern pike | Esox lucius | 42 | 0 | 3 | 211 | 90 | 346 | 0.258 |
| Orangespotted sunfish | Lepomis humilis | 7 | 1 | 0 | 0 | 119 | 127 | 0.095 |
| Paddlefish | Polyodon spathula | 0 | 0 | 1 | 10 | 4 | 15 | 0.011 |
| Pallid sturgeon | Scaphirhynchus albus | 0 | 2 | 2 | 0 | 0 | 4 | 0.003 |
| Pearl dace | Margariscus margarita | 1 | 0 | 0 | 0 | 0 | 1 | 0.001 |
| Plains minnow | Hybognathus placitus | 52 | 1 | 0 | 0 | 4 | 57 | 0.042 |
| Quillback | Carpiodes cyprinus | 1726 | 1 | 31 | 75 | 128 | 1961 | 1.462 |
| Rainbow smelt | Osmerus mordax | 8 | 13 | 1 | 1 | 0 | 23 | 0.017 |
| Rainbow trout | Oncorhynchus mykiss | 15 | 2 | 0 | 0 | 4 | 21 | 0.016 |
| Red shiner | Cyprinella lutrensis | 895 | 4 | 0 | 0 | 1483 | 2382 | 1.775 |
| Rock bass | Ambloplites rupestris | 0 | 0 | 0 | 0 | 22 | 22 | 0.016 |
| River carpsucker | Carpiodes carpio | 4766 | 13 | 57 | 522 | 1315 | 6673 | 4.974 |
| River redhorse | Moxostoma carinatum | 0 | 0 | 0 | 1 | 2 | 3 | 0.002 |
| River shiner | Notropis blennius | 571 | 3 | 0 | 0 | 302 | 876 | 0.653 |

| Common name | Scientific name | Seine | Trawl | Trammel | Gill Net | Electro | Total | Percent |
|---|---|---|---|---|---|---|---|---|
| Silverband shiner | Notropis shumardi | 1 | 0 | 0 | 0 | 1 | 2 | 0.001 |
| Striped x White bass | M. saxatilis x chrysops | 0 | 0 | 0 | 5 | 0 | 5 | 0.004 |
| Striped bass | Morone saxatilis | 6 | 0 | 0 | 5 | 10 | 21 | 0.016 |
| Slender madtom | Noturus exilis | 0 | 0 | 0 | 0 | 1 | 1 | 0.001 |
| Sicklefin chub | Macrhybopsis meeki | 20 | 689 | 0 | 0 | 0 | 709 | 0.528 |
| Spotfin shiner | Cyprinella spiloptera | 588 | 0 | 0 | 0 | 1163 | 1751 | 1.305 |
| Sturgeon chub | Macrhybopsis gelida | 98 | 1946 | 0 | 0 | 7 | 2051 | 1.529 |
| Sauger | Sander canadense | 47 | 15 | 56 | 104 | 378 | 600 | 0.447 |
| Sauger x Walleye | S. canadense x vitrieum | 0 | 0 | 0 | 2 | 8 | 10 | 0.007 |
| Shorthead redhorse | Moxost. macrolepidotum | 264 | 7 | 114 | 81 | 719 | 1185 | 0.883 |
| Skipjack herring | Alosa chrysochloris | 0 | 0 | 0 | 6 | 4 | 10 | 0.007 |
| Speckled chub | Macrhybopsis aestivalis | 97 | 228 | 0 | 0 | 1 | 326 | 0.243 |
| Smallmouth buffalo | Ictiobus bubalus | 131 | 1 | 23 | 99 | 217 | 471 | 0.351 |
| Smallmouth bass | Micropterus dolomieu | 77 | 0 | 3 | 5 | 322 | 407 | 0.303 |
| Suckermouth minnow | Phenacobius mirabilis | 3 | 0 | 0 | 0 | 7 | 10 | 0.007 |
| Shortnose gar | Lepisosteus platostomus | 18 | 6 | 51 | 383 | 149 | 607 | 0.452 |
| Shovelnose sturgeon | Scaphirhynchus platorynchus | 4 | 158 | 991 | 376 | 8 | 1537 | 1.146 |
| Sand shiner | Notropis stramineus | 640 | 2 | 0 | 0 | 51 | 693 | 0.517 |
| Striped shiner | Luxilus chrysocephalus | 1 | 0 | 0 | 0 | 0 | 1 | 0.001 |
| Spotted bass | Micropterus punctulatus | 5 | 0 | 0 | 1 | 52 | 58 | 0.043 |
| Stonecat | Noturus flavus | 9 | 261 | 5 | 3 | 64 | 342 | 0.255 |
| Spotted gar | Lepisosteus oculatus | 0 | 0 | 0 | 1 | 1 | 2 | 0.001 |
| Spottail shiner | Notropis hudsonius | 265 | 10 | 0 | 0 | 218 | 493 | 0.367 |
| Silver chub | Macrhybop. storeriana | 222 | 57 | 0 | 0 | 144 | 423 | 0.315 |
| Threadfin shad | Dorosoma petenense | 0 | 0 | 0 | 0 | 1 | 1 | 0.001 |
| Tadpole madtom | Noturus gyrinus | 0 | 0 | 0 | 0 | 1 | 1 | 0.001 |
| Unidentified buffalo | Ictiobus sp. | 19 | 0 | 0 | 0 | 0 | 19 | 0.014 |
| Unidentified sunfish | Unident. Centrarchidae | 16 | 0 | 0 | 0 | 62 | 78 | 0.058 |
| Unident. carpsucker | Carpiodes sp. | 318 | 0 | 0 | 0 | 25 | 343 | 0.256 |
| Unid. sucker | Unident. Catostomidae | 1834 | 1 | 0 | 4 | 149 | 1988 | 1.482 |
| Unid. minnow | Unidentified Cyprinidae | 358 | 31 | 0 | 0 | 332 | 721 | 0.537 |
| Unid. chub | Macrhybopsis sp. | 3 | 11 | 0 | 0 | 2 | 16 | 0.012 |
| Unid. Lepomis | Lepomis sp. | 3 | 0 | 0 | 0 | 34 | 37 | 0.028 |
| Unid. shiner | Notropis sp. | 128 | 2 | 0 | 0 | 266 | 396 | 0.295 |
| Unid. redhorse | Moxostoma sp. | 1 | 0 | 0 | 0 | 2 | 3 | 0.002 |
| Unid. Stizostedion | Stizostedion sp. | 66 | 2 | 0 | 0 | 63 | 131 | 0.098 |
| Unidentified | Unidentified | 116 | 6 | 0 | 1 | 8 | 131 | 0.098 |
| Walleye | Sander vitreum | 78 | 3 | 11 | 156 | 309 | 557 | 0.415 |
| W. silvery minnow | Hybognathus argyritis | 339 | 5 | 0 | 0 | 30 | 374 | 0.279 |
| White bass | Morone chrysops | 120 | 1 | 0 | 38 | 382 | 541 | 0.403 |

| Common name | Scientific name | Seine | Trawl | Trammel | Gill Net | Electro | Total | Percent |
|---|---|---|---|---|---|---|---|---|
| White crappie | Pomoxis annularis | 1129 | 1 | 0 | 36 | 313 | 1479 | 1.102 |
| White perch | Morone americana | 0 | 0 | 0 | 0 | 2 | 2 | 0.001 |
| White sucker | Catost, commersoni | 2052 | 9 | 14 | 23 | 106 | 2204 | 1.643 |
| Yellow bullhead | Ameiurus natalis | 1 | 0 | 0 | 3 | 2 | 6 | 0.004 |
| Yellow bass | M. mississippiensis | 2 | 0 | 0 | 0 | 4 | 6 | 0.004 |
| Yellow perch | Perca flavescens | 88 | 0 | 0 | 13 | 666 | 767 | 0.572 |

Table A1-7. Generalized distribution of incidental species according to Lee et al. (1980) and segment where found in the Missouri River during the Benthic Fishes Study.

| Distribution | Species | State and Segment in Benthic Fishes Study |
|---|---|---|
| Great Lakes states with isolated rare occurrences in the Missouri River basin as glacial relicts (*) or from upper Mississippi River | *banded killifish, *brook stickleback, common shiner, lake sturgeon, northern redbelly dace, pearl dace, logperch | ND; 12<br>MT, ND; 8, 12<br>MO; 27<br>MO; 25, 27<br>MT; 7<br>MT; 9<br>MO; 23, 25 |
| Canada with isolated populations in upper Missouri basin | lake chub, lake whitefish | MT; 3<br>MT; 8 |
| Lower Mississippi River mainstem and Ozark highlands | freckled madtom, silver band shiner, highfin carpsucker, spotted gar, bigeye shiner, largescale stoneroller, slender madtom | MO; 27<br>MO; 22, 27<br>SD, MO; 15, 22, 25, 27<br>MO; 25<br>MO; 22, 27<br>MO; 25<br>MO; 22 |
| Mississippi and Ohio Rivers are western edge of distribution, scattered and rare in lower Missouri; yellow bullhead most widely distributed | chestnut lamprey, river redhorse, tadpole madtom, threadfin shad, yellow bass, yellow bullhead, bowfin, northern hog sucker | MO; 25<br>IA, MO; 17, 22<br>MO; 22<br>IA; 17<br>MO; 25, 27<br>ND, IA, KA, MO; 10, 17, 19, 23<br>MO; 27<br>IA; 17 |
| Southeast and southcentral states | grass pickerel, longnose gar | SD; 15<br>MO; 25 |

Table A1-8. Details about the catch of four pallid sturgeon.

| Catch data | Pallid 1 | Pallid 2 | Pallid 3 | Pallid 4 |
|---|---|---|---|---|
| Data sheet number | 30090509 | 30090528 | 40100158 | 80220433 |
| Segment number | 9 | 9 | **10** | *22* |
| Fish length (mm) | 276 | 276 | **-** | 785 |
| Fish weight (g) | 64.5 | 62.7 | **-** | 1650 |
| Date captured | September 2, 1998 | September 3, 1998 | August 13, 1997 | August 25, 1998 |
| Macrohabitat | Inside bend | Inside bend | Tributary mouth | Inside bend |
| Mesohabitat | Channel border | Channel border | large | Channel border |
| Gear | Benthic trawl | Benthic trawl | Drifting trammel net | Drifting trammel net |
| Depth (m) | 2.7 | 1.7 | 4.8 | 1.7 |
| Velocity at 0.2 depth (m/s) | 1.0 | 1.0 | 0.9 | 0.7 |
| Velocity at 0.8 depth (m/s) | 1.0 | 1.0 | 0.8 | 0.5 |
| Conductivity *u*S | 634 | 631 | 444 | 590 |
| Turbidity (NTU) | 33.4 | 29.6 | 268 | 940 |
| Temperature | 21.7 | 21.2 | 19.5 | 28.9 |
| Substrate | Gravel 10% Sand 90% | Gravel 60% Sand 40% | Sand 100% | Sand 100% |

Table A1-9. Matrix of Morisita values showing similarity in relative abundance values for benthic fish species in segments of the Missouri River. Morisita Index ranges from zero (no similarity to one (high similarity).

| Segments | Least altered segments | | | Inter-reservoir segments | | | | | Channelized segments | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 5 | 9 | **7** | **8** | **10** | **12** | **14** | *15* | *17* | *19* | *22* | *23* | *25* | *27* |
| 3 | | 0.673 | 0.872 | 0.328 | 0.825 | 0.783 | 0.031 | 0.376 | 0.388 | 0.267 | 0.383 | 0.344 | 0.335 | 0.362 | 0.321 |
| 5 | 0.673 | | 0.756 | 0.262 | 0.460 | 0.430 | 0.008 | 0.439 | 0.439 | 0.347 | 0.504 | 0.696 | 0.724 | 0.802 | 0.566 |
| 9 | 0.872 | 0.756 | | 0.451 | 0.868 | 0.767 | 0.070 | 0.160 | 0.119 | 0.190 | 0.193 | 0.327 | 0.346 | 0.404 | 0.310 |
| **7** | 0.328 | 0.262 | 0.451 | | 0.545 | 0.457 | 0.471 | 0.293 | 0.200 | 0.419 | 0.330 | 0.302 | 0.271 | 0.392 | 0.517 |
| **8** | 0.825 | 0.460 | 0.868 | 0.545 | | 0.910 | 0.085 | 0.171 | 0.098 | 0.210 | 0.140 | 0.152 | 0.145 | 0.168 | 0.230 |
| **10** | 0.783 | 0.430 | 0.767 | 0.457 | 0.910 | | 0.045 | 0.232 | 0.146 | 0.257 | 0.162 | 0.201 | 0.201 | 0.145 | 0.213 |
| **12** | 0.031 | 0.008 | 0.070 | 0.471 | 0.085 | 0.045 | | 0.040 | 0.019 | 0.042 | 0.026 | 0.025 | 0.025 | 0.025 | 0.036 |
| **14** | 0.376 | 0.439 | 0.160 | 0.293 | 0.171 | 0.232 | 0.040 | | 0.938 | 0.831 | 0.951 | 0.776 | 0.748 | 0.726 | 0.821 |
| *15* | 0.388 | 0.439 | 0.119 | 0.200 | 0.098 | 0.146 | 0.019 | 0.938 | | 0.652 | 0.951 | 0.671 | 0.625 | 0.684 | 0.709 |
| *17* | 0.267 | 0.347 | 0.190 | 0.419 | 0.210 | 0.257 | 0.042 | 0.831 | 0.652 | | 0.776 | 0.843 | 0.829 | 0.669 | 0.884 |
| *19* | 0.383 | 0.504 | 0.193 | 0.330 | 0.140 | 0.162 | 0.026 | 0.951 | 0.951 | 0.776 | | 0.794 | 0.744 | 0.812 | 0.864 |
| *22* | 0.344 | 0.696 | 0.327 | 0.302 | 0.152 | 0.201 | 0.025 | 0.776 | 0.671 | 0.843 | 0.794 | | 0.986 | 0.891 | 0.895 |
| *23* | 0.335 | 0.724 | 0.346 | 0.271 | 0.145 | 0.201 | 0.025 | 0.748 | 0.625 | 0.829 | 0.744 | 0.986 | | 0.882 | 0.859 |
| *25* | 0.362 | 0.802 | 0.404 | 0.392 | 0.168 | 0.145 | 0.025 | 0.726 | 0.684 | 0.669 | 0.812 | 0.891 | 0.882 | | 0.898 |
| *27* | 0.321 | 0.566 | 0.310 | 0.517 | 0.230 | 0.213 | 0.036 | 0.821 | 0.709 | 0.884 | 0.864 | 0.895 | 0.859 | 0.898 | |

# APPENDIX 2
# FIGURES AND TABLES SHOWING CATCH PER EFFORT DATA BY GEAR, MACROHABITAT, AND SEGMENT

Figure A2-1 Catch per effort of channel catfish from 15 segments of the Missouri River.....175

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Table A2-3 Burbot catch per effort in Segments 3-*27* in the Missouri River.....184

Table A2-4 Emerald shiner catch per effort in Segments 3-*27* in the Missouri River.....185

Table A2-5 Fathead minnow catch per effort in Segments 3-*27* in the Missouri River.....186

Table A2-6 Flathead catfish catch per effort in Segments 3-*27* in the Missouri River.....187

Table A2-7 Flathead chub catch per effort in Segments 3-*27* in the Missouri River.....188

Table A2-8 Freshwater drum catch per effort in Segments 3-*27* in the Missouri River.....189

Table A2-9 Sand shiner catch per effort in Segments 3-*27* in the Missouri River.....190

Table A2-10 Smallmouth buffalo catch per effort in Segments 3-*27* in the Missouri River.....191

Table A2-11 Stonecat catch per effort in Segments 3-*27* in the Missouri River.....192

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Table A2-13 Walleye catch per effort in Segments 3-*27* in the Missouri River.....194

Table A2-14 White sucker catch per effort in Segments 3-*27* in the Missouri River.....195

Figure A2-1. Catch per effort of channel catfish from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability.

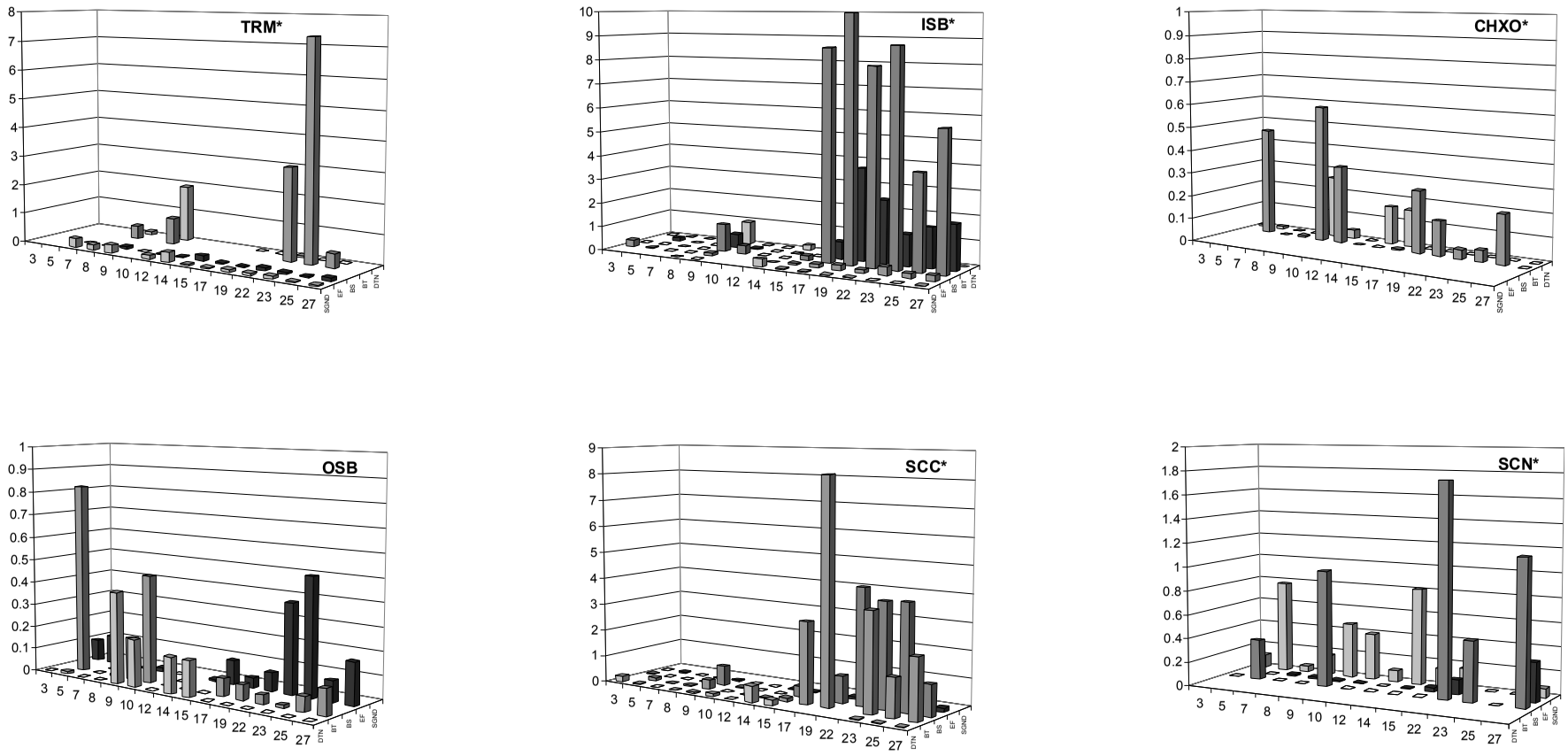


Figure A2-2. Catch per effort of common carp from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability.

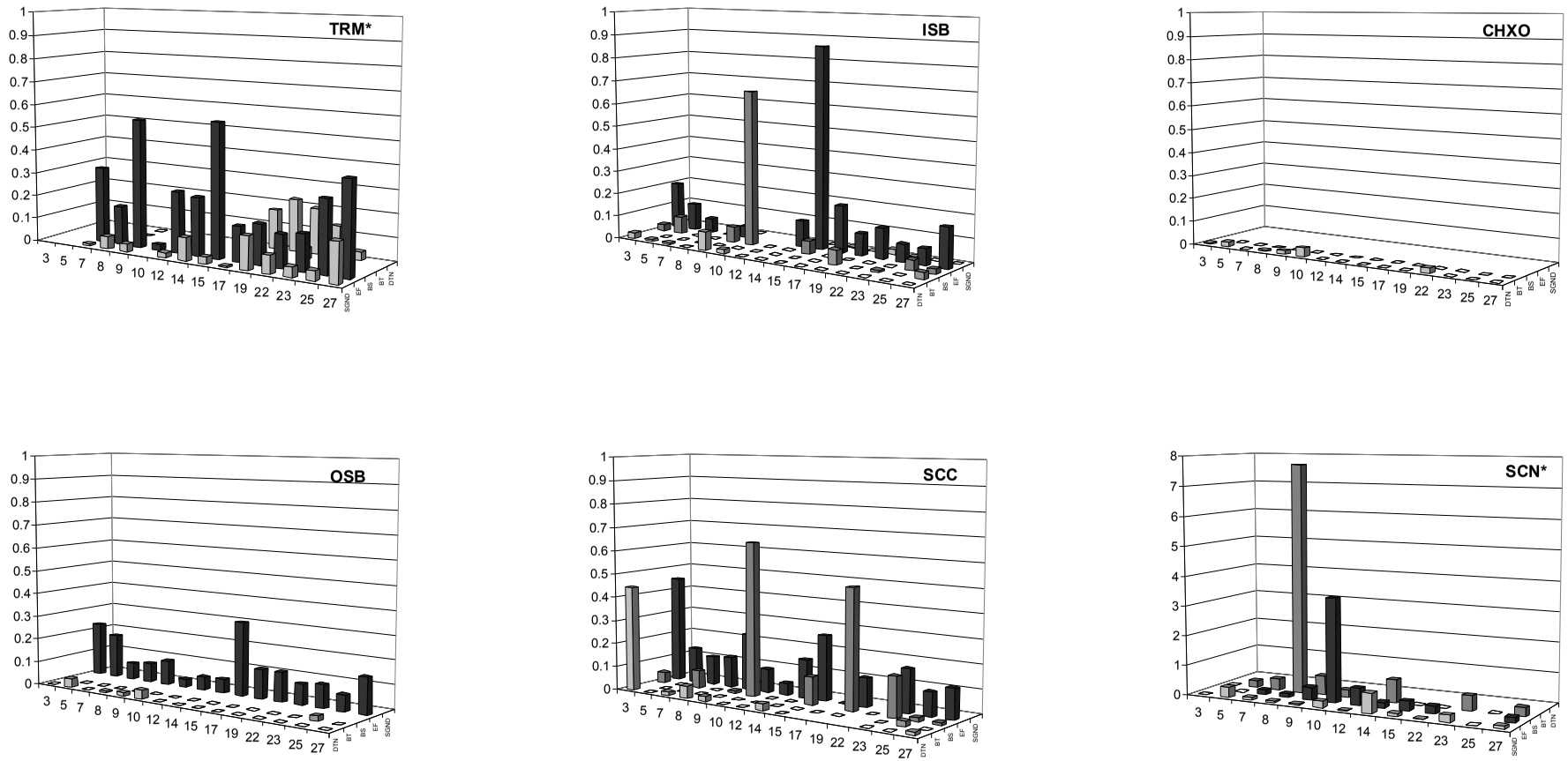
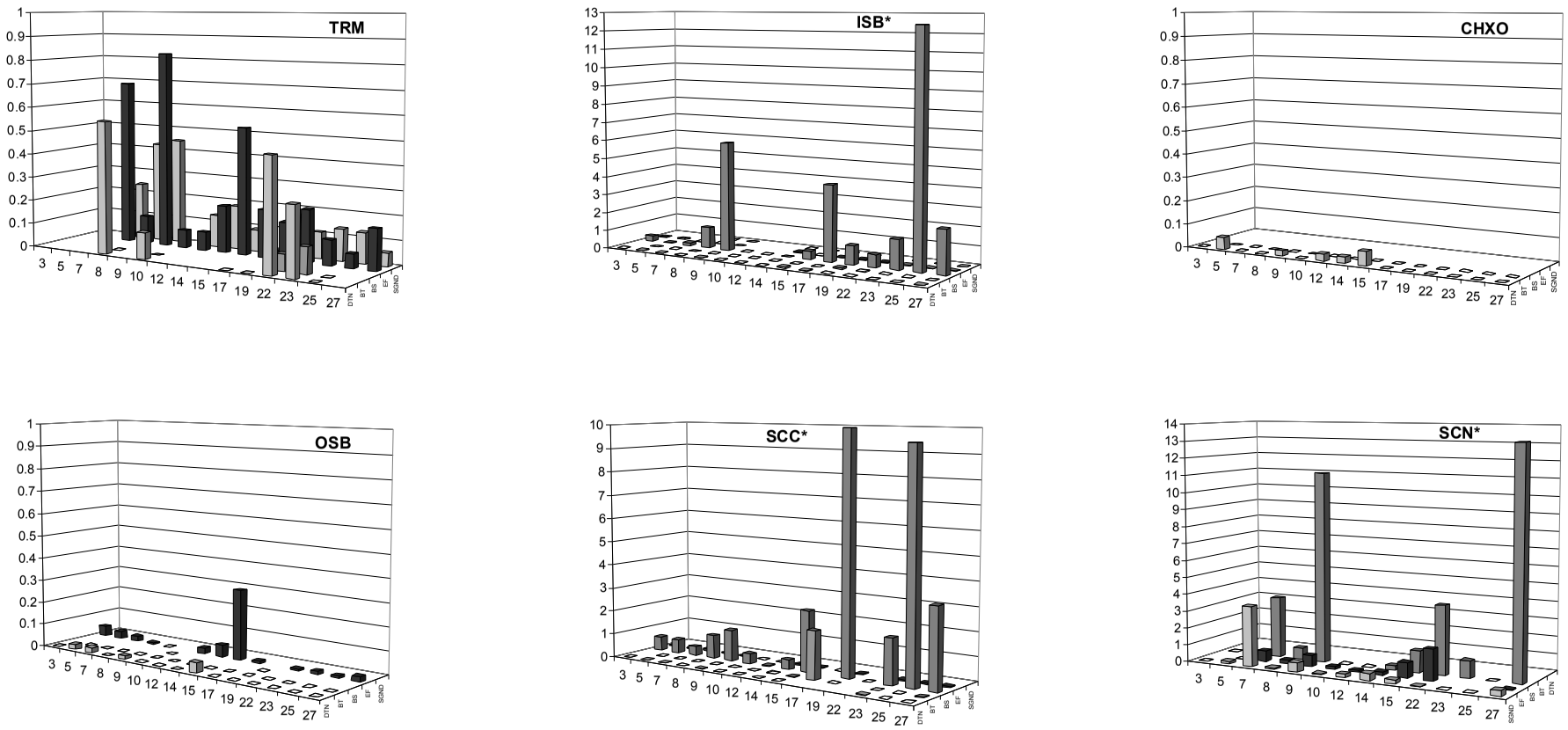


Figure A2-3. Catch per effort of river carpsucker from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability.



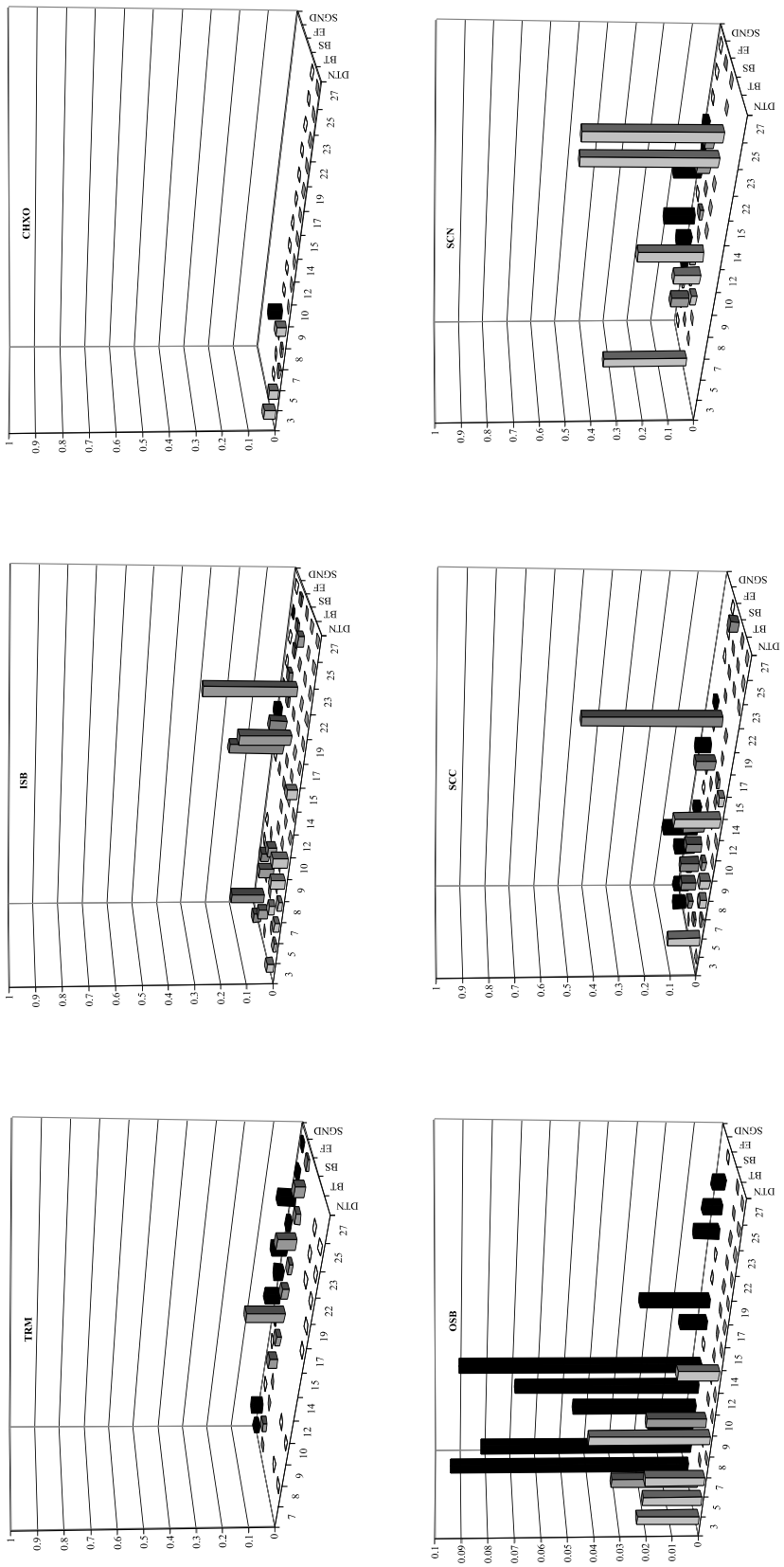
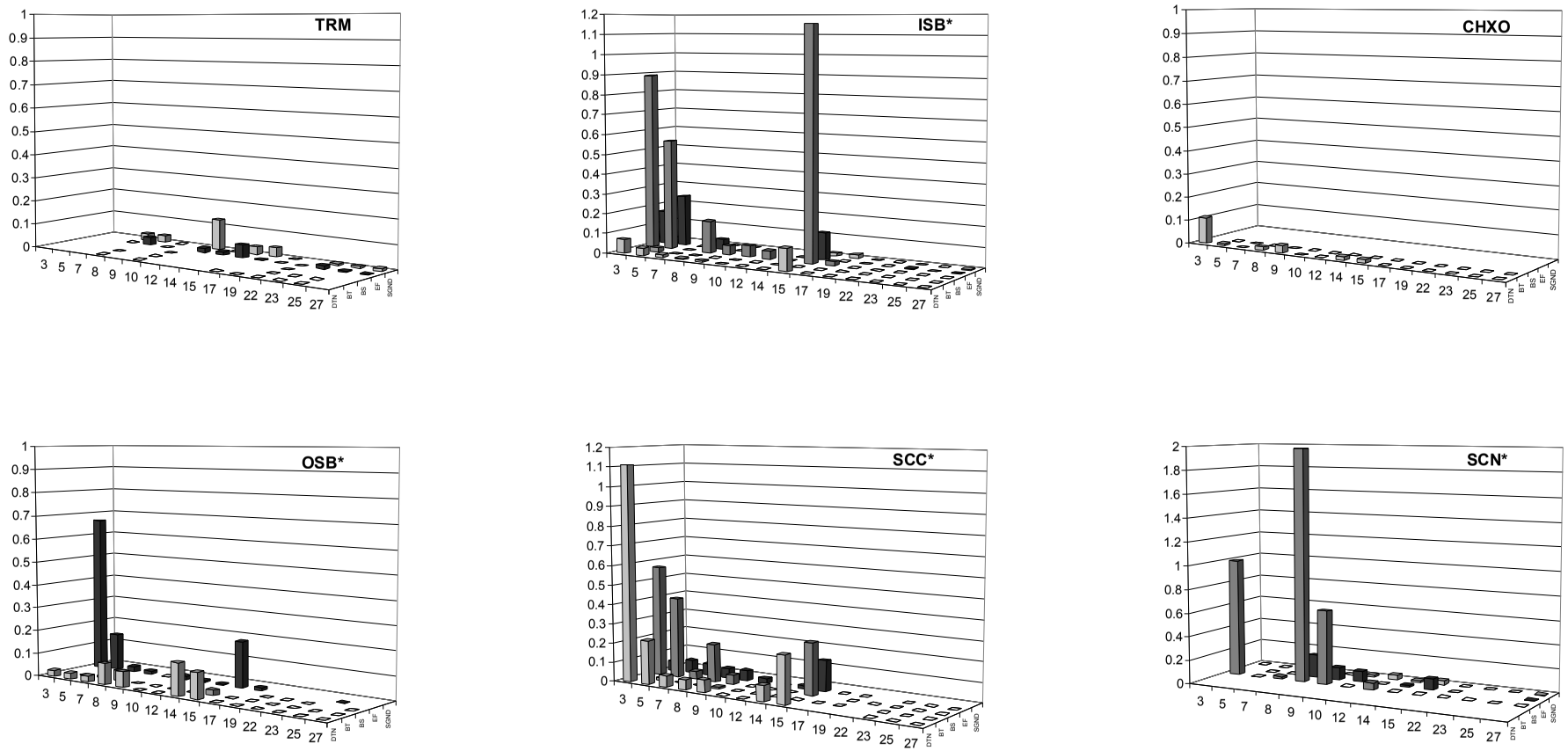



Figure A2-4. Catch per effort of sauger from 15 segments (3=Montana, 27=Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN=drifting trammel net (fish/100 m); BS=beach seine (fish/haul); EF=electrofishing (fish/min); SGND=stationary gill net (fish/hr); BT=benthic trawl (fish/100m). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability.

Figure A2-5. Catch per effort of shorthead redhorse from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability.



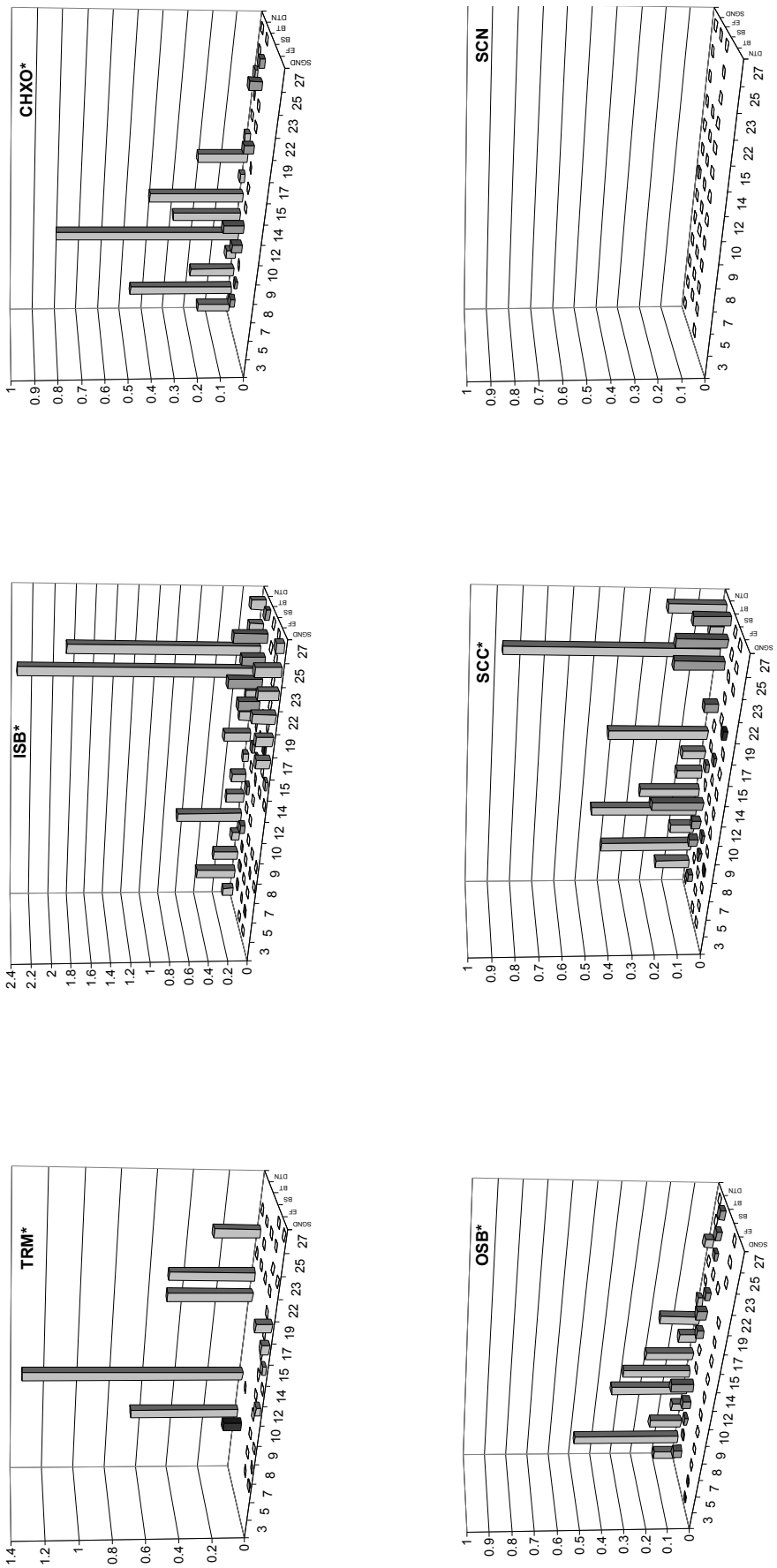
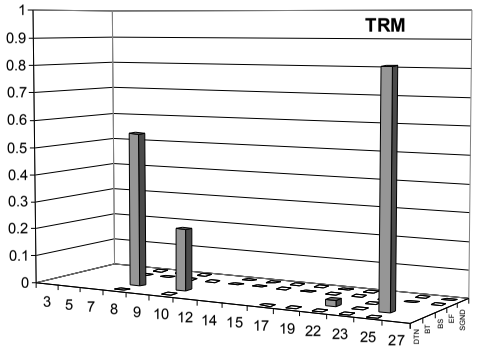
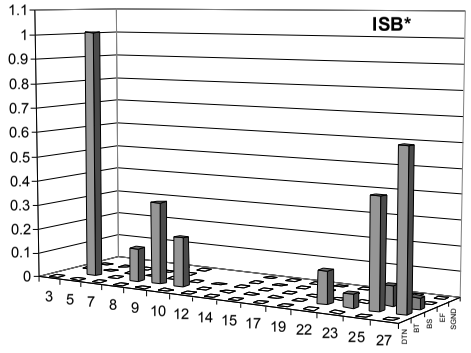
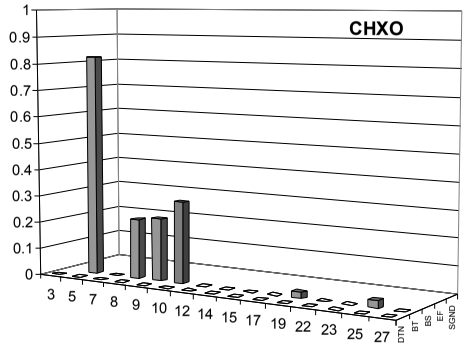


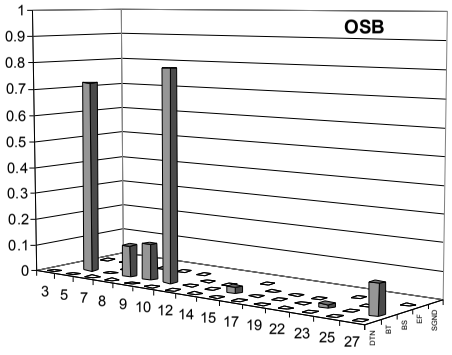

Figure A2-6. Catch per effort of shovelnose sturgeon from 15 segments (3 = Montana, 27 = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability.

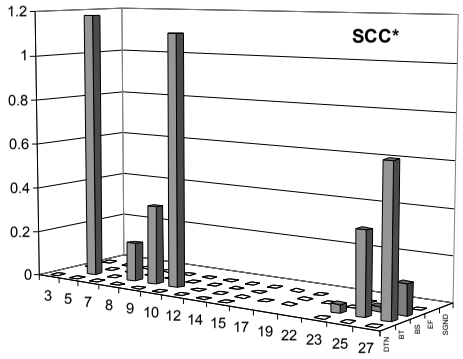
Figure A2-7. Catch per effort of sicklefin chub from 15 segments (3 = Montana, *27* = Missouri) of the Missouri River using five capture methods over three years (1996-1998). Empty boxes indicate no fish were caught with that gear in that segment. Missing boxes indicate no fishing effort was made with that gear in that segment. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr). An "*" indicates scale is greater than 1 or the order of the gears has been reversed to improve readability.



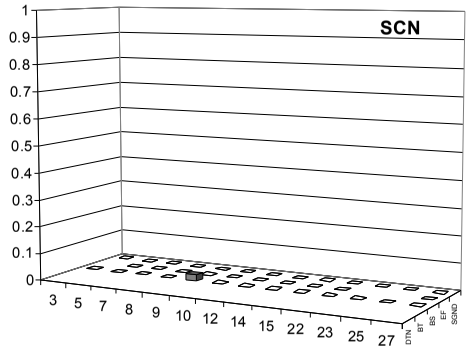



Table A2-1. Bigmouth buffalo catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electro fishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0.074 | 0.033 | 0.444 | 0.042 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | CHXO | | 0 | 0 | 0 | 0.007 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | 0 | 0 | 0.028 | 0 | 0 | | | 0 | 0 | 0.033 | 0 | 0 | 0 | 0 | 0 |
| BT | OSB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | SCC | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0 | 0 | 0 | |
| BS | CHXO | 3 | 5 | 7 | 8 | 9 | 10 | 12 | 14 | 15 | 17 | 19 | 22 | 23 | 25 | 27 |
| BS | ISB | | | | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.022 |
| BS | OSB | | 0 | | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 |
| BS | SCC | 0 | 0.056 | 0 | 0 | 0 | 1.241 | 0 | 0 | 0.019 | | 0 | 0 | 0 | 0 | 0 |
| BS | SCN | 0 | 0 | 0.037 | 3.519 | 0.022 | 0 | 1.111 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| BS | TRM | | | | | | 0 | | | | | | | 0 | | |
| EF | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EF | ISB | | | | | | | | | | | | | | | |
| EF | OSB | 0 | | 0.007 | | | | | | 0.004 | 0.007 | | | | | |
| EF | SCC | 0 | 0 | 0 | 0.005 | 0 | 0.025 | 0 | 0.003 | 0.010 | 0 | 0 | | 0 | 0 | 0 |
| EF | SCN | | 0 | 0 | 0 | 0.01 | 2.456 | 0.106 | 0 | 0.025 | | | 0 | | | 0 |
| EF | TRM | | | 0.067 | 0.017 | 0 | | 0 | 0.006 | 0.020 | 0.059 | 0.022 | 0.005 | | 0.013 | 0 |
| SGND | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | ISB | | | | | | | | | | | | | | | |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0.007 | 0.003 | 0 | 0 | 0.037 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| SGND | TRM | | | 0 | 0.020 | 0 | | 0 | 0 | 0 | 0 | 0 | 0.002 | 0.005 | 0 | 0 |

Table A2-2. Blue sucker catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0 | 0.022 | 0.044 | 0 | 0 | 0 | 0.044 | 0.000 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0.011 | 0.009 | 0 | 0 | 0.007 | 0 | 0 | 0 | 0.156 | 0.181 | 0 | 0.172 | 0.084 | 0 | 0.081 |
| DTN | OSB | 0.022 | 0.009 | 0 | 0 | 0.040 | 0 | 0 | 0 | 0.032 | 0.000 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0.000 | 0.043 | 0.020 | 0 | 0.007 | 0 | 0 | 0 | 0.195 | | | | 0.079 | 0.028 | 0.022 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0.333 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | | 0 | 0 | 0 | 0.008 | 0 | 0 | 0 | 0.007 | 0 | 0 | 0.022 | 0 | 0 | 0.015 |
| BT | OSB | | 0 | 0.010 | 0.007 | 0.013 | 0.022 | 0 | 0 | 0 | 0.044 | 0 | 0 | 0 | 0 | 0 |
| BT | SCC | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BS | OSB | | | | | | | 0 | 0 | | | | | | 0 | 0 |
| BS | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0.037 | 0 | 0 |
| BS | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 |
| BS | TRM | | | | | | 0 | | | | | | 0 | 0 | 0 | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0.011 | 0 | 0.014 | 0.062 | 0 | 0 |
| EF | OSB | 0.015 | 0.009 | 0 | 0 | 0 | 0 | | | 0.020 | 0.024 | 0.011 | 0.011 | 0.002 | | |
| EF | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.023 | 0 | 0 | | 0 | 0 | 0 |
| EF | SCN | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | | | 0 |
| EF | TRM | | | 0 | 0 | 0 | | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0 | 0.056 | 0.008 | 0 | 0 | 0 | 0 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 |
| SGND | TRM | | | 0 | 0 | 0 | | 0.093 | 0 | 0.011 | 0.009 | 0 | | | | 0 |

Table A2-3. Burbot catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0.022 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0 | 0 | 0.022 | 0.007 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0.007 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | | 0.022 | 0 | 0 | 0 | 0 | 0.111 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | OSB | | 0.018 | 0 | 0 | 0.014 | 0.022 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | SCC | | 0.027 | 0 | 0.085 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0 | 0 | 0 | 0 | 0 | 0.055 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BS | OSB | | | | | | | | | | | | | | | |
| BS | SCC | 0 | 0 | 0 | 0 | 0.022 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| BS | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| BS | TRM | | | | | | | | | | | | | | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0.033 | 0.131 | 0 | 0 | 0.15 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EF | OSB | 0.024 | 0.056 | 0 | 0 | 0.066 | 0.200 | 0.008 | 0 | 0.002 | 0 | 0 | 0 | 0 | 0 | 0 |
| EF | SCC | 0 | 0.277 | 0.02 | 0.007 | 0.01 | 0.025 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| EF | SCN | | 0 | 0 | 0 | 0.01 | 0.031 | 0 | 0 | 0 | | | 0 | | | 0 |
| EF | TRM | | | 0 | 0 | 0 | 0.025 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| SGND | TRM | | | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table A2-4. Emerald shiner catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.007 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.033 | 0.042 | 0.018 | 0.015 | 0 |
| BT | OSB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | SCC | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.015 | 0 | 0 | | 0.033 | 0 | 0.022 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0.033 | 0.044 | 0.111 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 7.911 | 4.452 | 0.089 | 0.044 | 1.611 | 2.083 | 0 | 0.667 | 4.344 | 5.567 | 0 | 37.806 | 12.833 | 12.733 | 6.467 |
| BS | OSB | | | | 0 | | | 0 | | | | | | | | |
| BS | SCC | 2.678 | 10.174 | 0.119 | 0.044 | 2.194 | 0.056 | 0 | 0.958 | 18.493 | | 1.750 | 22.750 | 6.602 | 5.799 | 5.444 |
| BS | SCN | 1.000 | 20.944 | 0.067 | 0.489 | 1.722 | 0.500 | 0 | 0 | 0 | | | 3.250 | 0.000 | 27.500 | 4.511 |
| BS | TRM | | | | | | | | | | | | | | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0.217 | 0.806 | 0 | 0 | 0.250 | | | 1.044 | 1.333 | 0.261 | 0.509 | 1.302 | 1.208 | 0.788 | 0.123 |
| EF | OSB | 1.852 | 1.586 | 0.033 | | 0.180 | 0.075 | | 1.766 | 10.466 | 0.144 | 0.011 | 0.653 | 0.310 | 0.449 | 0.154 |
| EF | SCC | 0.300 | 1.714 | 0.010 | 0 | 0.140 | 0.075 | 0 | 0.559 | 1.594 | 0.143 | 0.467 | | 0.510 | 0.196 | 0.184 |
| EF | SCN | | 0.100 | 0.014 | 0.042 | 1.144 | 0.169 | 0 | 0.188 | 0.656 | | | 0.200 | | | 0.318 |
| EF | TRM | | | 0.708 | 0.050 | 0.875 | 0.025 | 0.052 | 1.312 | 0.498 | 0.771 | 12.648 | 0.679 | 1.096 | 2.834 | 1.178 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0 | 0.001 | 0 | 0 | 0 | 0 | 0 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| SGND | TRM | | | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table A2-5. Fathead minnow catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | OSB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | SCC | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0.033 | 0 | 0.083 | 0.322 | 0.822 | 0 | 1.375 | 0 | 0 | 0.211 | 0 | 0 | 0 | 0 | 0.033 |
| BS | OSB | | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | | 0 | | 0 |
| BS | SCC | 0 | 0 | 0.133 | 0.078 | 0 | 0.130 | 0.111 | 0 | 0.111 | | 0.25 | 0 | 0 | 0 | 0 |
| BS | SCN | 0 | 0 | 5.339 | 0.678 | 0.089 | 0 | 7.522 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| BS | TRM | | | | | | 0 | | | | | | | | 0 | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0 | 0 | 0 | 0.033 | 0 | | | 0.011 | 0 | 0.022 | 0 | 0 | 0 | 0 | 0 |
| EF | OSB | 0 | | | | | | 0.206 | 0.004 | 0.003 | | | 0.004 | | 0.002 | |
| EF | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.003 | 0 | 0 | 0 | | 0.005 | 0 | 0 |
| EF | SCN | | 0 | 0.460 | 0.146 | 0.249 | 0.013 | 0 | 0.025 | 0 | | | 0 | | | 0 |
| EF | TRM | | | 0 | 0.017 | 0 | | 0.022 | 0.007 | 0 | 0.010 | 0.004 | 0.005 | 0.005 | 0 | 0 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| SGND | TRM | | | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 |

Table A2-6. Flathead catfish catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.021 | 0 | 0 | 0 |
| DTN | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.022 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 | |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | | |
| BT | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.022 | 0.022 | |
| BT | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.049 | 0.022 | 0 | 0 | |
| BT | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.027 | 0 | 0 | 0 | 0 | |
| BT | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0.028 | 0.042 | 0 | |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | 0 | | 0 | | | | | | 0 | 0 | 0.333 | | |
| BS | CHXO | | | | | | | | | | | | | | | 0 |
| BS | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| BS | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | 0 |
| BS | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| BS | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | |
| BS | TRM | | | 0 | | 0 | | | | | | | | | | |
| EF | CHXO | | | | | | | | | | | | | | | 0 |
| EF | ISB | 0 | 0 | 0 | 0 | | | 0 | 0.067 | 0.067 | 0.200 | 0.045 | 0.070 | 0.026 | 0.061 | 0 |
| EF | OSB | | | | | | | | 0.316 | 0.327 | 0.818 | 0.400 | 0.439 | 0.318 | 0.429 | 0 |
| EF | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0.003 | 0.106 | 0 | 0.033 | | 0.059 | 0.026 | 0.039 | |
| EF | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 0.053 | |
| EF | TRM | | 0 | 0 | 0 | | 0 | 0.005 | 0.042 | 0.007 | 0.055 | 0.020 | 0.024 | 0.045 | 0.015 | |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | 0 | 0 | | | 0 | 0 | 0.002 | 0.002 | 0 | 0 | 0 | 0 | |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | 0 |
| SGND | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.021 | | | 0 | 0 | 0 | |
| SGND | TRM | | 0 | | 0 | | 0 | 0 | 0.004 | 0 | 0.062 | 0.022 | 0.005 | 0.013 | 0.052 | |

Table A2-7. Flathead chub catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0.015 | 0.226 | 0 | 0.037 | 0.007 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0.015 | 0.068 | 0.037 | 0.059 | 0.022 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0.022 | 0.129 | 0.067 | 0.030 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0.129 | 0.081 | 0.053 | 0.016 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0.1111 | 0.0167 | 0.0222 | 0.1037 | 0.062 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | | 0.2019 | 0.0148 | 0.0148 | 0.2056 | 0.025 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | OSB | | 0.0963 | 0.0370 | 0.0074 | 0.0222 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | SCC | | 0.1185 | 0.0074 | 0.0363 | 0.2963 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 41.456 | 6.626 | 1.128 | 8.570 | 41.706 | 48.444 | 0 | 0 | 0 | 0.022 | 0 | 0.028 | 0.500 | 0.033 | 0 |
| BS | OSB | | | | | | | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| BS | SCC | 17.911 | 9.578 | 0.963 | 5.535 | 31.622 | 13.641 | 0 | 0 | 0.086 | | 0.250 | 0 | 0.074 | 0.012 | 0.012 |
| BS | SCN | 7.000 | 1.333 | 0.111 | 0.711 | 37.493 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0.022 |
| BS | TRM | | | | | | | | | | | | 0 | 0 | 0 | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0.800 | 0.686 | 0 | 0.367 | 0.150 | | | 0 | 0 | 0 | 0 | 0.012 | 0 | 0 | 0 |
| EF | OSB | 1.098 | 0.990 | 0.020 | 0.213 | 0.350 | 0.151 | | | | | | 0.002 | | | |
| EF | SCC | 0.300 | 0.539 | 0.010 | 0.385 | 0.337 | 0.300 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| EF | SCN | | 0.100 | 0 | 0.117 | 0.146 | 0.013 | 0 | 0 | 0 | | | 0 | | | 0 |
| EF | TRM | | | 0.117 | 0.017 | 0.075 | 0.725 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| SGND | TRM | | | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | | | | 0 |

Table A2-8. Freshwater drum catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0.167 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0.007 | 0.007 | 0.044 | 0 | 0.013 | 0 | 0 | 0 |
| BT | ISB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.124 | 4.548 | 0.209 | 0.018 | 0.193 | 0 |
| BT | OSB | | 0 | 0 | 0.044 | 0 | 0 | 0 | 0 | 0.007 | 0 | 0 | 0 | 0 | 0.022 | 0 |
| BT | SCC | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.200 | 40 | 3.019 | | 0 | 0.133 | 0.220 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 6.567 | 0.667 | 2.222 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0 | 0.111 | 0 | 0 | 0.111 | 0 | 0 | 0 | 0.044 | 1.756 | 7 | 1.528 | 0 | 3.567 | 1.822 |
| BS | OSB | | | | | | | 0 | 0 | | 0 | | | | | |
| BS | SCC | 0 | 0 | 0 | 0.012 | 0 | 0 | 0 | 0.014 | 1.023 | | 0.250 | 0 | 0.833 | 1.323 | 0.214 |
| BS | SCN | 0 | 0 | 0.078 | 0.133 | 0.267 | 2.75 | 0 | 0 | 0 | | | 0.250 | 2 | 4.000 | 6.828 |
| BS | TRM | | | | | | 0 | | | | | | | | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0.267 | 0.113 | 0 | 0 | 0 | | | 0 | 0.133 | 0 | 0 | 0.045 | 0.059 | 0.041 | 0.106 |
| EF | OSB | 0.278 | 0.188 | 0.005 | 0 | 0.020 | 0.010 | | | 0.056 | | 0.009 | 0.264 | 0.288 | 0.080 | 0.110 |
| EF | SCC | 0.200 | 0.103 | 0.010 | 0.007 | 0.051 | 0 | 0 | 0 | 0.054 | 0 | 0.025 | | 0.120 | 0.037 | 0.048 |
| EF | SCN | | 0 | 0.020 | 0.025 | 0.020 | 0.013 | 0 | 0.008 | 0.151 | | | 0.367 | | | 0.247 |
| EF | TRM | | | 0 | 0.017 | 0 | | 0 | 0.219 | 0.574 | 0.024 | 0.018 | 0.343 | 0.296 | 0.098 | 0.064 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0.006 | 0.002 | 0.004 | 0.020 | 0.007 | 0 | 0.008 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0 | 0.004 | 0.006 | 0.061 | 0 | 0.016 | 0.011 | | | 0.010 | 0 | 0 | 0.012 |
| SGND | TRM | | | 0.020 | 0.070 | 0 | | 0 | 0 | 0.032 | 0.006 | 0.031 | 0.044 | 0.035 | 0.034 | 0.122 |

Table A2-9. Sand shiner catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish.min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | OSB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | SCC | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0.044 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.489 | 1.422 | 0 | 0.347 | 0.556 | 0.744 | 0.456 |
| BS | OSB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | | 0 | 0 | |
| BS | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6.404 | | 0 | 0 | 0.259 | 0.119 | 0.407 |
| BS | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.500 | | | 0 | 0 | 0 | 2.111 |
| BS | TRM | | | | 0 | | 0 | | | | | | | 0 | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0.002 | 0.004 |
| EF | OSB | 0 | | | | | | | | 0.029 | | | 0.009 | | | 0.002 |
| EF | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| EF | SCN | | 0 | 0 | 0 | 0 | 0 | 0 | 0.023 | 0 | | | 0 | | | 0.003 |
| EF | TRM | | | 0 | 0 | 0 | | 0.005 | 0.003 | 0.028 | 0 | 0.007 | 0.007 | 0 | 0.005 | 0.013 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| SGND | TRM | | | 0 | | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |

Table A2-10. Smallmouth buffalo catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0.011 | 0 | 0 | 0.030 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.009 | 0.025 | 0.048 |
| DTN | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0 | 0.007 | 0.015 | 0 | 0 | 0 | 0 | | | | 0.060 | 0 | 0.030 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0.111 | | | | 0.167 | 0 | 0.060 | 0 | 0 | |
| BT | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.015 | 0 | 0 | 0 | 0 | 0 |
| BT | OSB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | SCC | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0.633 | 0 | 0 | 0.033 | 0.033 | 0.333 | 0 | 0 | 0.133 | 0.022 | 0 | 0 | 0 | 0 | 0 |
| BS | OSB | | | 0 | 0 | 0 | | 0 | | | | | | 0 | | |
| BS | SCC | 0.100 | 0 | 0.011 | 0 | 0 | 1.037 | 0 | 0 | 0.074 | | 0 | 0 | 0 | 0 | 0.012 |
| BS | SCN | 0 | 0.111 | 0.044 | 1.178 | 0.078 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0.022 |
| BS | TRM | | | | | | | | | | | | | | | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0 | 0.003 | 0.028 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0.006 | 0.013 |
| EF | OSB | 0.008 | 0.009 | | | | 0.004 | | 0.002 | 0.016 | 0.004 | 0.011 | 0.010 | | 0.002 | 0.004 |
| EF | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.007 | 0.015 | 0 | 0.008 | | 0 | 0 | 0.015 |
| EF | SCN | | 0 | 0 | 0 | 0.01 | 0.256 | 0 | 0.006 | 0.250 | | | 0 | | | 0.017 |
| EF | TRM | | | 0.192 | 0.017 | 0 | 0 | 0 | 0.003 | 0.018 | 0.039 | 0.010 | 0.010 | 0.011 | 0.038 | 0.048 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0.032 | 0 | 0 | 0 | 0 | 0.002 | 0 | 0.002 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0.148 | 0.015 | 0.008 | 0.094 | 0.130 | 0.006 | 0.093 | 0.030 | | | 0 | 0 | 0 | 0.103 |
| SGND | TRM | | | 0.140 | 0.013 | 0.095 | | 0 | 0.016 | 0 | 0.004 | 0.007 | 0.007 | 0.054 | 0.017 | 0.045 |

Table A2-11. Stonecat catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0.030 | 0 | 0 | 0.009 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0 | 0 | 0.025 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0 | 0 | 0 | 0 | 0 | 0.019 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0.250 | 0.009 | 0.007 | 0.207 | 0.012 | 0 | 0 | 0.022 | 0.022 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | | 0.126 | 0 | 0 | 0.259 | 0 | 0 | 0 | 0 | 0 | 0 | 0.020 | 0 | 0 | 0 |
| BT | OSB | | 0.583 | 0.047 | 0.237 | 0.844 | 0.344 | 0 | 0 | 0.007 | 0 | 0.022 | 0.013 | 0 | 0 | 0 |
| BT | SCC | | 0.119 | 0 | 0.015 | 0.126 | 0.111 | 0 | 0 | 0 | 0 | 0 | | 0.015 | 0 | 0.035 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0.038 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0.067 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BS | OSB | | | | | | | 0 | | | 0 | | | | 0 | |
| BS | SCC | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| BS | SCN | 0 | 0 | 0 | 0 | 0.019 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| BS | TRM | | | | 0 | | 0 | | | | | | | 0 | 0 | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0.033 | 0.016 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0.004 | 0.003 | 0.011 |
| EF | OSB | 0.013 | 0.024 | 0.000 | 0.007 | 0.007 | 0.039 | | 0.008 | 0.004 | | 0 | 0.004 | 0.009 | | 0.006 |
| EF | SCC | 0 | 0.006 | 0 | 0 | 0.020 | 0 | 0 | 0 | 0.004 | 0 | 0 | | 0 | 0.004 | 0.020 |
| EF | SCN | | 0.000 | 0 | 0 | 0.010 | 0 | 0 | 0 | 0 | | | 0 | | | 0.003 |
| EF | TRM | | | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0 | 0 | 0.006 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| SGND | TRM | | | 0 | | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 |

Table A2-12. Sturgeon chub catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 2.331 | 0.083 | 0.119 | 2.915 | 0.035 | 0 | 0 | 0 | 0 | 0.067 | 0.013 | 0.040 | 0 | 0 |
| BT | ISB | | 1.848 | 0.148 | 0.341 | 5.591 | 0.472 | 0 | 0 | 0 | 0.015 | 0.067 | 0.045 | 0.049 | 0.067 | 0 |
| BT | OSB | | 1.949 | 0.081 | 0.393 | 1.682 | 0.198 | 0 | 0 | 0 | 0.067 | 0.044 | 0.039 | 0.013 | 0 | 0 |
| BT | SCC | | 1.947 | 0.037 | 0.655 | 2.585 | 0.185 | 0 | 0 | 0 | 0 | 0 | | 0.145 | 0.096 | 0.078 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 1.333 | | 0 | | | | | | 0.028 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0 | 0 | 0 | 0.067 | 0.656 | 0.083 | 0 | 0 | 0 | 0 | 0 | 0.028 | 0 | 0 | 0 |
| BS | OSB | | | | | | | 0 | 0 | 0 | | | | | 0 | 0 |
| BS | SCC | 0 | 0.019 | 0 | 0.011 | 0.631 | 0.097 | 0 | 0 | 0 | | 0 | 0.250 | 0 | 0 | 0.083 |
| BS | SCN | 0 | 0 | 0 | 0 | 0.385 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| BS | TRM | | | | | | 0 | | | | | | | 0 | 0 | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0 | 0.010 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EF | OSB | 0 | 0.003 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0.002 | 0 | | |
| EF | SCC | 0 | 0 | 0.010 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| EF | SCN | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | | | 0 |
| EF | TRM | | | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| SGND | TRM | | | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | | | 0 |

Table A2-13. Walleye catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0 | 0.022 | 0 | 0 | 0 | 0 | 0.056 | 0.030 | 0.015 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0 | 0.011 | 0 | 0 | 0 | 0.007 | 0.019 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | OSB | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | SCC | | 0 | 0 | 0 | 0.111 | 0 | 0 | 0 | 0.007 | 0 | 0 | | 0 | 0 | 0 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0.056 | 0.033 | 0 | 0 | 0.044 | 0 | 0 | 0 | 0.089 | 0.133 | 0 | 0 | 0 | 0.033 | 0 |
| BS | OSB | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| BS | SCC | 0 | 0 | 0 | 0.046 | 0.133 | 0 | 0 | 0.042 | 0.095 | | 0 | 0 | 0 | 0 | 0 |
| BS | SCN | 0 | 0 | 0 | 0.756 | 0.233 | 0 | 0 | 0.750 | 0.250 | | | 0 | 0 | 0 | 0 |
| BS | TRM | | | | | | 0 | | | | | | 0 | 0 | 0 | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0.033 | 0.042 | 0 | 0 | 0 | | | 0 | 0 | 0.017 | 0 | 0 | 0 | 0 | 0.002 |
| EF | OSB | 0.034 | 0.043 | 0.005 | 0.027 | 0.013 | 0.006 | 0 | 0.023 | 0.044 | | | | | | |
| EF | SCC | 0.200 | 0.036 | 0.010 | 0.010 | 0.040 | 0 | 0 | 0 | 0.04 | 0 | 0 | | 0 | 0 | 0 |
| EF | SCN | | 0.100 | 0.010 | 0.054 | 0.068 | 0.013 | 0.013 | 0.008 | 0.156 | | | 0 | | | 0 |
| EF | TRM | | | 0 | 0.017 | 0 | | 0.209 | 0.127 | 0.223 | 0.030 | 0.004 | | | 0 | 0.003 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0.033 | 0.014 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0.003 | 0.105 | 0.041 | 0.051 | 0.020 | 0.022 | 0.059 | | | 0 | 0 | 0 | 0 |
| SGND | TRM | | | 0.015 | 0.110 | 0.105 | | 0.179 | 0.120 | 0.038 | 0.010 | 0.029 | 0.002 | 0.023 | | 0 |

Table A2-14. White sucker catch per effort in Segments 3-*27* in the Missouri River, where five gears were used to collect fish in six macrohabitats. DTN = drifting trammel net (fish/100m), BT = benthic trawl (fish/100m), BS = beach seine (fish/haul), EF = electrofishing (fish/min), SGND = stationary gill net (fish/hr), CHXO = channel crossover, ISB = inside bend, OSB = outside bend, SCC = secondary channel connected, SCN = secondary channel not connected, TRM = tributary mouth. Segments 3, 5, and 9 are least-altered segments; Segments **7**, **8, 10-15** are inter-reservoir segments; and Segments *17-27* are channelized segments.

| Gear and Habitat | | Segment | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 5 | **7** | **8** | 9 | **10** | **12** | **14** | **15** | *17* | *19* | *22* | *23* | *25* | *27* |
| DTN | CHXO | 0 | 0 | 0.037 | 0 | 0 | 0 | 0.044 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | ISB | 0 | 0 | 0.015 | 0 | 0 | 0 | 0.185 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | OSB | 0 | 0 | 0 | 0 | 0 | 0 | 0.019 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DTN | SCC | 0 | 0 | 0.022 | 0.007 | 0 | 0 | 0 | 0 | 0 | | | | 0 | 0 | 0 |
| DTN | SCN | | | | | | | | | | | | | | | |
| DTN | TRM | | | | 0 | | 0 | | | | 0 | 0 | 0 | 0 | 0 | |
| BT | CHXO | | 0 | 0.030 | 0.007 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | ISB | | 0 | 0.007 | 0.007 | 0 | 0 | 0.037 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | OSB | | 0 | 0.022 | 0.022 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BT | SCC | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| BT | SCN | | | | | | | | | | | | | | | |
| BT | TRM | | | | 0 | | 0 | | | | | | 0 | 0 | 0 | |
| BS | CHXO | | | | | | | | | | | | | | | |
| BS | ISB | 0.822 | 0.037 | 0.861 | 1.204 | 0.356 | 0 | 2.125 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BS | OSB | | | | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BS | SCC | 1.244 | 0.019 | 2.193 | 0.791 | 0.444 | 0.176 | 9.022 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| BS | SCN | 2.333 | 0 | 9.226 | 5.474 | 0.178 | 0 | 87.711 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| BS | TRM | | | | | | 0 | | | | | | 0 | 0 | 0 | |
| EF | CHXO | | | | | | | | | | | | | | | |
| EF | ISB | 0 | 0 | 0.028 | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EF | OSB | 0.002 | 0.002 | 0.012 | 0.007 | | | 0.061 | | | | | | | | |
| EF | SCC | 0 | 0 | 0.115 | 0.041 | 0 | 0 | 0.050 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| EF | SCN | | 0 | 0.083 | 0.293 | 0 | 0.019 | 0.119 | 0 | 0.009 | | | 0 | | | 0 |
| EF | TRM | | | 0.025 | 0.017 | 0.025 | | 0.019 | 0.028 | 0.003 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | CHXO | | | | | | | | | | | | | | | |
| SGND | ISB | | | | 0 | 0 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SGND | OSB | | | | | | | | | | | | | | | |
| SGND | SCC | | | | | | | | | | | | | | | |
| SGND | SCN | 0 | 0 | 0.004 | 0.026 | 0.002 | 0 | 0.024 | 0 | 0 | | | 0 | 0 | 0 | 0 |
| SGND | TRM | | | 0.007 | 0.036 | 0 | | 0.028 | 0 | 0 | 0 | 0 | | | | 0 |

# APPENDIX 3

## ANOVA OUTPUT TABLES FOR CATCH PER UNIT EFFORT DATA AND CONTRASTS AMONG YEARS, ZONES, SEGMENTS, AND MACROHABITATS

The contrasts description is presented across table columns when no possible contrasts for any ANOVA were possible. ANOVA were not possible for burbot, bigmouth buffalo, white sucker, and sand shiner. Output for blue catfish is in the Results section.

Table A3-1 ANOVA statistical table for blue sucker catch/effort by gear.....197–199

Table A3-2 ANOVA statistical table for channel catfish catch/effort by gear .....200–204

Table A3-3 ANOVA statistical table for common carp catch/effort by gear.....205–207

Table A3-4 ANOVA statistical table for emerald shiner catch/effort by gear .....208–210

Table A3-5 ANOVA statistical table for fathead minnow catch/effort by gear.....211–212

Table A3-6 ANOVA statistical table for flathead catfish catch/effort by gear.....213–214

Table A3-7 ANOVA statistical table for flathead chub catch/effort by gear .....215–216

Table A3-8 ANOVA statistical table for freshwater drum catch/effort by gear .....217–219

Table A3-9 ANOVA statistical table for river carpsucker catch/effort by gear.....220–224

Table A3-10 ANOVA statistical table for sauger catch/effort by gear .....225–229

Table A3-11 ANOVA statistical table for shorthead redhorse catch/effort by gear .....230–234

Table A3-12 ANOVA statistical table for shovelnose sturgeon catch/effort by gear.....235–237

Table A3-13 ANOVA statistical table for sicklefin chub catch/effort by gear.....238–240

Table A3-14 ANOVA statistical table for smallmouth buffalo catch/effort by gear .....241–245

Table A3-15 ANOVA statistical table for stonecat catch/effort by gear.....246–248

Table A3-16 ANOVA statistical table for sturgeon chub catch/effort by gear .....249–250

Table A3-17 ANOVA statistical table for walleye catch/effort by gear.....251–255

Table A3-1. Analysis of variance (ANOVA) probabilities with F-values in parentheses for blue sucker collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Drifting Trammel Net | | Electrofishing | |
|---|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 1 | ANOVA 2 |
| Analysis level | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 46 | 27 | 24 | 21 |
| Years | 1996-1998 | 1996-1998 | 1996-1998 | 1996-1998 |
| Segments | 3, 5, **7**, **8**, 9, **15**, *23, 27* | **8**, *17-23* | **15** vs. *17, 19, 23* | 3, 5, **15**, *17-23* |
| Macrohabitats | BEND, SCC | BEND, TRM | BEND, TRM | BEND |
| | | | | |
| Year | 0.681 (0.40) | 0.090 (4.05) | 0.287 (1.55) | 0.222 (1.71) |
| Segment | 0.011 (4.50) | 0.002 (25.03) | 0.225 (1.94) | 0.129 (2.10) |
| Macrohabitat | 0.191 (1.92) | 0.008 (18.13) | 0.008 (15.37) | |
| Year/segment interaction | 0.565 (0.92) | 0.083 (3.71) | 0.378 (1.30) | |
| Year/macrohabitat interaction | 0.771 (0.27) | 0.575 (0.62) | 0.245 (1.79) | |
| Segment/macrohabitat interaction | 0.430 (1.08) | 0.0009 (32.45) | 0.197 (2.14) | |
| **Contrasts** | | | | |
| **Year** | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* |
| 1996 vs. 1997 | 0.812 | 0.065 | 0.158 | 0.090 |
| 1996 vs. 1998 | 0.546 | 0.731 | 0.207 | 0.447 |
| 1997 vs. 1998 | 0.405 | 0.043 | 0.850 | 0.311 |
| **Segment** | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.0063 (0.1)$^{m}$<br>0.0031 (0.05)* | 0.05 (0.1)$^{m}$<br>0.025 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.02 (0.1)$^{m}$<br>0.01 (0.05)* |
| *Missouri –Yellowstone rivers* | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9)<br>**MOR_LA_VS_YSR_LA** | 0.948<br>3, 5 vs. 9 | | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**)<br>**FTP_IR_VS_YSR_LA** | 0.612<br>9 vs.**7**, **8** | | | |

| | | | | |
|---|---|---|---|---|
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | 0.673<br>3, 5 vs. **7**, **8** | | | |
| *3-Zones* | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.129<br>3, 5, 9 vs. **7**, **8**, **15** | | | 0.216<br>3, 5 vs. **15** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | 0.325<br>3, 5, 9 vs. *23*, *27* | | | 0.212<br>3, 5 vs. *17-23* |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.598<br>**7**, **8**, **15** vs. *23*, *27* | 0.0003*<br>**8** vs. *17-23* | 0.859<br>**15** vs. *17*, *19*, *23* | 0.690<br>**15** vs. *17-23* |
| *5-zones* | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.948<br>3, 5 vs. 9 | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | 0.673<br>3, 5 vs. **7, 8** | | | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | 0.0015*<br>3, 5 vs. **15** | | | 0.216<br>3, 5 vs. **15** |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | 0.396<br>3, 5 vs. *23, 27* | | | 0.212<br>3, 5 vs. *17-23* |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | 0.612<br>9 vs. **7, 8** | | | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | 0.0015*<br>9 vs. **15** | | | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | 0.427<br>9 vs. *23, 27* | | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | 0.0015*<br>**7, 8** vs. **15** | | | |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | 0.126<br>**7, 8** vs. *23, 27* | 0.0003*<br>**8** vs. *17-23* | | |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | 0.002*<br>**15** vs. 23, *27* | | 0.859<br>**15** vs. *17*, *19*, *23* | 0.690<br>**15** vs. *17-23* |

| | | | | |
|---|---|---|---|---|
| *Reservoir related* | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | 0.614<br>5 vs. **7** | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **SAK_IR_VS_BSAK_IR** | | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) AL&C_IR_VS_BL&C_IR | | | | |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1ST_CHAN** | | | 0.533<br>**15** vs. *17* | 0.813<br>**15** vs. *17* |
| *Channelized river* | | | | |
| Channelized above KC vs. channelized below KC (***17***, ***19***, ***22*** **vs.** ***23***, ***25***, ***27***) **AKC_CH_VS_BKC_CH** | | 0.257<br>*17-22* vs. *23* | 0.186<br>*17*, *19* vs. *23* | 0.020[m]<br>*17-22* vs. *23* |
| **Macrohabitat** | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)[m]<br>0.05 (0.05)* | 0.1 (0.1)[m]<br>0.05 (0.05)* | 0.1 (0.1)[m]<br>0.05 (0.05)* | |
| BEND vs. SCC | 0.191 | | | |
| BEND vs. SCN | | | | |
| BEND vs. TRM | | 0.008* | 0.008* | |
| SCC vs. SCN | | | | |
| SCC vs. TRM | | | | |
| SCN vs. TRM | | | | |

Table A3-2. Analysis of variance (ANOVA) probabilities with F-values in parentheses for channel catfish collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Beach seine | | Benthic trawl | | |
|---|---|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 1 | ANOVA 2 | ANOVA 3 |
| Analysis level | Macrohabitat | Replicate | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 46 | 78 | 46 | 23 | 26 |
| Years | 1996-1998 | 1996-1998 | 1996-1998 | 1996-1998 | 1996-1998 |
| Segments | 9, **15**, *22-27* | 9, **15**, *17*, *22-27* | 5, 9, **10**, *17*, *19*, *23-27* | **10**, *22-25* | **10**, *23*, *25* |
| Macrohabitats | BEND, SCC, SCN | BEND | BEND, SCC | BEND, TRM | BEND, SCC, TRM |
| | | | | | |
| Year | 0.332 (1.21) | 0.235 (1.49) | 0.803 (0.22) | 0.098 (3.84) | 0.246 (1.73) |
| Segment | 0.049 (3.13) | 0.012 (3.05) | 0.309 (1.35) | 0.204 (2.22) | 0.064 (4.19) |
| Macrohabitat | 0.060 (3.59) | | 0.080 (3.64) | 0.020 (11.24) | 0.052 (4.66) |
| Year/segment interaction | 0.119 (2.06) | 0.281 (1.24) | 0.700 (0.75) | 0.570 (0.87) | 0.369 (1.26) |
| Year/macrohabitat interaction | 0.193 (1.80) | | 0.832 (0.19) | 0.067 (4.88) | 0.036 (4.74) |
| Segment/macrohabitat interaction | 0.344 (1.27) | | 0.513 (0.94) | 0.193 (2.32) | 0.062 (3.73) |
| **Contrasts** | | | | | |
| **Year** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* |
| 1996 vs. 1997 | 0.253 | 0.180 | 0.657 | 0.039 | 0.114 |
| 1996 vs. 1998 | 0.706 | 0.948 | 0.527 | 0.185 | 0.510 |
| 1997 vs. 1998 | 0.186 | 0.110 | 0.848 | 0.227 | 0.265 |
| **Segment** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.025 (0.1)$^{m}$<br>0.0125 (0.05)* | 0.02 (0.1)$^{m}$<br>0.01 (0.05)* | 0.011 (0.1)$^{m}$<br>0.0056 (0.05)* | 0.05 (0.1)$^{m}$<br>0.025 (0.05)* | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* |
| *Missouri –Yellowstone rivers* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9)<br>**MOR_LA_VS_YSR_LA** | | | 0.787<br>5 vs. 9 | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) FTP_IR_VS_YSR_LA | | | | | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | | | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| *3-Zones* | | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.569<br>9 vs. **15** | 0.455<br>9 vs. **15** | 0.688<br>5, 9 vs. **10** | | |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | 0.018 [m]<br>9 vs. *22-27* | 0.003*<br>9 vs. *17*, *22-27* | 0.048<br>5, 9 vs. *17*, *19*, *23-27* | | |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.015 [m]<br>**15** vs. *22-27* | 0.0007*<br>**15** vs. *17, 22-27* | 0.051<br>**10** vs. *17, 19, 23-27* | 0.838<br>**10** vs. *22-25* | 0.207<br>**10** vs. *23, 25* |
| *5-zones* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | 0.787<br>5 vs. 9 | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | | 0.831<br>5 vs. **10** | | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | | | | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | | 0.082<br>5 vs. *17, 19, 23-27* | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | | 0.630<br>9 vs. **10** | | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | 0.569<br>9 vs. **15** | 0.455<br>9 vs. **15** | | | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | 0.018 [m]<br>9 vs. *22-27* | 0.003*<br>9 vs. *17*, *23*, *25*, *27* | 0.146<br>9 vs. *17, 19, 23-27* | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | | | | | |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | | | | | |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | 0.015 [m]<br>**15** vs. *22-27* | 0.0007*<br>**15** vs. *17, 22-27* | | | |
| *Reservoir related* | | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **SAK_IR_VS_BSAK_IR** | | | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) AL&C_IR_VS_BL&C_IR | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1ST_CHAN** | | 0.023 (**15** vs. *17*) | | | | |
| *Channelized river* | | | | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | 0.127 *22* vs. *23*, *25*, *27* | 0.927 *17*, *22* vs. *23*, *25*, *27*) | 0.650 17, 19 vs. 23-27 | 0.244 *22* vs. *23*, *25* | | |
| **Macrohabitat** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m] 0.017 (0.05)* | | 0.1 (0.1)[m] 0.05 (0.05)* | 0.1 (0.1)[m] 0.05 (0.05)* | | 0.033 (0.1)[m] 0.017 (0.05)* |
| BEND vs. SCC | 0.082 | | 0.080 [m] | | | 0.129 |
| BEND vs. SCN | 0.035 | | | | | |
| BEND vs. TRM | | | | 0.020* | | 0.019[m] |
| SCC vs. SCN | 0.249 | | | | | |
| SCC vs. TRM | | | | | | 0.191 |
| SCN vs. TRM | | | | | | |

| Statistic | Electrofishing | | | Stationary Gillnet | | |
|---|---|---|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 3 | ANOVA 1 | ANOVA 2 | ANOVA 3 |
| Analysis level | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 42 | 30 | 27 | 26 | 62 | 24 |
| Years | 1996-1998 | 1997, 1998 | 1996-1998 | 1997, 1998 | 1997, 1998 | 1997, 1998 |
| Segments | **15**, *17-27* | 3, 5, **15**, *17, 19, 23-27* | 3, 5, **15**, *17-27* | **14, 15,** *17-23, 27* | 5**, 7, 8,** 9, **10-15**, *27* | **7, 8,** 9, **12-15,** *17-27* |
| Macrohabitats | BEND, TRM | BEND, SCC | BEND | BEND, TRM | SCN | TRM |
| | | | | | | |
| Year | 0.017 (5.84) | 0.034 (8.38) | 0.140 (2.23) | 0.136 (3.46) | 0.737 (0.11) | 0.388 (0.81) |
| Segment | 0.017 (4.19) | 0.013 (9.26) | 0.027 (3.06) | 0.031 (8.14) | <0.0001 (6.93) | 0.187 (1.73) |
| Macrohabitat | 0.0003 (24.67) | 0.029 (9.15) | | 0.008 (24.40) | | |
| Year/segment interaction | 0.027 (3.20) | 0.179 (2.37) | | 0.034 (7.77) | | |
| Year/macrohabitat interaction | 0.119 (2.55) | 0.892 (0.02) | | 0.103 (4.42) | | |
| Segment/macrohabitat interaction | 0.013 (4.54) | 0.786 (0.53) | | 0.093 (4.20) | | |
| | | | | | | |
| **Year** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m] 0.017 (0.05)* | 0.1 (0.1)[m] 0.05 (0.05)* | 0.033 (0.1)[m] 0.017 (0.05)* | 0.1 (0.1)[m] 0.05 (0.05)* | 0.1 (0.1)[m] 0.05 (0.05)* | 0.1 (0.1)[m] 0.05 (0.05)* |
| 1996 vs. 1997 | 0.023 [m] | | 0.561 | | | |
| 1996 vs. 1998 | 0.007* | | 0.057 | | | |
| 1997 vs. 1998 | 0.550 | 0.034* | 0.164 | 0.136 | 0.737 | 0.388 |

| **Segment** | | | | | | |
|---|---|---|---|---|---|---|
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m]<br>0.017 (0.05)* | 0.02 (0.1)[m]<br>0.01 (0.05)* | 0.02 (0.1)[m]<br>0.01 (0.05)* | 0.017 (0.1)[m]<br>0.0083<br>(0.05)* | 0.0053 (0.1)[m]<br>0.0026<br>(0.05)* | 0.0083 (0.1)[m]<br>0.0042<br>(0.05)* |
| *Missouri –Yellowstone rivers* | | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9)<br>**MOR_LA_VS_YSR_LA** | | | | | 0.861<br>5 vs. 9 | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8)**<br>**FTP_IR_VS_YSR_LA** | | | | | 0.006<br>9 vs. **7, 8** | 0.937<br>9 vs. **7, 8** |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8)**<br>**MOR_LA_VS_FTP_IR** | | | | | 0.036<br>5 vs. **7, 8** | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | | | 0.119<br>**8** vs. **10** | |
| *3-Zones* | | | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | | 0.816<br>3, 5 vs. **15** | 0.936<br>3, 5 vs. **15** | | 0.417<br>5, 9 vs. **7, 8, 10-15** | 0.786<br>9 vs. **7, 8, 12-15** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | 0.029<br>3, 5 vs.*17 19, 23-27* | 0.035<br>3, 5 vs. *17-27* | | 0.001*<br>5, 9 vs. *27* | 0.081<br>9 vs. *17-27* |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.941<br>**15** vs. *17-27* | 0.053<br>**15** vs. *17, 19, 23-27* | 0.085<br>**15** vs. *17-27* | 0.006*<br>**14, 15** vs. *17-23, 27* | 0.002*<br>**7, 8, 10-15** vs. *27* | 0.014<br>**7, 8, 12-15** vs. *17-27* |
| *5-zones* | | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9)<br>**MOR_LA_VS_YSR_LA** | | | | | 0.861<br>5 vs. 9 | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | | | | 0.713<br>5 vs. **7, 8, 10-14** | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**)<br>**MOR_LA_VS_BL&C_IR** | | 0.816<br>3, 5 vs. **15** | 0.936<br>3, 5 vs. **15** | | 0.163<br>5 vs. **15** | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*)<br>**MOR_LA_VS_CH** | | 0.029<br>3, 5 vs.*17,19 23-27* | 0.035<br>3, 5 vs. *17-27* | | 0.012<br>5 vs. *27* | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**)<br>**YSR_LA_VS_IR_W/O_BL&C** | | | | | 0.788<br>9 vs. **7, 8, 10-14** | 0.833<br>9 vs. **7, 8, 12, 14** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | | | | 0.128<br>9 vs. **15** | 0.106<br>9 vs. **15** |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | | | | 0.002*<br>9 vs. *27* | 0.081<br>9 vs. *17-27* |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | | | | 0.013[m]<br>**14** vs. **15** | 0.139<br>**7, 8, 10-14** vs. **15** | 0.033<br>**7, 8, 12, 14** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | | | | 0.003*<br>**14** vs. *17-23, 27* | 0.0006*<br>**7, 8, 10,-14** vs. *27* | 0.0042*<br>**7, 8, 12, 14** vs. *17-27* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | 0.941<br>**15** vs. *17-27* | 0.053<br>**15** vs. *17, 19, 23-27* | 0.085<br>**15** vs. *17-27* | 0.532<br>**15** vs. *17-23, 27* | 0.360<br>**15** vs. 27 | 0.711<br>**15** vs. *17-27* |
| *Reservoir related* | | | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | | | 0.016<br>5 vs. **7** | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | | | 0.073<br>**10** vs. **12** | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | | | | 0.013[m]<br>**14** vs. **15** | <0.0001*<br>**14** vs. **15** | 0.031<br>**14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1[ST]_CHAN** | 0.116<br>**15** vs. *17* | 0.900<br>**15** vs. *17* | 0.986<br>**15** vs. *17* | 0.723<br>**15** vs. *17* | | 0.880<br>**15** vs. *17* |
| *Channelized river* | | | | | | |
| Channelized above KC vs. channelized below KC (*17, 19, 22* vs. *23, 25, 27*) **AKC_CH_VS_BKC_CH** | 0.073<br>*17-22 vs. 23-27* | 0.008*<br>*17, 19 vs. 23-27* | 0.110<br>*17-22* vs. *23-27* | 0.960<br>*17-22 vs. 23, 27* | | 0.491<br>*17-22 vs. 23-27* |
| **Macrohabitat** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)[m]<br>0.05 (0.05)* | 0.1 (0.1)[m]<br>0.05 (0.05)* | | 0.1 (0.1)[m]<br>0.05 (0.05)* | | |
| BEND vs. SCC | | 0.0292* | | | | |
| BEND vs. SCN | | | | | | |
| BEND vs. TRM | 0.0003* | | | 0.008* | | |
| SCC vs. SCN | | | | | | |
| SCC vs. TRM | | | | | | |
| SCN vs. TRM | | | | | | |

Table A3-3. Analysis of variance (ANOVA) probabilities with F-values in parentheses for common carp collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Electrofishing | | | Stationary Gillnet | | |
|---|---|---|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 3 | ANOVA 1 | ANOVA 2 | ANOVA 3 |
| Analysis level | Macrohabitat | Replicate | Macrohabitat | Average Year | Macrohabitat | Macrohabitat |
| N | 70 | 121 | 33 | 24 | 24 | 27 |
| Years | 1996-1998 | 1998 | 1996-1998 | 1996-1998 | 1996-1998 | 1996-1998 |
| Segments | **10-15,** *17, 19, 23-27* | **7, 8,** 9, **10-15,** *27* | 5, **10-15**, *17-27* | **8**, 9, **14, 15**, *22-27* | 5, **7, 8,** 9, **10, 14, 15,** *27* | **7, 8, 14, 15,** *19-27* |
| Macrohabitats | BEND, SCC, TRM | BEND, SCC, SCN, TRM | BEND | ISB, SCN, TRM | SCN | TRM |
| | | | | | | |
| Year | 0.778 (0.25) | | 0.908 (0.10) | | 0.044 (3.93) | 0.643 (0.45) |
| Segment | <0.0001 (25.66) | <0.0001 (9.31) | 0.007 (3.61) | 0.388 (1.15) | 0.254 (1.47) | 0.378 (1.16) |
| Macrohabitat | <0.0001 (48.72) | <0.0001 (37.17) | | 0.070 (3.24) | | |
| Year/segment interaction | 0.0004 (4.97) | | | | | |
| Year/macrohabitat interaction | 0.322 (1.25) | | | | | |
| Segment/macrohabitat interaction | 0.0001 (5.75) | <0.0001 (13.00) | | | | |
| **Contrasts** | | | | | | |
| **Year** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$ 0.017 (0.05)$^{*}$ | | 0.033 (0.1)$^{m}$ 0.017 (0.05)$^{*}$ | | 0.033 (0.1)$^{m}$ 0.017 (0.05)$^{*}$ | 0.033 (0.1)$^{m}$ 0.017 (0.05)$^{*}$ |
| 1996 vs. 1997 | 0.822 | | 0.958 | | 0.033 $^{m}$ | 0.407 |
| 1996 vs. 1998 | 0.597 | | 0.689 | | 0.026 | 0.438 |
| 1997 vs. 1998 | 0.560 | | 0.728 | | 0.899 | 0.956 |
| **Segment** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.013 (0.1)$^{m}$ 0.006 (0.05)$^{*}$ | 0.008 (0.1)$^{m}$ 0.004 (0.05)$^{*}$ | 0.008 (0.1)$^{m}$ 0.004 (0.05)$^{*}$ | 0.009 (0.1)$^{m}$ 0.005 (0.05)$^{*}$ | 0.006 (0.1) $^{m}$ 0.003 (0.05)* | 0.017 (0.1)$^{m}$ 0.008 (0.05)$^{*}$ |
| *Missouri –Yellowstone rivers* | | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | | | 0.182 5 vs. 9 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) **FTP_IR_VS_YSR_LA** | | 0.004*<br>9 vs.**7**, **8** | | 0.979<br>9 vs. **8** | 0.928<br>9 vs.**7**, **8** | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | | | | | 0.149<br>5 vs. **7**, **8** | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | <0.0001*<br>**8** vs. **10** | | | 0.368<br>**8** vs. **10** | |
| *3-Zones* | | | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | | 0.750<br>9 vs. **7**, **8**, **10-15** | 0.050<br>5 vs. **10-15** | 0.347<br>9 vs. **8**, **14**, **15** | 0.936<br>5, 9 vs. **7**, **8**, **10**, **14**, **15** | |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | 0.385<br>9 vs. *27* | 0.275<br>5 vs. *17-27* | 0.681<br>9 vs. *22-27* | 0.580<br>5, 9 vs. *27* | |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.034<br>**10-15** vs. *17*, *19*, *23-27* | 0.425<br>**7**, **8**, **10-15** vs. *27* | 0.097<br>**10-15** vs. *17-27* | 0.406<br>**8**, **14**, **15** vs. *22- 27* | 0.498<br>**7**, **8**, **10**, **14**, **15** vs. *27* | 0.184<br>**7**, **8**, **14**, **15** vs. *19-27* |
| *5-zones* | | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | | | 0.182<br>5 vs. 9 | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | | 0.004*<br>5 vs. **10-14** | | 0.502<br>5 vs. **7, 8, 10, 14** | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | | 0.184<br>5 vs. **15** | | 0.296<br>5 vs. **15** | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | | 0.275<br>5 vs. *17-27* | | 0.253<br>5 vs. *27* | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | 0.450<br>9 vs. **7, 8, 10-14** | | 0.226<br>9 vs. **8, 14** | 0.296<br>9 vs. **7, 8, 10, 14** | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | 0.138<br>9 vs. **15** | | 0.854<br>9 vs. **15** | 0.755<br>9 vs. **15** | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | 0.385<br>9 vs. *27* | | 0.681<br>9 vs. *22-27* | 0.836<br>9 vs. *27* | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | <0.0001*<br>**10-14** vs. **15** | 0.012<br>**7, 8, 10-14** vs. **15** | <0.0001*<br>**10-14** vs. **15** | 0.311<br>**8, 14** vs. **15** | 0.505<br>**7, 8, 10, 14** vs. **15** | 0.654<br>**7, 8, 14** vs. **15** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*)<br>**IR_W/O_BL&/C_VS_CH** | 0.020<br>**10-14** vs. *17, 19, 23-27* | 0.773<br>**7, 8, 10-14** vs. *27* | 0.002*<br>**10-14** vs. *17-27* | 0.231<br>**8, 14** vs. *22-27* | 0.427<br>**7, 8, 10, 14** vs. *27* | 0.290<br>**7, 8, 14** vs. 19-*27* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*)<br>**BL&C_IR_VS_CH** | <0.0001*<br>**15** vs. *17, 19, 23-27* | 0.017<br>**15** vs. *27* | 0.008[m]<br>**15** vs. *17-27* | 0.858<br>**15** vs. *22-27* | 0.917<br>**15** vs. *27* | 0.243<br>**15** vs. *19-27* |
| *Reservoir related* | | | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**)<br>**AFTP_LA_VS_BFTP_RI** | | | | | 0.262<br>5 vs. **7** | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**)<br>**ASAK_IR_VS_BSAK_IR** | 0.010[m]<br>**10** vs. **12** | <0.0001*<br>**10** vs. **12** | 0.158<br>**10** vs. **12** | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15)**<br>**AL&C_IR_VS_BL&C_IR** | <0.0001*<br>**14** vs. **15** | 0.0003*<br>**14** vs. **15** | 0.002*<br>**14** vs. **15** | 0.067<br>**14** vs. **15** | 0.054<br>**14** vs. **15** | 0.305<br>**14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*)<br>**BL&C_IR_VS_1[ST]_CHAN** | <0.0001*<br>**15** vs. *17* | | 0.078<br>**15** vs. *17* | | | |
| *Channelized river* | | | | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*)<br>**AKC_CH_VS_BKC_CH** | 0.001*<br>*17*, *19* vs. *23-27* | | 0.629<br>*17-22* vs. *23-27* | 0.746<br>*22* vs. *23- 27* | | 0.529<br>*19*, *22* vs. *23-27* |
| **Macrohabitat** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m]<br>0.017 (0.05)[*] | 0.017 (0.1)[m]<br>0.008 (0.05)[*] | | 0.033 (0.1)[m]<br>0.017 (0.05)[*] | | |
| BEND vs. SCC | 0.543 | 0.487 | | | | |
| BEND vs. SCN | | <0.0001* | | 0.023[m] | | |
| BEND vs. TRM | <0.0001* | 0.0001* | | 0.214 | | |
| SCC vs. SCN | | <0.0001* | | | | |
| SCC vs. TRM | 0.0004* | 0.004* | | | | |
| SCN vs. TRM | | <0.0001* | | 0.234 | | |

Table A3-4. Analysis of variance (ANOVA) probabilities with F-values in parentheses for emerald shiner collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Beach Seine | | | Electrofishing | | |
|---|---|---|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 3 | ANOVA 1 | ANOVA 2 | ANOVA 3 |
| Analysis level | Replicate | Replicate | Replicate | Macrohabitat | Replicate | Macrohabitat |
| N | 261 | 128 | 100 | 56 | 66 | 30 |
| Years | 1996-1998 | 1996-1998 | 1996-1998 | 1996-1998 | 1998 | 1996-1998 |
| Segments | 3, 5, 9, **15**, *22-27* | 3, 5, 9, **15**, *23-27* | 3, 5, 9, **15**, *17, 22-27* | **14**, **15,** *17,19, 23-27* | 9, **14, 15**, *27* | 3, 5, **14**, **15,** *17-27* |
| Macrohabitats | ISB, SCC, SCN | SCC | ISB | BEND, SCC, TRM | BEND, SCC, SCN, TRM | BEND |
| | | | | | | |
| Year | 0.036 (3.38) | 0.662 (0.41) | 0.008 (5.16) | 0.654 (0.44) | | 0.775 (0.26) |
| Segment | <0.0001 (4.99) | 0.0006 (4.31) | 0.030 (2.29) | 0.052 (2.67) | 0.587 (0.65) | 0.086 (2.10) |
| Macrohabitat | 0.885 (0.12) | | | 0.243 (1.54) | 0.714 (0.46) | |
| Year/segment interaction | 0.003 (2.51) | 0.004 (2.66) | 0.033 (1.91) | 0.123 (1.84) | | |
| Year/macrohabitat interaction | 0.775 (0.450) | | | 0.559 (0.77) | | |
| Segment/macrohabitat interaction | 0.018 (2.02) | | | 0.038 (2.56) | 0.529 (0.90) | |
| **Contrasts** | | | | | | |
| **Year** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* |
| 1996 vs. 1997 | 0.010* | 0.613 | 0.002* | 0.393 | | 0.503 |
| 1996 vs. 1998 | 0.247 | 0.368 | 0.050 | 0.377 | | 0.599 |
| 1997 vs. 1998 | 0.212 | 0.628 | 0.187 | 0.958 | | 0.884 |
| **Segment** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.011 (0.1)$^{m}$<br>0.0056 (0.05)* | 0.0125 (0.1)$^{m}$<br>0.0063 (0.05)* | 0.01 (0.1)$^{m}$<br>0.005 (0.05)* | 0.017 (0.1)$^{m}$<br>0.0083 (0.05)* | 0.0125 (0.1)$^{m}$<br>0.0063 (0.05)* | 0.01 (0.1)$^{m}$<br>0.005 (0.05)* |
| *Missouri –Yellowstone rivers* | | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9)<br>**MOR_LA_VS_YSR_LA** | 0.011 $^{m}$<br>(3, 5 vs. 9) | 0.062<br>(3, 5 vs. 9) | 0.133<br>(3, 5 vs. 9) | | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) FTP_IR_VS_YSR_LA | | | | | | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | | | | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *3-Zones* | | | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.635<br>3, 5, 9 vs. **15** | 0.0001*<br>3, 5, 9 vs. **15** | 0.939<br>3, 5, 9 vs. **15** | | 0.302<br>9 vs. **14**, **15** | 0.143<br>3, 5 vs. **14**, **15** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | 0.067<br>3, 5, 9 vs. *22-27* | 0.084<br>3, 5, 9 vs. *23-27* | 0.018<br>3, 5, 9 vs. *17*, *22- 27* | | | 0.208<br>3, 5 vs. *17-27* |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.070<br>**15** vs. *22- 27* | 0.026<br>**15** vs. *23- 27* | 0.072<br>**15** vs. *17*, *22-27* | 0.075<br>**14**, **15** vs. *17*, *19*, *23-27* | 0.257<br>**14**, **15** vs. *27* | 0.005*<br>**14**, **15** vs. *17-27* |
| *5-zones* | | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.011 [m]<br>(3, 5 vs. 9) | 0.062<br>(3, 5 vs. 9) | 0.133<br>(3, 5 vs. 9) | | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | | | | | 0.795<br>3, 5 vs. **14** |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | 0.305<br>3, 5 vs. **15** | 0.004*<br>3, 5 vs. **15** | 0.600<br>3, 5 vs. **15** | | | 0.013<br>3, 5 vs. **15** |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | 0.447<br>3, 5 vs. *22-27* | 0.394<br>3, 5 vs. *23-27* | 0.152<br>3, 5 vs. *17, 22-27* | | | 0.208<br>3, 5 vs. *17-27* |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | | | | 0.263<br>9 vs. **14** | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | 0.376<br>9 vs. **15** | <0.0001*<br>9 vs. **15** | 0.410<br>9 vs. **15** | | 0.515<br>9 vs. **15** | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | 0.0001*<br>9 vs. *22-27* | 0.007[m]<br>9 vs. *23-27* | 0.002*<br>9 vs. *17, 22-27* | | 0.988<br>9 vs. *27* | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | | | | 0.027<br>**14** vs. **15** | 0.645<br>**14** vs. **15** | 0.017<br>**14** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | | | | 0.938<br>**14** vs. *17, 19, 23-27* | 0.231<br>**14** vs. *27* | 0.499<br>**14** vs. *17-27* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | 0.070<br>**15** vs. *22-27* | 0.026<br>**15** vs. *23- 27* | 0.072<br>**15** vs. *17, 22-27* | 0.008*<br>**15** vs. *17, 19, 23-27* | 0.482<br>**15** vs. *27* | 0.0006*<br>**15** vs. *17-27* |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Reservoir related* | | | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | | | | 0.027<br>**14** vs. **15** | 0.645<br>**14** vs. **15** | 0.017<br>**14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1ST_CHAN** | | | 0.575<br>**15** vs. *17* | 0.018<br>**15** vs. *17* | | 0.003*<br>**15** vs. *17* |
| *Channelized river* | | | | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | 0.589<br>*22 vs. 23-27* | | 0.590<br>*17*, *22* vs. *23-27* | 0.349<br>*17*, *19* vs. *23-27* | | 0.941<br>*17*, *19*, *22* vs. *23*, *25*, *27* |
| **Macrohabitat** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m]<br>0.017 (0.05)* | | | 0.033 (0.1)[m]<br>0.017 (0.05)* | 0.017 (0.1)[m]<br>0.0083 (0.05)* | |
| BEND vs. SCC | 0.734 | | | 0.890 | 0.814 | |
| BEND vs. SCN | 0.655 | | | | 0.706 | |
| BEND vs. TRM | | | | 0.103 | 0.371 | |
| SCC vs. SCN | 0.792 | | | | 0.564 | |
| SCC vs. TRM | | | | 0.442 | 0.276 | |
| SCN vs. TRM | | | | | 0.644 | |

Table A3-5. Analysis of variance (ANOVA) probabilities with F-values in parentheses for fathead minnow collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Electrofishing | | |
|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 3 |
| Analysis level | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 24 | 15 | 12 |
| Years | 1996-1998 | 1998 | 1996-1998 |
| Segments | **12**, **14**, *17, 22* | **7**, **8**, 9, **12**, **14** | **12**, **14**, *17*, *22* |
| Macrohabitats | BEND, TRM | BEND, SCN, TRM | BEND |
| | | | |
| Year | 0.379 (1.15) | | 0.425 (0.99) |
| Segment | 0.433 (1.06) | 0.532 (0.85) | 0.485 (0.92) |
| Macrohabitat | 0.444 (0.67) | 0.032 (5.46) | |
| Year/segment interaction | 0.540 (0.92) | | |
| Year/macrohabitat interaction | 0.504 (0.77) | | |
| Segment/macrohabitat interaction | 0.573 (0.72) | | |
| **Contrasts** | | | |
| **Year** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* |
| 1996 vs. 1997 | 0.226 | | 0.254 |
| 1996 vs. 1998 | 0.941 | | 0.930 |
| 1997 vs. 1998 | 0.251 | | 0.286 |
| **Segment** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* | 0.05 (0.1)$^{m}$<br>0.025 (0.05)* | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* |
| *Missouri –Yellowstone rivers* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) **FTP_IR_VS_YSR_LA** | | 0.808<br>9 vs.**7**, **8** | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | | | |
| *3-Zones* | | | |

| | | | |
|---|---|---|---|
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | | 0.714<br>9 vs. **7**, **8**, **12, 14** | |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | | |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.355<br>**12**, **14** vs. *17*, *22* | | 0.383<br>**12**, **14** vs. *17*, *22* |
| *5-zones* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | 0.714<br>9 vs. **7**, **8**, **12, 14** | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | | | |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | 0.355<br>**12**, **14** vs. *17*, *22* | | 0.383<br>**12**, **14** vs. *17*, *22* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | | | |
| *Reservoir related* | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) AL&C_IR_VS_BL&C_IR | | | |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1$^{ST}$_CHAN** | | | |
| *Channelized river* | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) AKC_CH_VS_BKC_CH | | | |
| **Macrohabitat** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | |
| BEND vs. SCC | | | |
| BEND vs. SCN | | 0.019$^{m}$ | |
| BEND vs. TRM | 0.444 | 0.903 | |
| SCC vs. SCN | | | |
| SCC vs. TRM | | | |
| SCN vs. TRM | | 0.023 $^{m}$ | |

Table A3-6. Analysis of variance (ANOVA) probabilities with F-values in parentheses for flathead catfish collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Electrofishing | |
|---|---|---|
| | ANOVA 1 | ANOVA 2 |
| Analysis level | Macrohabitat | Macrohabitat |
| N | 42 | 35 |
| Years | 1996-1998 | 1997,1998 |
| Segments | ***15**, 17-27* | ***15**, 17, 19, 23-27* |
| Macrohabitats | BEND, TRM | BEND, SCC, TRM |
| | | |
| Year | 0.021 (5.45) | 0.026 (7.05) |
| Segment | 0.010 (4.79) | 0.008 (6.56) |
| Macrohabitat | <0.001 (172.69) | <0.0001 (150.31) |
| Year/segment interaction | 0.157 (1.82) | 0.860 (0.36) |
| Year/macrohabitat interaction | 0.094 (2.89) | 0.275 (1.50) |
| Segment/macrohabitat interaction | 0.055 (2.91) | 0.101 (2.41) |
| **Contrasts** | | |
| **Year** | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | 0.1 (0.1)$^{m}$<br>0.05 (0.05)$^{*}$ |
| 1996 vs. 1997 | 0.008$^{*}$ | |
| 1996 vs. 1998 | 0.037 | |
| 1997 vs. 1998 | 0.415 | 0.026$^{*}$ |
| **Segment** | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ |
| *Missouri –Yellowstone rivers* | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8)** FTP_IR_VS_YSR_LA | | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8) MOR_LA_VS_FTP_IR** | | |
| *3-Zones* | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | | |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | |

| | | |
|---|---|---|
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.321<br>**15** vs. 17-27 | 0.005*<br>**15** vs.17, 19, 23-27 |
| *5-zones* | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | | |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | | |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | 0.321<br>**15** vs. 17-27 | 0.005*<br>**15** vs.17, 19, 23-27 |
| *Reservoir related* | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) AL&C_IR_VS_BL&C_IR | | |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1ST_CHAN** | 0.070<br>**15** vs. 17 | 0.003*<br>**15** vs. 17 |
| *Channelized river* | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | 0.113<br>17-22 vs. 23-27 | 0.803<br>17,19 vs. 23-27 |
| **Macrohabitat** | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)m<br>0.05 (0.05)* | 0.033 (0.1)m<br>0.017 (0.05)* |
| BEND vs. SCC | | <0.0001* |
| BEND vs. SCN | | |
| BEND vs. TRM | <0.0001* | <0.0001* |
| SCC vs. SCN | | |
| SCC vs. TRM | | 0.215 |
| SCN vs. TRM | | |

Table A3-7. Analysis of variance (ANOVA) probabilities with F-values in parentheses for flathead chub collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Beach Seine | Electrofishing | |
|---|---|---|---|
| | ANOVA 1 | ANOVA 1 | ANOVA 2 |
| Analysis level | Replicate | Replicate | Replicate |
| N | 181 | 36 | 40 |
| Years | 1996-1998 | 1998 | 1997, 1998 |
| Segments | 3,5,**8**, 9, ***10*** | 5,**8**, 9, ***10*** | 3,5, ***10*** |
| Macrohabitats | ISB, SCC, SCN | BEND, SCC | BEND, SCC |
| | | | |
| Year | 0.904 (0.10) | | 0.004 (9.74) |
| Segment | <0.0001 (22.87) | 0.003 (6.01) | 0.056 (3.17) |
| Macrohabitat | 0.008 (4.93) | 0717 (0.13) | 0.636 (0.23) |
| Year/segment interaction | 0.0005 (3.72) | | 0.01 (5.46) |
| Year/macrohabitat interaction | 0.694 (0.56) | | 0.629 (0.24) |
| Segment/macrohabitat interaction | 0.238 (1.32) | 0.486 (0.83) | 0.225 (1.57) |
| **Contrasts** | | | |
| **Year** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | | 0.1 (0.1)$^{m}$<br>0.05 (0.05)$^{*}$ |
| 1996 vs. 1997 | 0.821 | | |
| 1996 vs. 1998 | 0.806 | | |
| 1997 vs. 1998 | 0.653 | | 0.004* |
| **Segment** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.014 (0.1)$^{m}$<br>0.007 (0.05)$^{*}$ | 0.014 (0.1)$^{m}$<br>0.007 (0.05)$^{*}$ | 0.1 (0.1)$^{m}$<br>0.05 (0.05)$^{*}$ |
| *Missouri –Yellowstone rivers* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9)<br>**MOR_LA_VS_YSR_LA** | <0.0001$^{*}$<br>3, 5 vs. 9 | 0.002*<br>5 vs. 9 | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.7, 8) **FTP_IR_VS_YSR_LA** | <0.0001$^{*}$<br>9 vs. **8** | 0.951<br>9 vs. **8** | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8)**<br>**MOR_LA_VS_FTP_IR** | 0.019<br>3, 5 vs. **8** | 0.001*<br>5 vs. **8** | |

| | | | |
|---|---|---|---|
| *3-Zones* | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.003* 3, 5, 9 vs. **8**, **10** | 0.018 5, 9 vs. **8**, **10** | 0.018* 3, 5 vs. **10** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | | |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | | | |
| *5-zones* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | <0.0001* 3, 5 vs. 9 | 0.002* 5 vs. 9 | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | 0.105 **8** vs. **10** | 0.611 **8** vs. **10** | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | 0.258 3, 5 vs. **8, 10** | 0.0006* 5 vs. **8, 10** | 0.018* 3, 5 vs. **10** |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | <0.0001* 9 vs. **8, 10** | 0.675 9 vs. **8, 10** | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | | | |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | | | |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | | | |
| *Reservoir related* | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) AL&C_IR_VS_BL&C_IR | | | |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1ST_CHAN** | | | |
| *Channelized river* | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) AKC_CH_VS_BKC_CH | | | |
| **Macrohabitat** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m] 0.017 (0.05)* | 0.1 (0.1)[m] 0.05 (0.05)* | 0.1 (0.1)[m] 0.05 (0.05)* |
| BEND vs. SCC | 0.370 | 0.717 | 0.636 |
| BEND vs. SCN | 0.002* | | |
| BEND vs. TRM | | | |
| SCC vs. SCN | 0.008* | | |
| SCC vs. TRM | | | |
| SCN vs. TRM | | | |

Table A3-8. Analysis of variance (ANOVA) probabilities with F-values in parentheses for freshwater drum collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Beach Seine | | Benthic Trawl | | Electrofishing | |
|---|---|---|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 1 | ANOVA 2 | ANOVA 1 | ANOVA 2 |
| Analysis level | | | | | | |
| N | 25 | 41 | 15 | 10 | 41 | 24 |
| Years | 1996, 1998 | 1996, 1998 | 1997, 1998 | 1997, 1998 | 1996-1998 | 1996-1998 |
| Segments | **15,** *22-27* | **15,** *17*, *22-27* | **15,** *17*, *19, 25* | **15,** *17-22, 25* | **14, 15,** *23-27* | 3, 5, **14, 15,** *22-27* |
| Macrohabitats | ISB, SCC, SCN | BEND | BEND, SCC | BEND | BEND, SCC, TRM | BEND |
| | | | | | | |
| Year | 0.338 (1.30) | 0.401 (0.73) | 0.003 (371.83) | 0.312 (1.34) | 0.619 (0.50) | 0.104 (2.67) |
| Segment | 0.107 (5.06) | 0.278 (1.33) | 0.002 (514.46) | 0.563 (0.85) | 0.2504 (1.55) | 0.003 (5.57) |
| Macrohabitat | 0.420 (1.18) | | 0.0009 (1053.25) | | 0.033 (4.60) | |
| Year/segment interaction | 0.128 (4.38) | 0.501 (0.89) | 0.0053 (187.45) | | 0.616 (0.80) | |
| Year/macrohabitat interaction | 0.262 (2.16) | | 0.016 (62.58) | | 0.627 (0.67) | |
| Segment/macrohabitat interaction | 0.137 (4.09) | | 0.002 (418.23) | | 0.234 (1.56) | |
| **Contrasts** | | | | | | |
| **Year** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* |
| 1996 vs. 1997 | | | | | 0.665 | 0.037 |
| 1996 vs. 1998 | 0.338 | 0.401 | | | 0.390 | 0.277 |
| 1997 vs. 1998 | | | 0.003* | 0.312 | 0.492 | 0.258 |
| **Segment** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.05 (0.1)$^{m}$<br>0.025 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.025 (0.1)$^{m}$<br>0.013 (0.05)* | 0.011 (0.1)$^{m}$<br>0.006 (0.05)* |
| *Missouri –Yellowstone rivers* | | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | | | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) FTP_IR_VS_YSR_LA | | | | | | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *3-Zones* | | | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | | | | | | <0.0001*<br>3, 5, vs. **14**, **15** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | | | | | 0.006*<br>3, 5 vs. *22-27* |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.049[m]<br>**15** vs. *22-27* | 0.157<br>**15** vs. *17*, *22-27* | 0.002*<br>**15** vs. *17*, *19*, *25* | 0.534<br>**15** vs. *17*-22, *25* | 0.797<br>**14**, **15** vs. *23-27* | 0.008[m]<br>**14**, **15** vs. *22-27* |
| *5-zones* | | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | | | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | | | | | 0.0002*<br>3, 5 vs. **14** |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | | | | | 0.002*<br>3, 5 vs. **15** |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | | | | | 0.008[m]<br>3, 5 vs. *22-27* |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | | | | | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | | | | | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | | | | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | | | | | 0.087<br>**14** vs. **15** | 0.308<br>**14** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | | | | | 0.369<br>**14** vs. *23-27* | 0.008[m]<br>**14** vs. *22-27* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | 0.049[m]<br>**15** vs. *22-27* | 0.157<br>**15** vs. *17*, *22-27* | 0.002*<br>**15** vs. *17*, *19*, *25* | 0.534<br>**15** vs. *17-22*, *25* | 0.202<br>**15** vs. *23-27* | 0.107<br>**15** vs. *22-27* |
| *Reservoir related* | | | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | | | | | 0.087<br>**14** vs. **15** | 0.308<br>**14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1ST_CHAN** | | 0.339<br>**15** vs. *17* | 0.0009*<br>**15** vs. *17* | 0.879<br>**15** vs. *17* | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Channelized river* | | | | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | 0.730 *22* vs. *23-27* | 0.690 *17*, *22* vs. *23-27* | 0.0009* *17*, *19* vs. *25* | 0.622 *17-22* vs. *25* | | 0.379 *22* vs. *23-27* |
| **Macrohabitat** | | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m] 0.017 (0.05)* | | 0.1(0.1)[m] 0.05 (0.05)* | | 0.033 (0.1)[m] 0.017 (0.05)* | |
| BEND vs. SCC | 0.997 | | 0.0009* | | 0.879 | |
| BEND vs. SCN | 0.237 | | | | | |
| BEND vs. TRM | | | | | 0.015* | |
| SCC vs. SCN | 0.237 | | | | | |
| SCC vs. TRM | | | | | 0.076 | |
| SCN vs. TRM | | | | | | |

Table A3-9. Analysis of variance (ANOVA) probabilities with F-values in parentheses for river carpsucker collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Beach Seine | | |
|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 3 |
| Analysis level | Macrohabitat | Macrohabitat | Replicate |
| N | 24 | 14 | 53 |
| Years | 1997, 1998 | 1997, 1998 | 1997 |
| Segments | *7, **8**, 9, 27* | *7, **8**, 9, **15**, 17, 25, 27* | *7, **8**, 9, **15**, 19, 25, 27* |
| Macrohabitats | ISB, SCC, SCN | BEND | SCC |
| | | | |
| Year | 0.445 (0.67) | 0.676 (0.19) | |
| Segment | 0.069 (4.02) | 0.701 (0.64) | <0.0001 (9.60) |
| Macrohabitat | 0.096 (3.55) | | |
| Year/segment interaction | 0.043 (5.14) | | |
| Year/macrohabitat interaction | 0.591 (0.58) | | |
| Segment/macrohabitat interaction | 0.577 (0.85) | | |
| **Contrasts** | | | |
| **Year** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)$^{m}$<br>0.05 (0.05)$^{*}$ | 0.1 (0.1)$^{m}$<br>0.05 (0.05)$^{*}$ | 0.011 (0.1)$^{m}$<br>0.006 (0.05)$^{*}$ |
| 1996 vs. 1997 | | | |
| 1996 vs. 1998 | | | |
| 1997 vs. 1998 | 0.445 | 0.676 | |
| **Segment** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | 0.01 (0.1)$^{m}$<br>0.005 (0.05)$^{*}$ | 0.011 (0.1)$^{m}$<br>0.006 (0.05)$^{*}$ |
| *Missouri –Yellowstone rivers* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) **FTP_IR_VS_YSR_LA** | 0.120<br>9 vs.**7**, **8** | 0.448<br>9 vs.**7**, **8** | 0.583<br>9 vs.**7**, **8** |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | | | |

| | | | |
|---|---|---|---|
| *3-Zones* | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.120<br>9 vs. **7**, **8** | 0.388<br>9 vs. **7**, **8**, **15** | 0.476<br>9 vs. **7**, **8**, **15** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | 0.223<br>9 vs. *27* | 0.765<br>9 vs. *17*, *25*, *27* | <0.0001*<br>9 vs. *19*, *25*, *27* |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.015*<br>**7**, **8** vs. *27* | 0.129<br>**7**, **8, 15** vs. *17*, *25*, *27* | <0.0001*<br>**7**, **8, 15** vs. *19*, *25*, *27* |
| *5-zones* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | 0.120<br>9 vs. **7**, **8** | 0.448<br>9 vs.**7**, **8** | 0.583<br>9 vs.**7**, **8** |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | 0.418<br>9 vs. **15** | 0.437<br>9 vs. **15** |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | 0.223<br>9 vs. *27* | 0.765<br>9 vs. *17*, *25*, *27* | <0.0001*<br>9 vs. *19*, *25*, *27* |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | | 0.853<br>**7, 8** vs. **15** | 0.756<br>**7, 8** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | 0.015*<br>**7**, **8** vs. *27* | 0.188<br>**7, 8** vs. *17, 25, 27* | <0.0001*<br>**7, 8** vs. *19, 25, 27* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | | 0.217<br>**15** vs. *17, 25, 27* | <0.0001*<br>**15** vs. *19, 25, 27* |
| *Reservoir related* | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) AL&C_IR_VS_BL&C_IR | | | |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1ST_CHAN** | | 0.381<br>**15** vs. *17* | |

| | | | | |
|---|---|---|---|---|
| *Channelized river* | | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | | | 0.765<br>*17* vs. *25*, *27* | 0.0007*<br>*19* vs. *25*, *27* |
| **Macrohabitat** | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m]<br>0.017 (0.05)* | | | |
| BEND vs. SCC | 0.888 | | | |
| BEND vs. SCN | 0.067 | | | |
| BEND vs. TRM | | | | |
| SCC vs. SCN | 0.055 | | | |
| SCC vs. TRM | | | | |
| SCN vs. TRM | | | | |
| Statistic | Electrofishing | | Stationary Gillnet | |
| | ANOVA 1 | ANOVA 2 | ANOVA 1 | ANOVA 2 |
| Analysis level | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 63 | 28 | 54 | 30 |
| Years | 1996-1998 | 1998 | 1996-1998 | 1996-1998 |
| Segments | ***12-15,*** *17, 19,* ***23-27*** | *7,* ***8,*** *9,* ***12-15,*** *27* | *7,* ***8,*** *9,* ***12-15,*** *22-27* | *7,* ***8,12-15,*** *19-27* |
| Macrohabitats | BEND, SCC, TRM | BEND, SCC, SCN, TRM | SCN, TRM | TRM |
| | | | | |
| Year | 0.880 (0.13) | | 0.074 (3.27) | 0.501 (0.72) |
| Segment | 0.0003 (7.29) | 0.051 (2.64) | 0.224 (1.59) | 0.239 (1.45) |
| Macrohabitat | <0.0001 (17.08) | 0.0009 (8.69) | 0.865 (0.03) | |
| Year/segment interaction | 0.494 (1.00) | | 0.871 (0.56) | |
| Year/macrohabitat interaction | 0.983 (0.09) | | 0.065 (3.46) | |
| Segment/macrohabitat interaction | 0.288 (1.31) | | 0.357 (1.24) | |
| **Contrasts** | | | | |
| **Year** | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m]<br>0.017 (0.05)* | | 0.033 (0.1)[m]<br>0.017 (0.05)* | 0.033 (0.1)[m]<br>0.017 (0.05)* |
| 1996 vs. 1997 | 0.774 | | 0.034 | 0.583 |
| 1996 vs. 1998 | 0.644 | | 0.073 | 0.532 |
| 1997 vs. 1998 | 0.754 | | 0.755 | 0.247 |
| **Segment** | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.014 (0.1)[m]<br>0.007 (0.05)* | 0.01 (0.1)[m]<br>0.005 (0.05)* | 0.009 (0.1)[m]<br>0.005 (0.05)* | 0.017 (0.1)[m]<br>0.008 (0.05)* |
| *Missouri –Yellowstone rivers* | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | | |

| | | | | |
|---|---|---|---|---|
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) **FTP_IR_VS_YSR_LA** | | 0.292<br>9 vs.**7**, **8** | 0.898<br>9 vs.**7**, **8** | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | | |
| *3-Zones* | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | | 0.244<br>9 vs. **7**, **8**, **12-15** | 0.574<br>9 vs. **7**, **8**, **12-15** | |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | 0.040<br>9 vs. *27* | 0.063<br>9 vs. *22-27* | |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.002*<br>**12-15** vs. *17*, *19*, *23-27* | 0.115<br>**7**, **8**, **12-15** vs. *27* | 0.035<br>**7**, **8**, **12-15** vs.*22-27* | 0.113<br>**7**, **8**, **12-15** vs. *19-27* |
| *5-zones* | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | | | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | | | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | 0.118<br>9 vs. **7, 8, 12, 14** | 0.698<br>9 vs. **7, 8, 12, 14** | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | 0.611<br>9 vs. **15** | 0.311<br>9 vs. **15** | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | 0.040<br>9 vs. *27* | 0.063<br>9 vs. *22-27* | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | <0.0001*<br>**12, 14** vs. **15** | 0.034<br>**7, 8, 12, 14** vs. **15** | 0.320<br>**7, 8, 12, 14** vs. **15** | 0.120<br>**7, 8, 12, 14** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. 17-27) **IR_W/O_BL&C_VS_CH** | 0.637<br>**12, 14** vs. *17, 19, 23-27* | 0.259<br>**7, 8, 12, 14** vs. *27* | 0.026<br>**7, 8, 12, 14** vs. *22-27* | 0.048<br>**7, 8, 12, 14** vs. *19-27* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. 17-27) **BL&C_IR_VS_CH** | <0.0001*<br>**15** vs. *17, 19, 23-27* | 0.014<br>**15** vs. *27* | 0.354<br>**15** vs. *22-27* | 0.715<br>**15** vs. *19-27* |
| Reservoir related | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | | |

| | | | | |
|---|---|---|---|---|
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**)<br>**AL&C_IR_VS_BL&C_IR** | 0.0004*<br>**14** vs. **15** | 0.126<br>**14** vs. **15** | 0.605<br>**14** vs. **15** | 0.468<br>**14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. 17)<br>**BL&C_IR_VS_1ST_CHAN** | 0.0001*<br>**15** vs. *17* | | | |
| Channelized river | | | | |
| Channelized above KC vs. channelized below KC (17, 19, 22 vs. 23, 25, 27)<br>**AKC_CH_VS_BKC_CH** | 0.885<br>*17, 19* vs. *23- 27* | | 0.769<br>*22* vs. *23, 25, 27* | 0.625<br>*19, 22* vs. *23, 25, 27* |
| **Macrohabitat** | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)m<br>0.017 (0.05)* | 0.017 (0.1)m<br>0.008 (0.05)* | 0.1 (0.1)m<br>0.05 (0.05)* | |
| BEND vs. SCC | 0.581 | 0.875 | | |
| BEND vs. SCN | | 0.0009* | | |
| BEND vs. TRM | <0.0001* | 0.003* | | |
| SCC vs. SCN | | 0.001* | | |
| SCC vs. TRM | 0.004* | 0.005* | | |
| SCN vs. TRM | | 0.563 | 0.865 | |

Table A3-10. Analysis of variance (ANOVA) probabilities with F-values in parentheses for sauger collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Beach Seine | Drifting Trammel Net | Electrofishing | | |
|---|---|---|---|---|---|
| | ANOVA 1 | ANOVA 1 | ANOVA 1 | ANOVA 2 | ANOVA 3 |
| Analysis level | Average Year | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 33 | 40 | 47 | 24 | 27 |
| Years | 1996-1998 | 1996-1998 | 1996-1998 | 1998 | 1996-1998 |
| Segments | 3, 5, **7**, **8**, *9*, **10**, **15**, *22-27* | 3, 5, **7**, **8**, 9, **14**, **15** | **10**, **14**, **15**, *17, 23, 25* | **7**, **8**, 9, **10**, **14**, **15** | 3, 5, **10**, **14**, **15**, *17, 22-25* |
| Macrohabitats | ISB, SCC, SCN | BEND, SCC | BEND, SCC, TRM | BEND, SCC, SCN, TRM | BEND |
| | | | | | |
| Year | | 0.524 (0.69) | 0.499 (0.73) | | 0.816 (0.21) |
| Segment | 0.305 (1.28) | 0.685 (0.66) | 0.070 (2.69) | 0.027 (3.50) | 0.004 (4.85) |
| Macrohabitat | 0.077 (2.92) | 0.211 (1.78) | 0.540 (0.65) | 0.927 (0.15) | |
| Year/segment interaction | | 0.621 (0.84) | 0.032 (3.04) | | |
| Year/macrohabitat interaction | | 0.557 (0.62) | 0.574 (0.75) | | |
| Segment/macrohabitat interaction | | 0.593 (0.80) | 0.076 (2.34) | | |
| **Contrasts** | | | | | |
| **Year** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ |
| 1996 vs. 1997 | | 0.291 | 0.782 | | 0.586 |
| 1996 vs. 1998 | | 0.815 | 0.384 | | 0.585 |
| 1997 vs. 1998 | | 0.402 | 0.317 | | 0.999 |
| **Segment** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.006 (0.1)$^{m}$<br>0.003 (0.05)$^{*}$ | 0.009 (0.1)$^{m}$<br>0.005 (0.05)$^{*}$ | 0.014 (0.1)$^{m}$<br>0.007 (0.05)$^{*}$ | 0.014 (0.1)$^{m}$<br>0.007 (0.05)$^{*}$ | 0.008 (0.1)$^{m}$<br>0.004 (0.05)$^{*}$ |
| *Missouri –Yellowstone rivers* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9)<br>**MOR_LA_VS_YSR_LA** | 0.943<br>3, 5 vs. 9 | 0.776<br>3, 5 vs. 9 | | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**)<br>**FTP_IR_VS_YSR_LA** | 0.697<br>9 vs.**7**, **8** | 0.473<br>9 vs.**7**, **8** | | 0.469<br>9 vs.**7**, **8** | |

| | | | | | |
|---|---|---|---|---|---|
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | 0.697<br>3, 5 vs. **7**, **8** | 0.314<br>3, 5 vs. **7**, **8** | | | |
| *3-Zones* | | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.811<br>3, 5, 9 vs. **7**, **8**, **10**, **15** | 0.451<br>3, 5, 9 vs. **7**, **8**, **14**, **15** | | 0.768<br>9 vs. **7**, **8**, **10**, **14**, **15** | 0.005[m]<br>3, 5, vs. **10**, **14**, **15** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | 0.436<br>3, 5, 9 vs. *22-27* | | | | <0.0001[*]<br>3, 5, vs. *17*, *22-25* |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.276<br>**7**, **8**, **10**, **15** vs. *22-27* | | 0.175<br>**10**, **14**, **15** vs. *17*, *23*, *25* | | 0.060<br>**10**, **14**, **15** vs. *17*, *22- 25* |
| *5-zones* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.943<br>3, 5 vs. 9 | 0.776<br>3, 5 vs. 9 | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | 0.545<br>**8** vs. **10** | | | 0.635<br>**8** vs. **10** | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | 0.981<br>3, 5 vs. **7, 8, 10** | 0.560<br>3, 5 vs. **7, 8, 14** | | | 0.018<br>3, 5 vs. **10, 14** |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | 0.655<br>3, 5 vs. **15** | 0.392<br>3, 5 vs. **15** | | | 0.009<br>3, 5 vs. **15** |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | 0.471<br>3, 5 vs. *22-27* | | | | <0.0001[*]<br>3, 5 vs. *17, 22-25* |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | 0.924<br>9 vs. **7, 8, 10** | 0.803<br>9 vs. **7, 8, 14** | | 0.283<br>9 vs. **7, 8, 10, 14** | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | 0.654<br>9 vs. **15** | 0.553<br>9 vs. **15** | | 0.032<br>9 vs. **15** | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | 0.630<br>9 vs. 22-27 | | | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | 0.649<br>**7, 8, 10** vs. **15** | 0.631<br>**7, 8, 14** vs. **15** | 0.009[m]<br>**10, 14** vs. **15** | 0.0009[*]<br>**7, 8, 10, 14** vs. **15** | 0.430<br>**10, 14** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | 0.399<br>**7, 8, 10** vs. *22-27* | | 0.984<br>**10, 14** vs. *17, 23, 25* | | 0.045<br>**10, 14** vs. *17, 22-25* |

| | | | | | |
|---|---|---|---|---|---|
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | 0.978<br>**15** vs. *22-27* | | 0.006*<br>**15** vs. *17, 23, 25* | | 0.439<br>**15** vs. *17*, *22-27* |
| *Reservoir related* | | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**)<br>**AFTP_LA_VS_BFTP_RI** | 0.998<br>5 vs. **7** | 0.219<br>5 vs. **7** | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**)<br>**ASAK_IR_VS_BSAK_IR** | | | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | | 0.230<br>**14** vs. **15** | 0.009m<br>**14** vs. **15** | 0.003*<br>**14** vs. **15** | 0.417<br>**14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*)<br>**BL&C_IR_VS_1ST_CHAN** | | | 0.046<br>**15** vs. *17* | | 0.980<br>**15** vs. *17* |
| *Channelized river* | | | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*)<br>**AKC_CH_VS_BKC_CH** | 0.019<br>*22* vs. *23- 27* | | 0.758<br>*17* vs. *23, 25* | | 0.411<br>*17, 22* vs. *23, 25* |
| **Macrohabitat** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)m<br>0.017 (0.05)* | 0.1 (0.1)m<br>0.05 (0.05)* | 0.033 (0.1)m<br>0.017 (0.05)* | 0.017 (0.1)m<br>0.008 (0.05)* | |
| BEND vs. SCC | 0.914 | 0.211 | 0.406 | 0.747 | |
| BEND vs. SCN | 0.055 | | | 0.770 | |
| BEND vs. TRM | | | 0.654 | 0.837 | |
| SCC vs. SCN | 0.045 | | | 0.540 | |
| SCC vs. TRM | | | 0.279 | 0.906 | |
| SCN vs. TRM | | | | 0.619 | |

| Statistic | Stationary Gillnet | | |
|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 1 |
| Analysis level | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 15 | 12 | 18 |
| Years | 1997, 1998 | 1997, 1998 | 1997, 1998 |
| Segments | **14, 15**, *22* | **7, 8**, 9, **10**, **14**, **15** | **7, 8**, **14, 15**, *17-25* |
| Macrohabitats | ISB, SCN, TRM | SCN | TRM |
| | | | |
| Year | 0.728 (0.21) | 0.941 (0.01) | 0.250 (1.54) |
| Segment | 0.512 (1.41) | 0.338 (1.48) | 0.508 (0.99) |
| Macrohabitat | 0.969 (0.03) | | |
| Year/segment interaction | 0.277 (6.01) | | |
| Year/macrohabitat interaction | 0.355 (3.47) | | |

| | | | |
|---|---|---|---|
| Segment/macrohabitat interaction | 0.434 (2.56) | | |
| **Contrasts** | | | |
| **Year** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)[m]<br>0.05 (0.05)[*] | 0.1 (0.1)[m]<br>0.05 (0.05)[*] | 0.1 (0.1)[m]<br>0.05 (0.05)[*] |
| 1996 vs. 1997 | | | |
| 1996 vs. 1998 | | | |
| 1997 vs. 1998 | 0.728 | 0.941 | 0.250 |
| **Segment** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.025 (0.1)[m]<br>0.013 (0.05)[*] | 0.014 (0.1)[m]<br>0.007 (0.05)[*] | 0.014 (0.1)[m]<br>0.007 (0.05)[*] |
| *Missouri –Yellowstone rivers* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) **FTP_IR_VS_YSR_LA** | | 0.917<br>9 vs.**7**, **8** | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | 0.129<br>**8** vs. **10** | |
| *3-Zones* | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | | 0.442<br>9 vs. **7**, **8**, **10**, **14**, **15** | |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | | |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.349<br>**14**, **15** vs. *22* | | 0.380<br>**7**, **8**, **14**, **15** vs. *17-25* |
| *5-zones* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | 0.347<br>9 vs. **7, 8, 10, 14** | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | 0.964<br>9 vs. **15** | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | 0.959<br>**14** vs. **15** | 0.323<br>**7, 8, 10, 14** vs. **15** | 0.128<br>**7, 8, 14** vs. **15** |

| | | | |
|---|---|---|---|
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. 17-27) **IR_W/O_BL&C_VS_CH** | 0.381<br>**14** vs. *22* | | 0.860<br>**7, 8, 14** vs. *17-25* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. 17-27) **BL&C_IR_VS_CH** | 0.437<br>**15** vs. *22* | | 0.092<br>**15** vs. *17-25* |
| Reservoir related | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | 0.959<br>**14** vs. **15** | 0.343<br>**14** vs. **15** | 0.062<br>**14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. 17) **BL&C_IR_VS_1ST_CHAN** | | | 0.412<br>**15** vs. 17 |
| Channelized river | | | |
| Channelized above KC vs. channelized below KC (17, 19, 22 vs. 23, 25, 27) **AKC_CH_VS_BKC_CH** | | | 0.689<br>17-22 vs. 23, 25 |
| **Macrohabitat** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m]<br>0.017 (0.05)[*] | | |
| BEND vs. SCC | | | |
| BEND vs. SCN | 0.856 | | |
| BEND vs. TRM | 0.858 | | |
| SCC vs. SCN | | | |
| SCC vs. TRM | | | |
| SCN vs. TRM | 0.976 | | |

Table A3-11. Analysis of variance (ANOVA) probabilities with F-values in parentheses for shorthead redhorse collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Beach Seine | Drifting Trammel Net |
|---|---|---|
| | ANOVA 1 | ANOVA 1 |
| Analysis level | Macrohabitat | Macrohabitat |
| N | 41 | 40 |
| Years | 1996-1998 | 1996-1998 |
| Segments | *3, 5,* ***8, 9, 15*** | *3, 5, 7,* ***8, 9, 14, 15*** |
| Macrohabitats | ISB, SCC, SCN | BEND, SCC |
| | | |
| Year | 0.576 (0.58) | 0.513 (0.71) |
| Segment | 0.162 (1.98) | 0.007 (5.94) |
| Macrohabitat | 0.348 (1.16) | 0.0003 (28.37) |
| Year/segment interaction | 0.144 (1.95) | 0.092 (2.35) |
| Year/macrohabitat interaction | 0.022 (4.32) | 0.953 (0.05) |
| Segment/macrohabitat interaction | 0.122 (2.08) | 0.014 (4.88) |
| **Contrasts** | | |
| **Year** | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ |
| 1996 vs. 1997 | 0.378 | 0.575 |
| 1996 vs. 1998 | 0.976 | 0.553 |
| 1997 vs. 1998 | 0.363 | 0.260 |
| **Segment** | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.014 (0.1)$^{m}$<br>0.007 (0.05)$^{*}$ | 0.009 (0.1)$^{m}$<br>0.005 (0.05)$^{*}$ |
| *Missouri –Yellowstone rivers* | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.086<br>3, 5 vs. 9 | 0.001$^{*}$<br>3, 5 vs. 9 |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) **FTP_IR_VS_YSR_LA** | 0.155<br>9 vs. **8** | 0.855<br>9 vs.**7**, **8** |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | 0.778<br>3, 5 vs. **8** | 0.0004$^{*}$<br>3, 5 vs. **7**, **8** |
| *3-Zones* | | |

| | | |
|---|---|---|
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.876<br>3, 5, 9 vs. **8, 15** | 0.003*<br>3, 5, 9 vs. **7**, **8**, **14**, **15** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | | |
| *5-zones* | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.086<br>3, 5 vs. 9 | 0.001*<br>3, 5 vs. 9 |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | 0.778<br>3, 5 vs. **8** | 0.0003*<br>3, 5 vs. **7, 8, 14** |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | 0.621<br>3, 5 vs. **15** | 0.019<br>3, 5 vs. **15** |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | 0.155<br>9 vs. **8** | 0.978<br>9 vs. **7, 8, 14** |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | 0.395<br>9 vs. **15** | 0.140<br>9 vs. **15** |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | 0.774<br>**8** vs. **15** | 0.075<br>**7, 8, 14** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | | |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | | |
| *Reservoir related* | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | 0.166<br>5 vs. **7** |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | | 0.208<br>**14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1ST_CHAN** | | |
| *Channelized river* | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) AKC_CH_VS_BKC_CH | | |
| **Macrohabitat** | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m]<br>0.017 (0.05)* | 0.1 (0.1)[m]<br>0.05 (0.05)* |
| BEND vs. SCC | 0.274 | 0.0003* |
| BEND vs. SCN | 0.639 | |
| BEND vs. TRM | | |
| SCC vs. SCN | 0.199 | |
| SCC vs. TRM | | |

| SCN vs. TRM | | | | | |
|---|---|---|---|---|---|
| Statistic | Electrofishing | | Stationary Gillnet | | |
| | ANOVA 1 | ANOVA 2 | ANOVA 1 | ANOVA 2 | ANOVA 3 |
| Analysis level | Replicate | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 58 | 16 | 22 | 21 | 18 |
| Years | 1996-1998 | 1998 | 1997, 1998 | 1996-1998 | 1997, 1998 |
| Segments | *3, 5, **10, 15*** | ***8**, 9, **10, 15*** | ***14, 15**, 17, 23-27* | *7, **8, 10-15**, 27* | *7, **8, 12-15**, 17, 23-27* |
| Macrohabitats | BEND | BEND, SCC, SCN, TRM | ISB, TRM | SCN | TRM |
| | | | | | |
| Year | 0.292 (1.27) | | 0.404 (0.94) | 0.753 (0.29) | 0.458 (0.61) |
| Segment | <0.0001 (30.57) | 0.655 (0.56) | 0.217 (2.75) | 0.583 (0.81) | 0.652 (0.75) |
| Macrohabitat | | 0.175 (2.07) | 0.846 (0.04) | | |
| Year/segment interaction | 0.301 (1.25) | | 0.879 (0.31) | | |
| Year/macrohabitat interaction | | | 0.851 (0.04) | | |
| Segment/macrohabitat interaction | | | 0.259 (2.33) | | |
| **Contrasts** | | | | | |
| **Year** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)[m]<br>0.017 (0.05)[*] | | 0.1 (0.1)[m]<br>0.05 (0.05)[*] | 0.033 (0.1)[m]<br>0.017 (0.05)[*] | 0.1 (0.1)[m]<br>0.05 (0.05)[*] |
| 1996 vs. 1997 | 0.147 | | | 0.593 | |
| 1996 vs. 1998 | 0.224 | | | 0.857 | |
| 1997 vs. 1998 | 0.811 | | 0.404 | 0.478 | 0.458 |
| **Segment** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.025 (0.1)[m]<br>0.013 (0.05)[*] | 0.017 (0.1)[m]<br>0.008 (0.05)[*] | 0.017 (0.1)[m]<br>0.008 (0.05)[*] | 0.014 (0.1)[m]<br>0.007 (0.05)[*] | 0.014 (0.1)[m]<br>0.007 (0.05)[*] |
| *Missouri –Yellowstone rivers* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) **FTP_IR_VS_YSR_LA** | | 0.430<br>9 vs.**8** | | | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | | | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | 0.554<br>**8** vs. **10** | | 0.660<br>**8** vs. **10** | |
| *3-Zones* | | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | <0.0001[*]<br>3, 5, vs. **10**, **15** | 0.398<br>9 vs. **8**, **10, 15** | | | |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | | | 0.063<br>**14**, **15** vs. *17*, *23-27* | 0.286<br>**7**, **8**, **10-15** vs. *27* | 0.221<br>**7**, **8**, **12-15** vs. *17*, *23-27* |
| *5-zones* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | <0.0001*<br>3, 5 vs. **10** | | | | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | 0.0009*<br>3, 5 vs. **15** | | | | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | | | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | 0.564<br>9 vs. **8**, **10** | | | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | 0.284<br>9 vs. **15** | | | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | | | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | 0.0035*<br>**10** vs. **15** | 0.492<br>**8**, **10** vs. **15** | 0.713<br>**14** vs. **15** | 0.389<br>**7, 8, 10-14** vs. **15** | 0.968<br>**7, 8, 12, 14** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | | | 0.176<br>**14** vs. *17, 23-27* | 0.360<br>**7, 8, 10-14** vs. *27* | 0.248<br>**7, 8, 12, 14** vs. *17, 23-27* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | | | 0.102<br>**15** vs. *17, 23-27* | 0.178<br>**15** vs. *27* | 0.430<br>**15** vs. *17, 23-27* |
| *Reservoir related* | | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | | 0.505<br>**10** vs. **12** | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | | | 0.713<br>**14** vs. **15** | 0.295<br>**14** vs. **15** | 0.354<br>**14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1ST_CHAN** | | | 0.399<br>**15** vs. *17* | | 0.628<br>**15** vs. *17* |

| | | | | | |
|---|---|---|---|---|---|
| *Channelized river* | | | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | | | 0.113 *17* vs. *23-27* | | 0.810 *17* vs. *23-27* |
| **Macrohabitat** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | | 0.017 (0.1)[m] 0.008 (0.05)[*] | 0.1 (0.1)[m] 0.05 (0.05)[*] | | |
| BEND vs. SCC | | 0.681 | | | |
| BEND vs. SCN | | 0.076 | | | |
| BEND vs. TRM | | 0.800 | 0.846 | | |
| SCC vs. SCN | | 0.148 | | | |
| SCC vs. TRM | | 0.511 | | | |
| SCN vs. TRM | | 0.050 | | | |

Table A3-12. Analysis of variance (ANOVA) probabilities with F-values in parentheses for shovelnose sturgeon collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Benthic trawl | | Drifting trammel net | | Stationary gillnet |
|---|---|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 1 | ANOVA 2 | ANOVA 1 |
| Analysis level | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 58 | 33 | 57 | 33 | 36 |
| Years | 1996-1998 | 1996-1998 | 1996-1998 | 1996-1998 | 1996-1998 |
| Segments | 5, **7**, 9, **10**, **15**, *17*, *19*, *23-27* | 5, **7**, 9, **10**, **15**, *17-27* | 3, 5, **7**, **8**, 9, **10**, **12**, **15**, *23, 27* | 3, 5, **7**, **8**, 9, **10**, **12**, **15**, 22, 23, *27* | *17-27* |
| Macrohabitats | BEND, SCC | BEND | BEND, SCC | BEND | BEND, TRM |
| | | | | | |
| Year | 0.017 (5.28) | 0.237 (1.55) | 0.003 (8.99) | 0.200 (1.75) | 0.749 (0.30) |
| Segment | 0.014 (3.50) | 0.275 (1.34) | 0.002 (5.29) | 0.0006 (5.57) | 0.714 (0.58) |
| Macrohabitat | 0.083 (3.43) | | 0.876 (0.03) | | 0.001 (19.57) |
| Year/segment interaction | 0.044 (2.37) | | 0.546 (0.95) | | 0.812 (0.56) |
| Year/macrohabitat interaction | 0.027 (4.58) | | 0.141 (2.24) | | 0.552 (0.63) |
| Segment/macrohabitat interaction | 0.603 (0.83) | | 0.312 (1.30) | | 0.528 (0.88) |
| **Contrasts** | | | | | |
| **Year** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* |
| 1996 vs. 1997 | 0.006* | 0.843 | 0.259 | 0.402 | 0.886 |
| 1996 vs. 1998 | 0.278 | 0.173 | 0.009* | 0.324 | 0.483 |
| 1997 vs. 1998 | 0.054 | 0.122 | 0.001* | 0.076 | 0.574 |
| **Segment** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.006 (0.1)$^{m}$<br>0.003 (0.05)* | 0.006 (0.1)$^{m}$<br>0.003 (0.05)* | 0.006 (0.1)$^{m}$<br>0.003 (0.05)* | 0.005 (0.1)$^{m}$<br>0.003 (0.05)* | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* |
| *Missouri –Yellowstone rivers* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.658<br>5 vs. 9 | 0.658<br>5 vs. 9 | 0.012<br>3, 5 vs. 9 | 0.019<br>3, 5 vs. 9 | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) **FTP_IR_VS_YSR_LA** | 0.380<br>9 vs.**7** | 0.437<br>9 vs.**7** | 0.004$^{m}$<br>9 vs.**7**, **8** | 0.001*<br>9 vs.**7**, **8** | |

| | | | | | |
|---|---|---|---|---|---|
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | 0.658<br>5 vs. **7** | 0.734<br>5 vs. **7** | 0.907<br>3, 5 vs. **7**, **8** | 0.139<br>3, 5 vs. **7**, **8** | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | 0.120<br>**8** vs. **10** | 0.144<br>**8** vs. **10** | |
| *3-Zones* | | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.596<br>5, 9 vs. **7**, **10**, **15** | 0.969<br>5, 9 vs. **7**, **10**, **15** | 0.173<br>3, 5, 9 vs. **7**, **8**, **10**, **12**, **15** | 0.018<br>3, 5, 9 vs. **7**, **8**, **10**, **12**, **15** | |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | 0.028<br>5, 9 vs. *17*, *19*, *23-27* | 0.200<br>5, 9 vs. *17-27* | 0.381<br>3, 5, 9 vs. *23*, *27* | 0.440<br>3, 5, 9 vs. *22, 23, 27* | |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.053<br>**7**, **10**, **15** vs. *17*, *19*, *23-27* | 0.129<br>**7**, **10**, **15** vs. *17-27* | 0.019<br>**7**, **8**, **10**, **12**, **15** vs. *23, 27* | 0.002*<br>**7**, **8**, **10**, **12**, **15** vs. *22, 23, 27* | |
| *5-zones* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.658<br>5 vs. 9 | 0.658<br>5 vs. 9 | 0.012<br>3, 5 vs. 9 | 0.019<br>3, 5 vs. 9 | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | 0.255<br>5 vs. **7, 10** | 0.684<br>5 vs. **7, 10** | 0.839<br>3, 5 vs. **7, 8, 10, 12** | 0.327<br>3, 5 vs. **7, 8, 10, 12** | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | 0.752<br>5 vs. **15** | 0.908<br>5 vs. **15** | 0.386<br>3, 5 vs. **15** | 0.555<br>3, 5 vs. **15** | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17, 19, 22, 23, 25, 27*) **MOR_LA_VS_CH** | 0.046<br>5 vs. *17, 19, 23-27* | 0.209<br>5 vs. *17-27* | 0.086<br>3, 5 vs. *23. 27* | 0.080<br>3, 5 vs. *22, 23. 27* | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | 0.518<br>9 vs. **7, 10** | 0.917<br>9 vs. **7, 10** | 0.002*<br>9 vs. **7, 8, 10, 12** | 0.002*<br>9 vs. **7, 8, 10, 12** | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | 0.451<br>9 vs. **15** | 0.578<br>9 vs. **15** | 0.067<br>9 vs. **15** | 0.013<br>9 vs. **15** | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | 0.128<br>9 vs. *17, 19, 23-27* | 0.487<br>9 vs. *17-27* | 0.167<br>9 vs. *23, 27* | 0.226<br>9 vs. *22, 23, 27* | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | 0.140<br>**7, 10** vs. **15** | 0.590<br>**7, 10** vs. **15** | 0.198<br>**7, 8, 10, 12** vs. **15** | 0.904<br>**7, 8, 10, 12** vs. **15** | |

| | | | | | |
|---|---|---|---|---|---|
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17, 19, 22, 23, 25, 27*) **IR_W/O_BL&C_VS_CH** | 0.271<br>**7, 10** vs. *17, 19, 23-27* | 0.286<br>**7, 10** vs. *17-27* | 0.012<br>**7, 8, 10, 12** vs. *23, 27* | 0.003*<br>**7, 8, 10, 12** vs. *22, 23, 27* | |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17, 19, 22, 23, 25, 27*) **BL&C_IR_VS_CH** | 0.021<br>**15** vs. *17, 19, 23-27* | 0.162<br>**15** vs. *17-27* | 0.419<br>**15** vs. *23, 27* | 0.049<br>**15** vs. *22, 23, 27* | |
| *Reservoir related* | | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | 0.658<br>5 vs. **7** | 0.734<br>5 vs. **7** | 0.941<br>5 vs. **7** | 0.106<br>5 vs. **7** | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | 0.211<br>**10** vs. **12** | 0.974<br>**10** vs. **12** | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) AL&C_IR_VS_BL&C_IR | | | | | |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1ST_CHAN** | 0.567<br>**15** vs. *17* | 0.821<br>(**15** vs. *17*) | | | |
| *Channelized river* | | | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | 0.042<br>*17*, *19*, vs. *23-27* | 0.611<br>*17-22* vs. *23-27* | | 0.005[m]<br>*22* vs. *23*, *27* | 0.452<br>*17-22* vs. *23-27* |
| **Macrohabitat** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)[m]<br>0.05 (0.05)* | | 0.1 (0.1)[m]<br>0.05 (0.05)* | | 0.1 (0.1)[m]<br>0.05 (0.05)* |
| BEND vs. SCC | 0.083 | | 0.876 | | |
| BEND vs. SCN | | | | | |
| BEND vs. TRM | | | | | 0.001* |
| SCC vs. SCN | | | | | |
| SCC vs. TRM | | | | | |
| SCN vs. TRM | | | | | |

Table A3-13. Analysis of variance (ANOVA) probabilities with F-values in parentheses for sicklefin chub collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Benthic Trawl |
|---|---|
| | ANOVA 1 |
| Analysis level | Replicate |
| N | 155 |
| Years | 1996-1998 |
| Segments | 5, **8,** 9, **10**, *25, 27* |
| Macrohabitats | BEND, SCC |
| | |
| Year | 0.031 (3.58) |
| Segment | <0.0001 (8.71) |
| Macrohabitat | 0.046 (4.08) |
| Year/segment interaction | 0.0035 (2.81) |
| Year/macrohabitat interaction | 0.525 (0.65) |
| Segment/macrohabitat interaction | 0.744 (0.54) |
| **Contrasts** | |
| **Year** | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* |
| 1996 vs. 1997 | 0.987 |
| 1996 vs. 1998 | 0.033$^{m}$ |
| 1997 vs. 1998 | 0.018$^{m}$ |
| **Segment** | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.0091 (0.1)$^{m}$<br>0.0045 (0.05)* |
| *Missouri –Yellowstone rivers* | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.0001*<br>5 vs. 9 |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8)** **FTP_IR_VS_YSR_LA** | 0.186<br>9 vs. **8** |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. 7, **8) MOR_LA_VS_FTP_IR** | <0.0001*<br>5 vs. **8** |
| *3-Zones* | |

| | |
|---|---|
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.096<br>5, 9 vs. **8**, **10** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | 0.0003*<br>5, 9 vs. *25*, *27* |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.141<br>**8**, **10** vs. *25*, *27* |
| *5-zones* | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.0001*<br>5 vs. 9 |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | 0.003*<br>**8** vs. **10** |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | 0.0005*<br>5 vs. **8, 10** |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | <0.0001*<br>5 vs. *25, 27* |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | 0.523<br>9 vs. **8, 10** |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | 0.520<br>9 vs. *25, 27* |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | 0.141<br>**8**, **10** vs. *25*, *27* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | |
| *Reservoir related* | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) AL&C_IR_VS_BL&C_IR | |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1$^{ST}$_CHAN** | |
| *Channelized river* | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) AKC_CH_VS_BKC_CH | |
| **Macrohabitat** | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* |
| BEND vs. SCC | 0.046* |
| BEND vs. SCN | |
| BEND vs. TRM | |

| | |
|---|---|
| SCC vs. SCN | |
| SCC vs. TRM | |
| SCN vs. TRM | |

Table A3-14. Analysis of variance (ANOVA) probabilities with F-values in parentheses for smallmouth buffalo collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Beach Seine | Drifting Trammel Net | |
|---|---|---|---|
| | ANOVA 1 | ANOVA 1 | ANOVA 2 |
| Analysis level | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 48 | 24 | 16 |
| Years | 1996-1998 | 1996-1998 | 1996-1998 |
| Segments | 3, **8**, 9, **10**, **15**, *27* | **8**, 9, *23, 27* | **8**,*22, 23* |
| Macrohabitats | ISB, SCC, SCN | BEND, SCC | BEND, TRM |
| | | | |
| Year | 0.633 (0.47) | 0.936 (0.07) | 0.608 (0.64) |
| Segment | 0.178 (1.80) | 0.356 (1.31) | 0.344 (1.91) |
| Macrohabitat | 0.564 (0.60) | 0.086 (4.20) | 0.745 (0.14) |
| Year/segment interaction | 0.013 (3.71) | 0.123 (2.74) | 0.723 (0.56) |
| Year/macrohabitat interaction | 0.227 (1.61) | 0.581 (0.60) | 0.511 (0.96) |
| Segment/macrohabitat interaction | 0.458 (1.05) | 0.288 (1.59) | 0.275 (2.64) |
| **Contrasts** | | | |
| **Year** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ |
| 1996 vs. 1997 | 0.399 | 0.732 | 0.671 |
| 1996 vs. 1998 | 0.432 | 0.822 | 0.375 |
| 1997 vs. 1998 | 0.951 | 0.906 | 0.588 |
| **Segment** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.006 (0.1)$^{m}$<br>0.003 (0.05)$^{*}$ | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | 0.05 (0.1)$^{m}$<br>0.025 (0.05)$^{*}$ |
| *Missouri –Yellowstone rivers* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.581<br>3 vs. 9 | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) **FTP_IR_VS_YSR_LA** | 0.196<br>9 vs. **8** | 0.927<br>9 vs. **8** | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | 0.635<br>3 vs. **8** | | |

| | | | |
|---|---|---|---|
| *3-Zones* | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.117<br>3, 9 vs. **8**, **10**, **15** | 0.927<br>9 vs. **8** | |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | 0.570<br>3, 9 vs. *27* | 0.162<br>9 vs. *23, 27* | |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.042<br>**8**, **10**, **15** vs. *27* | 0.189<br>**8** vs. *23, 27* | 0.449<br>**8** vs. *22, 23* |
| *5-zones* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.581<br>3 vs. 9 | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | 0.166<br>**8** vs. **10** | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | 0.244<br>3 vs. **8, 10** | | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | 0.849<br>3 vs. **15** | | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | 0.487<br>3 vs. *27* | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | 0.031<br>9 vs. **8, 10** | 0.927<br>9 vs. **8** | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | 0.435<br>9 vs. **15** | | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | 0.851<br>9 vs. *27* | 0.162<br>9 vs. *23, 27* | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | 0.306<br>**8, 10** vs. **15** | | |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | 0.021<br>**8, 10** vs. *27* | 0.189<br>**8** vs. *23, 27* | 0.449<br>**8** vs. *22, 23* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | 0.141<br>**15** vs. *27* | | |
| *Reservoir related* | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) AL&C_IR_VS_BL&C_IR | | | |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1$^{ST}$_CHAN** | | | |
| *Channelized river* | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | | | 0.228<br>*22* vs. *23* |
| **Macrohabitat** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | 0.1 (0.1)$^{m}$<br>0.05 (0.05)$^{*}$ | 0.1 (0.1)$^{m}$<br>0.05 (0.05)$^{*}$ |

| | | | | | |
|---|---|---|---|---|---|
| BEND vs. SCC | | | 0.809 | 0.086 | |
| BEND vs. SCN | | | 0.379 | | |
| BEND vs. TRM | | | | | 0.745 |
| SCC vs. SCN | | | 0.297 | | |
| SCC vs. TRM | | | | | |
| SCN vs. TRM | | | | | |
| Statistic | Electrofishing | | | Stationary Gillnet | |
| | ANOVA 1 | ANOVA 2 | ANOVA 3 | ANOVA 1 | ANOVA 2 |
| Analysis level | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 41 | 20 | 20 | 48 | 24 |
| Years | 1997, 1998 | 1998 | 1997, 1998 | 1996-1998 | 1996-1998 |
| Segments | **10, 14, 15**, *17, 19, 25, 27* | **7, 10, 14, 15,** *27* | 3, 5, **10, 14, 15,** *17-22, 25, 27* | **7, 8,** 9, **14, 15,** *22-27* | 5, **7, 8,** 9, **10, 14, 15,** *27* |
| Macrohabitats | BEND, SCC, TRM | BEND, SCC, SCN, TRM | BEND | SCN, TRM | SCN |
| | | | | | |
| Year | 0.018 (7.64) | | 0.568 (0.35) | 0.378 (1.07) | 0.013 (5.97) |
| Segment | 0.086 (2.54) | 0.648 (0.63) | 0.542 (0.93) | 0.288 (1.44) | 0.468 (1.00) |
| Macrohabitat | 0.011 (6.99) | 0.386 (1.10) | | 0.230 (1.63) | |
| Year/segment interaction | 0.223 (1.65) | | | 0.518 (1.00) | |
| Year/macrohabitat interaction | 0.189 (1.95) | | | 0.097 (2.97) | |
| Segment/macrohabitat interaction | 0.231 (1.57) | | | 0.415 (1.14) | |
| **Contrasts** | | | | | |
| **Year** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)[m]<br>0.05 (0.05)[*] | | 0.1 (0.1)[m]<br>0.05 (0.05)[*] | 0.033 (0.1)[m]<br>0.017 (0.05)[*] | 0.033 (0.1)[m]<br>0.017 (0.05)[*] |
| 1996 vs. 1997 | | | | 0.316 | 0.008[*] |
| 1996 vs. 1998 | | | | 0.191 | 0.012[*] |
| 1997 vs. 1998 | 0.018* | | 0.568 | 0.694 | 0.864 |
| **Segment** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.014 (0.1)[m]<br>0.007 (0.05)[*] | 0.02 (0.1)[m]<br>0.01 (0.05)[*] | 0.009 (0.1)[m]<br>0.005 (0.05)[*] | 0.009 (0.1)[m]<br>0.005 (0.05)[*] | 0.006 (0.1)[m]<br>0.003 (0.05)[*] |
| *Missouri –Yellowstone rivers* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9)<br>**MOR_LA_VS_YSR_LA** | | | | | 0.519<br>5 vs. 9 |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7, 8)**<br>**FTP_IR_VS_YSR_LA** | | | | 0.242<br>9 vs.**7, 8** | 0.203<br>9 vs.**7, 8** |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7, 8)**<br>**MOR_LA_VS_FTP_IR** | | | | | 0.055<br>5 vs. **7, 8** |

| | | | | | |
|---|---|---|---|---|---|
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | | | 0.130<br>**8** vs. **10** |
| *3-Zones* | | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | | | 0.529<br>3, 5 vs. **10**, **14**, **15** | 0.192<br>9 vs. **7**, **8**, **14**, **15** | 0.152<br>5, 9 vs. **7**, **8**, **10**, **14**, **15** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | | 0.613<br>3, 5 vs. 17-22, 25, 27 | 0.045<br>9 vs. *22- 27* | 0.732<br>5, 9 vs. 27 |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.018<br>**10**, **14**, **15** vs. *17*, *19*, *25*, *27* | 0.906<br>**7**, **10**, **14**, **15** vs. 27 | 0.832<br>**10**, **14**, **15** vs. 17-22, 25, 27 | 0.179<br>**7**, **8**, **14**, **15** vs. *22- 27* | 0.456<br>**7**, **8**, **10**, **14**, **15** vs. 27 |
| *5-zones* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | | | | 0.519<br>5 vs. 9 |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | | 0.158<br>3, 5 vs. **10, 14** | | 0.170<br>5 vs. **7**, **8, 10**, **14** |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | | 0.320<br>3, 5 vs. **15** | | 0.141<br>5 vs. **15** |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | | 0.613<br>3, 5 vs. 17-22, 25, 27 | | 0.537<br>5 vs. *27* |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | | | 0.260<br>9 vs. **7, 8, 14** | 0.552<br>9 vs. **7, 8, 10, 14** |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | | | 0.134<br>9 vs. **15** | 0.384<br>9 vs. **15** |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | | | 0.045<br>9 vs. *22- 27* | 0.978<br>9 vs. *27* |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | 0.173<br>**10, 14** vs. **15** | 0.470<br>**7, 10, 14** vs. **15** | 0.046<br>**10, 14** vs. **15** | 0.422<br>**7, 8, 14** vs. **15** | 0.607<br>**7, 8, 10, 14** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. 17-27) **IR_W/O_BL&C_VS_CH** | 0.010[m]<br>**10, 14** vs. *17, 19, 25, 27* | 0.946<br>**7, 10, 14** vs. *27* | 0.220<br>**10, 14** vs. 17-22, 25, 27 | 0.135<br>**7, 8, 14** vs. *22- 27* | 0.529<br>**7, 8, 10, 14** vs. 27 |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. 17-27) **BL&C_IR_VS_CH** | 0.397<br>**15** vs. *17, 19, 25, 27* | 0.591<br>**15** vs. *27* | 0.149<br>**15** vs. 17-22, 25, 27 | 0.627<br>**15** vs. *22- 27* | 0.370<br>**15** vs. 27 |

| | | | | | |
|---|---|---|---|---|---|
| Reservoir related | | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | | | 0.099<br>5 vs. **7** |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | 0.346<br>**14** vs. **15** | 0.921<br>**14** vs. **15** | 0.091<br>**14** vs. **15** | 0.398<br>**14** vs. **15** | 0.393<br>**14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. 17) **BL&C_IR_VS_1$^{ST}$_CHAN** | 0.282<br>**15** vs. 17 | | 0.127<br>**15** vs. 17 | | |
| Channelized river | | | | | |
| Channelized above KC vs. channelized below KC (17, 19, 22 vs. 23, 25, 27) **AKC_CH_VS_BKC_CH** | 0.440<br>17, 19 vs. 25, 27 | | 0.423<br>17-22 vs. 25, 27 | 0.739<br>22 vs. 23-27 | |
| **Macrohabitat** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)$^{*}$ | 0.017 (0.1)$^{m}$<br>0.008 (0.05)$^{*}$ | | 0.1 (0.1)$^{m}$<br>0.05 (0.05)$^{*}$ | |
| BEND vs. SCC | 0.621 | 0.921 | | | |
| BEND vs. SCN | | 0.639 | | | |
| BEND vs. TRM | 0.005$^{*}$ | 0.154 | | | |
| SCC vs. SCN | | 0.571 | | | |
| SCC vs. TRM | 0.017$^{*}$ | 0.131 | | | |
| SCN vs. TRM | | 0.319 | | 0.230 | |

Table A3-15. Analysis of variance (ANOVA) probabilities with F-values in parentheses for stonecat collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Electrofishing | | |
|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 3 |
| Analysis level | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 31 | 16 | 24 |
| Years | 1997, 1998 | 1998 | 1996-1998 |
| Segments | 3, 5, **10**, **14**, **15**, *23-27* | 5, 9, **10**, **14**, **15**, *23-27* | 3, 5, **10**, **14**, **15**, *23-27* |
| Macrohabitats | BEND, SCC | BEND, SCC | BEND |
| | | | |
| Year | 0.201 (2.06) | | 0.130 (2.37) |
| Segment | 0.761 (0.57) | 0.619 (0.79) | 0.576 (0.84) |
| Macrohabitat | 0.173 (2.39) | 0.373 (0.90) | |
| Year/segment interaction | 0.620 (0.79) | | |
| Year/macrohabitat interaction | 0.627 (0.26) | | |
| Segment/macrohabitat interaction | 0.670 (0.71) | | |
| **Contrasts** | | | |
| **Year** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* | | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* |
| 1996 vs. 1997 | | | 0.567 |
| 1996 vs. 1998 | | | 0.054 |
| 1997 vs. 1998 | 0.201 | | 0.150 |
| **Segment** | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.011 (0.1)$^{m}$<br>0.0056 (0.05)* | 0.007 (0.1)$^{m}$<br>0.004 (0.05)* | 0.011 (0.1)$^{m}$<br>0.006 (0.05)* |
| *Missouri –Yellowstone rivers* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | 0.879<br>5 vs. 9 | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) FTP_IR_VS_YSR_LA | | | |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | |

| | | | |
|---|---|---|---|
| *3-Zones* | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.969<br>3, 5, vs. **10**, **14**, **15** | 0.743<br>5, 9 vs. **10**, **14**, **15** | 0.797<br>3, 5, vs. **10**, **14**, **15** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | 0.712<br>3, 5 vs. *23-27* | 0.978<br>5, 9 vs. *23-27* | 0.281<br>3, 5 vs. *23-27* |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | 0.670<br>**10**, **14**, **15** vs. *23-27* | 0.691<br>**10**, **14**, **15** vs. *23-27* | 0.353<br>**10**, **14**, **15** vs. *23-27* |
| *5-zones* | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | 0.879<br>5 vs. 9 | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | 0.822<br>3, 5 vs. **10, 14** | 0.703<br>5 vs. **10, 14** | 0.851<br>3, 5 vs. **10, 14** |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | 0.637<br>3, 5 vs. **15** | 0.799<br>5 vs. **15** | 0.383<br>3, 5 vs. **15** |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | 0.082<br>3, 5 vs. *23-27* | 0.908<br>5 vs. *23-27* | 0.281<br>3, 5 vs. *23-27* |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | | 0.580<br>9 vs. **10, 14** | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | | 0.918<br>9 vs. **15** | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | 0.943<br>9 vs. *23-27* | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | 0.476<br>**10, 14** vs. **15** | 0.505<br>**10, 14** vs. **15** | 0.308<br>**10, 14** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | 0.486<br>**10, 14** vs. *23-27* | 0.515<br>**10, 14** vs. *23-27* | 0.204<br>**10, 14** vs. *23-27* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | 0.833<br>**15** vs. *23-27* | 0.844<br>**15** vs. *23-27* | 0.947<br>**15** vs. *23-27* |
| *Reservoir related* | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | 0.955<br>**14** vs. **15** | 0.732<br>**14** vs. **15** | 0.953<br>**14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1$^{ST}$_CHAN** | | | |
| *Channelized river* | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) AKC_CH_VS_BKC_CH | | | |

| **Macrohabitat** | | | |
|---|---|---|---|
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)[m]<br>0.05 (0.05)* | 0.1 (0.1)[m]<br>0.05 (0.05)* | |
| BEND vs. SCC | 0.173 | 0.373 | |
| BEND vs. SCN | | | |
| BEND vs. TRM | | | |
| SCC vs. SCN | | | |
| SCC vs. TRM | | | |
| SCN vs. TRM | | | |

Table A3-16. Analysis of variance (ANOVA) probabilities with F-values in parentheses for sturgeon chub collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Benthic trawl |
|---|---|
| | ANOVA 1 |
| Analysis level | Macrohabitat |
| N | 81 |
| Years | 1996-1998 |
| Segments | 5, **8**, 9 |
| Macrohabitats | BEND, SCC |
| | |
| Year | 0.166 (1.85) |
| Segment | <0.0001 (28.68) |
| Macrohabitat | 0.496 (0.47) |
| Year/segment interaction | <0.0001 (7.42) |
| Year/macrohabitat interaction | 0.882 (0.13) |
| Segment/macrohabitat interaction | 0.485 (0.73) |
| **Contrasts** | |
| **Year** | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* |
| 1996 vs. 1997 | 0.148 |
| 1996 vs. 1998 | 0.909 |
| 1997 vs. 1998 | 0.082 |
| **Segment** | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.025 (0.1)$^{m}$<br>0.013 (0.05)* |
| *Missouri –Yellowstone rivers* | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.008*<br>5 vs. 9 |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) **FTP_IR_VS_YSR_LA** | <0.0001*<br>9 vs.**8** |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | <0.0001*<br>5 vs. **8** |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | |

| | |
|---|---|
| *3-Zones* | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | <0.0001*<br>5, 9, vs. **8** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | |
| *5-zones* | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.008*<br>5 vs. 9 |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | <0.0001*<br>5 vs. **8** |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | <0.0001*<br>9 vs.**8** |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | |
| *Reservoir related* | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) AL&C_IR_VS_BL&C_IR | |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1$^{ST}$_CHAN** | |
| *Channelized river* | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) AKC_CH_VS_BKC_CH | |
| **Macrohabitat** | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* |
| BEND vs. SCC | 0.496 |
| BEND vs. SCN | |
| BEND vs. TRM | |
| SCC vs. SCN | |
| SCC vs. TRM | |
| SCN vs. TRM | |

Table A3-17. Analysis of variance (ANOVA) probabilities with F-values in parentheses walleye collected by multiple sampling gears from the Missouri and lower Yellowstone Rivers. Multiple ANOVAs reflect differences in analysis level, segments, and macrohabitats included in the analyses. See Statistical Analyses in Methods for explanation of analysis levels. A blank cell indicates no contrast was possible. Segments listed under the Statistic column represent planned contrasts, whereas those under the ANOVA columns were included in the analysis. Insufficient data were present in planned segment contrasts that were not analyzed. Contrasts marginally significant at 0.1 and significant at 0.05 based on a Bonferroni-adjusted alpha are indicated by $^{m}$ and *, respectively. Segments in the least-altered zone are above the six Corps of Engineers mainstem reservoirs and are identified by underlining. Inter-reservoir segments are between or below the mainstem reservoirs and are identified in **bold** font. Segments in the channelized portion of the lower Missouri River are in *italic* font. Segments are in the Missouri River unless indicated otherwise. MOR = Missouri River, YSR = Yellowstone River, KC = Kansas City.

| Statistic | Beach seine | | Electrofishing | | |
|---|---|---|---|---|---|
| | ANOVA 1 | ANOVA 2 | ANOVA 1 | ANOVA 2 | ANOVA 3 |
| Analysis level | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat | Macrohabitat |
| N | 38 | 63 | 31 | 20 | 18 |
| Years | 1996-1998 | 1996-1998 | 1996-1998 | 1998 | 1996-1998 |
| Segments | 3, **8, 9, 14, 15** | 3, **8, 9, 15**, *17* | **12, 14, 15,** *17* | **8, 9, 12-15** | 3, 5, **12-15**, *17* |
| Macrohabitats | ISB, SCC, SCN | BEND | BEND, SCC, TRM | BEND, SCC, SCN, TRM | BEND |
| | | | | | |
| Year | 0.914 (0.09) | 0.054 (3.11) | 0.340 (1.26) | | 0.080 (3.30) |
| Segment | 0.730 (0.51) | 0.740 (0.49) | 0.437 (1.03) | 0.917 (0.23) | 0.298 (1.42) |
| Macrohabitat | 0.223 (1.78) | 0.859 (0.49) | 0.012 (8.93) | 0.077 (2.92) | |
| Year/segment interaction | 0.365 (1.26) | | 0.313 (1.46) | | |
| Year/macrohabitat interaction | 0.929 (0.21) | | 0.839 (0.35) | | |
| Segment/macrohabitat interaction | 0.805 (0.53) | | 0.583 (0.83) | | |
| **Contrasts** | | | | | |
| **Year** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* | | 0.033 (0.1)$^{m}$<br>0.017 (0.05)* |
| 1996 vs. 1997 | 0.796 | 0.034 | 0.188 | | 0.028 $^{m}$ |
| 1996 vs. 1998 | 0.688 | 0.686 | 0.630 | | 0.288 |
| 1997 vs. 1998 | 0.853 | 0.047 | 0.280 | | 0.181 |
| **Segment** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.01 (0.1)$^{m}$<br>0.005 (0.05)* | 0.008 (0.1)$^{m}$<br>0.004 (0.05)* | 0.02 (0.1)$^{m}$<br>0.01 (0.05)* | 0.017 (0.1)$^{m}$<br>0.008 (0.05)* | 0.01 (0.1)$^{m}$<br>0.006 (0.05)* |
| *Missouri –Yellowstone rivers* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9)<br>**MOR_LA_VS_YSR_LA** | 0.460<br>3 vs. 9 | 0.945<br>3 vs. 9 | | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7, 8)**<br>**FTP_IR_VS_YSR_LA** | 0.586<br>9 vs. **8** | 0.537<br>9 vs.**8** | | 0.873<br>9 vs. **8** | |

| | | | | | |
|---|---|---|---|---|---|
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | 0.259<br>3 vs. **8** | 0.508<br>3 vs. **8** | | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | | | | |
| *3-Zones* | | | | | |
| Least-altered vs. inter-reservoir (3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.214<br>3, 9 vs. **8**, **14**, **15** | 0.789<br>3, 9 vs. **8**, **15** | | 0.776<br>9 vs. **8**, **12-15** | 0.191<br>3, 5, vs. **12-15** |
| Least-altered vs. channelized (3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | 0.351<br>3, 9 vs. *17* | | | 0.123<br>3, 5 vs. *17* |
| Inter-reservoir vs. channelized (**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | | 0.280<br>**8**, **15** vs. *17* | 0.156<br>**12**, **14**, **15** vs. *17* | | 0.513<br>**12**, **14**, **15** vs. *17* |
| *5-zones* | | | | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | 0.460<br>3 vs. 9 | 0.945<br>3 vs. 9 | | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | 0.204<br>3 vs. **8, 14** | 0.508<br>3 vs. **8** | | | 0.079<br>3, 5 vs. **12, 14** |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | 0.323<br>3 vs. **15** | 0.836<br>3 vs. **15** | | | 0.956<br>3, 5 vs. **15** |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | 0.413<br>3 vs. *17* | | | 0.123<br>3, 5 vs. *17* |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | 0.483<br>9 vs. **8, 14** | 0.537<br>9 vs. **8** | | 0.866<br>9 vs. **8, 12, 14** | |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | 0.660<br>9 vs. **15** | 0.780<br>9 vs. **15** | | 0.627<br>9 vs. **15** | |
| Least-altered lower YSR vs. channelized zone segments (9 vs. *17-27*) **YSR_LA_VS_CH** | | 0.371<br>9 vs. *17* | | | |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | 0.935<br>**8, 14** vs. **15** | 0.407<br>**8** vs. **15** | 0.612<br>**12, 14** vs. **15** | 0.669<br>**8, 12, 14** vs. **15** | 0.129<br>**12, 14** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments (**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | | 0.178<br>**8** vs. *17* | 0.212<br>**12, 14** vs. *17* | | 0.931<br>**12, 14** vs. *17* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments (**15** vs. *17-27*) **BL&C_IR_VS_CH** | | 0.537<br>**15** vs. *17* | 0.146<br>**15** vs. *17* | | 0.162<br>**15** vs. *17* |
| *Reservoir related* | | | | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | | | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | 0.876 **14** vs. **15** | | 0.487 **14** vs. **15** | 0.927 **14** vs. **15** | 0.359 **14** vs. **15** |
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*) **BL&C_IR_VS_1$^{ST}$_CHAN** | | 0.537 **15** vs. *17* | 0.146 **15** vs. *17* | | 0.162 **15** vs. *17* |
| *Channelized river* | | | | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | | | | | |
| **Macrohabitat** | | | | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.033 (0.1)$^{m}$ 0.017 (0.05)* | | 0.033 (0.1)$^{m}$ 0.017 (0.05)* | 0.017 (0.1)$^{m}$ 0.008 (0.05)* | |
| BEND vs. SCC | 0.990 | | 0.631 | 0.950 | |
| BEND vs. SCN | 0.148 | | | 0.320 | |
| BEND vs. TRM | | | 0.006* | 0.024 | |
| SCC vs. SCN | 0.099 | | | 0.350 | |
| SCC vs. TRM | | | 0.032$^{m}$ | 0.027 | |
| SCN vs. TRM | | | | 0.146 | |

| Statistic | Stationary Gillnet | |
|---|---|---|
| | ANOVA 1 | ANOVA 2 |
| Analysis level | Macrohabitat | Replicate |
| N | 24 | 54 |
| Years | 1997, 1998 | 1997, 1998 |
| Segments | **7**, **8**, 9, **12-15** | **7**, **8**, 9, **12-15,** *17, 19* |
| Macrohabitats | SCN, TRM | TRM |
| | | |
| Year | 0.114 (3.65) | 0.023 (5.65) |
| Segment | 0.503 (0.99) | 0.099 (1.89) |
| Macrohabitat | 0.437 (0.71) | |
| Year/segment interaction | 0.804 (0.44) | 0.625 (0.76) |
| Year/macrohabitat interaction | 0.774 (0.09) | |
| Segment/macrohabitat interaction | 0.794 (0.46) | |
| **Contrasts** | | |
| **Year** | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)$^{m}$ 0.05 (0.05)* | 0.1 (0.1)$^{m}$ 0.05 (0.05)* |
| 1996 vs. 1997 | | |
| 1996 vs. 1998 | | |
| 1997 vs. 1998 | 0.114 | 0.023 |

| **Segment** | | |
|---|---|---|
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.017 (0.1)[m]<br>0.008 (0.05)* | 0.009 (0.1)[m]<br>0.005 (0.05)* |
| *Missouri –Yellowstone rivers* | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | |
| Least-altered lower YSR vs. inter-reservoir MOR below Fort Peck Dam to YSR (9 vs.**7**, **8**) **FTP_IR_VS_YSR_LA** | 0.724<br>9 vs.**7**, **8** | 0.558<br>9 vs.**7**, **8** |
| Least-altered MOR segments vs. inter-reservoir MOR segments below Fort Peck Dam to YSR (3, 5 vs. **7**, **8**) **MOR_LA_VS_FTP_IR** | | |
| *3-Zones* | | |
| Least-altered vs. inter-reservoir<br>(3, 5, 9 vs. **7**, **8**, **10**, **12**, **14**, **15**) **LA_VS_IR** | 0.726<br>9 vs. **7**, **8**, **12-15** | 0.683<br>9 vs. **7**, **8**, **12-15** |
| Least-altered vs. channelized<br>(3, 5, 9 vs. *17*, *19*, *22*, *23*, *25*, *27*) **LA_VS_CH** | | 0.248<br>9 vs. *17*, *19* |
| Inter-reservoir vs. channelized<br>(**7**, **8**, **10**, **12**, **14**, **15** vs. *17*, *19*, *22*, *23*, *25*, *27*) **IR_VS_CH** | | 0.068<br>**7**, **8**, **12-15** vs. *17*, *19* |
| *5-zones* | | |
| Least-altered MOR vs. least-altered YSR (3, 5 vs. 9) **MOR_LA_VS_YSR_LA** | | |
| Inter-reservoir MOR below Fort Peck Dam to YSR vs. Inter-reservoir MOR from YSR to Lake Sakakawea headwaters (**8** vs. **10**) **BWFP_IR-VS-ASAK_IR** | | |
| Least-altered MOR segments vs. inter-reservoir segments above Gavins Point Dam (3, 5 vs. **7, 8, 10, 12, 14**) **MOR_LA_VS_IR_W/O_BL&C** | | |
| Least-altered MOR segments vs. inter-reservoir segment below Gavins Point Dam (3, 5 vs. **15**) **MOR_LA_VS_BL&C_IR** | | |
| Least-altered MOR segments vs. channelized zone segments (3, 5 vs. *17-27*) **MOR_LA_VS_CH** | | |
| Least-altered lower YSR vs. inter-reservoir segments above Gavins Point Dam (9 vs. **7, 8, 10, 12, 14**) **YSR_LA_VS_IR_W/O_BL&C** | 0.711<br>9 vs.**7**, **8, 12, 14** | 0.745<br>9 vs. **7, 8, 12, 14** |
| Least-altered lower YSR vs. inter-reservoir segment below Gavins Point Dam (9 vs. **15**) **YSR_LA_VS_BL&C_IR** | 0.855<br>9 vs. **15** | 0.502<br>9 vs. **15** |
| Least-altered lower YSR vs. channelized zone segments<br>(9 vs. *17-27*) **YSR_LA_VS_CH** | | 0.248<br>9 vs. *17, 19* |
| Inter-reservoir segments above Gavins Point Dam vs. inter-reservoir segment below Gavins Point Dam (**7, 8, 10, 12, 14** vs. **15**) **IR_W/O_BL&C_VS_BL&C_IR** | 0.888<br>**7, 8, 12, 14** vs. **15** | 0.483<br>**7, 8, 12, 14** vs. **15** |
| Inter-reservoir segments above Gavins Point Dam vs. channelized zone segments<br>(**7, 8, 10, 12, 14** vs. *17-27*) **IR_W/O_BL&C_VS_CH** | | 0.056<br>**7, 8, 12, 14** vs. *17, 19* |
| Inter-reservoir segment below Gavins Point Dam vs. channelized zone segments<br>(**15** vs. *17-27*) **BL&C_IR_VS_CH** | | 0.446<br>**15** vs. *17, 19* |
| *Reservoir related* | | |
| Least-altered segment above Fort Peck Lake vs. inter-reservoir segment below Fort Peck Dam (5 vs. **7**) **AFTP_LA_VS_BFTP_RI** | | |
| Inter-reservoir MOR from YSR to Lake Sakakawea headwaters vs. inter-reservoir Garrison Dam to Lake Oahe headwaters (**10** vs. **12**) **ASAK_IR_VS_BSAK_IR** | | |
| Inter-reservoir between Fort Randall Dam and Lewis and Clark Lake headwaters vs. inter-reservoir below Gavins Point Dam (**14** vs. **15**) **AL&C_IR_VS_BL&C_IR** | 0.774<br>**14** vs. **15** | 0.068<br>**14** vs. **15** |

| | | |
|---|---|---|
| Inter-reservoir segment below Gavins Point Dam vs. first channelized river segment (**15** vs. *17*)<br>**BL&C_IR_VS_1$^{ST}$_CHAN** | | 0.321<br>**15** vs. *17* |
| *Channelized river* | | |
| Channelized above KC vs. channelized below KC (*17*, *19*, *22* vs. *23*, *25*, *27*) **AKC_CH_VS_BKC_CH** | | |
| **Macrohabitat** | | |
| Bonferroni-adjusted alpha (experiment-wise alpha) | 0.1 (0.1)$^{m}$<br>0.05 (0.05)* | |
| BEND vs. SCC | | |
| BEND vs. SCN | | |
| BEND vs. TRM | | |
| SCC vs. SCN | | |
| SCC vs. TRM | | |
| SCN vs. TRM | 0.437 | |

# APPENDIX 4
# PHYSICAL HABITAT: STATISTICS

Table A4-1 One-way ANOVA and logistic regression for presence/absence of bigmouth buffalo, blue catfish, blue sucker, and burbot .....257–258

Table A4-2 One-way ANOVA and logistic regression for presence/absence of common carp, channel catfish, emerald shiner, and fathead minnow.....259–260

Table A4-3 One-way ANOVA and logistic regression for presence/absence of flathead catfish, flathead chub, freshwater drum, and river carpsucker.....261–262

Table A4-4 One-way ANOVA and logistic regression for presence/absence of sand shiner, sauger, shorthead redhorse, and shovelnose sturgeon .....263–264

Table A4-5 One-way ANOVA and logistic regression for presence/absence of sicklefin chub, smallmouth buffalo, stonecat, and sturgeon chub.....265–266

Table A4-6 One-way ANOVA and logistic regression for presence/absence of walleye and white sucker .....267–268

Table A4-1. One-way ANOVA and logistic regression for presence/absence of bigmouth buffalo, blue catfish, blue sucker, and burbot. One-way ANOVA tested mean differences between sites with and without a species for each of the habitat variables measured based on transformed data (see text for transformations used); means are back transformed values. Stepwise logistic regression tested the ability of each of the habitat parameters to predict the presence of a species based on untransformed data. NU stands for "not used in logistic regression". NS stands for "not significant in logistic regression".

| | Mean with fish/mean without fish<br>(ANOVA: N, % variance accounted for, P-value)<br>[Logistic regression: parameter estimate, P-value] | | | |
|---|---|---|---|---|
| | Bigmouth Buffalo | Blue Catfish | Blue Sucker | Burbot |
| Water velocity (m/sec) | 0.111/0.206<br>(176, 2.3, 0.045)<br>[NS] | 0.473/0.190<br>(213, 22.7, <0.0001)<br>[2.553, 0.002] | 0.602/0.353<br>(562, 7.7, <0.0001)<br>[2.27, 0.0001] | 0.635/0.466<br>(141, 9.5, 0.0002)<br>[3.831, <0.0001] |
| Water depth (m) | 1.261/1.081<br>(180, 0.5, 0.354)<br>[NS] | 2.608/1.307<br>(214, 21.5, <0.0001)<br>[0.572, 0.0009] | 2.433/1.555<br>(566, 5.9, <0.0001)<br>[NS] | 1.761/0.817<br>(141, 17.0, <0.0001)<br>[NS] |
| Water temperature (°C) | 22.07/19.94<br>(180, 3.65, 0.010)<br>[0.168, 0.005] | 26.13/24.58<br>(207, 9.4, <0.0001)<br>[0.375, <0.0001] | 23.60/22.12<br>(560, 1.7, 0.002)<br>[NS] | 20.89/21.50<br>(141, 1.0, 0.240)<br>[-0.176, 0.019] |
| Water turbidity (NTU) | 38.50/34.44<br>(177, 0.17, 0.588)<br>[NS] | 120.96/68.67<br>(213, 9.7, <0.0001)<br>[NS] | 51.99/45.20<br>(561, 0.2, 0.258)<br>[NS] | 59.01/42.50<br>(139, 1.9, 0.103)<br>[NS] |

| | | | | |
|---|---|---|---|---|
| Water conductivity (uS/cm) | 703.57/683.17<br>(180, 0.1, 0.668)<br>[NS] | 663.54/669.16<br>(204, 0.0, 0.761)<br>[-0.003, 0.016] | 691.12/624.60<br>(558, 1.4, 0.006)<br>[0.002, 0.003] | 446.36/464.89<br>(141, 1.3, 0.180)<br>[NS] |
| Substrate geometric mean | 0.101/0.261<br>(178, 4.84, 0.003)<br>[NS] | 2.751/0.203<br>(214, 28.7, <0.0001)<br>[NS] | 4.739/0.713<br>(564, 9.6, <0.0001)<br>[0.045, 0.001] | 2.981/2.598<br>(141, 0.2, 0.640)<br>[NS] |
| Proportion gravel | 0.001/0.003<br>(178, 0.55, 0.327)<br>[NU] | 0.029/0.005<br>(214, 8.8, <0.0001)<br>[NU] | 0.077/0.042<br>(564, 0.9, 0.023)<br>[NU] | 0.194/0.232<br>(141, 0.3, 0.504)<br>[NU] |
| Proportion sand | 0.169/0.466<br>(178, 5.34, 0.002)<br>[NU] | 0.466/0.231<br>(214, 7.0, <0.0001)<br>[NU] | 0.602/0.411<br>(564, 2.2, 0.0004)<br>[NU] | 0.512/0.423<br>(141, 1.3, 0.186)<br>[NU] |
| Proportion silt | 0.820/0.499<br>(178, 5.48, 0.002)<br>[NU] | 0.399/0.719<br>(214, 10.1, <0.0001)<br>[NU] | 0.175/0.430<br>(564, 4.0, <0.0001)<br>[NU] | 0.179/0.205<br>(141, 0.3, 0.548)<br>[NU] |
| | | | | |
| Logistic regression R-squared | 0.05 | 0.34 | 0.10 | 0.14 |
| Logistic regression % concordance | 66.8 | 84.8 | 77.6 | 73.2 |
| Intercept only AIC value | 154.8 | 278.7 | 467.7 | 172.3 |
| Full model AIC value | 148.1 | 204.1 | 415.2 | 154.8 |

Table A4-2. One-way ANOVA and logistic regression for presence/absence of common carp, channel catfish, emerald shiner, and fathead minnow. One-way ANOVA tested mean differences between sites with and without a species for each of the habitat variables measured based on transformed data (see text for transformations used); means are back transformed values. Stepwise logistic regression tested the ability of each of the habitat parameters to predict the presence of a species based on untransformed data. NU stands for "not used in logistic regression". NS stands for "not significant in logistic regression". NV stands for "no variables were significant in the logistic regression".

| | Mean with fish/mean without fish<br>(ANOVA: N, % variance accounted for, P-value)<br>[Logistic regression: parameter estimate, P-value] | | | |
|---|---|---|---|---|
| | Common Carp | Channel Catfish | Emerald Shiner | Fathead Minnow |
| Water velocity (m/sec) | 0.323/0.322<br>(711, 0.0, 0.985)<br>[-1.339, 0.0001] | 0.339/0.323<br>(743, 0.0, 0.4937)<br>[-0.9253, <0.005] | 0.350/0.333<br>(523, 0.1, 0.569)<br>[NS] | 0.247/0.307<br>(356, 0.6, 0.142)<br>[NS] |
| Water depth (m) | 1.912/1.295<br>(723, 7.1, <0.0001)<br>[0.491, <0.0001] | 1.883/1.226<br>(755, 8.2, <0.0001)<br>[0.6463, <0.0001] | 1.669/1.589<br>(535, 0.1, 0.491)<br>[NS] | 1.505/1.594<br>(363, 0.1, 0.521)<br>[NS] |
| Water temperature (°C) | 23.25/20.84<br>(715, 7.9, <0.0001)<br>[0.112, <0.0001] | 23.68/20.07<br>(747, 18.1, <0.0001)<br>[0.2340, <0.0001] | 23.94/23.89<br>(528, 0.0, <0.864)<br>[NS] | 20.64/20.48<br>(362, 0.0, 0.799)<br>[NS] |
| Water turbidity (NTU) | 47.98/35.82<br>(710, 1.6, 0.0008)<br>[NS] | 53.69/29.03<br>(742, 7.1, <0.0001)<br>[NS] | 48.72/41.35<br>(524, 0.4, 0.134)<br>[NS] | 30.44/28.07<br>(355, 0.1, 0.619)<br>[NS] |

| | | | | |
|---|---|---|---|---|
| Water conductivity (uS/cm) | 673.21/629.63<br>(711, 1.1, 0.005)<br>[NS] | 649.43/600.70<br>(743, 1.4, 0.001)<br>[NS] | 660.51/704.14<br>(523, 0.9, 0.031)<br>[-0.001, 0.025] | 658.20/665.81<br>(361, 0.0, 0.770)<br>[NS] |
| Substrate geometric mean | 0.562/0.634<br>(721, 0.1, 0.467)<br>[0.051, 0.005] | 0.696/0.635<br>(753, 0.0, 0.580)<br>[NS] | 0.937/0.660<br>(533, 0.4, 0.130)<br>[NS] | 0.577/0.510<br>(363, 0.0, 0.680)<br>[NS] |
| Proportion gravel | 0.020/0.029<br>(721, 0.4, 0.086)<br>[NU] | 0.030/0.037<br>(753, 0.1, 0.334)<br>[NU] | 0.051/0.033<br>(533, 0.5, 0.113)<br>[NU] | 0.014/0.023<br>(363, 0.3, 0.299)<br>[NU] |
| Proportion sand | 0.312/0.575<br>(721, 7.6, <0.0001)<br>[NU] | 0.335/0.513<br>(753, 3.5, <0.0001)<br>[NU] | 0.332/0.432<br>(533, 1.0, 0.019)<br>[NU] | 0.393/0.431<br>(363, 0.1, 0.558)<br>[NU] |
| Proportion silt | 0.574/0.306<br>(721, 6.5, <0.0001)<br>[NU] | 0.525/0.337<br>(753, 3.2, <0.0001)<br>[NU] | 0.478/0.427<br>(533, 0.2, 0.304)<br>[NU] | 0.481/0.450<br>(363, 0.0, 0.673)<br>[NU] |
| | | | | |
| Logistic regression R-squared | 0.14 | 0.25 | 0.01 | NV |
| Logistic regression % concordance | 71.3 | 79.6 | 54.9 | NV |
| Intercept only AIC value | 926.65 | 970.67 | 569.27 | NV |
| Full model AIC value | 831.02 | 771.99 | 566.18 | NV |

Table A4-3. One-way ANOVA and logistic regression for presence/absence of flathead catfish, flathead chub, freshwater drum, and river carpsucker. One-way ANOVA tested mean differences between sites with and without a species for each of the habitat variables measured based on transformed data (see text for transformations used); means are back transformed values. Stepwise logistic regression tested the ability of each of the habitat parameters to predict the presence of a species based on untransformed data. NU stands for "not used in logistic regression". NS stands for "not significant in logistic regression".

| | Mean with fish/mean without fish<br>(ANOVA: N, % variance accounted for, P-value)<br>[Logistic regression: parameter estimate, P-value] | | | |
|---|---|---|---|---|
| | Flathead Catfish | Flathead Chub | Freshwater Drum | River Carpsucker |
| Water velocity (m/sec) | 0.480/0.235<br>(312, 16.2, <0.0001)<br>[NS] | 0.419/0.165<br>(230, 9.5,<0.0001)<br>[4.282, <0.0001] | 0.360/0.344<br>(464, 0.1, 0.570)<br>[NS] | 0.256/0.423<br>(668, 7.2, <0.0001)<br>[-2.021, <0.0001] |
| Water depth (m) | 2.712/1.303<br>(316, 27.4, <0.0001)<br>[0.720, <0.0001] | 1.048/1.389<br>(230, 1.6, 0.055)<br>[-1.081, <0.0001] | 1.922/1.480<br>(476, 3.2, <0.0001)<br>[NS] | 1.573/1.759<br>(680, 0.6, 0.038)<br>[NS] |
| Water temperature (°C) | 25.22/24.33<br>(311, 3.0, 0.002)<br>[NS] | 20.92/20.26<br>(230, 0.5, 0.298)<br>[NS] | 24.35/23.93<br>(469, 0.5, 0.111)<br>[NS] | 22.91/21.58<br>(672, 2.3, <0.0001)<br>[0.069, 0.0003] |
| Water turbidity (NTU) | 74.95/59.84<br>(313, 1.6, 0.027)<br>[NS] | 51.76/42.99<br>(228, 0.4, 0.321)<br>[NS] | 61.72/31.15<br>(466, 9.5, <0.0001)<br>[0.004, 0.0005] | 43.13/35.78<br>(668, 0.7, 0.037)<br>[NS] |

| | | | | |
|---|---|---|---|---|
| Water conductivity (uS/cm) | 721.95/692.25<br>(308, 0.7, 0.140)<br>[NS] | 497.02/600.08<br>(230, 8.2, <0.0001)<br>[-0.004, 0.033] | 660.26/711.36<br>(464, 1.5, 0.008)<br>[NS] | 688.66/632.83<br>(668, 1.8, 0.0005)<br>[0.001, 0.011] |
| Substrate geometric mean | 2.080/0.242<br>(314, 20.0, <0.0001)<br>[0.207, <0.0001] | 1.382/0.132<br>(230, 16.0, <0.0001)<br>[NS] | 0.951/0.735<br>(474, 0.3, 0.238)<br>[0.027, 0.020] | 0.436/0.976<br>(678, 3.2, <0.0001)<br>[NS] |
| Proportion gravel | 0.022/0.010<br>(314, 1.9, 0.015)<br>[NU] | 0.126/0.009<br>(230, 6.0, 0.0002)<br>[NU] | 0.033/0.043<br>(474, 0.2, 0.339)<br>[NU] | 0.017/0.038<br>(678, 2.1, 0.0002)<br>[NU] |
| Proportion sand | 0.410/0.362<br>(314, 0.3, 0.350)<br>[NU] | 0.460/0.201<br>(230, 4.6, 0.0011)<br>[NU] | 0.303/0.429<br>(474, 2.1, 0.002)<br>[NU] | 0.322/0.534<br>(678, 5.0, <0.0001)<br>[NU] |
| Proportion silt | 0.442/0.574<br>(314, 1.5, 0.028)<br>[NU] | 0.274/0.750<br>(230, 13.66, <0.0001)<br>[NU] | 0.543/0.397<br>(474, 2.0, 0.002)<br>[NU] | 0.580/0.312<br>(678, 6.4, <0.0001)<br>[NU] |
| | | | | |
| Logistic regression R-squared | 0.37 | 0.17 | 0.06 | 0.11 |
| Logistic regression % concordance | 84.6 | 83.3 | 64.9 | 70.0 |
| Intercept only AIC value | 415.97 | 179.56 | 610.24 | 864.97 |
| Full model AIC value | 282.14 | 141.91 | 587.58 | 792.70 |

Table A4-4. One-way ANOVA and logistic regression for presence/absence of sand shiner, sauger, shorthead redhorse, and shovelnose sturgeon. One-way ANOVA tested mean differences between sites with and without a species for each of the habitat variables measured based on transformed data (see text for transformations used); means are back transformed values. Stepwise logistic regression tested the ability of each of the habitat parameters to predict the presence of a species based on untransformed data. NU stands for "not used in logistic regression". NS stands for "not significant in logistic regression".

| | Mean with fish/mean without fish<br>(ANOVA: N, % variance accounted for, P-value)<br>[Logistic regression: parameter estimate, P-value] | | | |
|---|---|---|---|---|
| | Sand Shiner | Sauger | Shorthead Redhorse | Shovelnose Sturgeon |
| Water velocity (m/sec) | 0.352/0.299<br>(390, 0.5, 0.175)<br>[NS] | 0.334/0.341<br>(692, 0.0, 0.772)<br>[NS] | 0.377/0.311<br>(666, 1.0, 0.010)<br>[NS] | 0.593/0.272<br>(595, 25.6, <0.0001)<br>[3.253, <0.0001] |
| Water depth (m) | 1.749/1.753<br>(402, 0.0, 0.983)<br>[NS] | 1.721/1.570<br>(704, 0.4, 0.103)<br>[NS] | 1.540/1.534<br>(678, 0.0, 0.943)<br>[NS] | 2.385/1.282<br>(599, 18.4, <0.0001)<br>[0.468, <0.0001] |
| Water temperature (°C) | 24.86/23.56<br>(395, 2.3, 0.003)<br>[0.155, 0.0003] | 22.15/22.89<br>(696, 0.8, 0.019)<br>[-0.038, 0.047] | 21.51/22.17<br>(670, 0.5, 0.060)<br>[NS] | 22.82/21.90<br>(593, 1.2, 0.008)<br>[NS] |
| Water turbidity (NTU) | 56.82/34.56<br>(392, 2.6, 0.001)<br>[NS] | 45.42/47.15<br>(691, 0.0, 0.671)<br>[NS] | 33.83/42.22<br>(665, 0.8, 0.022)<br>[-0.004, 0.0004] | 57.61/44.00<br>(593, 1.5, 0.003)<br>[NS] |

| | | | | |
|---|---|---|---|---|
| Water conductivity (uS/cm) | 739.63/722.42<br>(392, 0.1, 0.476)<br>[NS] | 629.66/659.92<br>(692, 0.5, 0.070)<br>[NS] | 624.42/622.43<br>(666, 0.0, 0.907)<br>[NS] | 619.99/602.36<br>(591, 0.2, 0.285)<br>[NS] |
| Substrate geometric mean | 1.465/0.505<br>(400, 3.4, 0.0002)<br>[NS] | 0.575/0.751<br>(702, 0.3, 0.139)<br>[NS] | 0.977/0.575<br>(676, 1.3, 0.003)<br>[0.034, 0.002] | 3.128/0.419<br>(597, 21.1, <0.0001)<br>[NS] |
| Proportion gravel | 0.019/0.013<br>(400, 0.4, 0.226)<br>[NU] | 0.041/0.033<br>(702, 0.1, 0.323)<br>[NU] | 0.068/0.025<br>(676, 3.1, <0.0001)<br>[NU] | 0.069/0.031<br>(597, 2.5, 0.0001)<br>[NU] |
| Proportion sand | 0.554/0.381<br>(400, 2.1, 0.004)<br>[NU] | 0.307/0.439<br>(702, 1.9, 0.0003)<br>[NU] | 0.410/0.439<br>(676, 0.1, 0.455)<br>[NU] | 0.630/0.345<br>(597, 9.4, <0.0001)<br>[NU] |
| Proportion silt | 0.314/0.522<br>(400, 2.5, 0.002)<br>[NU] | 0.539/0.414<br>(702, 1.3, 0.003)<br>[NU] | 0.377/0.439<br>(676, 0.3, 0.147)<br>[NU] | 0.184/0.519<br>(597, 12.4, <0.0001)<br>[NU] |
| | | | | |
| Logistic regression R-squared | 0.04 | 0.01 | 0.04 | 0.27 |
| Logistic regression % concordance | 62.6 | 56.2 | 62.2 | 83.0 |
| Intercept only AIC value | 372.7 | 839.1 | 799.3 | 786.2 |
| Full model AIC value | 359.1 | 837.2 | 774.9 | 610.1 |

Table A4-5. One-way ANOVA and logistic regression for presence/absence of sicklefin chub, smallmouth buffalo, stonecat, and sturgeon chub. One-way ANOVA tested mean differences between sites with and without a species for each of the habitat variables measured based on transformed data (see text for transformations used); means are back transformed values. Stepwise logistic regression tested the ability of each of the habitat parameters to predict the presence of a species based on untransformed data. NU stands for "not used in logistic regression". NS stands for "not significant in logistic regression".

| | Mean with fish/mean without fish<br>(ANOVA: N, % variance accounted for, P-value)<br>[Logistic regression: parameter estimate, P-value] | | | |
|---|---|---|---|---|
| | Sicklefin Chub | Smallmouth Buffalo | Stonecat | Sturgeon Chub |
| Water velocity (m/sec) | 0.610/0.360<br>(229, 23.5, <0.0001)<br>[4.059, <0.0001] | 0.242/0.367<br>(692, 3.0, <0.0001)<br>[-1.967, <0.0001] | 0.642/0.467<br>(378, 7.7, <0.0001)<br>[3.654, <0.0001] | 0.571/0.364<br>(119, 20.8, <0.0001)<br>[4.066, 0.003] |
| Water depth (m) | 2.190/1.079<br>(230, 19.5, <0.0001)<br>[0.629, 0.0004] | 1.614/1.618<br>(704, 0.0, 0.969)<br>[NS] | 2.018/1.538<br>(383, 2.1, 0.004)<br>[NS] | 1.645/0.833<br>(119, 23.5, <0.0001)<br>[0.821, 0.014] |
| Water temperature (°C) | 21.10/22.87<br>(226, 4.5, 0.001)<br>[-0.118, 0.009] | 23.24/22.49<br>(696, 0.6, 0.036)<br>[NS] | 22.66/23.15<br>(379, 0.3, 0.282)<br>[NS] | 19.81/20.38<br>(119, 0.6, 0.422)<br>[NS] |
| Water turbidity (NTU) | 80.05/69.14<br>(227, 0.5, 0.289)<br>[NS] | 46.80/46.53<br>(691, 0.0, 0.955)<br>[NS] | 64.97/48.77<br>(376, 0.9, 0.062)<br>[NS] | 49.83/36.80<br>(118, 2.6, 0.083)<br>[NS] |

| | | | | |
|---|---|---|---|---|
| Water conductivity (uS/cm) | 517.50/575.66<br>(226, 5.8, 0.0003)<br>[-0.005, 0.0007] | 664.33/646.3<br>(692, 0.1, 0.348)<br>[NS] | 537.10/638.49<br>(378, 6.4, <0.0001)<br>[-0.005, <0.0001] | 518.48/508.98<br>(119, 0.2, 0.605)<br>[NS] |
| Substrate geometric mean | 2.115/1.242<br>(230, 3.5, 0.0046)<br>[NS] | 0.464/0.768<br>(702, 0.9, 0.014)<br>[0.039, 0.002] | 3.567/1.921<br>(382, 2.7, 0.001)<br>[NS] | 1.889/1.113<br>(119, 3.3, 0.048)<br>[NS] |
| Proportion gravel | 0.085/0.050<br>(230, 1.5, 0.064)<br>[NU] | 0.021/0.040<br>(702, 0.7, 0.027)<br>[NU] | 0.162/0.059<br>(382, 4.9, <0.0001)<br>[NU] | 0.120/0.098<br>(119, 0.3, 0.576)<br>[NU] |
| Proportion sand | 0.648/0.616<br>(230, 0.2, 0.498)<br>[NU] | 0.240/0.441<br>(702, 3.5, <0.0001)<br>[NU] | 0.557/0.638<br>(382, 0.9, 0.064)<br>[NU] | 0.623/0.499<br>(119, 2.4, 0.090)<br>[NU] |
| Proportion silt | 0.183/0.234<br>(230, 0.9, 0.141)<br>[NU] | 0.636/0.404<br>(702, 3.4, <0.0001)<br>[NU] | 0.163/0.193<br>(382, 0.3, 0.296)<br>[NU] | 0.164/0.278<br>(119, 4.2, 0.026)<br>[NU] |
| | | | | |
| Logistic regression R-squared | 0.34 | 0.05 | 0.15 | 0.25 |
| Logistic regression % concordance | 85.1 | 63.1 | 76.3 | 80.5 |
| Intercept only AIC value | 305.7 | 703.0 | 372.8 | 154.4 |
| Full model AIC value | 221.6 | 675.0 | 317.5 | 124.0 |

Table A4-6. One-way ANOVA and logistic regression for presence/absence of walleye and white sucker. One-way ANOVA tested mean differences between sites with and without a species for each of the habitat variables measured based on transformed data (see text for transformations used); means are back transformed values. Stepwise logistic regression tested the ability of each of the groups of bed-form parameters to predict the presence of a species based on untransformed data. NU stands for "not used in logistic regression". NS stands for "not significant in logistic regression".

| | Mean with fish/mean without fish<br>(ANOVA: N, % variance accounted for, P-value)<br>[Logistic regression: parameter estimate, P-value] | |
|---|---|---|
| | Walleye | White Sucker |
| Water velocity (m/sec) | 0.263/0.376<br>(487, 2.9, 0.0002)<br>[-1.318, 0.0002] | 0.309/0.350<br>(209, 0.4, 0.357)<br>[NS] |
| Water depth (m) | 1.562/1.487<br>(498, 0.1, 0.455)<br>[NS] | 1.213/1.424<br>(209, 1.4, 0.088)<br>[-0.428, 0.008] |
| Water temperature (°C) | 21.83/20.72<br>(497, 1.5, 0.006)<br>[0.080, 0.002] | 16.88/17.64<br>(208, 0.9, 0.170)<br>[-0.078, 0.040] |
| Water turbidity (NTU) | 33.49/25.83<br>(487, 1.3, 0.012)<br>[NS] | 23.15/26.34<br>(208, 0.4, 0.364)<br>[NS] |

| | | |
|---|---|---|
| Water conductivity | 700.91/623.08<br>(496, 2.8, 0.0002)<br>[NS] | 596.55/604.66<br>(209, 0.1, 0.743)<br>[NS] |
| Substrate geometric mean | 0.446/0.884<br>(496, 2.1, 0.001)<br>[NS] | 0.584/0.656<br>(209, 0.1, 0.690)<br>[NS] |
| Proportion gravel | 0.028/0.057<br>(496, 1.3, 0.012)<br>[NU] | 0.034/0.062<br>(209, 0.9, 0.163)<br>[NU] |
| Proportion sand | 0.327/0.465<br>(496, 1.9, 0.002)<br>[NU] | 0.476/0.426<br>(209, 0.2, 0.480)<br>[NU] |
| Proportion silt | 0.544/0.338<br>(496, 3.4, <0.0001)<br>[NU] | 0.374/0.373<br>(209, 0.0, 0.997)<br>[NU] |
| | | |
| Logistic regression R-squared | 0.05 | 0.05 |
| Logistic regression % concordance | 63.0 | 60.2 |
| Intercept only AIC value | 562.8 | 288.7 |
| Full model AIC value | 543.7 | 282.4 |