Niobrara River Fish Community Downstream of Spencer Dam, Nebraska

2008 Progress Report

By

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Abstract. — The Niobrara River retains a natural hydrograph and temperature regime, which provides important seasonal habitats for native fishes downstream of the confluence in an inter-reservoir reach of the Missouri River. Two major threats to the fauna in the Niobrara River include water diversion for agricultural purposes and invasive Asian carp entering the river. However, knowledge was lacking on the fish community within the Niobrara River. Our objectives were to examine the fish community in Niobrara River downstream of Spencer Dam, Nebraska. Fish sampling included drifted trammel nets that occurred from May through September and electrofishing from July through September 2008. Trammel nets captured large-bodied fish with the most common fish species captured were river carpsucker *Carpiodes carpio* (N = 385) and channel catfish *Ictalurus punctatus* (N = 138). Additionally, 14 shovelnose sturgeon *Scaphirhynchus platorynchus* and two pallid sturgeon *S. albus* were captured with trammel nets. Electrofishing predominately captured small-bodied and young of the year of large-bodied fishes with the most common species captured were river carpsucker (N = 1,538) and red shiners *Notropis lutrensis* (N = 1,467). No Asian carp were collected in either gear. Fish communities within this section of the Niobrara River were compared among three distinct geomorphic reaches and across months sampled. Trammel net data showed few significant differences in the fish community among months, while some differences where found among river reaches with sauger *Sander canadense* in higher abundance just downstream of Spencer Dam. Electrofishing data found significant differences among river reaches with red shiners and sand shiners *Notropis stramineus* in higher abundances just downstream of Spencer Dam and significant differences among months with the increase of young of the year fish each month. Our results showed that large-bodied fish generally used the entire Niobrara River downstream

of Spencer Dam throughout the sampling period while small-bodied and young of the year fish relative abundance were more spatially and temporally variable.

Introduction

The Niobrara River in Nebraska is the only major tributary to an inter-reservoir reach of the Missouri River between Fort Randall and Gavins Point dams (Figure 1). This reach of the Missouri River was designated as pallid sturgeon *Scaphirhynchus albus* Recovery Priority Management Area (RPMA) 3 (U.S. Fish and Wildlife Service 1993). Although RPMA 3 retains historic physical riverine characteristics, construction and operations of the mainstem Missouri River dams have greatly altered the historic river hydrograph including seasonal water temperatures and turbidity. Additionally, asynchronous operations of Fort Randall and Gavins Point Dams create highly fluctuating daily and seasonal river stages.

The Niobrara River retains a natural hydrograph and temperature regime, which likely provides important seasonal habitats for native fishes. Many studies have reported the importance of the Niobrara River to the Missouri River downstream of the confluence including increased relative abundance of native fish (Shuman et al. 2009), increase relative abundance of invertebrates (Grohs 2008), increased shovelnose sturgeon *S. platorynchus* condition (Wanner 2006), and increased levels of recruitment of sauger *Sander canadense* (Graeb 2006) and paddlefish *Polyodon spathula* (B. Pracheil, personal communication). However, there is limited information on the fish communities within the Niobrara River.

The natural hydrograph of the Niobrara River is currently in jeopardy as water is increasingly being diverted for agricultural irrigation development. The Niobrara River is principally groundwater fed and is at higher risk due to over-withdrawal from irrigation.

Reduced flows will likely jeopardize native fish populations and eliminate some productivity of fish and invertebrates in the Niobrara and downstream of the Missouri/Niobrara confluence. Additionally, Spencer Dam (owned and operated by Nebraska Public Power District) is approximately 63.3 river kilometers (rkm) upstream of the Niobrara/Missouri River confluence and since construction in 1927, has functioned as a complete barrier to upstream fish migration. Although Spencer Dam is a barrier, it is operated as a run of river dam with little adverse affects to the natural hydrograph and temperature regime. However, Hesse and Newcomb (1982) recommended a fish bypass at Spencer Dam to provide upstream access for spawning sauger, walleye *Sander vitreus*, and channel catfish *Ictalurus punctatus*. The Niobrara River, including sites upstream of Spencer Dam, may also provide critical sturgeon spawning sites, distance necessary for larval sturgeon drift, as well as nursery habitat for young of the year sturgeon, which could contribute to recovery of endangered pallid sturgeon.

An additional threat to the Niobrara River is invasive Asian carp (i.e., bighead *Hypophthalmichthys nobilis*, silver *H. molitrix*, grass *Ctenopharyngodon idella*, and black carp *Mylopharyngodon piceus*). Asian carp have been found just downstream of Gavins Point Dam (U.S. Fish and Wildlife Service 2003; Klumb 2007; Stukel et al. 2008), the last barrier on the Missouri River downstream of the Niobrara River. Because of the natural hydrograph and temperature regime of the Niobrara River, Asian carp are likely to colonize this area if they are present in the Missouri River upstream of Gavins Point Dam. The high spring flows and turbid water are ideal spawning conditions for Asian carp (Kolar et al. 2005). Detection of Asian carp in the Niobrara River would be easily achieved through systematic sampling. Spencer Dam acts as a fish barrier to upstream migration in the Niobrara River. A bypass would allow access to upstream reaches for many fish populations, including aquatic nuisance species such as Asian carp. Before a bypass would be recommended, we need to ensure that Asian carp have not colonized the Niobrara River downstream of Spencer Dam.

The objectives of this study were to evaluate the fish community population characteristics in Niobrara River downstream of Spencer Dam in 2008 and 2009 to: 1) measure baseline relative abundance, size structure, condition, and habitat use of the fish community while the Niobrara River retains a natural hydrograph; 2) gain insight into the benefits of providing a fish bypass at Spencer Dam; 3) initiate monitoring of the fish community prior to Asian carp invasions; 4) detect Asian carp occurrence; 5) use larval drift studies to investigate occurrence of spawning; with the ultimate goal of providing information on the value of a sturgeon bypass at Spencer Dam and record river flows necessary for successful spawning; 6) complete a fish faunal survey; and 7) observe fish movements in and out of the Missouri and Niobrara rivers.

In 2009, additional objectives will be to: 1) measure baseline relative abundance, size structure, and condition of all fish in the Niobrara River upstream of Spencer Dam to Box Butte Reservoir, Nebraska (rkm 547) while the river retains a natural hydrograph; 2) complete a fish faunal survey at different geomorphic reaches of the river (Alexander et al 2009); and 3) collect bony structures from sauger and channel catfish for age and growth analysis upstream and downstream of Spencer Dam.

Study Area

The Niobrara River watershed is approximately 28,000 km^2 (Gutzmer et al. 2002) and extends approximately 800 km from its headwaters in Wyoming to its confluence with the Missouri River near Niobrara, Nebraska. The lower Niobrara River is characterized as highly braided with multiple river channels and transports an estimated 300 metric tons of sediment per day (Hotchkiss et al. 1993). Our first study site in 2008 and 2009 consisted of 63.3 km of the Niobrara River from Spencer Dam to the confluence (Figure 1). Nebraska Public Power District (NPPD) operates Spencer Dam for hydroelectric power generation. Spencer Dam functions as a sediment trap so the 486 ha upstream reservoir requires sediment flushing each spring and fall (Gutzmer et al. 2002). During normal dam operations, the river's depth varies between 0.1 and 1.0 m and discharge ranges between 28 and 34 m^3/s (J. King, NPPD, personal communication). In 2009, the additional study site will include the Niobrara River upstream of Spencer Dam to Box Butte Reservoir, Nebraska.

The study area downstream of Spencer Dam was divided into three distinct geomorphic reaches (Alexander et al. 2009). Immediately downstream of Spencer Dam is the "single thread" reach (Bends 15 – 16; 54.7 rkm – 62.8 rkm) (Figure 2). This reach is characterized by a predominant single river channel with depths from 0.3 to 2.0 m, alternating from bank to bank with alternating sand bars. The "braided" reach (Bends 6 – 14; 19.3 rkm – 54.7 rkm) is characterized as highly braided with no distinct channel and relatively shallow (0.1 – 0.3 m) (Figure 3). The "delta" reach (Bends 1 – 5; 0.0 rkm – 19.3 rkm) is characterized with multiple channels in between permanent vegetated islands (Figure 4). These river channels are relatively deep (0.7 – 3.0 m) with high water velocity (0.8 – 1.8 m/s).

Methods

Sampling

The Niobrara River from Spencer Dam downstream to the confluence with the Missouri River was equally divided into 2.4 mile "bends" for a total of 16 bends. A minimum of eight randomly selected bends were sampled every month from May to September by drifting multifilament trammel nets with a goal of six subsamples (drifts) per selected bend. Trammel nets were drifted on the bottom of the river for a target distance of 300 m. A global positioning system (GPS) was used to quantify distance sampled. Trammel nets were 1.8 m deep and 15.2 m (TN50) or 23.0 m (TN12) long. The outside wall panel was 15.24-cm bar mesh and inside wall panel of 2.54-cm bar mesh with a float line of 1.27-cm poly-foam core and a lead line of 22.7-kg lead core. Sturgeon were measured to fork length (FL; mm) and weighed (g). All other fish species were measured to total length (TL; mm) and other important native (river carpsucker *Carpiodes carpio* and shorthead redhorse *Moxostoma macrolepidotum*), recreational (channel catfish, sauger, walleye), or invasive (carp) fish were also weighed. Depth, water temperature, and distance sampled were recorded for each trammel net drift and turbidity, substrate, dissolved oxygen, conductivity, and water velocity were measured at nearly every other subsample.

A minimum of six bends were sampled each month from July to September 2008 using an electrofishing tote barge (EFTB). The tote barge was outfitted with a Smith and Root 2.5 GPP (Smith-Root, Inc., Vancouver, Washington) electrofishing system rated at 2,500 watts of output power, using pulsed DC at 1-3 amps and 60 pulses per second. Four transects were sampled in each selected bend and electrofished for 5 – 10 min for a total sampling time of 20 - 40 min per bend. Maximum sampling for a transect was 10 min to reduce stress to captured fish. Each electrofishing transect was recorded in seconds. All identified microhabitats (e.g., pools, open water, vegetated shoreline, etc.) in each bend were sampled with the tote barge electrofisher. The entire microhabitat was sampled if the electrofished transect was < 10 min. Depth, water temperature, turbidity, substrate, dissolved oxygen, conductivity, water velocity and distance sampled were recorded for each electrofishing transect.

Trot lines were deployed in April 2008. The main line was 30.8 m long and was anchored at both ends to secure the line to the bottom of the river. Twenty octopus circle hooks, size 1/0 baited with earthworms *Lumbriscus terrestris*, were attached to the line at 1.6 m intervals using 0.3 m droppers. Trotlines were only deployed in the first two bends downstream of Spencer Dam and the first two bends upstream from the Niobrara/Missouri River confluence.

A bag seine that was 9.1 m long by 1.8 m high with a bag that measured 1.8 m long, 1.8 m high, and 1.8 wide was used in the same six selected bends where electrofishing was conducted during July 2008. The seine was an “Ace” nylon mesh (6.4 mm) with a 29.5 kg lead core line that was pulled downstream in a rectangular fashion (BSRD). The area swept by the seine was measured to the nearest tenth of a meter.

Larval fish were sampled from 23 April to 19 August 2008 nearly every week at two sample sites. One sample site was 0.6 km above the confluence of the Missouri River in the Niobrara River and the other site was 0.4 km downstream of Spencer Dam. Larval fish drift can vary throughout the day, therefore, each site was sampled at a minimum of once in the morning (0600 to 1100 hours) and once in the afternoon (1600 to 2000 hours) per week to address diel occurrence of larval fish. A minimum of eight subsamples were conducted at each site per diel period. Larval nets were fished on the bottom of the river for a maximum of 10 minutes (one sub-sample), depending on detrital loads. The larval net mouth opening was 0.5 m high, 1 m wide, and 5 m long with 500 μm mesh. Each net was outfitted with a mechanical flow meter to determine the volume of water sampled. Depth, water temperature, turbidity, substrate, dissolved oxygen, conductivity, and water velocity were measured at each larval net subsample. Larval fish samples were stored in a 10% buffered formalin solution containing “Rose Bengal” dye. All larval fish will be identified at a minimum to family and enumerated. Larval sturgeon (Snyder 2002) and Asian carp (Soin and Sukhanova 1972) will be identified to species.

Water temperature was monitored with four HOBO waterproof temperature loggers (Onset Computer Corporation, Bourne, Massachusetts). Temperature was recorded every 0.5 h at three sites along the Niobrara River. The most upstream site was at the intake of Spencer Dam (rkm 63), another logger was set at the Redbird Bridge (rkm 43), and two loggers were placed at the railroad bridge near the mouth of the river (rkm 0.6) (Figure 1).

Statistical Analysis

Water temperature analysis

A two-way ANOVA was used to compare daily mean water temperature among months and between the two temperature loggers at the railroad bridge and another two-way ANOVA was used to compare daily mean water temperature among the three sites along the Niobrara River. An additional two-way ANOVA was used to compare daily mean ambient air temperature at O'Neill, Nebraska (www.noaa.gov/) to the water temperature in the Niobrara River at the mouth (54 km apart).

Fish sampling data analysis

Mean catch per unit effort (CPUE) was calculated as number of fish/100 m for drifted trammel nets, number of fish/hr electrofishing, number of fish/m^2 seining, number of fish/hook night for trot lines, and number of larval fish/100 m^3 of water filtered. Mean CPUE was compared among geomorphic reaches along the Niobrara River and among months for all gears. The mean CPUE data was checked for independent and normal distributions. If the data were normally distributed, mean CPUE among reaches and months were compared with a two-way analysis of variance (ANOVA). When differences in mean CPUE were significant ($P \leq 0.05$), the conservative Bonferroni multiple range test was used to determine which means varied significantly ($P \leq 0.10$). When the interaction term was significant, a one-way ANOVA test was performed.

Size structure was assessed by determining proportional size distribution (PSD) and relative size distribution (RSD) (Guy et al. 2007) of important native, recreational, and invasive fish. Proportional size distribution = (number of fish ≥ minimum quality length / number of fish ≥ minimum stock length) X 100. Relative size distribution = (number of fish ≥ specified length / number of fish ≥ minimum stock length) X 100 (Wege and Anerson 1978).

Spatial and temporal differences in the fish community were tested using analysis of similarity (ANOSIM). First, species composition was compared among geomorphic reaches using all fish presence/absence data. Only river bends where trammel nets and electrofishing were conducted were included in the species composition analysis. Second, species structure was compared among geomorphic reaches, bends, and months using a Bray-Curtis similarity matrix calculated from relative abundance data (Bray and Curtis 1957). Trammel net and electrofishing data was separated for this analysis. Relative abundance data were square-root transformed to meet analysis assumptions of multivariate normality. Fish community patterns in compositional and structural changes were identified using SAS (SAS institute Inc. 1999) and Primer (v5; Primer-E Ltd 2001). Mantel correlations were used to compare the fish community among habitat variables including water temperature, turbidity, conductivity, dissolved oxygen, minimum depth, maximum depth, average depth, substrate, and the presence/absence of submerged vegetation.

Nonparametric multidimensional scaling (NMDS) plots were additionally used to map the relative association between samples for both the trammel net and electrofishing relative abundance data. Because of the relative association among samples, the NMDS plots do not have a numeric axis. The distance rankings among data points can become distorted or “stressed”; therefore; lower stress values indicate a more precise representation of the fish community (Primer-E Ltd. 2001). The NMDS plots were used to graphically illustrate the differences in the fish community structure through time (months) and among river reaches.

Fish condition was assessed using relative weight (*Wr*) (Wege and Anderson 1978). A two-way ANOVA test with interactions was used to compare mean *Wr* among months and geomorphic reaches only during months where fish were collected in each reach. If significance was found in the two-way ANOVA, a Tukey-Kramer multiple-comparison test was used to determine where differences occurred ($P \leq 0.10$). When the interaction term was significant, a one-way ANOVA test was performed. Additionally, for fish species that were captured every month, but not in every reach, a one-way ANOVA test was performed. Only stock length fish were used for condition analyses.

Results and Discussion

Water temperature and discharge

Water temperature had substantial variability with fluctuations ranging from 0.2 to 11.6 °C in a 24-h period at the mouth of the Niobrara River (Figure 5). No significant interactions were found for ANOVA analyses between the temperature loggers at the railroad bridge near the river mouth or among the three logger sites (Table 1). No significant differences were found between the two loggers on the railroad bridge or among the three sites along the Niobrara River

(Table 1 and Figure 6). Significant differences were found among months; however, Tukey-Kramer multiple comparisons tests revealed that there were no significant differences ($P > 0.100$) between loggers during any particular month.

Water temperature of the Niobrara River tracked closely with the ambient air temperature due to the river's shallow depths. No significant interactions were found between air and water temperature and among months (Table 1). Air temperature was significantly lower than the Niobrara River water temperature from April to October (Figure 7). Multiple comparison tests revealed that air temperature was significantly ($P < 0.10$) lower than river temperatures during the months of April, May, and August in 2008.

Water discharge was variable, especially during the spring and early summer months (Figure 8). Large precipitation events were evident with peaks in the hydrograph throughout the sampling period. On 5 June 2008, 4.5 inches of rain fell near Spencer Dam (P. Spencer, NPPD, personal communication).

Fish sampling data

On 7 April 2008, fish sampling began using a 15.2 m trammel net (TN50). Due to safety concerns and weather related issues, only four subsamples were collected in April (Table 2). No fish were captured using this gear. From 21-23 April 2008, trot lines were attempted to capture large-bodied fishes. In 180 hook-nights over three days, only three channel catfish (237 – 309 mm) and two common carp *Cyprinus carpio* (388 and 500 mm) were captured. Large amounts of detritus and woody substrate fouled the hooks and made sampling with trot lines difficult and likely reduced capture success. Sedimentation of the trot lines also likely reduced capture success.

A minimum of eight bends were sampled each month from May to September 2008 using a 23.0 m trammel net (TN12) (Table1). A total of 705 fish were captured with trammel nets that included 19 species of fish (Table 3). The most abundant species captured with this gear were river carpsucker *Carpiodes carpio*, channel catfish, sauger, and shorthead redhorse *Moxostoma macrolepidotum*. Trammel net catch statistics for all species by month and geomorphic reach are reported in Appendix A. Large amounts of small and large woody substrate made drifting trammel nets in May 2008 difficult and substantially increased sampling time for each subsample. Since June, less woody substrate made drifting trammel nets more manageable, which resulted in increased sampling effort (Table 2).

On 29 July 2008, two pallid sturgeon (460 and 514 mm in length) were captured by drifting trammel nets. The sturgeon were captured 1.9 km upstream of the mouth, both in the same sample. Both pallid sturgeon had passive integrated transponder (PIT) tags in them, indicating that they were hatchery-reared pallid sturgeon stocked in the Missouri River. The 514 mm fish was age-6 and the 460 mm was age-3. Both fish were released into the Missouri River at age 1 (FL ≈ 290 mm), four miles downstream of the Niobrara/Missouri River Confluence near the Standing Bear Bridge, South Dakota and Nebraska. These two individual pallid sturgeon were from different year classes, stocked at different times, appeared to be healthy and growing, and moved upstream into the Niobrara River in the same habitat. These fish were the only two pallid sturgeon captured in the Niobrara River during 2008.

Shovelnose sturgeon were captured throughout the study area. Two shovelnose sturgeon were collected 9 to 12 km downstream of Spencer Dam in June, three shovelnose sturgeon were collected from 1.5 to 14 km downstream of Spencer Dam in July, and nine shovelnose sturgeon were captured throughout the 63 km study area during August. One shovelnose sturgeon that was captured in August had a floy tag from a previous study in the Missouri River. This shovelnose sturgeon was last seen six miles downstream of the Niobrara River confluence with the Missouri River near the mouth of Bazille Creek in April 2007. All shovelnose sturgeon captured in the Niobrara River were floy tagged in 2008.

Beginning in July 2008, sauger captured in the Niobrara River were floy tagged to investigate population size and movements into and out of the Missouri River and back into the Niobrara River. Since July, 57 sauger were floy tagged during 2008 with no recaptures. To date, no floy tagged sauger have been captured in the Niobrara or Missouri rivers (unpublished data).

One blue sucker *Cycleptus elongatus* that was floy tagged in the Missouri River five miles upstream of the Niobrara River mouth in April 2007 was captured in the Niobrara River 1 km upstream from the mouth in May 2008. No other blue suckers were captured in the Niobrara River during 2008.

A minimum of six bends were sampled each month from July to September 2008 using a tote barge electrofisher (Table 2). A total of 7,226 fish were collected while electrofishing, which included 32 species (Table 3). The dominant species collected were red shiners *Cyprinella lutrensis*, sand shiners *Notropis stramineus*, flathead chubs *Platygobio gracilis*, gizzard shad *Dorosoma cepedianum*, channel catfish, and river carpsuckers. Electrofishing catch statistics for all species by month and geomorphic reach are reported in Appendix B. Electrofishing was effective at capturing multiple size classes including young of the year fish for many species.

A total of 16 subsamples in four bends were sampled with a bag seine during July 2008. A total of 443 fish were captured with the bag seine, which included 16 species. Bag seine catch statistics for all species by geomorphic reach are reported in Appendix C. The tote-barge electrofisher sampled a higher total number of fish and more species; therefore, bag seine sampling was discontinued to increase the effort of electrofishing and trammel netting during this study.

Between trammel netting and tote barge electrofishing, 11 species of fish were captured that were not detected in three previous studies that used electrofishing, seining, primacord, and a fish kill to collect fish in the last 30 years. (Hesse et al. 1979; Hesse and Newcomb 1982; Gutzmer et al. 2002) in this reach of the Niobrara River (Table 3). However, the previous studies did capture 13 other species that were not detected in this study. Partial explanation of this may be due to the fact that Hesse et al. (1979) and Gutzmer et al. (2002) both had sample sites upstream of Spencer Dam. This study documented the first records of bigmouth buffalo *Ictiobus cyprinellus*, smallmouth buffalo *I. bubalus*, blue sucker, and bluntnose minnow *Pimephales notatus* in the Niobrara River (Schainost 2008).

Trammel nets predominately captured large-bodied adult fish while electrofishing captured small-bodied fish and YOY fish. The presence of YOY indicate suitable spawning and rearing conditions exist in the Niobrara River for many species. River carpsucker was the most abundant fish captured and ranged in length from 27 – 565 mm (Figure 9). Important for recreational angling, channel catfish ranged in length from 23 – 765 mm (Figure 10) and sauger ranged 137 – 482 mm (Figure 11). Another native fish, shorthead redhorse ranged 39 – 408 mm (Figure 12). Common carp *Cyprinus carpio* ranged 77 – 746 mm (Figure 13). Shovelnose sturgeon were only captured by trammel net and ranged from 548 – 658 mm (Figure 14), which is similar in length to shovelnose sturgeon captured in the Missouri River downstream of Fort Randall Dam, South Dakota (Shuman et al. 2009). Electrofishing captured adult red shiners

(Figure 15), sand shiners (Figure 16), YOY and adult flathead chubs (Figure 17), and only YOY gizzard shad (Figure 18).

Anglers downstream of Spencer Dam consistently stated during April and May 2008 that large channel catfish were slow to migrate upstream in the Niobrara River due to unseasonably cool spring temperatures. Large channel catfish were only found in the furthest downstream reach of the Niobrara River in May and PSD values in the three geomorphic reaches among months, supported angler observations (Figure 19). Large channel catfish did not appear in the single thread reach downstream of Spencer Dam until June. During August, it appeared that large channel catfish may have migrated out of the study area only to return in large numbers in September.

Fish community composition analysis revealed no significant differences among geomorphic reaches (Global R = 0.321; P = 0.120). There were little differences in species richness among bends 2-15 (Figure 19). However, bend 1 (0.0 – 3.9 rkm) had 30% more species of fish compared to the next highest bend. Individual fish species found only in bend 1 were pallid sturgeon, blue sucker, bigmouth buffalo, smallmouth buffalo, bluntnose minnow, northern pike *Esox lucius*, and pumpkinseed *Lepomis gibbosus*.

Species structure analysis using trammel net data (large-bodied fishes) revealed no significant differences in the fish community among geomorphic reaches (Global R = 0.012; P = 0.151) and river bends (Global R = 0.028; P = 0.119). Significant differences were found among months (Global R = 0.025; P = 0.050); however, the low Global R value suggests differences were not large. The NMDS plots for trammel net data additionally suggested that there were little differences in the fish community among months and geomorphic reaches (Figure 21). All month and river reach groups were loosely grouped and nearly completely overlapped each other in the NMDS plots.

Species structure analysis using electrofishing data revealed significant differences in the fish community among geomorphic reaches (Global R = 0.226; P = 0.001), river bends (Global R = 0.213; P = 0.001), and months (Global R = 0.103; P = 0.001). Species-specific contributions to differences among reaches and months were identified by calculating dissimilarity values from the Bray-Curtis similarity matrix and SIMPER procedures provided information on the fish community. Shifts in spatial and temporal relative abundance of red shiner, gizzard shad, sand shiner, river carpsucker, channel catfish, flathead chub, green sunfish *Lepomis cyanellus*, spotfin shiner *Notropis spilopterus*, shorthead redhorse, and largemouth bass *Micropterus salmoides* contributed to over 90% of the differences among reaches (Table 4). The NMDS plots additionally illustrated that the fish community was more distinct in the single thread reach, while the braided and delta reaches overlapped and also slightly overlapped with the single thread reach (Figure 21). Similarly, red shiner, gizzard shad, sand shiner, river carpsucker, channel catfish, flathead chub, green sunfish, spotfin shiner, largemouth bass, common carp, and bluegill *Lepomis macrochirus* contributed over 90% of the differences among months (Table 5). The NMDS plots illustrated that months were grouped loosely and overlapped, but illustrated shifts in the fish community from one month to the next (Figure 22). This seasonality may partially be explained by YOY fish appearing and recruiting to the electrofishing gear. From the electrofishing data, no significant differences in species structure were found with the presence or absence of submerged vegetation (Global R = 0.098; P = 0.060). Mantel correlations were low, but did reveal that minimum depth, average depth, silt substrate, and organic substrate (submerged vegetation present) had the highest correlation to differences among fish communities (correlation = 0.305). However, average depth and organic substrate had a similar correlation = 0.292.

We investigated trammel net mean CPUE differences among months and river reaches for individual fish species using a one-way or two-way ANOVA for the most common species captured in the Niobrara River: river carpsucker, channel catfish, sauger, shorthead redhorse, common carp, and shortnose gar *Lepisosteus platostomus*. A significant interaction term was found for river carpsucker in the two-way ANOVA (Table 6). Using a one-way ANOVA, river carpsucker mean CPUE significantly differed among months ($F = 4.35$, $df = 4$, $P = 0.002$) as relative abundance declined in September and significantly differed among reaches ($F = 23.97$, $df = 2$, $P < 0.001$) with the highest relative abundance in the single thread reach downstream of Spencer Dam (Figure 23). Channel catfish relative abundance did not significantly differ among months (Table 6); however, relative abundance was consistently highest in the single thread reach (Figure 24). A significant interaction term was found for sauger in the two-way ANOVA (Table 6). Sauger relative abundance significantly differed among months with an increase in July and August followed by a decline in September. Sauger relative abundance was significantly higher in the single thread and braided reach compared to the delta reach (Figure 25). Significant differences in relative abundance were found for shorthead redhorse only among river reaches (Table 6) with highest catches in the single thread reach but, Bonferroni pair-wise comparisons indicated no significant differences ($P > 0.100$) among months and reaches (Figure 26). No significant differences were found among months or reaches for common carp (Table 6 and Figure 27). Shortnose gar relative abundance significantly increased in July and August compared to all other months with no differences among river reaches (Table 6 and Figure 28).

The relative abundance data for the most common fish species captured with electrofishing was compared among months and reaches: river carpsucker, channel catfish, flathead chubs, gizzard shad, red shiners, and sand shiners. The relative abundance of most fish did not significantly differ among months, while differences were often found among reaches (Table 7). River carpsucker were found in higher relative abundance in the braided and delta reaches compared to the single thread reach (Figure 29). An opposite trend to that found in trammel nets. No significant seasonal and spatial differences in relative abundance were found for channel catfish (Figure 24) and flathead chubs (Figure 30). Gizzard shad mean CPUE significantly differed among months ($F = 15.03$, $df = 2$, $P < 0.001$) with the relative abundance significantly increasing each month from July to September (Figure 31). Additionally, gizzard shad mean CPUE significantly differed among reaches ($F = 3.52$, $df = 2$, $P = 0.035$) with mean CPUE in the delta reach significantly higher than the single thread reach. Both red shiner (Figure 32) and sand shiner (Figure 33) relative abundance was significantly higher in the single thread reach compared to the braided and delta reaches but did not vary seasonally (Table 7).

Mean relative weights (Wr) were analyzed for the most common large-bodied fish captured in the Niobrara River: common carp, channel catfish, river carpsucker, sauger, shorthead redhorse, and shovelnose sturgeon. There were relatively few differences in mean Wr among length categories for all species of fish (Table 8). In the condition analysis among months and reaches, a significant interaction was found for river carpsucker (Table 9). River carpsucker mean Wr did significantly differ among months ($F = 18.00$, $df = 4$, $P \leq 0.001$) and reaches ($F = 12.71$, $df = 2$, $P \leq 0.001$) (Figure 34). River carpsucker mean Wr was highest during May and June during the spawning season and was consistently highest for fish in the delta reach. No significant differences were found in mean *Wr* among months or reaches for all other fish species.

Sampling for larval fish began the last week of April and continued through the third week of August 2008 (Table 1). The first larval fish appeared the first week of May and with no larvae captured after the second week of August. Larval fish are currently being identified and enumerated in a lab in Pierre, South Dakota. The occurrence and relative abundance of larval fish will be correlated to water temperature and to discharge measured at the U.S. Highway 281 Bridge near Spencer Dam and the Pischelville Bridge (Figure 1).

Based on the first year of this study, it is evident that multiple gears (trammel nets and electrofishing) are needed to accurately describe the fish community in terms of relative abundance and size structure. Trammel nets were effective at capturing large-bodied fish while electrofishing captured juveniles and YOY of large-bodied fish as well as small-bodied fish. Although channel catfish were collected with trammel nets, baited hoop nets may be more effective and easier to deploy. Our results showed that large-bodied fish generally used the entire Niobrara River downstream of Spencer Dam throughout the sampling period while small-bodied and young of the year were more spatially and temporally variable. Changes in the hydrograph due to additional water withdrawals would likely have adverse impacts on the fish community. Decreased water discharge and the timing of discharge would likely reduce spawning success and rearing habitat. Maintaining the natural hydrograph would protect the current productivity of the Niobrara River.

Acknowledgments

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References

Alexander, J. S., R. B. Zelt, and N. J. Schaepe. 2009. Geomorphic segmentation, hydraulic geometry, and hydraulic microhabitats of the Niobrara River, Nebraska – methods and initial results. U.S. Geological Survey Scientific Investigations Report 2009-5008, 51 pages.

Bray, J. R., and J. T. Curtis. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecological Monographs 27:325-349.

Graeb, B. D. S. 2006. Sauger population ecology in three Missouri River mainstem reservoirs. Doctor of Philosophy Dissertation. South Dakota State University, Brookings.

Grohs, K. L. 2008. Macroinvertebrate composition and patterns of prey use by juvenile pallid sturgeon (*Scaphirhynchus albus*) in the Missouri River, South Dakota and Nebraska. Master's Thesis. South Dakota State University, Brookings.

Gutzmer, M. P., J. W. King, D. P Overhue, and E. Y. Chrisp. 2002. Fish-species richness trends in the Niobrara River, Nebraska, below the Spencer Dam. Transactions of the Nebraska Academy of Science 28:57-63.

Guy, C. S., R. M. Neumann, D. W. Willis, and R. O. Anderson. 2007. Proportional size distribution (PSD): A further refinement of population size structure index terminology. Fisheries 32 (7): 348.

Hesse, L. W., G. Zuerlein, R. Vancil, L. Kolziol, B. Newcomb, and L. A. Retelsdorf. 1979. Niobrara-Missouri River Fishery Investigations. Nebraska Technical Series No. 5. Nebraska Game and Parks Commission, Lincoln, Nebraska.

Hesse, L. W., and B. A. Newcomb. 1982. Effects of flushing Spencer Hydro on water quality, fish, and insect fauna in the Niobrara River, Nebraska. North American Journal of Fisheries Management 2:45-52.

Hotchkiss, R. H., X. Huang, and M. P. Gutzmer. 1993. Achieving a sediment balance across dams; stepping up a technology. Environmental and Natural Resources of the Niobrara River Basin Research Symposium.

Klumb, R. A. 2007. Shallow water fish communities in the Missouri River downstream of Fort Randall and Gavins Point dams in 2003 and 2004 with emphasis on Asian carps. Prepared for the Aquatic Nuisance Species Coordinator, U.S. Fish and Wildlife Service – Region 6, Lakewood, Colorado. U.S. Fish and Wildlife Service, Great Plains Fish and Wildlife Management Assistance Office, Pierre, South Dakota.

Kolar, C. S., D. C. Chapman, W. R. Courtenay, C. M. Housel, J. D. Williams, and D. P. Jennings. 2005. Asian carps of the genus *Hypophthalmichthys* (Pisces, Cyprinidae) – a biological synopsis and environmental risk assessment. Report to the U. S. Fish and Wildlife Service. U. S. Geological Survey , LaCrosse, WI. 184 pages.

Primer-E Ltd. 2001. Primer for Windows version 5.2.4. Plymouth, United Kingdom.

SAS Institute Inc. 1999. The SAS system for Windows. Release 8.01. Cary, North Carolina.

Schainost, S. 2008. Fish collections in the Niobrara River basin, Nebraska 1893-2005. Nebraska Game and Parks Commission, Alliance, Nebraska.

Shuman. D. A, R. A. Klumb, and G. A. Wanner. 2009. Pallid sturgeon population assessment and associated fish community monitoring for the Missouri River: segments 5 and 6. Prepared for the U.S. Army Corps of Engineers, Kansas City and Oamaha Districts. U. S. Fish and Wildlife Service, Great Plains Fish and Wildlife Management Assistance Office, Annual Report, Pierre, South Dakota.

Snyder, D. E. 2002. Pallid and shovelnose sturgeon larvae – morphological description and identification. Journal of Applied Ichthyology 18:240-265.

Soin, S. G., and A. I. Sukhanova. 1972. Comparative morphological analysis of the development of the grass carp, the black carp, the silver carp, and the bighead carp (Cyprinidae). Journal of Ichthyology 12:61-71.

Stukel, S., J. Kral, and S. LaBay. 2008. 2007 Annual Report. Pallid sturgeon population assessment and associated fish community monitoring for the Missouri River: segment 7. Prepared for the U.S. Army Corps of Engineers, Kansas City and Oamaha Districts. South Dakota Game, Fish and Parks, Yankton, South Dakota.

U.S. Fish and Wildlife Service. 1993. Pallid sturgeon recovery plan. U. S. Fish and Wildlife Service, Bismarck, North Dakota. 55 pp.

U.S. Fish and Wildlife Service. 2003. An evaluation of sampling techniques and life history information on bighead carp in the Missouri River below Gavins Point Dam, South Dakota and Nebraska. U.S. Fish and Wildlife Service, Great Plains Fish and Wildlife Management Assistance Office, Pierre, South Dakota.

Wanner, G. A. 2006. Sampling techniques for juvenile pallid sturgeon and the condition and food habits of sturgeon in the Missouri River below Fort Randall Dam, South Dakota. Master's Thesis. South Dakota State University, Brookings.

Wege, G. J., and R. O. Anderson. 1978. Relative weight (*Wr*): a new index of condition for largemouth bass. Pages 79-71 *in* G. D. Novinger and J. G. Dillard, editors. New approaches to the management of small impoundments. American Fisheries Society, North Central Division, Special Publication 5, Bethesda, Maryland.

Table 1. Two-way analysis of variance (ANOVA) comparing water temperature among temperature logger locations and months in the Niobrara River downstream of Spencer Dam, Nebraska during 2008. Railroad bridge and backup loggers were located at rkm 0.6, Redbird bridge logger at rkm 43, and Spencer Dam logger at rkm 63. Ambient air temperature was recorded at O'Neill, Nebraska.

Source	*F*	df	*P*
Railroad bridge vs. backup (6 May – 29 July 2008)			
Location	0.81	1	0.370
Month	292.74	2	< 0.001
Location*month	0.35	2	0.705
Spencer, Redbird, and railroad bridges (24 April – 11 August 2008)			
Location	1.13	2	0.323
Month	385.99	4	< 0.001
Location*month	0.17	8	0.994
Ambient air vs. railroad bridge (7 April – 31 October 2008)			
Location	80.91	1	< 0.001
Month	244.66	6	< 0.001
Location*month	0.95	6	0.461

Table 2. Number of samples for each gear deployed in the Niobrara River downstream of Spencer Dam, Nebraska from April to September 2008.

	Month					
Gear	April	May	June	July	August	September
Trammel net (15.2 m)	4					
Trammel net (23.0 m)		38	57	63	73	72
Tote barge electrofisher				24	24	22
Seine				24		
Trot lines (20 hooks/line)	9					
Larval drift net	40	184	134	144	96	

Table 3. Fish species captured during this study with trammel nets and tote barge electrofishing compared to previous studies. Gutzmer et al. (2002) sampled with backpack electrofishing and seining, Hesse and Newcomb (1982) collected fish from a fish kill, and Hesse et al. (1979) collected fish by seining and primacord explosives. Fish species in bold are unique comparing sampling in 2008 to previous studies.

This study			Past studies		
Trammel (TN12)	**Tote barge electrofishing**	**Bag seine**	**Gutzmer et al. 2002**	**Hesse and Newcomb 1982**	**Hesse et al. 1979**
Bigmouth buffalo	**Bigmouth buffalo**	Bigmouth shiner	Bigmouth shiner	Bluegill	Bigmouth shiner
Bluegill	Bigmouth shiner	**Bluntnose minnow**	Black bullhead	**Brown trout**	Black bullhead
Blue Sucker	Black bullhead	Common carp	**Black crappie**	Bullhead sp.	Bluegill
Channel catfish	Bluegill	Channel catfish	Bluegill	Channel catfish	Channel catfish
Common carp	**Bluntnose minnow**	Emerald shiner	Brassy minnow	Common carp	Common carp
Flathead chub	Brassy minnow	Flathead chub	Channel catfish	Crappie sp.	**Creek chub**
Freshwater drum	Channel catfish	Grass pickerel	Common carp	Freshwater drum	Emerald shiner
Green sunfish	Common carp	Gizzard shad	**Creek chub**	Gizzard shad	**Fathead minnow**
Pallid sturgeon	Emerald shiner	Red shiner	Emerald shiner	**Goldeye**	Flathead catfish
River carpsucker	Flathead catfish	River carpsucker	**Fathead minnow**	Green sunfish	Flathead chub
Sauger	Flathead chub	**Spotfin shiner**	Flathead chub	Largemouth bass	Freshwater drum
Saugeye	Freshwater drum	Sauger	Grass pickerel	Madtom	Green sunfish
Shorthead redhorse	Gizzard shad	Shorthead redhorse	Largemouth bass	Minnow sp.	Largemouth bass
Shortnose gar	Grass pickerel	Sand shiner	Longnose dace	Northern pike	**Plains killifish**
Shovelnose sturgeon	Green sunfish	Silver chub	Red shiner	River carpsucker	**Plains minnow**
Smallmouth buffalo	Largemouth bass	White crappie	**River shiner**	Sauger	Red shiner
Walleye	Longnose dace		River carpsucker	Shorthead redhorse	**River shiner**
White bass	Northern pike		Sand shiner	**Smallmouth bass**	River carpsucker
White crappie	**Orange-spotted sunfish**		Sauger	Stonecat	Sand shiner
	Pumpkinseed		Shorthead redhorse	Walleye	Sauger
	Red shiner		Stonecat	**White sucker**	Shorthead redhorse
	River carpsucker		White crappie		Silver chub
	Sand shiner		**White sucker**		Stonecat
	Sauger		**Yellow bullhead**		**Stoneroller**
	Shorthead redhorse		**Yellow perch**		White bass
	Shortnose gar				White crappie
	Silver chub				
	Spotfin shiner				
	Stonecat				
	Walleye				
	White bass				
	White crappie				

Table 4. Species specific contributions to differences among Niobrara River geomorphic reaches during 2008. Mean relative abundance with SE in parenthesis for catches with electrofishing. Data for the Bray-Curtis dissimilarity comparison provided information corresponding to differences in species abundance among groups that described a minimum cumulative total of 90% of the dissimilarity among the three reaches.

Species	Mean relative abundance (fish/h)			Mean dissimilarity and contribution (%)		
	Single thread (group 1)	Braided (group 2)	Delta (group 3)	1 versus 2	1 versus 3	2 versus 3
Channel catfish	112.03 (26.01)	75.54 (12.80)	87.93 (12.98)	7.05 (11)	8.22 (11)	6.63 (9)
Flathead chub	35.29 (14.52)	37.99 (8.93)	32.07 (9.60)	3.59 (6)	4.09 (6)	4.11 (6)
Gizzard shad	25.02 (10.76)	153.34 (80.94)	139.24 (37.76)	7.55 (12)	9.22 (13)	13.55 (19)
Green sunfish	47.84 (20.87)	3.91 (1.79)	23.32 (6.20)	3.11 (5)	3.88 (5)	1.91 (3)
Largemouth bass	6.76 (2.99)	7.30 (2.77)	25.45 (5.28)		2.01 (3)	2.12 (3)
Red shiner	321.79 (54.83)	160.97 (30.43)	48.10 (12.67)	15.83 (25)	21.00 (29)	12.00 (17)
River carpsucker	54.79 (19.91)	268.15 (103.61)	96.62 (20.76)	12.22 (19)	6.72 (9)	14.01 (20)
Sand shiner	125.19 (30.79)	98.00 (26.72)	7.86 (3.21)	8.49 (13)	8.79 (12)	7.36 (10)
Shorthead redhorse	5.46 (1.48)	18.00 (5.17)	8.17 (2.67)			1.51 (2)
Spotfin shiner	0.38 (0.38)	0.52 (0.52)	30.52 (10.41)		2.06 (3)	2.15 (3)

Table 5. Species specific contributions to differences among months during 2008 in the Niobrara River. Mean relative abundance with SE in parenthesis for catches with electrofishing. Data for the Bray-Curtis dissimilarity comparison provided information corresponding to differences in species abundance among groups that described a minimum cumulative total of 90% of the dissimilarity among the three months.

Species	Mean relative abundance (fish/h)			Mean dissimilarity and contribution (%)		
	July (group 1)	August (group 2)	September (group 3)	1 versus 2	1 versus 3	2 versus 3
Bluegill	3.00 (1.44)	7.91 (2.94)	16.98 (11.53)			1.85 (3)
Channel catfish	89.65 (19.39)	87.27 (13.96)	91.29 (14.50)	8.82 (13)	6.48 (9)	5.73 (9)
Common carp	14.24 (7.01)	2.45 (0.76)	3.79 (1.91)	1.23 (2)		
Flathead chub	28.73 (10.59)	30.55 (8.97)	45.77 (11.71)	4.48 (7)	3.89 (5)	3.96 (6)
Gizzard shad	19.70 (7.73)	55.91 (24.51)	284.65 (86.32)	5.29 (8)	15.74 (22)	16.45 (24)
Green sunfish	14.31 (6.20)	16.09 (5.15)	37.94 (15.73)	2.31 (3)	2.96 (4)	2.98 (4)
Largemouth bass	8.28 (3.70)	18.27 (3.82)	18.79 (6.32)	2.03 (3)	1.73 (2)	1.97 (3)
Red shiner	190.33 (36.51)	111.55 (27.86)	146.54 (44.88)	15.42 (23)	13.52 (19)	11.68 (17)
River carpsucker	187.75 (99.58)	115.09 (33.18)	127.64 (28.34)	12.73 (19)	10.63 (15)	9.34 (14)
Sand shiner	97.99 (27.68)	35.45 (13.62)	61.51 (21.86)	7.51 (11)	7.46 (10)	5.98 (9)
Spotfin shiner	2.00 (1.56)	7.91 (14.86)	30.95 (13.70)		2.19 (3)	2.37 (4)

Table 6. Two-way analysis of variance (ANOVA) comparing trammel net mean catch per unit effort (CPUE; fish/100 m) among months and reaches in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

Source	*F*	df	*P*
Common carp			
Month	0.75	4	0.561
Reach	1.79	2	0.168
Month*reach	1.00	8	0.435
Channel catfish			
Month	1.70	4	0.150
Reach	20.87	2	< 0.001*
Month*reach	1.49	8	0.159
River carpsucker			
Month	6.00	4	< 0.001*
Reach	29.52	2	< 0.001*
Month*reach	4.97	8	< 0.001*
Sauger			
Month	6.02	4	< 0.001*
Reach	6.31	2	0.002*
Month*reach	2.94	8	0.004*
Shorthead redhorse			
Month	0.86	4	0.487
Reach	7.55	2	< 0.001*
Month*reach	1.60	8	0.123
Shortnose gar			
Month	4.07	4	0.003*
Reach	1.27	2	0.283
Month*reach	0.65	8	0.735

Table 7. Two-way analysis of variance (ANOVA) comparing electrofishing mean catch per unit effort (CPUE; fish/h) among months and reaches in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

Source	*F*	df	*P*
	Channel catfish		
Month	1.12	2	0.334
Reach	0.30	2	0.741
Month*reach	1.06	4	0.386
	Flathead chub		
Month	1.45	2	0.242
Reach	1.53	2	0.224
Month*reach	2.19	4	0.081
	Gizzard shad		
Month	12.43	2	< 0.001*
Reach	2.69	2	0.076
Month*reach	4.09	4	0.005*
	Red shiner		
Month	0.70	2	0.499
Reach	13.09	2	< 0.001*
Month*reach	2.12	4	0.089
	River carpsucker		
Month	0.55	2	0.577
Reach	5.35	2	0.007*
Month*reach	0.75	4	0.562
	Sand shiner		
Month	0.38	2	0.684
Reach	18.86	2	< 0.001*
Month*reach	0.78	4	0.544

Table 8. Relative weight (*Wr*) with SE in parenthesis, proportional size distribution (PSD[a]), and incremental relative size distribution (RSD[b]) for six species of fish in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

Species	Mean *Wr*	PSD	S-Q RSD	S-Q *Wr*	Q-P RSD	Q-P *Wr*	P-M RSD	P-M *Wr*	M-T RSD	M-T *Wr*
Common carp	80 (2)	76	47	81 (3)	39	74 (3)	10	85 (3)	4	105 (2)
Channel catfish	90 (1)	48	47	81 (2)	35	78 (2)	10	81 (4)	8	80 (3)
River carpsucker	81 (1)	62	43	77 (1)	8	79 (3)	46	84 (1)	3	79 (2)
Sauger	80 (1)	57	49	80 (2)	34	80 (2)	17	77 (2)	0	
Shorthead redhorse	79 (1)	61	56	78 (2)	19	78 (2)	9	82 (2)	0	
Shovelnose sturgeon	92 (2)	100	0		0		69	92 (3)	31	92 (4)

[a]PSD = (# of fish ≥ quality length / # of fish ≥ stock length) * 100. Length categories defined as % of the world record length: stock to quality (S-Q), quality to preferred (Q-P), preferred to memorable (P-M), and memorable to trophy (M-T).
[b]RSD = (# of fish of a specified length class / # of fish ≥ minimum stock length) * 100.

Table 9. One-way and two-way analysis of variance (ANOVA) comparing mean relative weight (*Wr*) among months and reaches for stock length fish collected in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

Source	*F*	df	*P*
Common carp (May – September)			
Month	0.23	4	0.921
Reach	2.71	2	0.087
Channel catfish (June – September)			
Month	0.25	3	0.862
Reach	2.36	2	0.101
Month*reach	1.36	6	0.239
River carpsucker (May – September)			
Month	7.37	4	< 0.001*
Reach	1.72	2	0.180
Month*reach	2.16	8	0.030*
Sauger (July-August)			
Month	0.27	1	0.605
Reach	0.01	2	0.991
Month*reach	0.19	2	0.830
Shorthead redhorse (May – September)			
Month	0.96	4	0.448
Reach	2.14	2	0.138
Shovelnose sturgeon (June – August)			
Month	1.60	2	0.246
Reach	0.05	2	0.954

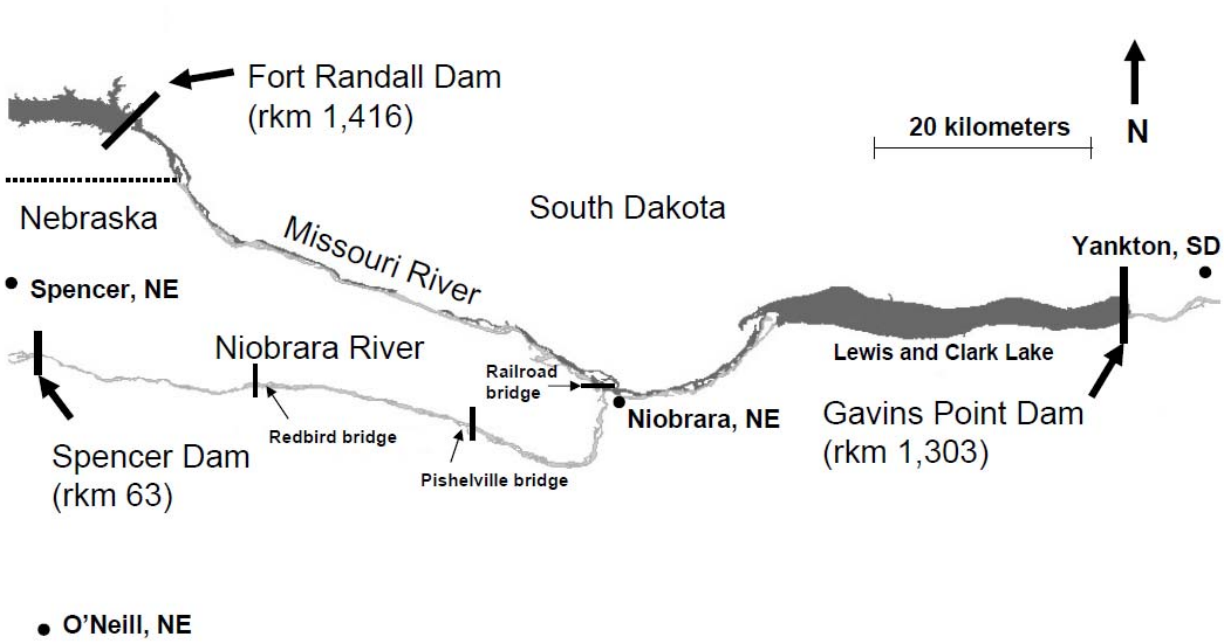

Figure 1. Niobrara river downstream of Spencer Dam, Nebraska and the Missouri River downstream of Fort Randall Dam to Gavins Point Dam, South Dakota and Nebraska.

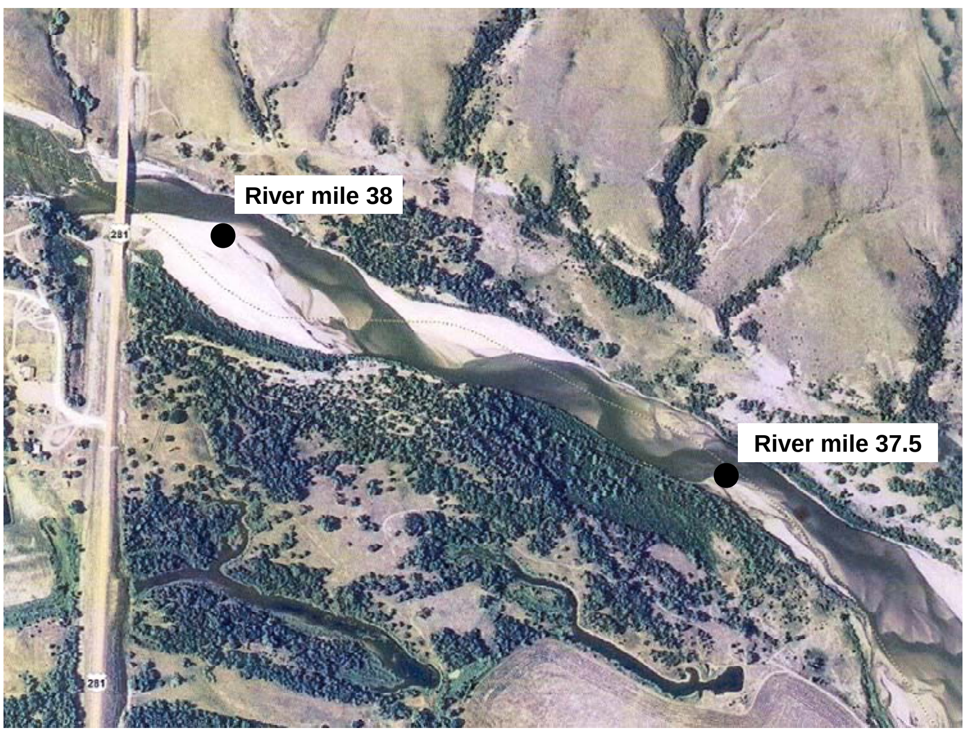

Figure 2. Example of the single thread reach in the Niobrara River downstream of Spencer Dam, Nebraska.

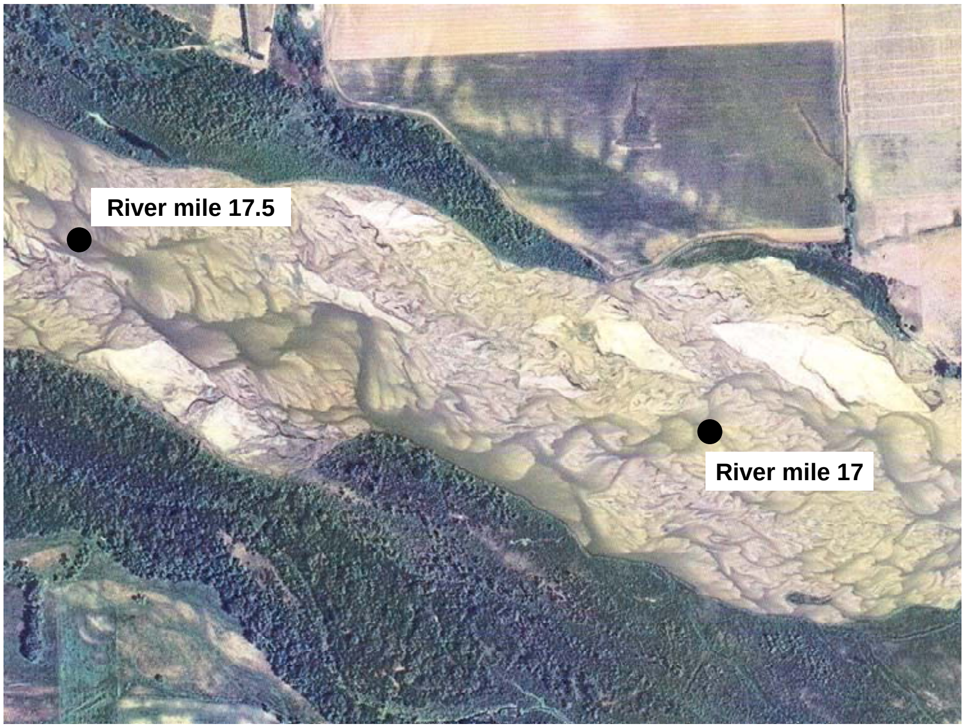

Figure 3. Example of the braided reach in the Niobrara River downstream of Spencer Dam, Nebraska.

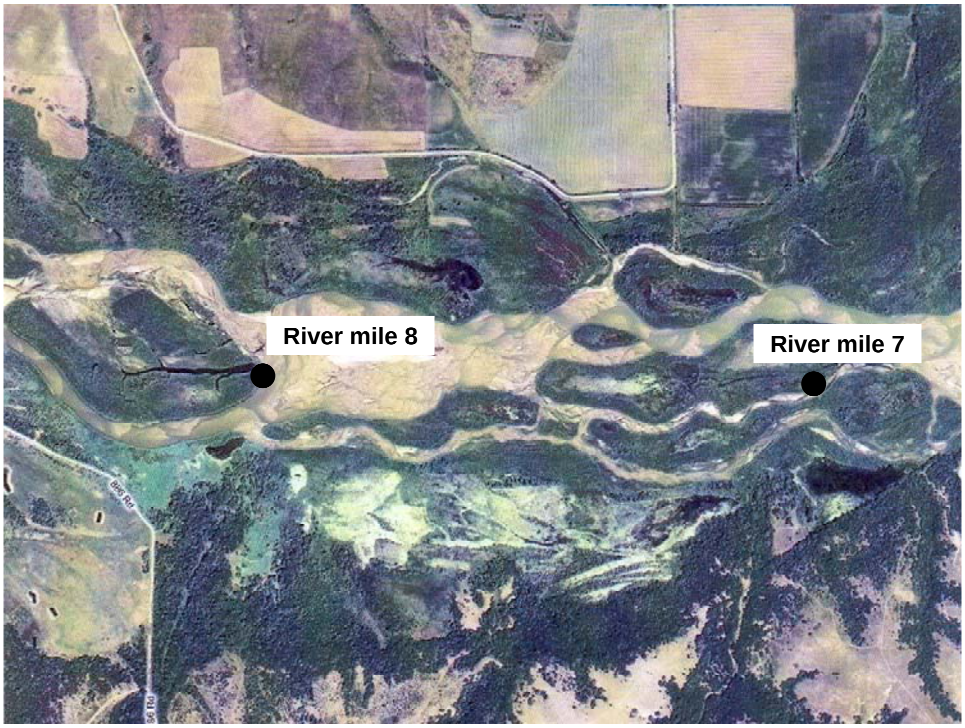

Figure 4. Example of the delta reach in the Niobrara River downstream of Spencer Dam, Nebraska.

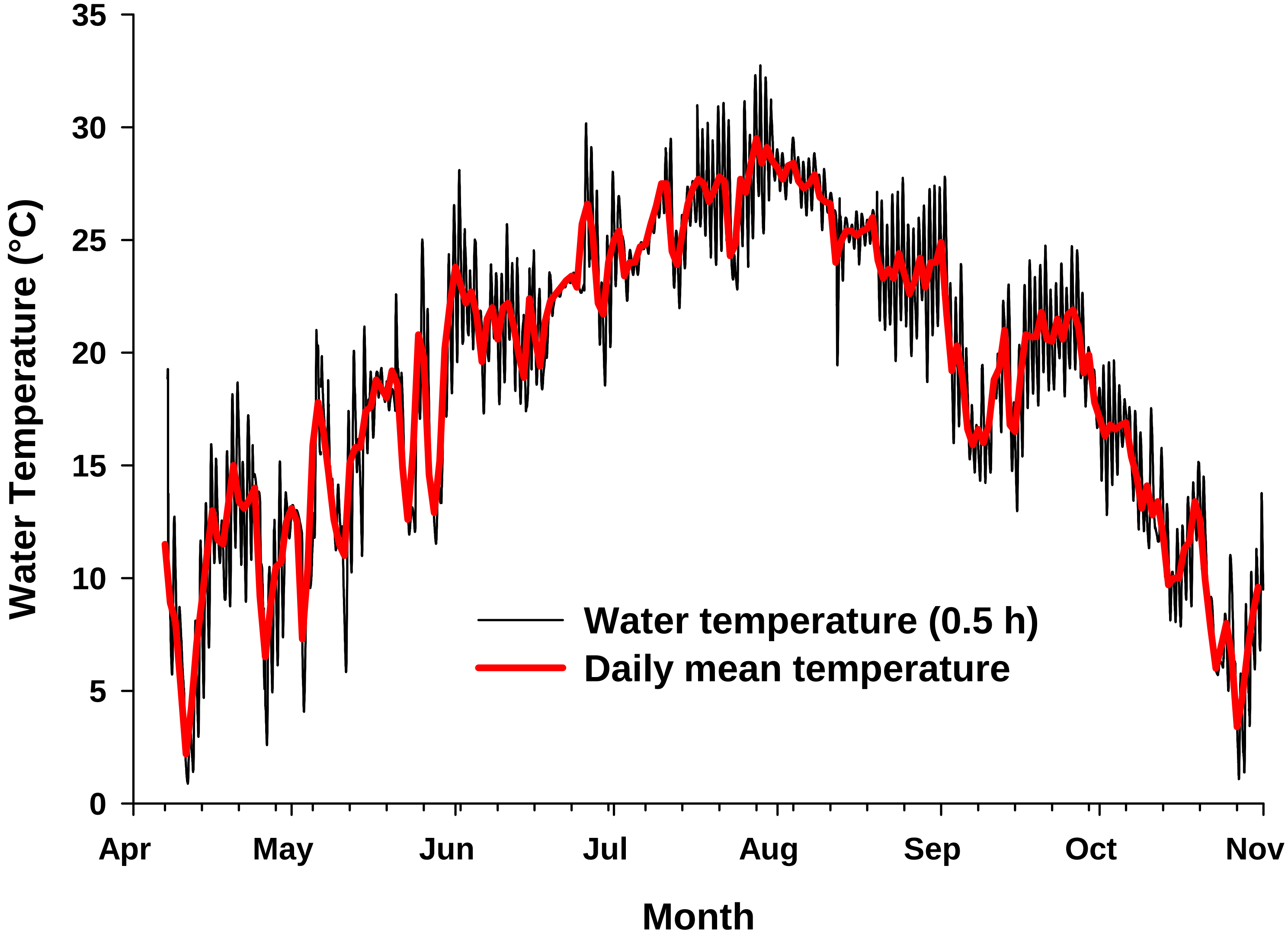

Figure 5. Water temperature measured every 0.5 h at the mouth of the Niobrara River (rkm 1) from April through November 2008.

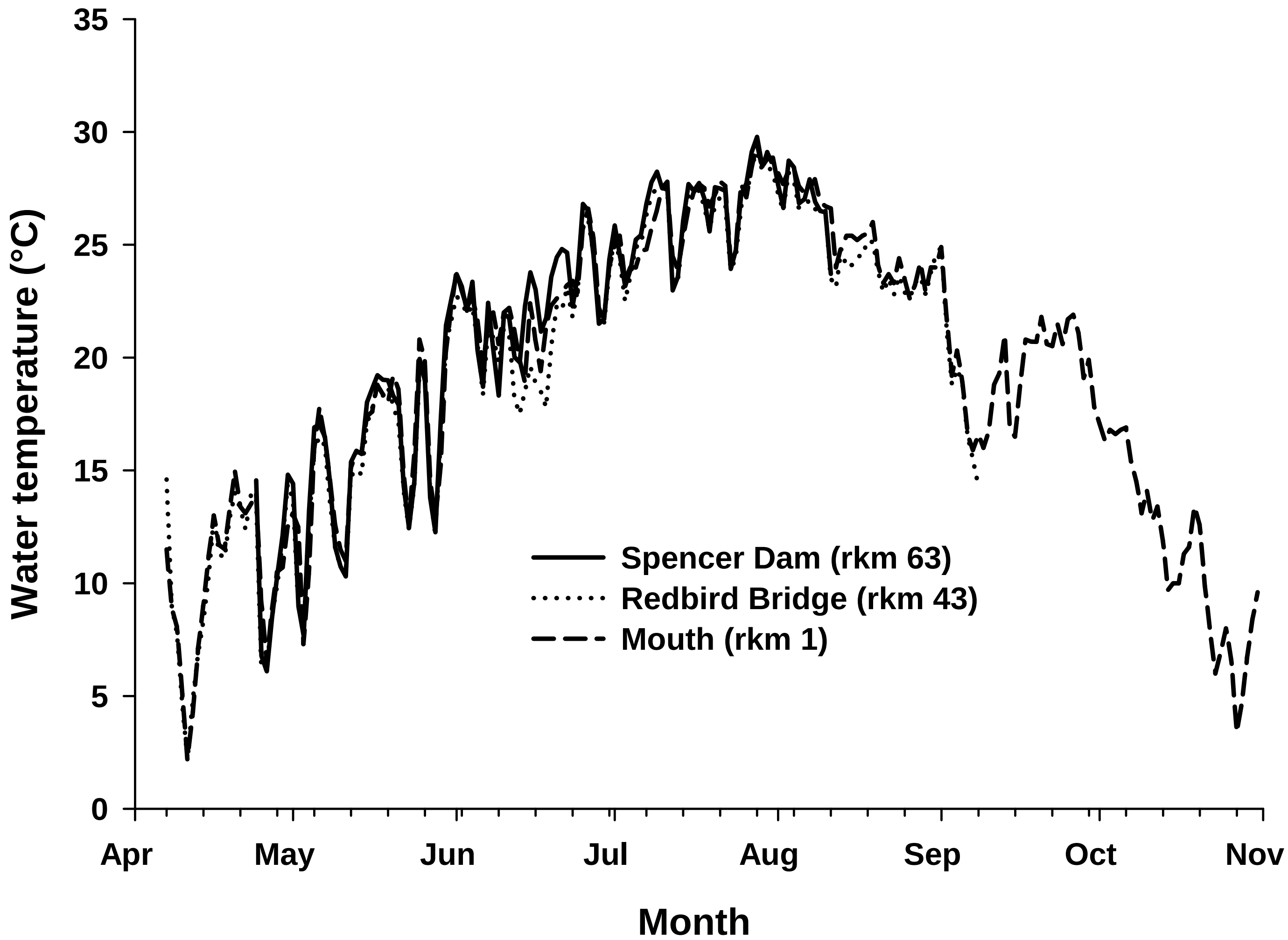

Figure 6. Niobrara daily mean water temperatures measured at three locations downstream of Spencer Dam, Nebraska from April to November 2008.

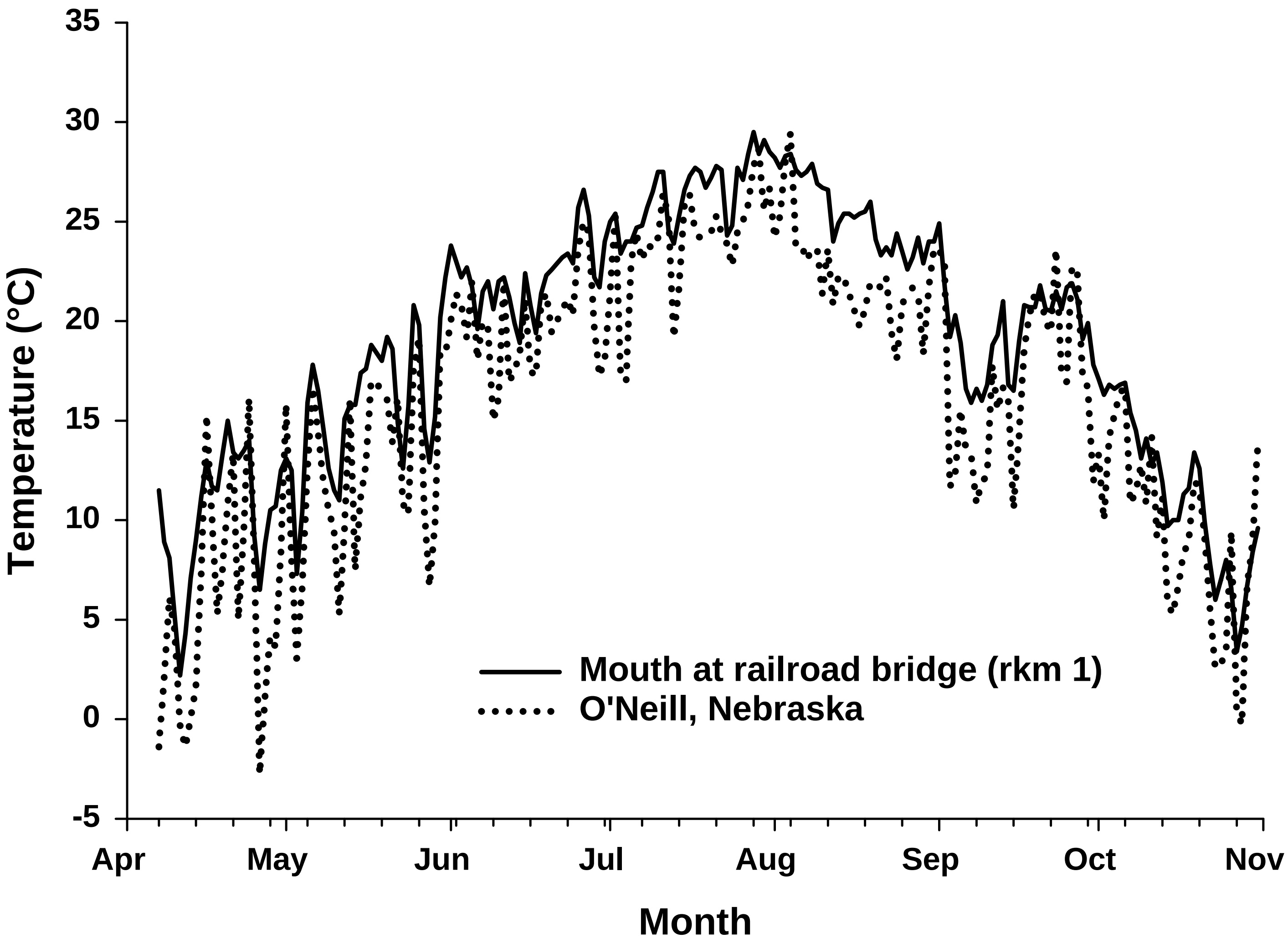

Figure 7. Ambient air temperature at O'Neill, Nebraska versus water temperature at the mouth of the Niobrara River. O'Neill is located 54 km from the mouth of the Niobrara River.

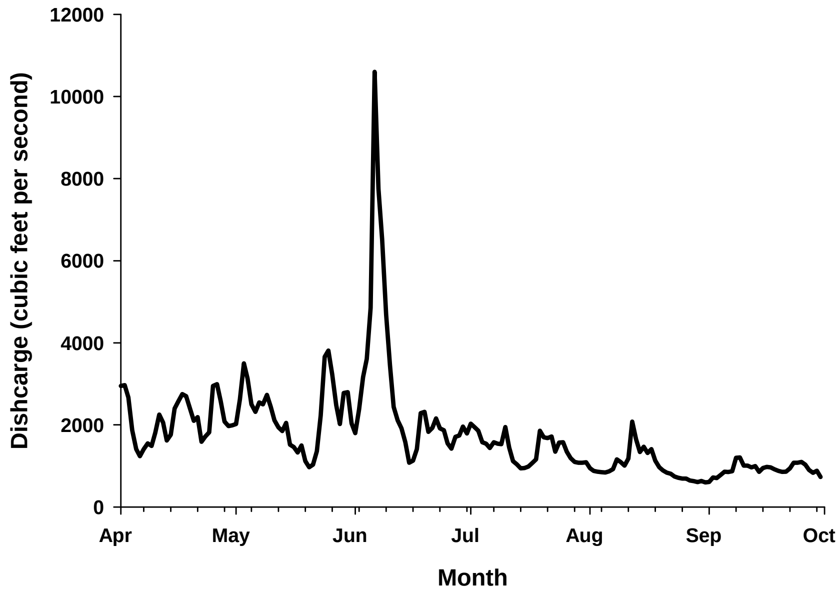

Figure 8. Niobrara River daily mean discharge measured in cubic feet per second at the Pischelville Bridge from April to October 2008 (http://waterdata.usgs.gov/usa/nwis/uv?site_no=06465500).

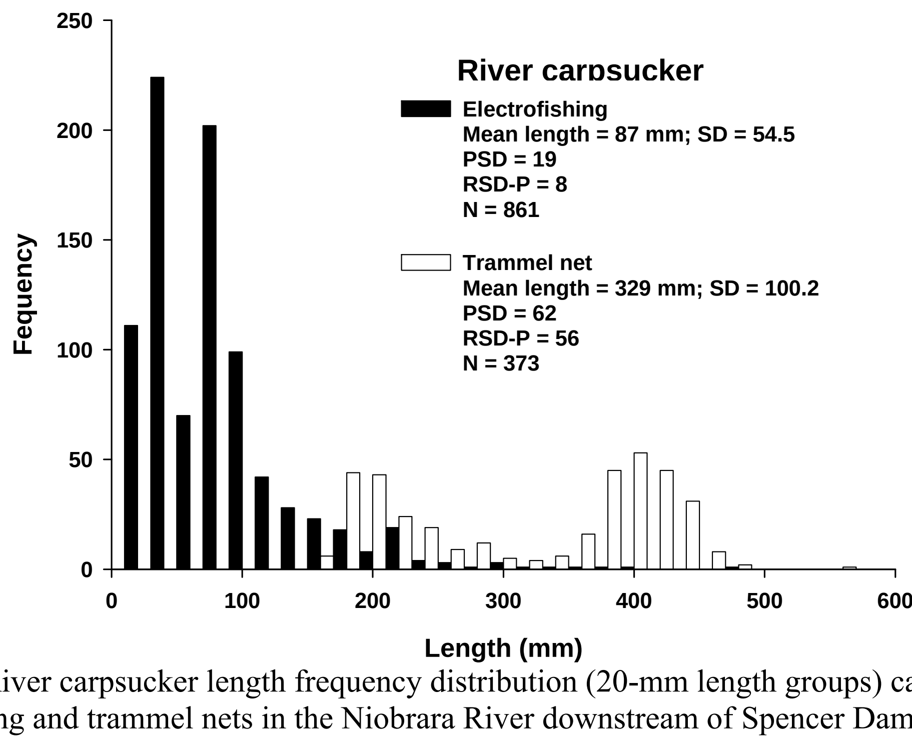

Figure 9. River carpsucker length frequency distribution (20-mm length groups) captured by electrofishing and trammel nets in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

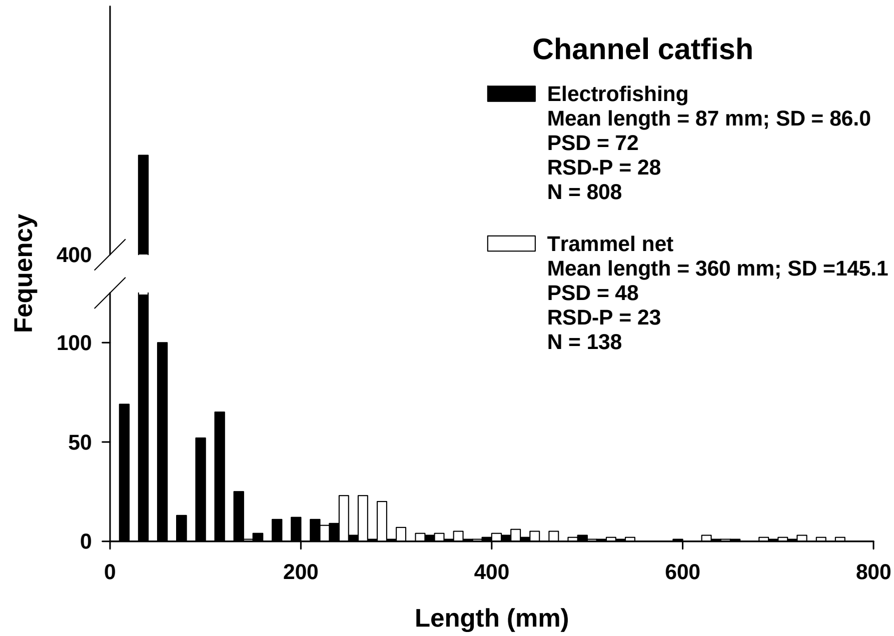

Figure 10. Channel catfish length frequency distribution (20-mm length groups) captured by electrofishing and trammel nets in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

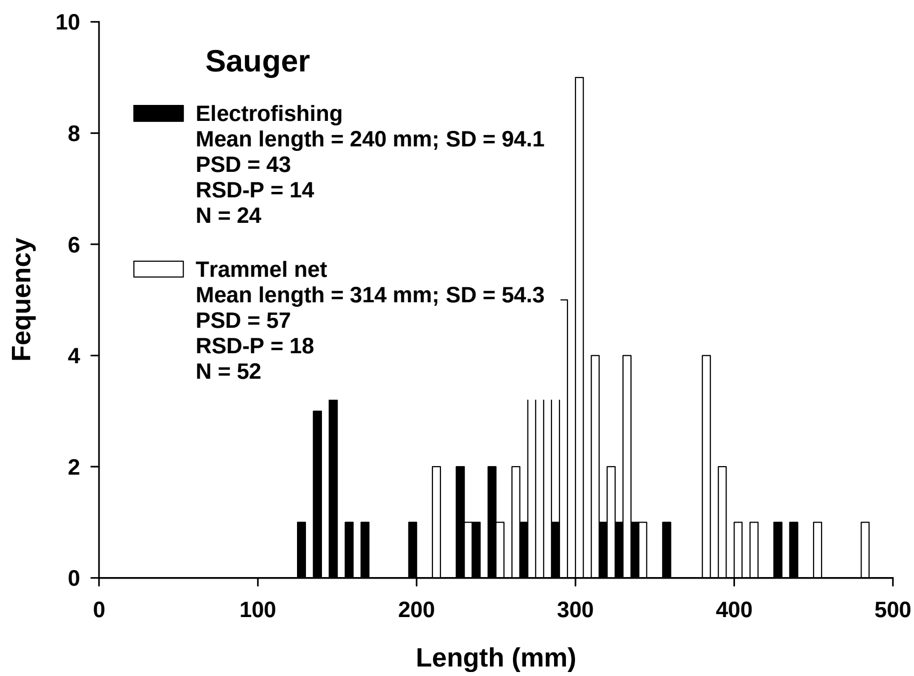

Figure 11. Sauger length frequency distribution (10-mm length groups) captured by electrofishing and trammel nets in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

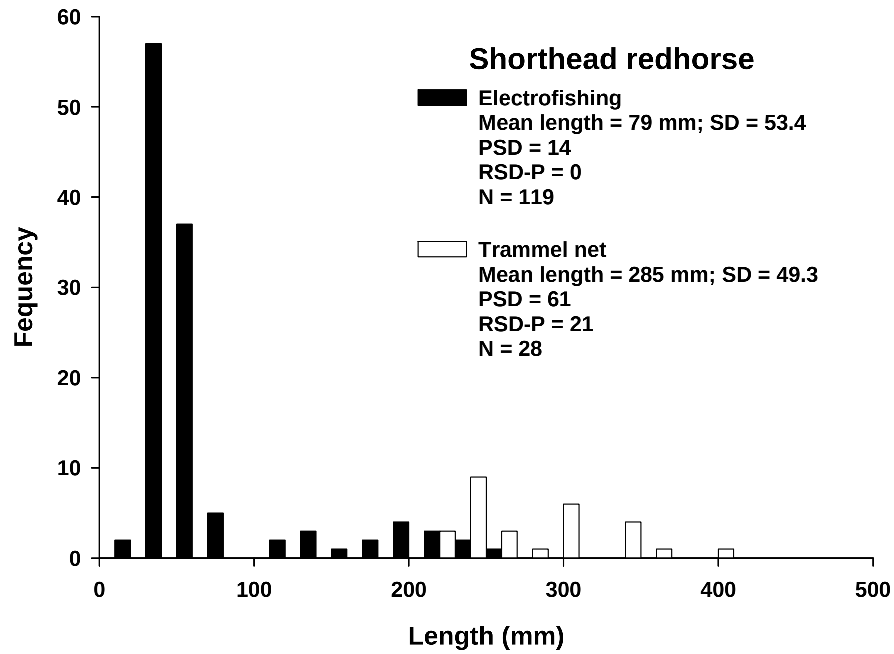

Figure 12. Shorthead redhorse length frequency distribution (20-mm length groups) captured by electrofishing and trammel nets in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

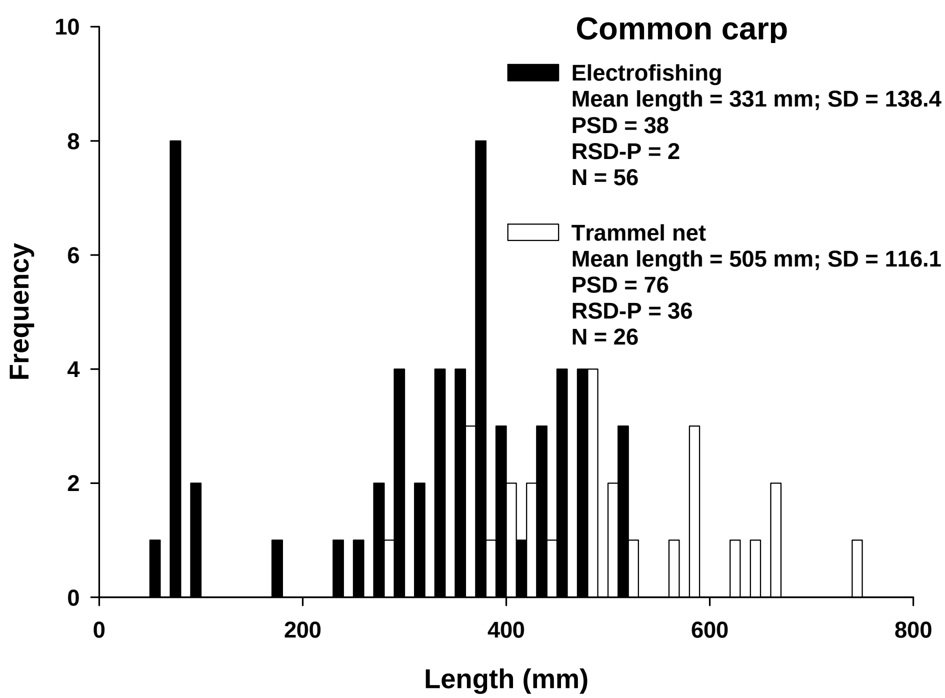

Figure 13. Common carp length frequency distribution (20-mm length groups) captured by electrofishing and trammel nets in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

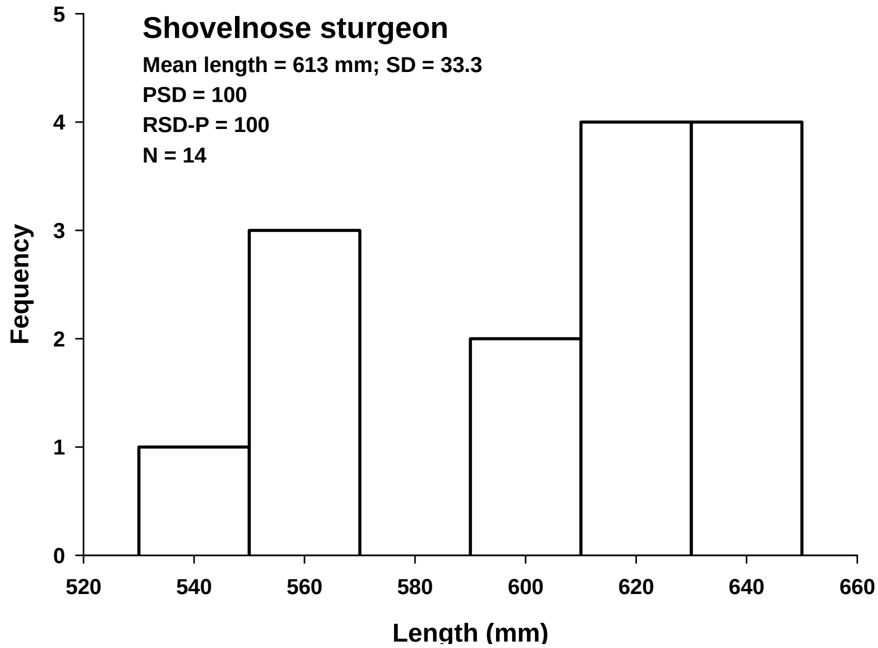

Figure 14. Shovelnose sturgeon length frequency distribution (20-mm length groups) captured by trammel nets in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

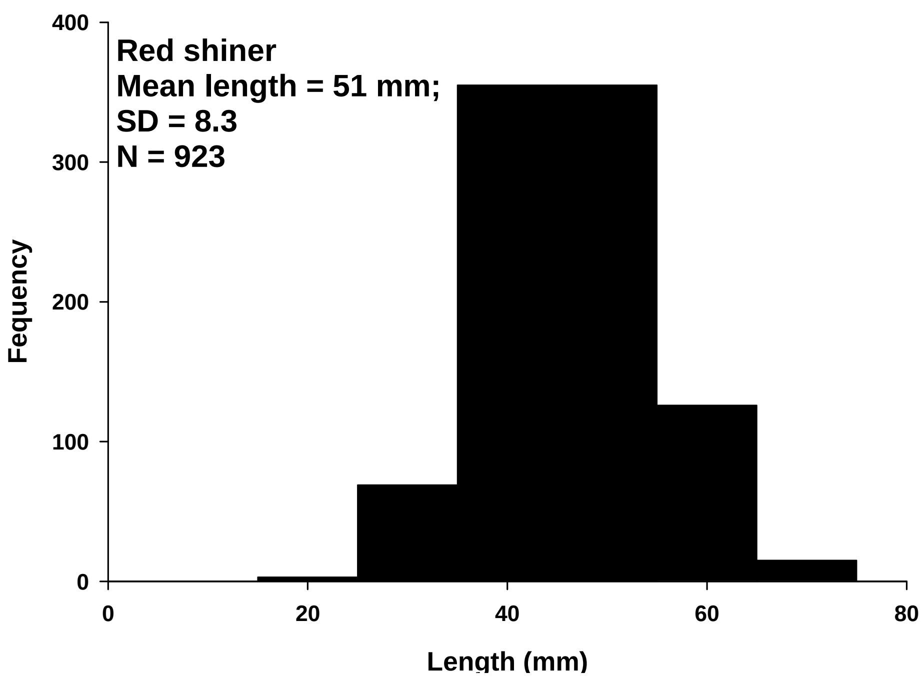

Figure 15. Red shiner length frequency distribution (10-mm length groups) captured by electrofishing in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

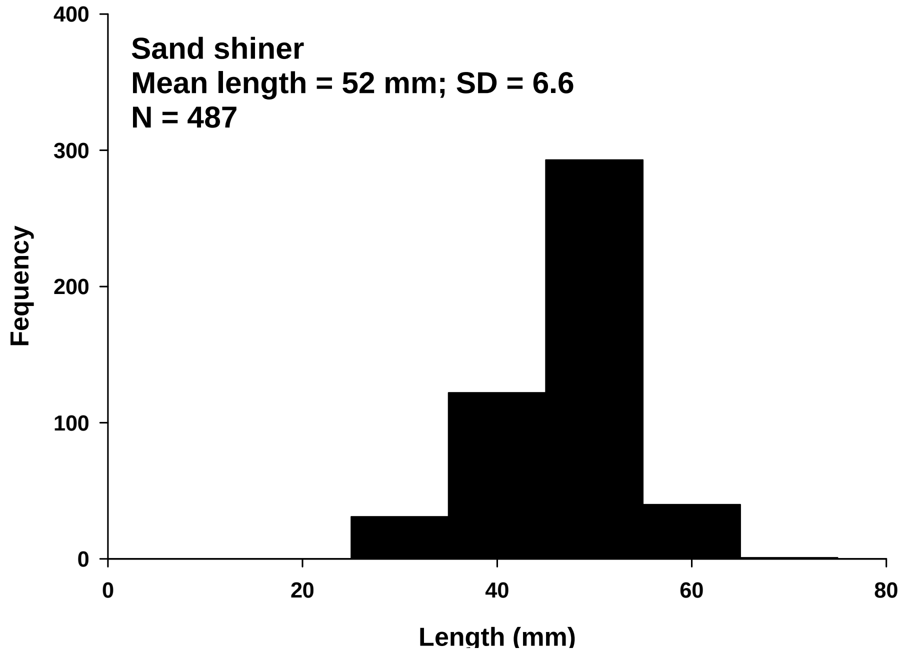

Figure 16. Sand shiner length frequency distribution (10-mm length groups) captured by electrofishing in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

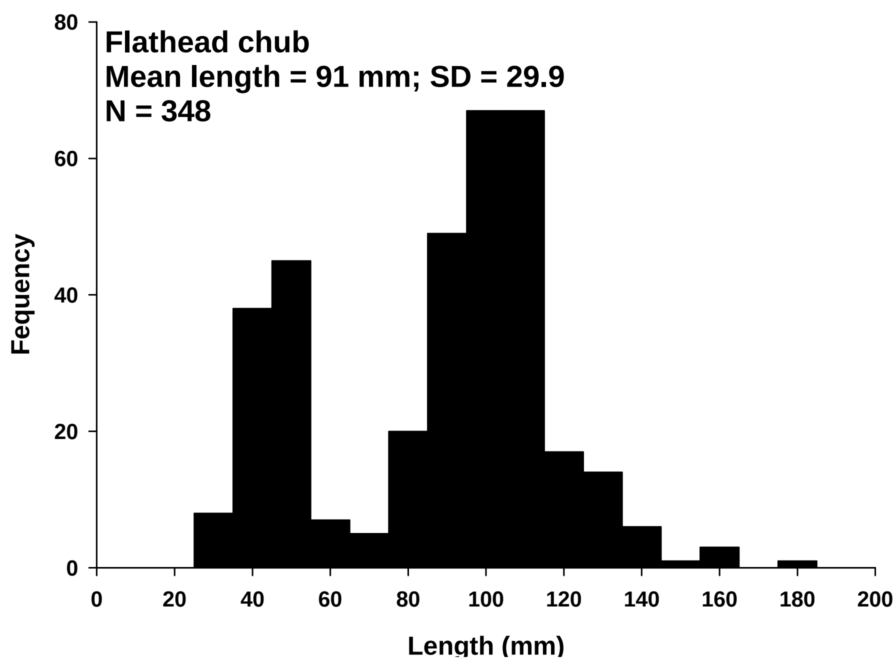

Figure 17. Flathead chub length frequency distribution (10-mm length groups) captured by electrofishing in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

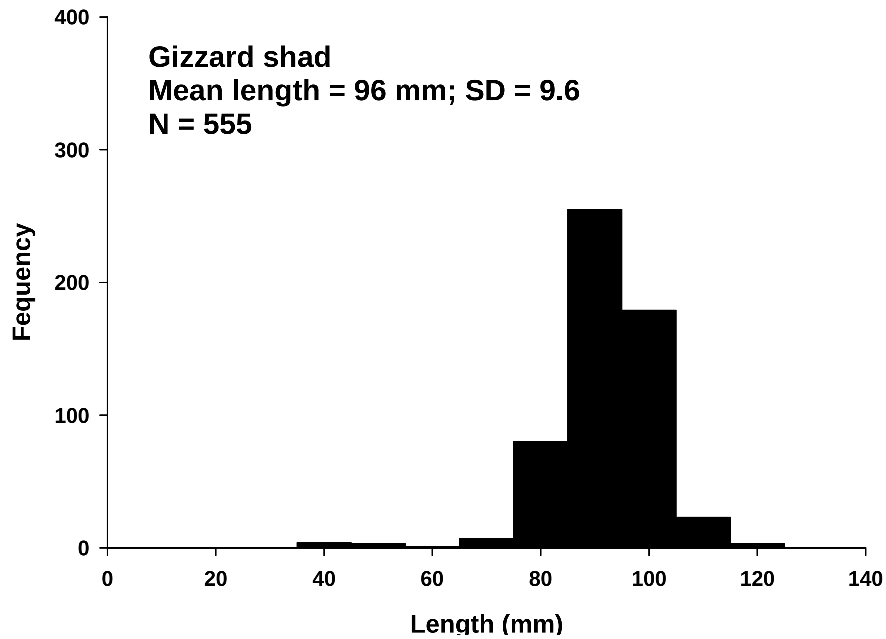

Figure 18. Gizzard shad length frequency distribution (10-mm length groups) captured by electrofishing in the Niobrara River downstream of Spencer Dam, Nebraska in 2008.

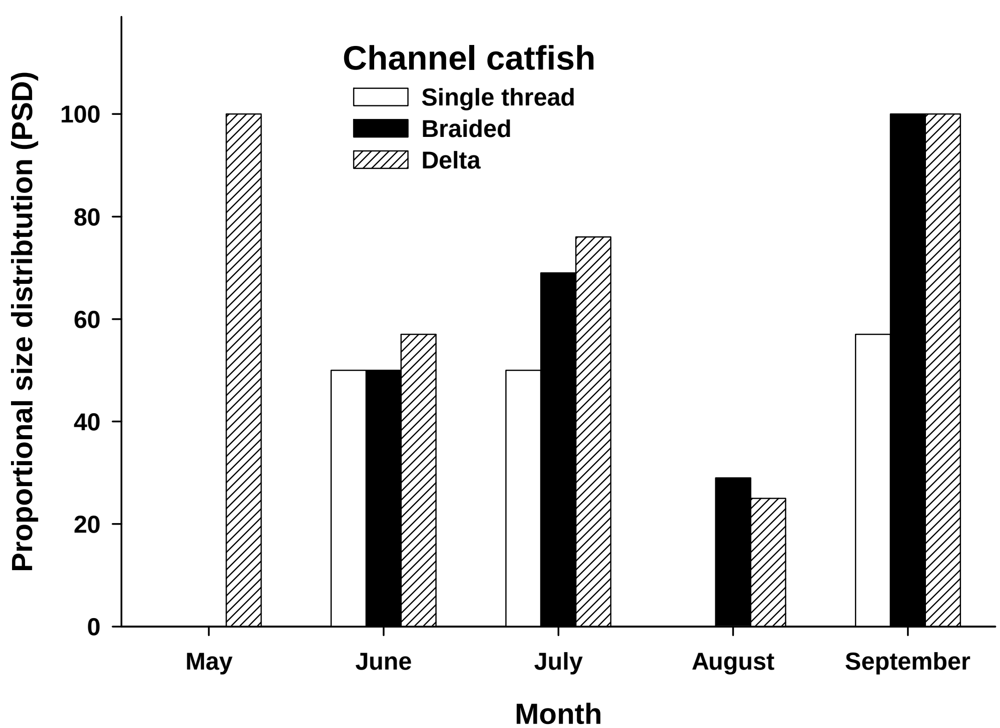

Figure 19. Channel catfish proportional size distribution (PSD) among months and Niobrara River reaches downstream of Spencer Dam, Nebraska in 2008.

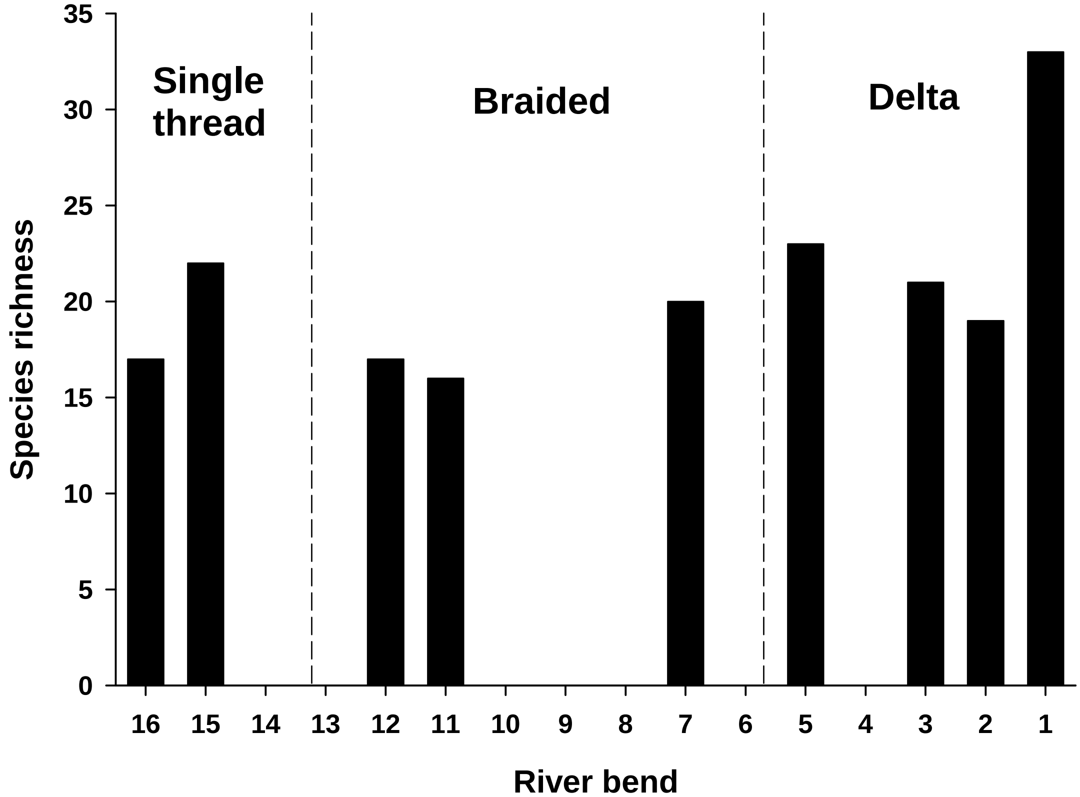

Figure 20. Species richness in the Niobrara River downstream of Spencer Dam, Nebraska in 2008. River bend 16 is just downstream of the dam and bend 1 is the last 3.9 km of the Niobrara River at the mouth.

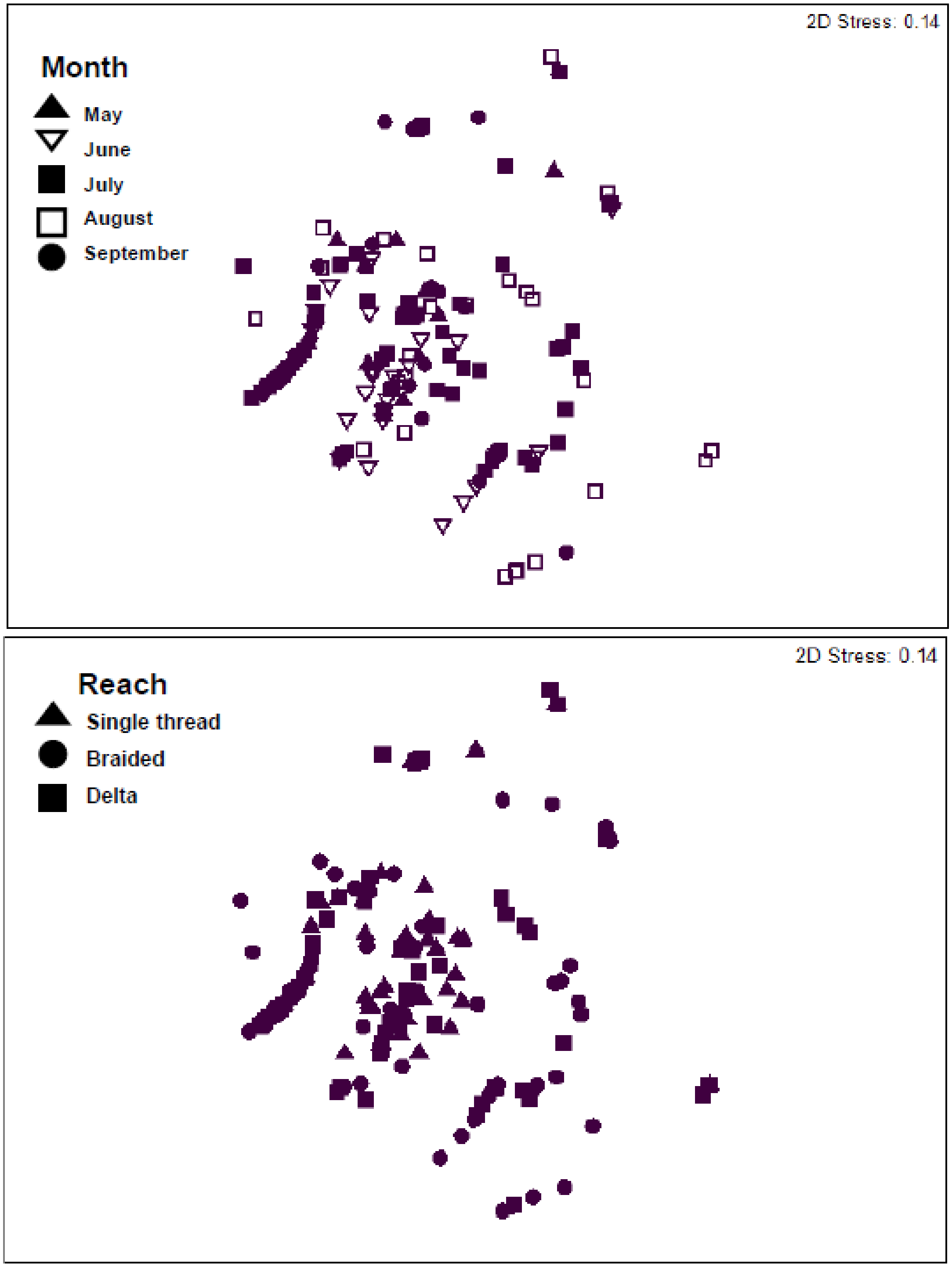

Figure 21. Nonparametric multidimensional scaling for the Niobrara River fish community from trammel net data among months (top) and river reaches (bottom) in 2008.

Figure 22. Nonparametric multidimensional scaling for the Niobrara River fish community from electrofishing data in 2008.

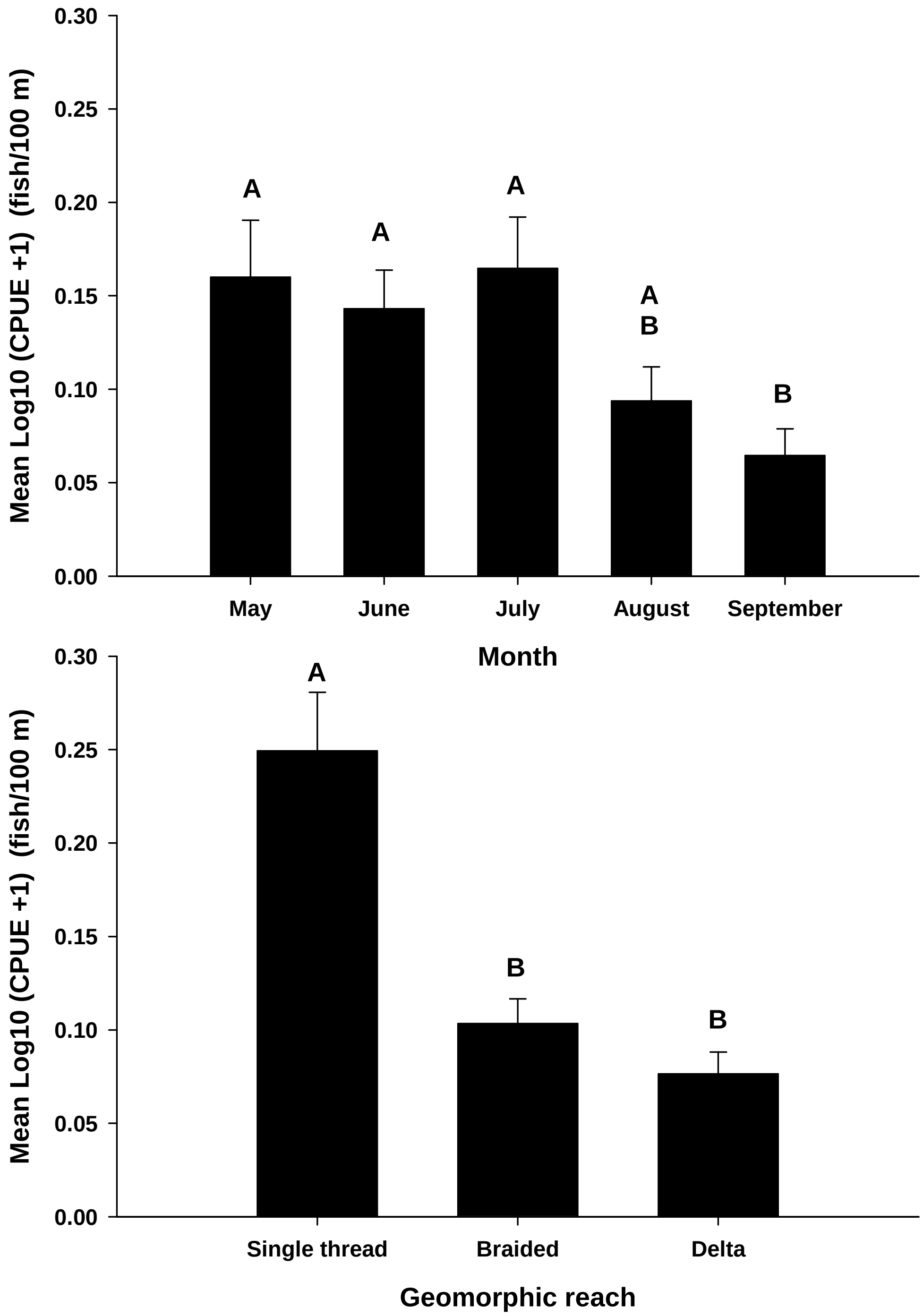

Figure 23. River carpsucker trammel net mean catch per unit effort (CPUE) compared among months (top) and reaches (bottom) using a one-way analysis of variance (ANOVA). Letters that are similar are not significantly different (P > 0.100).

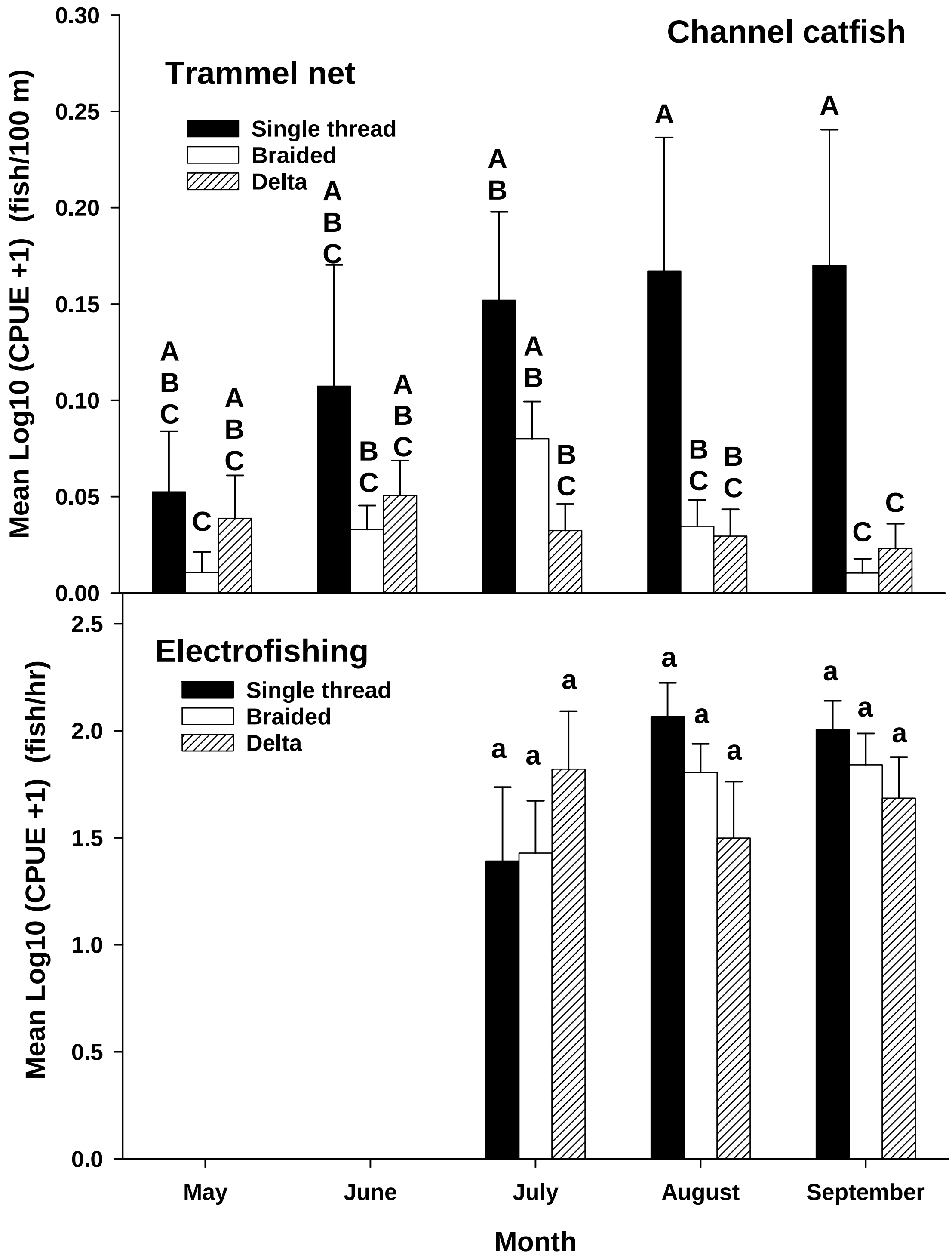

Figure 24. Channel catfish trammel net (top) and electrofishing (bottom) mean catch per unit effort (CPUE) compared among months (top) and reaches (bottom) using a two-way analysis of variance (ANOVA). Letters that are similar are not significantly different (P > 0.100).

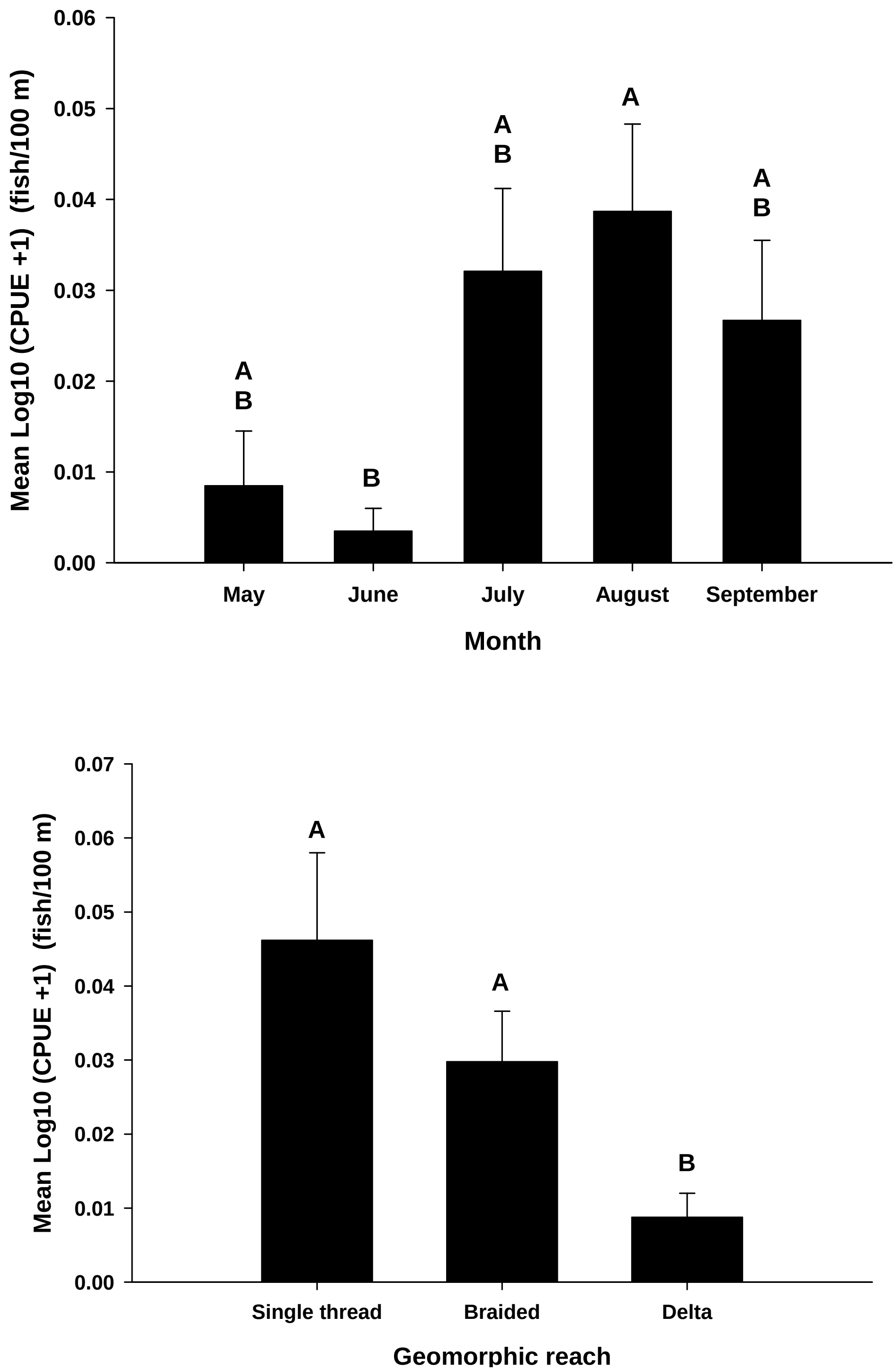

Figure 25. Sauger trammel net mean catch per unit effort (CPUE) compared among months (top) and reaches (bottom) using a one-way analysis of variance (ANOVA). Letters that are similar are not significantly different (P > 0.100).

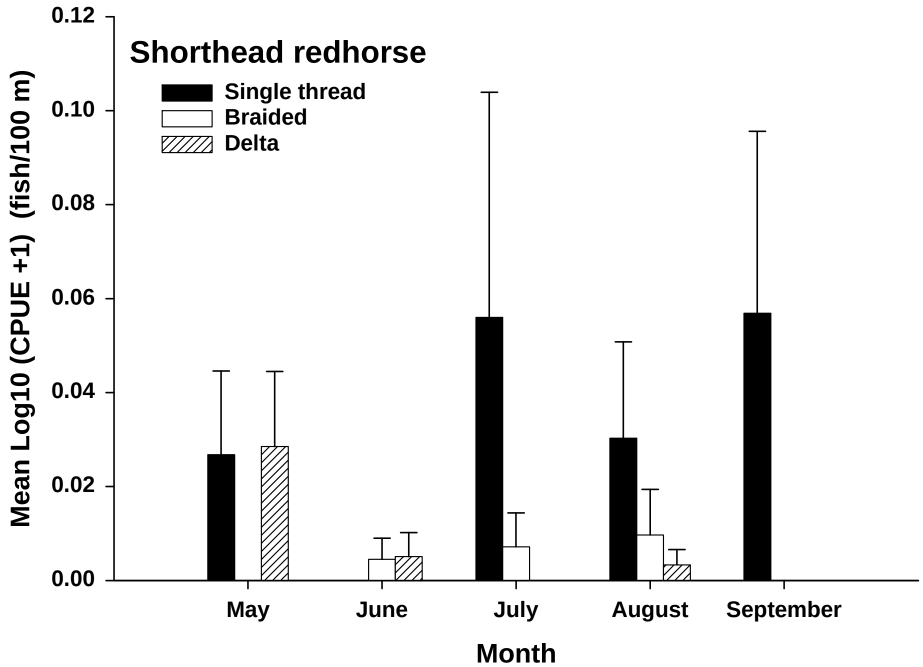

Figure 26. Shorthead redhorse trammel net mean catch per unit effort (CPUE) compared among months and reaches using a two-way analysis of variance (ANOVA). No significant differences were found among months and reaches (P > 0.100).

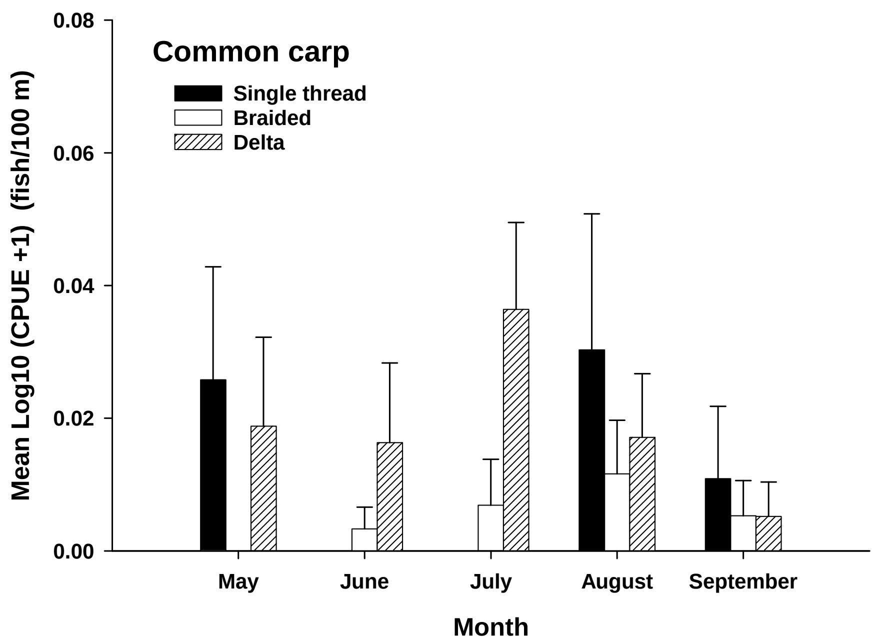

Figure 27. Common carp trammel net mean catch per unit effort (CPUE) compared among months and reaches using a two-way analysis of variance (ANOVA). No significant differences were found among months and reaches (P > 0.100).

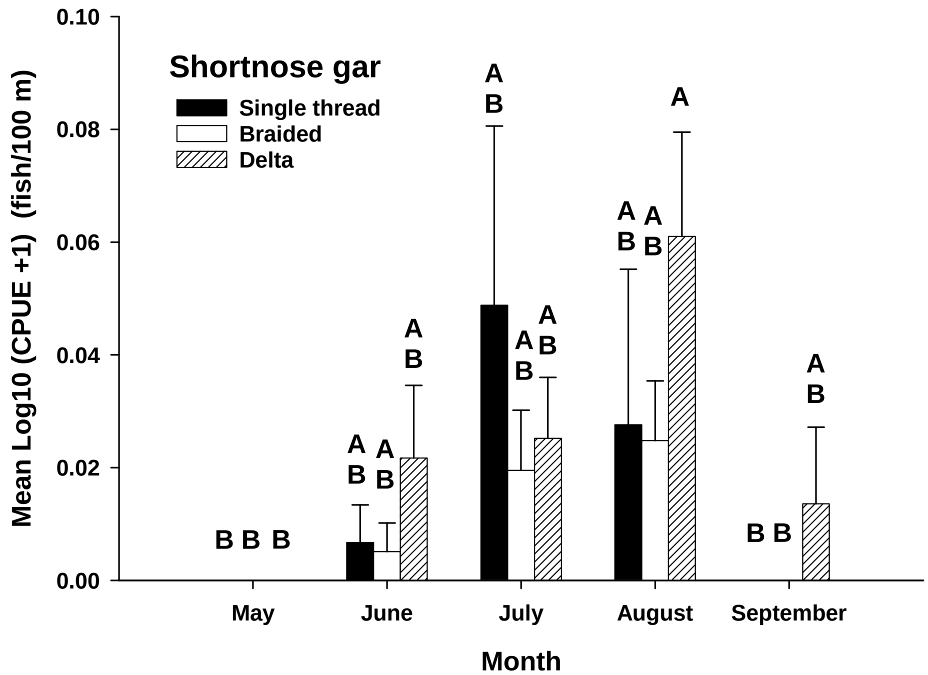

Figure 28. Shortnose gar trammel net mean catch per unit effort (CPUE) compared among months and reaches using a two-way analysis of variance (ANOVA). Letters that are similar are not significantly different (P > 0.100).

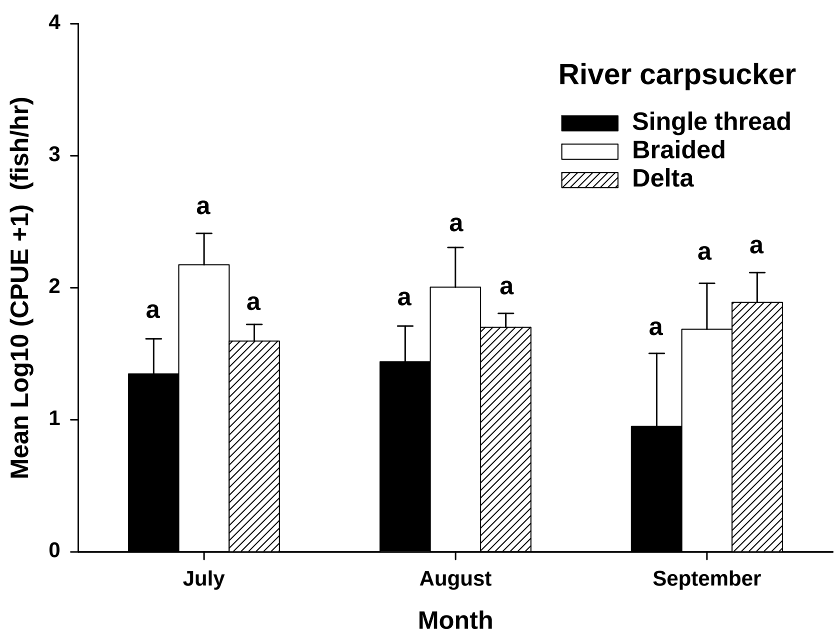

Figure 29. River carpsucker electrofishing mean catch per unit effort (CPUE) compared among months and reaches using a two-way analysis of variance (ANOVA). Letters that are similar are not significantly different (P > 0.100).

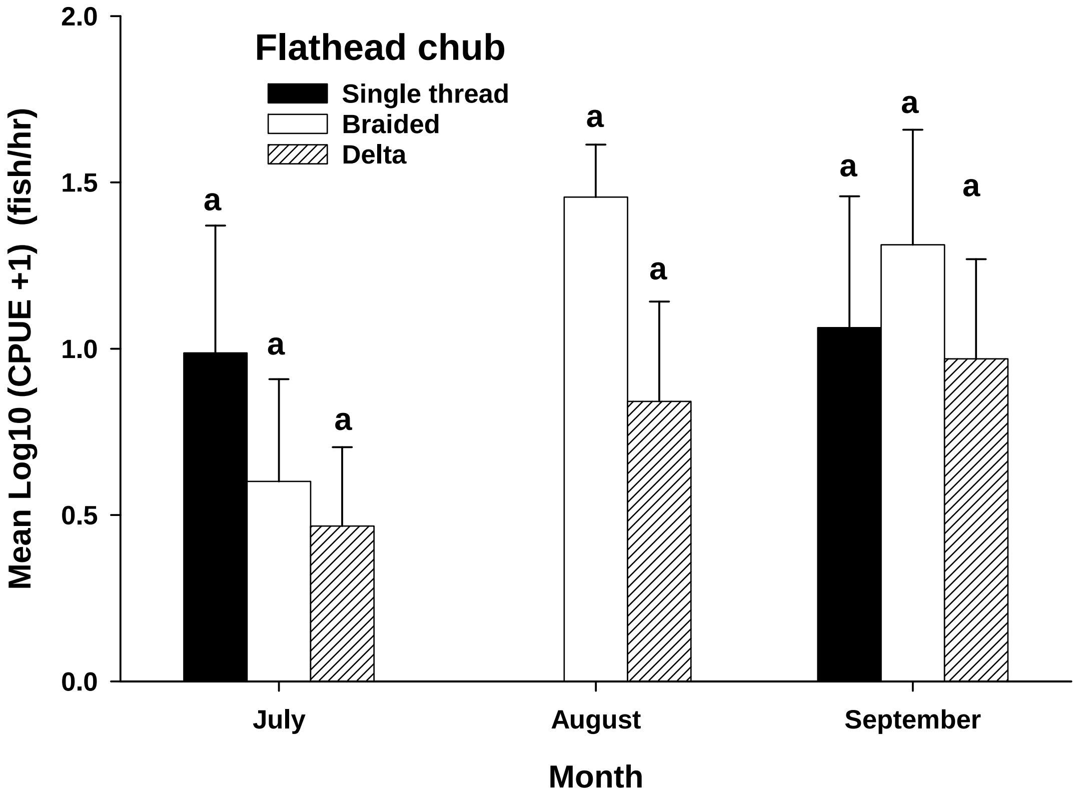

Figure 30. Flathead chub electrofishing mean catch per unit effort (CPUE) compared among months and reaches using a two-way analysis of variance (ANOVA). Letters that are similar are not significantly different ($P > 0.100$).

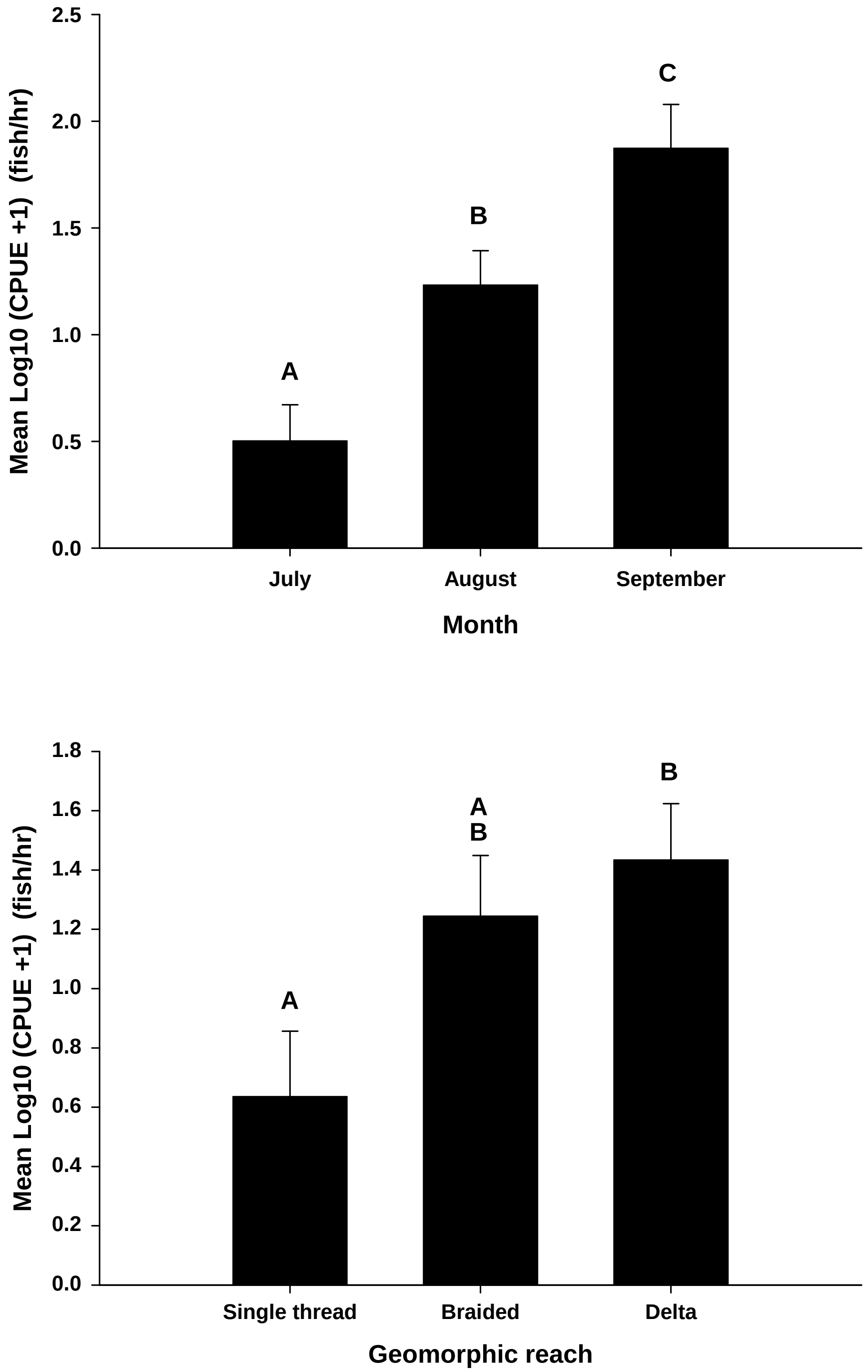

Figure 31. Gizzard shad electrofishing mean catch per unit effort (CPUE) compared among months (top) and reaches (bottom) using a one-way analysis of variance (ANOVA). Letters that are similar are not significantly different (P > 0.100).

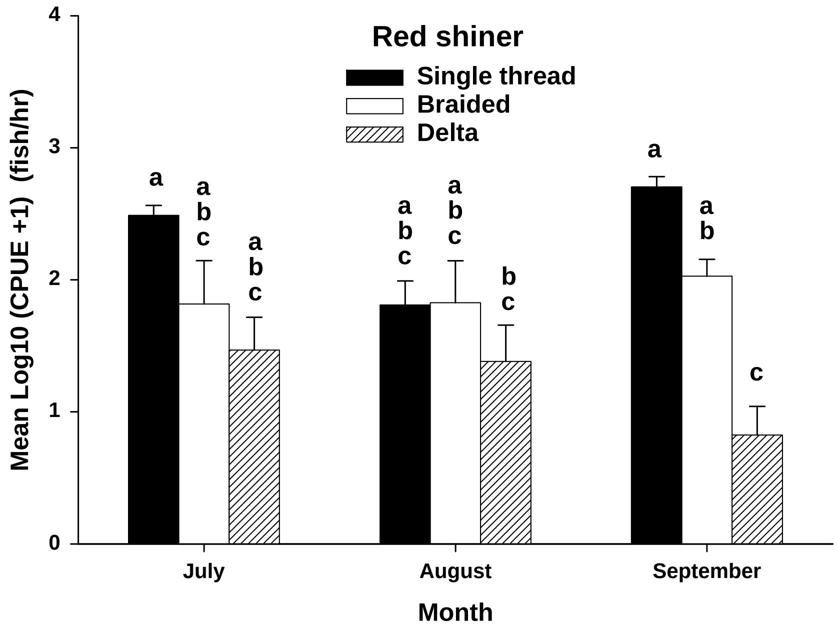

Figure 32. Red shiner electrofishing mean catch per unit effort (CPUE) compared among months and reaches using a two-way analysis of variance (ANOVA). Letters that are similar are not significantly different (P > 0.100).

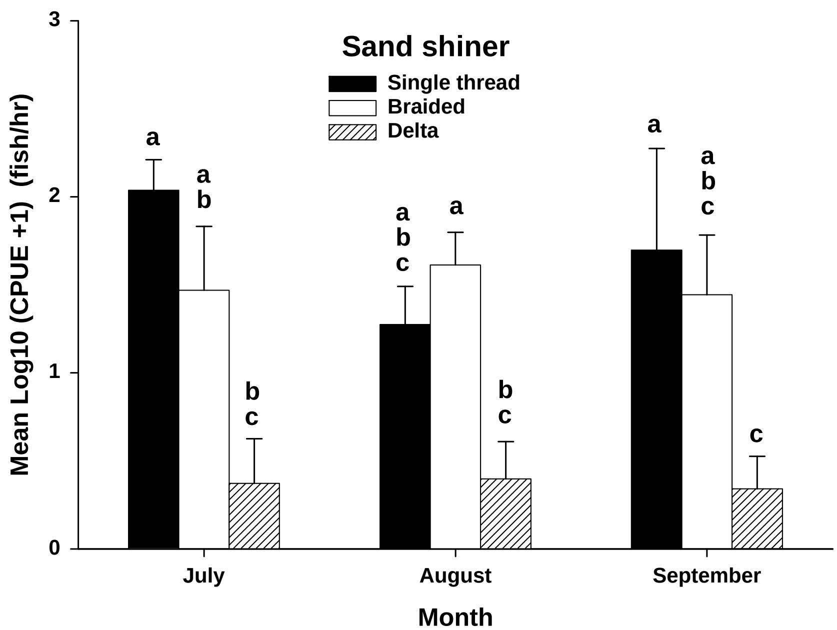

Figure 33. Sand shiner electrofishing mean catch per unit effort (CPUE) compared among months and reaches using a two-way analysis of variance (ANOVA). Letters that are similar are not significantly different (P > 0.100).

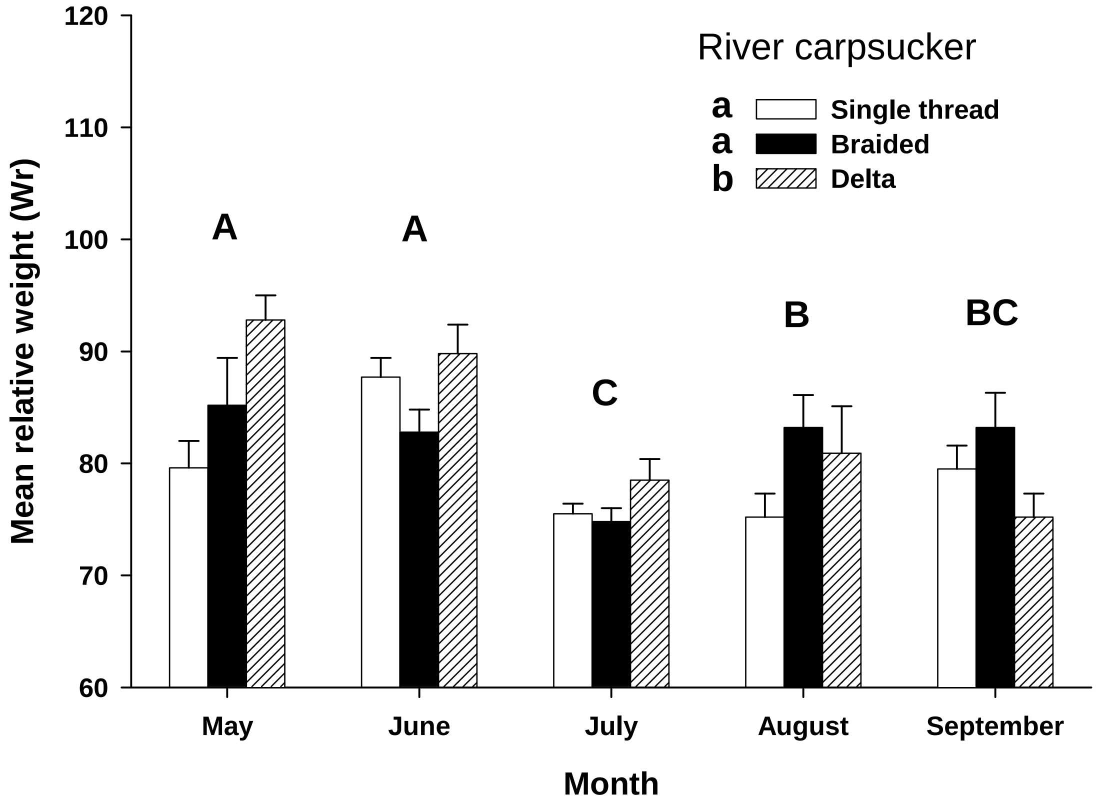

Figure 34. River carpsucker mean relative weight (*Wr*) compared among months and reaches using a one-way analysis of variance (ANOVA). Letter that are similar are not significantly different (P > 0.100).

Appendix A. Trammel net total catch and mean catch per unit effort (CPUE; fish/100 m) with standard error in parentheses in each month and reach in the Niobrara River downstream of Spencer Dam from May to September 2008.

Species	Total catch	Overall mean CPUE (fish/hr)	May			June			July			August			September		
			Single thread	Braided	Delta	Single thread	Braided	Delta	Single thread	Braided	Delta	Single thread	Braided	Delta	Single thread	Braided	Delta
Bigmouth buffalo	1	0.001	0	0	0	0	0	0	0	0	0.012	0	0	0	0	0	0
Ictiobus cyprinellus		(0.001)									(0.012)						
Bluegill	4	0.005	0	0	0.180	0	0	0.051	0	0	0	0	0	0	0	0	0
Lepomis macrochirus		(0.004)			(0.018)			(0.051)									
Blue sucker	1	0.001	0	0	0.180	0	0	0	0	0	0	0	0	0	0	0	0
Cycleptus elongatus		(0.001)			(0.018)												
Channel catfish	138	0.187	0.155	0.028	0.127	0.522	0.090	0.145	0.527	0.227	0.097	0.763	0.105	0.084	0.757	0.029	0.070
Ictalurus punctatus		(0.032)	(0.100)	(0.028)	(0.076)	(0.397)	(0.034)	(0.054)	(0.216)	(0.055)	(0.042)	(0.423)	(0.042)	(0.040)	(0.371)	(0.022)	(0.040)
Common carp	28	0.037	0.068	0	0.055	0	0.008	0.047	0	0.019	0.104	0.087	0.034	0.047	0.029	0.015	0.014
Cyprinus carpio		(0.008)	(0.045)		(0.040)		(0.008)	(0.036)		(0.019)	(0.038)	(0.059)	(0.024)	(0.026)	(0.029)	(0.015)	(0.014)
Flathead chub	1	0.001	0	0	0	0	0	0	0	0	0.013	0	0	0	0	0	0
Platygobio gracilis		(0.001)									(0.013)						
Freshwater drum	2	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0.016	0	0
Aplodinotus grunniens		(0.001)													(0.016)		
Green sunfish	1	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0.038	0	0
Lepomis cyanellus		(0.001)													(0.038)		
Pallid sturgeon	2	0.003	0	0	0	0	0	0	0	0	0.033	0	0	0	0	0	0
Scaphirhynchus albus		(0.003)									(0.033)						
River carpsucker	385	0.453	0.715	0.188	0.730	0.800	0.565	0.243	2.318	0.519	0.235	0.932	0.304	0.118	0.589	0.187	0.093
Carpiodes carpio		(0.048)	(0.296)	(0.089)	(0.202)	(0.338)	(0.113)	(0.081)	(0.491)	(0.224)	(0.071)	(0.404)	(0.100)	(0.045)	(0.257)	(0.054)	(0.047)
Sauger	53	0.071	0	0	0.046	0	0.012	0.011	0.205	0.137	0.024	0.342	0.083	0.049	0.109	0.153	0
Sander canadense		(0.012)			(0.032)		(0.012)	(0.011)	(0.083)	(0.062)	(0.018)	(0.121)	(0.032)	(0.030)	(0.063)	(0.063)	
Saugeye	1	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0
S. canadense X S. vitreum		(0.002)														(0.020)	
Shorthead redhorse	29	0.037	0.071	0	0.084	0	0.012	0.013	0.251	0.020	0	0.087	0.034	0.008	0.201	0	0
Moxostoma macrolepidotum		(0.012)	(0.047)		(0.048)		(0.012)	(0.013)	(0.229)	(0.020)		(0.059)	(0.034)	(0.008)	(0.138)		
Shortnose gar	39	0.055	0	0	0	0.017	0.014	0.062	0.160	0.053	0.071	0.095	0.071	0.176	0	0	0.052
Lepisosteus platostomus		(0.011)				(0.017)	(0.014)	(0.038)	(0.114)	(0.029)	(0.031)	(0.095)	(0.030)	(0.054)			(0.052)
Shovelnose sturgeon	14	0.018	0	0	0	0	0.023	0	0.053	0.026	0	0.066	0.050	0.047	0	0	0
Scaphirhynchus platorynchus		(0.005)					(0.016)		(0.037)	(0.026)		(0.047)	(0.024)	(0.027)			
Smallmouth buffalo	1	0.001	0	0	0	0	0	0	0	0	0.010	0	0	0	0	0	0
Ictiobus bubalus		(0.001)									(0.010)						
Walleye	2	0.002	0	0	0	0	0.012	0	0	0	0	0	0	0.011	0	0	0
Sander vitreum		(0.001)					(0.012)							(0.011)			
White bass	2	0.003	0	0	0	0	0	0	0	0.019	0.013	0	0	0	0	0	0
Morone chrysops		(0.002)								(0.019)	(0.013)						
White crappie	1	0.002	0	0	0	0	0	0	0	0	0.019	0	0	0	0	0	0
Pomoxis annularis		(0.002)									(0.019)						
All fish	706	0.883	1.044	0.216	1.077	1.340	0.736	0.572	3.515	1.019	0.641	2.372	0.681	0.542	1.740	0.404	0.229
		(0.084)	(0.335)	(0.095)	(0.300)	(0.716)	(0.138)	(0.134)	(0.866)	(0.242)	(0.104)	(1.023)	(0.128)	(0.108)	(0.641)	(0.116)	(0.074)

Appendix B. Electrofishing total catch and mean catch per unit effort (CPUE; fish/hr) with standard error in parentheses in each month and reach in the Niobrara River downstream of Spencer Dam from July to September 2008.

Species	Total catch	Overall mean CPUE (fish/hr)	July			August			September		
			Single thread	Braided	Delta	Single thread	Braided	Delta	Single thread	Braided	Delta
Bigmouth buffalo	1	0.088	0	0	0	0	0	0	0	0	0.545
Ictiobus cyprinellus		(0.088)									(0.545)
Bigmouth shiner	33	3.144	0	16.972	0.750	0	9.000	0	0	0	0
Notropis dorsalis		(1.611)		(10.755)	(0.750)		(7.348)				
Black bullhead	3	0.249	0	0	0	0	0	0	4.227	0	0
Ameiurus melas		(0.182)							(2.638)		
Bluegill	99	9.110	3.750	3.000	2.250	21.000	0.750	8.400	13.500	6.857	24.682
Lepomis macrochirus		(3.888)	(2.987)	(3.000)	(1.578)	(11.358)	(0.750)	(3.816)	(13.500)	(4.616)	(22.750)
Bluntnose minnow	2	0.176	0	0	0	0	0	1.200	0	0	0
Pimephales notatus		(0.124)						(0.800)			
Brassy minnow	3	0.265	0	1.500	0	0	0	0	1.500	0	0
Hybognathus hankinsoni		(0.196)		(1.500)					(1.500)		
Channel catfish	884	89.410	98.262	53.677	117.000	136.500	84.000	70.200	115.091	90.857	82.909
Ictalurus punctatus		(9.310)	(47.675)	(20.168)	(26.928)	(38.681)	(23.622)	(17.665)	(33.170)	(23.327)	(22.966)
Common carp	56	7.047	29.738	9.232	3.750	0	3.000	3.000	2.864	1.714	5.455
Cyprinus carpio		(2.610)	(20.068)	(4.410)	(2.987)		(1.134)	(1.342)	(1.657)	(1.107)	(3.747)
Emerald shiner	9	0.882	0.750	0	1.500	0	0.750	2.400	0	0	1.091
Notropis atherinoides		(0.339)	(0.750)		(1.500)		(0.750)	(1.327)			(1.091)
Flathead catfish	19	2.110	0	0	8.250	0	3.750	1.800	1.364	0.857	1.636
Pylodictis olivaris		(0.625)			(3.750)		(1.943)	(1.281)	(1.364)	(0.857)	(1.170)
Flathead chub	353	34.829	57.214	21.472	7.500	0	39.750	35.400	26.727	54.857	46.909
Platygobio gracilis		(6.042)	(25.992)	(14.903)	(4.355)		(10.074)	(17.262)	(17.487)	(20.720)	(18.988)
Freshwater drum	5	0.441	0	0	0	0	0	1.800	0	0	1.091
Aplodinotus grunniens		(0.229)						(0.917)			(1.091)
Gizzard shad	1,321	117.136	0	23.863	35.250	70.500	11.250	85.800	29.591	463.714	263.455
Dorosoma cepedianum		(32.052)		(14.624)	(16.797)	(24.541)	(3.092)	(52.070)	(24.443)	(235.642)	(74.671)
Green sunfish	251	22.53	11.417	3.000	28.500	40.500	4.500	15.600	128.045	4.286	26.591
Lepomis cyanellus		(5.845)	(7.391)	(3.000)	(16.343)	(15.174)	(2.471)	(7.960)	(71.980)	(4.286)	(9.348)
Grass pickerel	24	2.480	0.833	4.500	6.750	0	0	3.600	6.000	0.857	0.545
Esox americanus		(0.645)	(0.833)	(2.196)	(2.644)			(1.833)	(6.000)	(0.857)	(0.545)
Largemouth bass	166	14.914	0.833	4.500	19.500	22.500	7.500	25.200	2.864	10.286	30.000
Micropterus salmoides		(2.747)	(0.833)	(3.157)	(9.803)	(7.890)	(4.910)	(5.919)	(1.657)	(6.767)	(11.122)

Appendix B continued.

Species	Total catch	Overall mean CPUE (fish/hr)	July: Single thread	July: Braided	July: Delta	August: Single thread	August: Braided	August: Delta	September: Single thread	September: Braided	September: Delta
Longnose dace	1	0.088	0	0	0	0	0	0	0	0.857	0
Rhinichthys cararactae		(0.088)								(0.857)	
Northern pike	1	0.088	0	0	0	0	0	0.600	0	0	0
Esox lucius		(0.088)						(0.600)			
Orange-spotted sunfish	32	2.890	0	0	0.750	0	0	4.200	0	0	13.500
Lepomis humilis		(1.093)			(0.750)			(2.200)			(5.528)
Pumpkinseed	1	0.088	0	0	0	0	0	0.600	0	0	0
Lepomis gibbosus		(0.088)						(0.600)			
Red shiner	1,467	150.674	339.964	172.525	58.500	78.000	174.000	75.000	529.227	132.857	16.091
Notropis lutrensis		(21.452)	(59.330)	(58.765)	(20.931)	(22.450)	(62.806)	(30.295)	(94.016)	(33.238)	(5.866)
River carpsucker	1,538	144.794	64.571	446.926	51.750	48.00	213.750	63.000	42.000	126.000	159.818
Carpiodes carpio		(37.550)	(36.249)	(285.995)	(15.378)	(30.397)	(79.671)	(14.567)	(27.166)	(42.305)	(47.322)
Sand shiner	621	65.957	159.976	123.503	10.500	27.000	74.250	7.800	153.818	96.000	6.000
Notropis stramineus		(13.041)	(46.245)	(59.995)	(8.910)	(15.199)	(32.960)	(4.821)	(66.783)	(46.068)	(3.963)
Sauger	24	2.824	3.750	0	9.000	1.500	0	0.600	0	4.286	4.364
Sander canadense		(0.875)	(2.987)		(5.892)	(1.500)		(0.600)		(1.714)	(1.636)
Shorthead redhorse	119	10.858	4.238	1.500	0.750	6.000	16.500	9.600	7.364	38.571	12.273
Moxostoma macrolepidotum		(2.182)	(2.119)	(1.500)	(0.750)	(4.243)	(7.917)	(5.455)	(1.551)	(10.625)	(4.691)
Shortnose gar	7	0.764	0	1.243	2.250	0	0	2.400	0	0	0
Lepisosteus platostomus		(0.316)		(1.243)	(1.578)			(1.327)			
Silver chub	10	0.980	2.333	0	0	0	1.500	0	1.500	0.857	2.182
Macrhybopsis storeriana		(0.448)	(1.609)				(1.500)		(1.500)	(0.857)	(2.182)
Spotfin shiner	146	13.279	0	0	6.000	1.500	0	16.800	0	1.714	60.818
Notropis spilopterus		(4.760)			(4.536)	(1.500)		(5.919)		(1.714)	(24.666)
Stonecat	2	0.176	0	0	0	0	0.750	0	0	0.857	0
Noturus flavus		(0.124)					(0.750)			(0.857)	
Walleye	5	0.441	0	0	0	0	0	1.200	0	0	1.636
S. vitreum		(0.229)						(0.800)			(1.170)
White bass	11	0.971	0	0	0	0	1.500	3.000	0	0	2.182
Morone chrysops		(0.409)					(1.500)	(2.049)			(1.220)
White crappie	10	0.874	0	0	0	4.500	0	0	7.364	0.857	0.545
Pomoxis annularis		(0.337)				(2.872)			(2.899)	(0.857)	(0.545)
All fish	7,224	700.559	777.631	887.413	370.500	457.500	646.500	439.200	1,073.045	1,037.143	764.318
		(60.468)	(131.560)	(352.014)	(54.836)	(11.325)	(111.126)	(93.714)	(227.919)	(227.919)	(99.835)

Appendix C. Bag seine total catch and mean catch per unit effort (CPUE; fish/100 m^2) with standard error in parentheses for each reach of the Niobrara River downstream of Spencer Dam in July 2008.

Species	Total catch	Overall mean CPUE (fish/100 m^2)	Single thread	Braided	Delta
Bigmouth shiner *Notropis dorsalis*	2	0.032 (0.032)	0	0.064 (0.064)	0
Bluntnose minnow *Pimephales notatus*	1	0.014 (0.014)	0	0	0.057 (0.057)
Channel catfish *Ictalurus punctatus*	13	0.253 (0.101)	0.330 (0.330)	0.233 (0.127)	0.216 (0.125)
Common carp *Cyprinus carpio*	1	0.017 (0.017)	0.067 (0.067)	0	0
Emerald shiner *Notropis atherinoides*	7	0.091 (0.049)	0.134 (0.134)	0.063 (0.063)	0.102 (0.102)
Flathead chub *Platygobio gracilis*	3	0.037 (0.026)	0	0.032 (0.032)	0.085 (0.085)
Gizzard shad *Dorosoma cepedianum*	5	0.083 (0.061)	0	0	0.331 (0.217)
Grass pickerel *Esox americanus*	1	0.014 (0.014)	0	0	0.057 (0.057)
Red shiner *Notropis lutrensis*	258	4.669 (1.547)	10.368 (4.347)	3.466 (1.679)	1.377 (0.652)
River carpsucker *Carpiodes carpio*	47	0.815 (0.315)	0.587 (0.278)	1.078 (0.611)	0.519 (0.276)
Sand shiner *Notropis stramineus*	56	1.016 (0.532)	1.062 (0.197)	1.439 (1.058)	0.127 (0.127)
Sauger *Sander canadense*	3	0.076 (0.076)	0	0	0.305 (0.305)
Shorthead redhorse *Moxostoma macrolepidotum*	1	0.027 (0.027)	0.110 (0.110)	0	0
Shortnose gar *Lepisosteus platostomus*	3	0.038 (0.022)	0	0.076 (0.040)	0
Silver chub *Macrhybopsis storeriana*	1	0.027 (0.027)	0.110 (0.110)	0	0
Spotfin shiner *Notropis spilopterus*	39	0.629 (0.338)	0	0.246 (0.163)	20.23 (1.131)
White crappie *Pomoxis annularis*	2	0.029 (0.029)	0	0	0.114 (0.114)
All fish	443	7.868 (2.056)	12.767 (4.456)	6.696 (3.332)	5.313 (1.351)